AVR Mega328 Controller based MPPT for PhotoVoltaic (PV) System

A
THESIS

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DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING

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CERTIFICATE

This is to certify that the thesis entitled **"AVR Mega328 Controller based MPPT for Photovoltaic(PV) System"** which is being submitted herewith for the award of Master of Technology Degree in Electrical and Electronics Engineering with specialization of Power Systems Engineering during session 2019-2021 is the result of the work completed by **K.Surya Gangadhararao** bearing a **19U41D4201** under my supervision and guidance and the same has not been submitted elsewhere for the award of any degree.

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DECLARATION

I hereby declare that the dissertation entitled **"AVR Mega328 Controller based MPPT for Photovoltaic(PV) System"** was carried out and written by me under the guidance of **Mr G.JAGADEESH**, Assistant Professor, Department of Electrical and Electronics Engineering, Dadi Institute of Engineering & Technology. This work has not been previously formed the basis for the award of any degree of diploma or certificate nor has been submitted elsewhere for the award of any degree or diploma.

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ABSTRACT

The general output of photovoltaic (PV) bases on sun based light intensity and surrounding temperature. It is well known fact in the electrical sector the extreme output from the every design is the primary criteria, so to make the extreme outcomes of PV array as with individual PV cells output power, this new design develops paper based on the controller AVR Mega328 controller in the PV power scheme environment. The control regulator is worn for execution of the anticipated for both Incremental Conductance (IncCond) and Perturbation & Observe (P&O)"Maximum Power Point Tracking (MPPT)" methods with pulse width modulation (PWM) to coerce the D.C-D.C boost-converter in the PV system, and most importantly to oblige the individual PV cell to control at MPP. By using of AVR Mega328 which design had openness to extend the work for prospect applications and made the system low cost and easy to maneuver.

Keywords: Maximum Power Point Tracking (MPPT); Photovoltaic Cell (PVC); AVR Mega328 Controller; Inc Cond method; Perturbation and Observe (P&O); Pulse width Modulation (PWM).

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CHAPTER – 1

INTRODUCTION

OF

PHOTOVOLTAIC (PV) CELLS

INTRODUCTION

Energy whatever the form of energy it is, which is indispensable primary source for the every spice on earth and mostly for the human beings, and their monetary activities too. Nowadays with the escalating stipulate for the energy, fossil energy has become the focal point for the energy treasury is flattering exhausted. Fossil fuels are extensively acknowledged a quick solution to enhance source for energies. [1] Production and protection of energy is renowned as the vital demand theme of the universal enlargement. Over demand on one-side and energy dearth on other-side enforced to search for other forms of energy sources mostly based on the renewable energy resources (RESs) [2]. As the present scenario show many renewable energy resources (RESs) technologies are able-bodied urbanized, reliable and outstandingly cost efficient with advanced features for numerous utilities which main concern in the electrical network which compared to the fuel and other abounding generators.

Solar type RESs are which less pollute and is in attendance ubiquitously with hefty number of applications. Mostly from the 1980 end which began for 1990's this kind of energies had develop into further admired. The world statics for the photovoltaic PV industry in the entire world has greater than before which is 31% as per over the preceding decades. Conversely the little elevated price and the energy adaptation efficiency is 2-foremost factorial parameters confine for execution of the PV methods. Then the question arises how to increase the efficiency of adaptation for the fuel cells with low cost equipment and to get the utmost output power and efficiency as of the solar cells has become a big hotspot.

A PV array is form of the non linear power sources, as well as its output power bases on the, PV cells, I.R, T and voltages load. The PV energy exchange systems function close to the MPP, for obtaining utmost efficiency from the PV system. In the development process of the PV systems there are various approaches have been come across reportedly in implementation of MPPT, some of such methods are of the Perturbation and Observe method, the Hill climbing method, the Constant Voltage Tracking Method, the fuzzy logic (FL) control method, the short circuit method, Genetic Algorithm (GA) and the Incremental Conductance, [3] [4] etc… It is a well know concept that advantages always along with disadvantages as each individual MPPT method had their own advantages and disadvantages.

ANALYSES OF OUTPUT CHARACTERISTICS OF PHOTO VOLTAIC (PV) CELLS

In this section the scrutiny and understating of PV cells for MPPT as the prime stride, a solar cell is principally consist of semi-conductor substances those transforms solar radiation into dc current by means of PV result. Solar cells are finished with combination of string and similar meld to make PV array. The role of load resistance, array temperature and solar radiation levels which decides an output current and voltage generated by the PV array. Mostly the prototype of PV array is betel by (I-V) characteristics as well as by using the corresponding circuit illustrated in figure 1.1
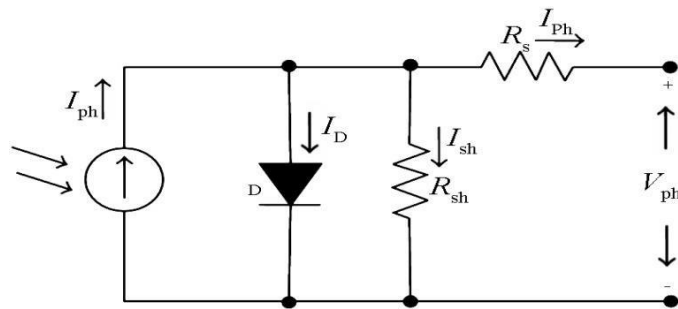
Figure: 1.1 Equivalent Circuit for a P.V solar Cell.

Whereas,

I_{pv} = PV array output load current

V_{ph} = PV array output voltage

I_{ph}= Generated Photo current for a set solar irradiance

I_D = Cell unit P-N junction dark current

Q = Charge of an electron = 1.6 x 10^{-19}

n = PN junction curve constant,

For PV cell high output voltage, n=1 unless n=2.

T = Absolute temperature of cell (K)

K = Boltzmann's constant = 1.38 x 10^{-23} J/K

R_s&R_{sh}= PV array associated intrinsic resistance

Rs = PV array equivalent series resistance

R_{sh}= PV array equivalent shunt resistance, where the value of $R_{sh}$is thousands ohms (Ω)

The affiliation among the O/P Power & Temperature (T), light intensity is beneath. Fig: 2 shows O/P characteristics curve of the PV cell for various temperatures. As with representation we can evidently visualize that the O/P power of PV cell decreases by way of the modifications in other circumstances the ambient temperature raises. It can be obviously visual from the figure: 3, the light intensity nourish because of O/P power of PV cells increases, while the other things will be unaffected. Well at fastidious light intensity, there will be an inimitable Power Maximum P_M for the PV cell, which is known as the MPP [5] [6].
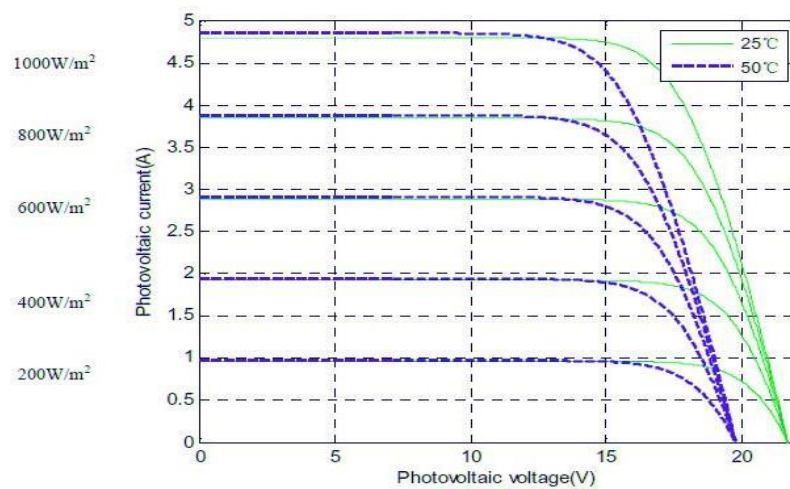
Figure: 1.2(a) Output characteristics of V-I curve at different temperatures.
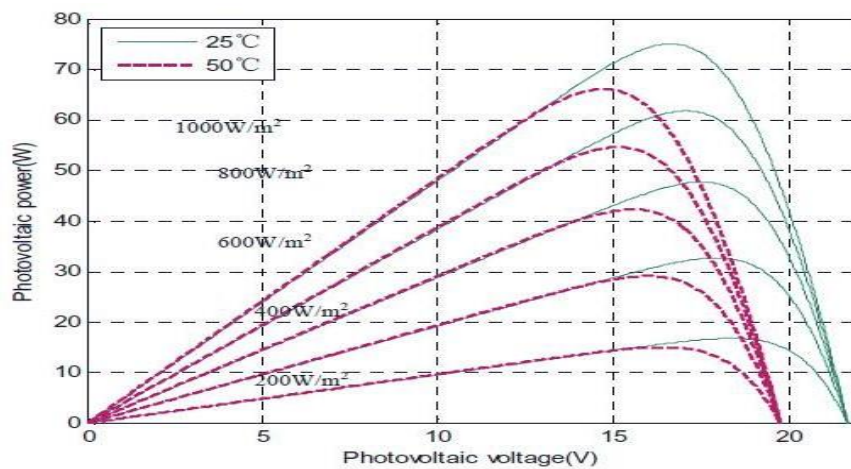
Figure: 1.2(b) Output characteristics of P-V curve at various temperatures.
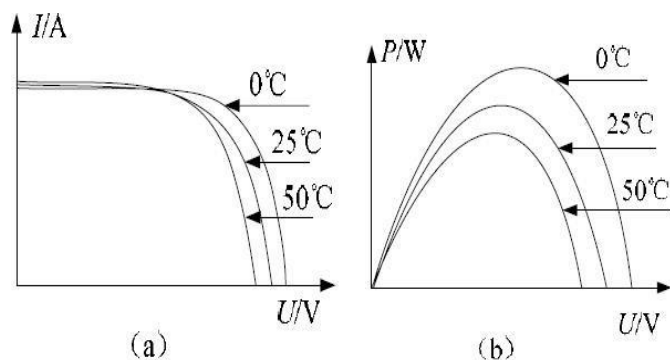
Figure: 1.3 O/P characteristics for various PV cell for dissimilar light intensities: (a) V-I curve at dissimilar light intensities (b) P-V curve for various light intensities.

PHOTOVOLTAIC CELL

A photovoltaic (PV) cell is an energy harvesting technology, that converts solar energy into useful electricity through a process called the photovoltaic effect. There are several different types of PV cells which all use semiconductors to interact with incoming photons from the Sun in order to generate an electric current.

Figure: 1.4 A solar panel, consisting of many photovoltaic cells.

Layers of a photovoltaic cell

A photovoltaic cell is comprised of many layers of materials, each with a specific purpose. The most important layer of a photovoltaic cell is the specially treated semiconductor layer. It is comprised of two distinct layers (p-type and n-type—see Figure 4.3), and is what actually converts the Sun's energy into useful electricity through a process called the photovoltaic effect (see below). On either

side of the semiconductor is a layer of conducting material which "collects" the electricity produced. Note that the backside or shaded side of the cell can afford to be completely covered in the conductor, whereas the front or illuminated side must use the conductors sparingly to avoid blocking too much of the Sun's radiation from reaching the semiconductor. The final layer which is applied only to the illuminated side of the cell is the anti-reflection coating. Since all semiconductors are naturally reflective, reflection loss can be significant. The solution is to use one or several layers of an anti-reflection coating (similar to those used for eyeglasses and cameras) to reduce the amount of solar radiation that is reflected off the surface of the cell.
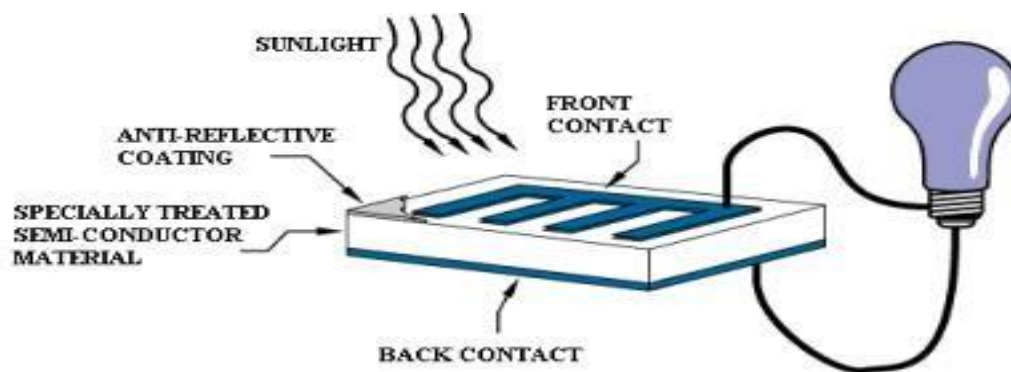
Figure: 1.5 The basic operation of a PV cell.

Photovoltaic Effect

The photovoltaic effect is a process that generates voltage or electric current in a photovoltaic cell when it is exposed to sunlight. These solar cells are composed of two different types of semiconductors—a p-type and an n-type—that are joined together to create a p-n junction. By joining these two types of semiconductors, an electric field is formed in the region of the junction as electrons move to the positive p-side and holes move to the negative n-side. This field causes negatively charged particles to move in one direction and positively charged particles in the other direction. Light is composed of photons, which are simply small bundles of electromagnetic radiation or energy. When light of a suitable wavelength is incident on these cells, energy from the photon is transferred to an electron of the semiconducting material, causing it to jump to a higher energy state known as the conduction band. In their excited state in the conduction band, these electrons are free to move through the material, and it is this motion of the electron that creates an electric current in the cell.
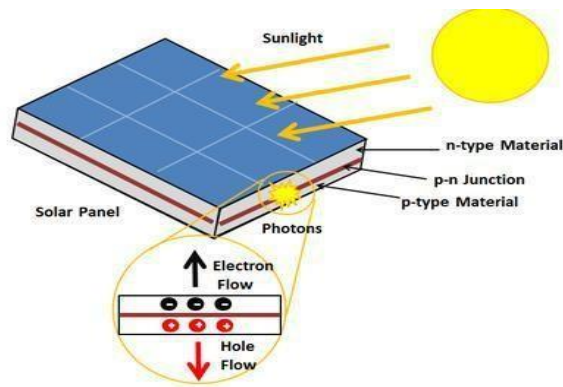
Figure: 1.6 A diagram showing the photovoltaic effect.

Solar cell efficiency

Efficiency is a design concern for photovoltaic cells, as there are many factors that limit their efficiency. The main factor is that 1/4 of the solar energy to the Earth cannot be converted into electricity by a silicon semiconductor. The physics of semiconductors requires a minimum photon energy to remove an electron from a crystal structure, known as the band-gap energy. If a photon has less energy than the band-gap, the photon gets absorbed as thermal energy. For silicon, the band-gap energy is 1.12 electron volts. Since the energy in the photons from the sun cover a wide range of energies, some of the incoming energy from the Sun does not have enough energy to knock off an electron in a silicon PV cell. Even from the light that *can* be absorbed, there is still a problem. Any energy *above* the band-gap energy will be transformed into heat. This also cuts the efficiency because that heat energy is not being used for any useful task. Of the electrons that are made available, not all of them will actually make it to the metal contact and generate electricity. This is because some of them will not be accelerated sufficiently by the voltage inside the semiconductor. Because of the reasons listed, the theoretical efficiency of silicon PV cells is about 33%.

There are ways to improve the efficiency of PV cells, all of which come with an increased cost. Some of these methods include increasing the purity of the semiconductor, using a more efficient semiconducting material such as Gallium Arsenide, by adding additional layers or p-n junctions to the cell, or by concentrating the Sun's energy using concentrated photovoltaic's. On the other hand, PV cells will also degrade, outputting less energy over time, due to a variety of factors including UV exposure and weather cycles. A comprehensive report from the National Renewable Energy Laboratory (NREL) states that the median degradation rate is 0.5% per year.

Types of photovoltaic cells

Photovoltaic cells or PV cells can be manufactured in many different ways and from a variety of different materials. Despite this difference, they all perform the same task of harvesting solar energy and converting it to useful electricity. The most common material for solar panel construction is silicon which has semiconducting properties.[2] Several of these solar cells are required to construct a solar panel and many panels make up a photovoltaic array.

There are three types of PV cell technologies that dominate the world market: mono crystalline silicon, polycrystalline silicon, and thin film. Higher efficiency PV technologies, including gallium arsenide and multi-junction cells, are less common due to their high cost, but are ideal

for use in concentrated photovoltaic systems and space applications.[3] There is also an assortment of emerging PV cell technologies which include Perovskite cells, organic solar cells, dye-sensitized solar cells and quantum dots.

Mono crystalline Silicon Cell

The first commercially available solar cells were made from monocrystalline silicon, which is an extremely pure form of silicon. To produce these, a seed crystal is pulled out of a mass of molten silicon creating a cylindrical ingot with a single, continuous, crystal lattice structure. This crystal is then mechanically sawn into thin wafers, polished and doped to create the required p-n junction. After an anti-reflective coating and the front and rear metal contacts are added, the cell is finally wired and packaged alongside many other cells into a full solar panel.[3] Monocrystalline silicon cells are highly efficient, but their manufacturing process is slow and labour intensive, making them more expensive than their polycrystalline or thin film counterparts.

Polycrystalline silicon cell

Instead of a single uniform crystal structure, polycrystalline (or multicrystalline) cells contain many small grains of crystals (see figure 2). They can be made by simply casting a cube-shaped ingot from molten silicon, then sawn and packaged similar to monocrystalline cells. Another method known as edge-defined film-fed growth (EFG) involves drawing a thin ribbon of polycrystalline silicon from a mass of molten silicon. A cheaper but less efficient alternative, polycrystalline silicon PV cells dominate the world market, representing about 70% of global PV production in 2015.
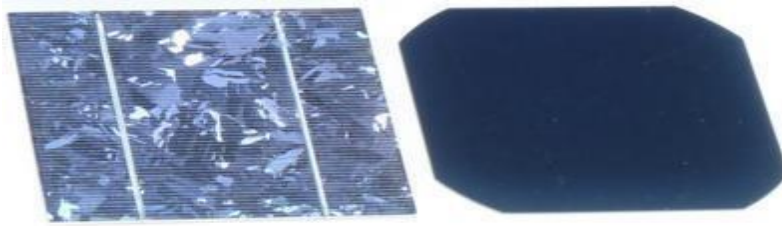
Figure: 1.7 An image comparing a polycrystalline silicon cell (left) and a mono crystalline silicon cell (right).

Thin film cells

Although crystalline PV cells dominate the market, cells can also be made from thin films— making them much more flexible and durable. One type of thin film PV cell is amorphous silicon (a-Si) which is produced by depositing thin layers of silicon on to a glass substrate. The result is a very thin and flexible cell which uses less than 1% of the silicon needed for a crystalline cell. Due to this reduction in raw material and a less energy intensive manufacturing process, amorphous silicon cells are much cheaper to produce. Their efficiency, however, is greatly reduced because the silicon atoms are much less ordered than in their crystalline forms leaving 'dangling bonds' that combine with other elements making them electrically inactive. These cells also suffer from a 20% drop in efficiency within the first few months of operation before stabilizing, and are therefore sold with power ratings based on their degraded output.

Other types of thin film cells include copper indium gallium dieseline (CIGS) and cadmium telluride (CdTe). These cell technologies offer higher efficiencies than amorphous silicon, but contain rare and toxic elements including cadmium which requires extra precautions during manufacture and eventual recycling.

Figure: 1.8 A thin film solar panel composed of non-crystalline silicon deposited on a flexible material.

CHAPTER – 2

MAXIMUM POWER POINT TRACKING (MPPT)

MAXIMUM POWER POINT TRACKING (MPPT)

Maximum power point tracking (MPPT) or sometimes just power point tracking (PPT), is a technique used with sources with variable power to maximize energy extraction under all conditions. The technique is most commonly used with photovoltaic (PV) solar systems, but can also be used with wind turbines, optical power transmission and thermo photo voltaics.

PV solar systems exist in many different configurations with regard to their relationship to inverter systems, external grids, battery banks, or other electrical loads. Regardless of the ultimate destination of the solar power, the central problem addressed by MPPT is that the efficiency of power transfer from the solar cell depends on the amount of sunlight falling on the solar panels, the temperature of the solar panel and the electrical characteristics of the load. As these conditions vary, the load characteristic that gives the highest power transfer efficiency changes. The efficiency of the system is optimized when the load characteristic changes to keep the power transfer at highest efficiency. This load characteristic is called the maximum power point (MPP). MPPT is the process of finding this point and keeping the load characteristic there. Electrical circuits can be designed to present arbitrary loads to the photovoltaic cells and then convert the voltage, current, or frequency to suit other devices or systems, and MPPT solves the problem of choosing the best load to be presented to the cells in order to get the most usable power out.

Solar cells have a complex relationship between temperature and total resistance that produces a non-linear output efficiency which can be analyzed based on the I-V curve.[6][7] It is the purpose of the MPPT system to sample the output of the PV cells and apply the proper resistance (load) to obtain maximum power for any given environmental conditions.[8] MPPT devices are typically integrated into an electric power converter system that provides voltage or current conversion, filtering, and regulation for driving various loads, including power grids, batteries, or motors.

Solar inverters convert the DC power to AC power and may incorporate MPPT: such inverters sample the output power (I-V curve) from the solar modules and apply the proper resistance (load) so as to obtain maximum power.

The power at the MPP (P_{mpp}) is the product of the MPP voltage (V_{mpp}) and MPP current (I_{mpp}).

BACKGROUND

Photovoltaic cells have a complex relationship between their operating environment and the maximum power they can produce. The fill factor, abbreviated FF, is a parameter which characterizes the non-linear electrical behavior of the solar cell. Fill factor is defined as the ratio of the maximum power from the solar cell to the product of open circuit voltage V_{oc} and short-circuit current I_{sc}. In tabulated data it is often used to estimate the maximum power that a cell can provide with an optimal load under given conditions, $P=FF*V_{oc}*I_{sc}$. For most purposes, FF, V_{oc}, and I_{sc} are enough information to give a useful approximate model of the electrical behavior of a photovoltaic cell under typical conditions.
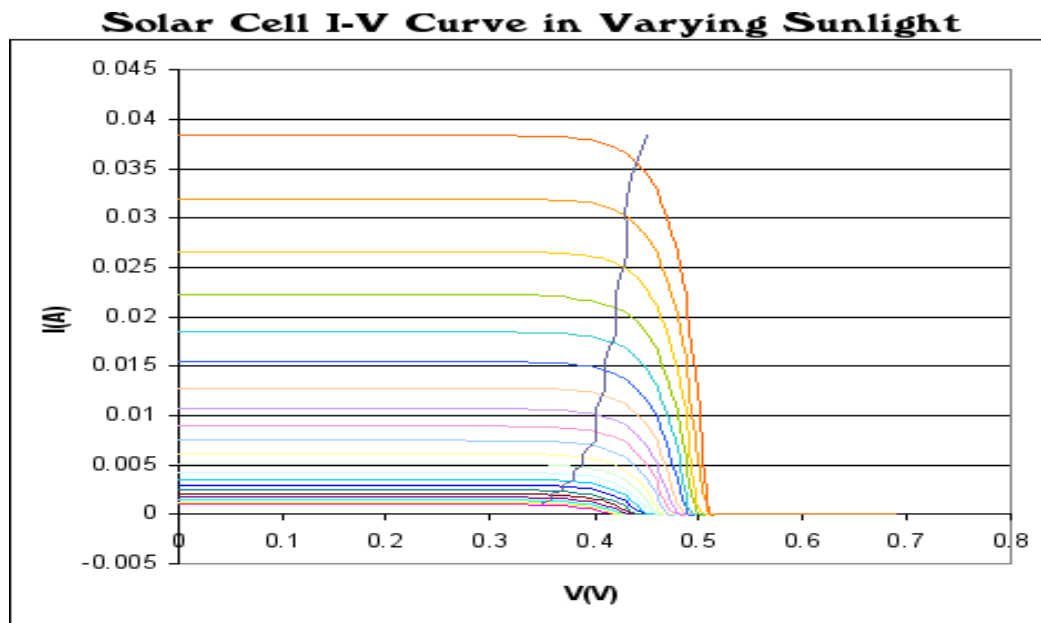
Figure: 2.1 Photovoltaic solar cell I-V curves where a line intersects the knee of the curves where the maximum power transfer points is located.

For any given set of operational conditions, cells have a single operating point where the values of the current (I) and voltage (V) of the cell result in a maximum power output. These values correspond to a particular load resistance, which is equal to V / I as specified by Ohm's law. The power P is given by $P=V*I$. A photovoltaic cell, for the majority of its useful curve, acts as a constant current source.[10] However, at a photovoltaic cell's MPP region, its curve has an approximately inverse exponential relationship between current and voltage. From basic circuit theory, the power delivered from or to a device is optimized where the derivative (graphically, the

slope) dI/dV of the I-V curve is equal and opposite the I/V ratio (where dP/dV=0).[11] This is known as the maximum power point (MPP) and corresponds to the "knee" of the curve.

A load with resistance R=V/I equal to the reciprocal of this value draws the maximum power from the device. This is sometimes called the 'characteristic resistance' of the cell. This is a dynamic quantity which changes depending on the level of illumination, as well as other factors such as temperature and the age of the cell. If the resistance is lower or higher than this value, the power drawn will be less than the maximum available, and thus the cell will not be used as efficiently as it could be. Maximum power point trackers utilize different types of control circuit or logic to search for this point and thus to allow the converter circuit to extract the maximum power available from a cell.
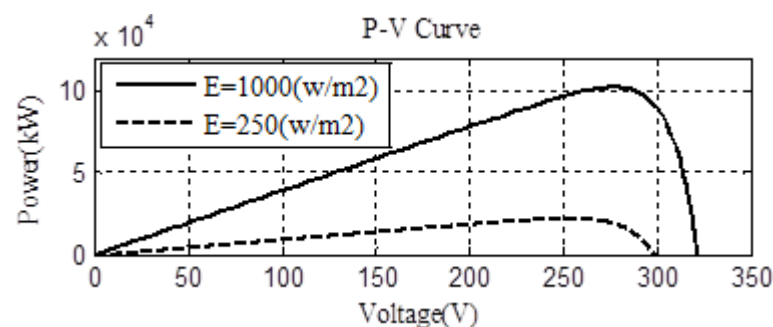
Figure: 2.2 Power – Voltage (P-V) Curve.

CLASIFICATION

Controllers can follow several strategies to optimize the power output of an array. Maximum power point trackers may implement different algorithms and switch between them based on the operating conditions of the array.

Perturb and observe

In this method the controller adjusts the voltage by a small amount from the array and measures power; if the power increases, further adjustments in that direction are tried until power no longer increases. This is called perturb and observe method and is most common, although this method can result in oscillations of power output. It is referred to as a hill climbing method, because it depends on the rise of the curve of power against voltage below the maximum power point, and the fall above that point. Perturb and observe is the most commonly used MPPT method due to its ease of

implementation. Perturb and observe method may result in top-level efficiency, provided that a proper predictive and adaptive hill climbing strategy is adopted.

Current sweep

The current sweep method uses a sweep waveform for the PV array current such that the I-V characteristic of the PV array is obtained and updated at fixed time intervals. The maximum power point voltage can then be computed from the characteristic curve at the same intervals.

Constant voltage

The term "constant voltage" in MPP tracking is used to describe different techniques by different authors, one in which the output voltage is regulated to a constant value under all conditions and one in which the output voltage is regulated based on a constant ratio to the measured open circuit voltage (V_{OC}). The latter technique is referred to in contrast as the "open voltage" method by some authors. If the output voltage is held constant, there is no attempt to track the maximum power point, so it is not a maximum power point tracking technique in a strict sense, though it does have some advantages in cases when the MPP tracking tends to fail, and thus it is sometimes used to supplement an MPPT method. In the "constant voltage" MPPT method (also known as the "open voltage method"), the power delivered to the load is momentarily interrupted and the open-circuit voltage with zero current is measured. The controller then resumes operation with the voltage controlled at a fixed ratio, such as 0.76, of the open-circuit voltage V_{OC}. This is usually a value which has been determined to be the maximum power point, either empirically or based on modelling, for expected operating conditions. The operating point of the PV array is thus kept near the MPP by regulating the array voltage and matching it to the fixed reference voltage $V_{ref} = k V_{OC}$. The value of V_{OC} may be also chosen to give optimal performance relative to other factors as well as the MPP, but the central idea in this technique is that V_{ref} is determined as a ratio to V_{OC}. One of the inherent approximations in the "constant voltage" ratio method is that the ratio of the MPP voltage to V_{OC} is only approximately constant, so it leaves room for further possible optimization.

Temperature method

This method of MPPT estimates the MPP voltage (V_{mpp}) by measuring the temperature of the solar module and comparing it against a reference.[25] Since changes in irradiation levels have a negligible effect on the maximum power point voltage, its influences may be ignored - the voltage is assumed to vary linearly with the temperature changes.

This algorithm calculates the following equation:

$$V_{mpp}(T) = V_{mpp}(T_{ref}) + uV_{mpp}(T - T_{ref})$$

Where:

V_{mpp} is the voltage at the maximum power point for a given temperature;

T_{ref} is a reference temperature;

T is the measured temperature;

uV_{mpp} is the temperature coefficient of V_{mpp} (available in the datasheet).

Advantage

- Simplicity: This algorithm solves one linear equation. Therefore, it does not consume much computational power.

- Can be implemented as an analog or digital circuit.

- Since temperature varies slowly with time, there are no steady-state oscillation and instability.

- Low cost: temperature sensors are usually very cheap.

- Robust against noise.

Disadvantages

- Estimation error might not be negligible for low irradiation levels (e.g. below 200 W/m^2).

COMPARISON OF METHODS

Both perturb and observe, and incremental conductance, are examples of "hill climbing" methods that can find the local maximum of the power curve for the operating condition of the PV array, and so provide a true maximum power point.

The perturb and observe method requires oscillating power output around the maximum power point even under steady state irradiance.

The incremental conductance method has the advantage over the perturb and observe (P&O) method that it can determine the maximum power point without oscillating around this value. It can perform maximum power point tracking under rapidly varying irradiation conditions with higher accuracy than the perturb and observe method. However, the incremental conductance method can produce oscillations (unintentionally) and can perform erratically under rapidly changing atmospheric conditions. The sampling frequency is decreased due to the higher complexity of the algorithm compared to the P&O method.

In the constant voltage ratio (or "open voltage") method, the current from the photovoltaic array must be set to zero momentarily to measure the open circuit voltage and then afterwards set to a predetermined percentage of the measured voltage, usually around 76%. Energy may be wasted during the time the current is set to zero. The approximation of 76% as the V_{MPP}/V_{OC} ratio is not necessarily accurate. Although simple and low-cost to implement, the interruptions reduce array efficiency and do not ensure finding the actual maximum power point. However, efficiencies of some systems may reach above 95%.

MPPT PLACEMENT

Traditional solar inverters perform MPPT for the entire PV array (module association) as a whole. In such systems the same current, dictated by the inverter, flows through all modules in the string (series). Because different modules have different I-V curves and different MPPs (due to manufacturing tolerance, partial shading,[26] etc.) this architecture means some modules will be performing below their MPP, resulting in lower efficiency.[27]

Some companies (see power optimizer) are now placing a maximum power point tracker into individual modules, allowing each to operate at peak efficiency despite uneven shading, soiling or electrical mismatch.

Data suggests having one inverter with one MPPT for a project that has identical number of east and west-facing modules presents no disadvantages when compared to having two inverters or one inverter with more than one MPPT.

OPERATION WITH BATTERIES

At night, an off-grid PV system may use batteries to supply loads. Although the fully charged battery pack voltage may be close to the PV panel's maximum power point voltage, this is unlikely to be true at sunrise when the battery has been partially discharged. Charging may begin at a voltage considerably below the PV panel maximum power point voltage, and an MPPT can resolve this mismatch.

When the batteries in an off-grid system are fully charged and PV production exceeds local loads, an MPPT can no longer operate the panel at its maximum power point as the excess power has no load to absorb it. The MPPT must then shift the PV panel operating point away from the peak power point until production exactly matches demand. (An alternative approach commonly used in spacecraft is to divert surplus PV power into a resistive load, allowing the panel to operate continuously at its peak power point in order to keep the panel cooler as much as possible.

In a grid-connected photovoltaic system, all delivered power from solar modules will be sent to the grid. Therefore, the MPPT in a grid connected PV system will always attempt to operate the PV modules at its maximum power point.

CHAPTER – 3

MPPT METHODS & ALGORITHMS

EXECUTION OF MPPT METHODS & ALGORITHMS

With the clear analysis and discussions in the above section for the current and power characteristics curves, it's oblivious to articulate the PV array is non linear in nature. Thus, an MPPT algorithm obligation to be enacts to vigour the system for constantly manoeuvre the system at the maximum power point (MPP).

As we know huge number of methods has been planned for tracking MPP, as described in the foreword section. Mostly two algorithm methods are implemented to track the MPP, which are acknowledged for their names as P&O technique& IncCond methods. The P&O technique are far and wide practical in MPPT controller for PV cells operation because for their straightforwardness and trouble-free implementation, which limited only to compare two points, as the current manoeuvre point and ensuing perturbation point, subsequently to scrutinize their modifications in power and consequently make a decision whether rise or fall in solar array voltage. The P&O algorithm fluctuates approximately the MPP, ensuing within the failure of PV power, particularly in the condition of hastily altering solar radiation.

Perturbation and Observe (P&O) Method

Perturbation and Observe [9] is also known as Hill Climbing (HC) Method, with the functioning principal by assembly a minute dynamic voltage perturbation in a definite operational voltage of PV cells and haul outthe alter direction of the output power. The perturbation is reserved in the similarway with the increase in the output power, or else unique direction will be complete aligned with the perturbation. Tracking diagram for P&O is appeared in figure 4.
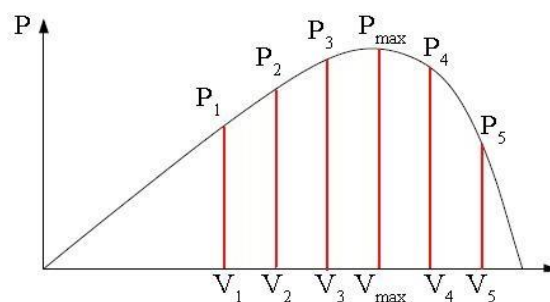
Figure: 3.1 P&O tracking diagram.

In generally there are fixed step and variable in the P&O, due to the reduction of effect of tracking significantly variable P&O is taking into consideration in this paper; as the controller design merelyrequirements one direct loop to diminish the intend obscurity. With the duty cycle (D) the relation for PV and output power (P) in figure 5.
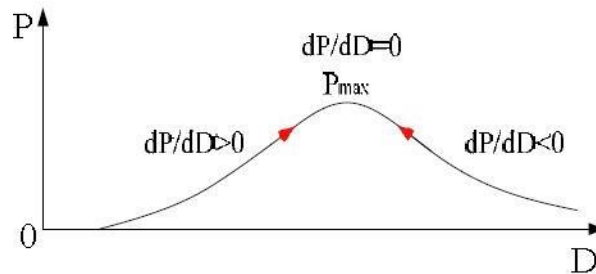
Figure: 3.2 Schematic diagram for P-D relation.

Implementation of Incremental Conductance (IncCond) Algorithm

In this the IncCond method algorithm is implementing on the actuality of that inclination ofpower curve of PV array in figure2 is zero at the MPP, positive on the left of the MPP and negative on the right of MPP.

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$$\frac{\square\square}{\square\square} = \frac{\square\square\square}{\square\square} = \square + \square * \frac{\square\square}{\square\square} \cong \square + \square * \frac{\Delta\square}{\Delta\square}$$

$$\frac{\Delta\square}{\Delta\square} = -\frac{\square}{\square}, \qquad \square\square \ \square\square\square$$

$$\frac{\Delta\square}{\Delta\square} > -\frac{\square}{\square}, \qquad \square\square\square \ \square\square\square\square \ \square\square \ \square\square\square$$

$$\frac{\Delta\square}{\Delta\square} < -\frac{\square}{\square}, \ \square\square\square \ \square\square\square h\square \ \square\square \ \square\square\square \ ....(2)$$

Thus MPP be able to consequently be traced by assessment instant conductance (I/V) to the IncCond ($\frac{\Delta I}{\Delta V}$) as illustrated in equation (2) [6]. Automatically tuned iterative step size is for

the converter duty cycle. The PV power is unswervingly engaged to the duty cycle. V(t) and I(t) are

the output voltages and currents at time interval of K. with the duty cycle (D) and the variation in duty cycle as ΔD correspondingly.

START

$$\Delta I = I(t) - I(t - \Delta t)$$
$$\Delta V = I(t) - I(t - \Delta t)$$

$\Delta V = 0$

$$\frac{\Delta V}{\Delta V} = -\frac{I}{V}$$

$\Delta I = 0$

$$\frac{\Delta V}{\Delta V} \geq -\frac{I}{V}$$

$\Delta I > 0$

Decrease V$_{ref}$

Increase V$_{ref}$

Increase V$_{ref}$

Decrease V$_{ref}$

$$I(t - \Delta t) = I(t)$$
$$V(t - \Delta t) = V(t)$$

STOP
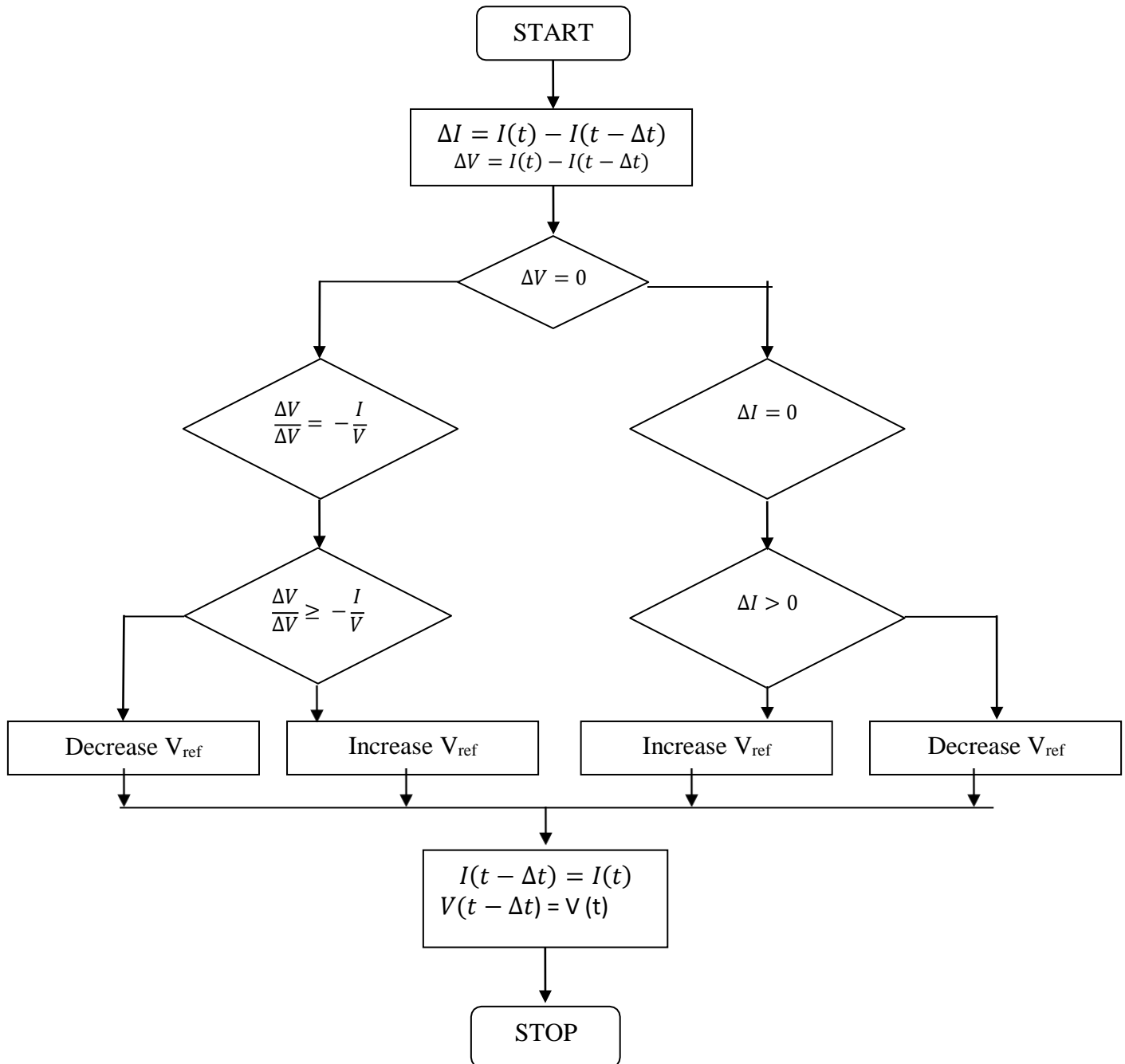
Figure: 3.3 Implementation of (IncCond) Algorithm.

MPPT CONTROLLER

Well in most important section of the whole design, as stated to the theory of the maximum power transfer, MPPT means that the PV generator is for all time made-up to maneuver at utmost output voltage. MPPT controller basically it is a D.C-D.C controller converter, mostly utilized in the PV power systems for a corresponding crossing point among the load and PV Panel. Consequently, basic purpose of a MPPT regulator is to fiddle with the output of the panel voltage in which the utmost energy changes from panel to the load via converter controller power toggle transistor On/Off timings. This happens when the internal impedance of source meets the load impedance then the power supplied to the load will reaches the upper limit [7].

It is necessary to design and implement lofty performance, dependable and low cost converter to avoid the some internal conditions like switching losses, power losses and importantly for the high frequency extraction over an extensive variety of utilizations to convey the utmost power to the load side utilities.

A D.C-D.C converter is utilized to crossing point the PV output to Load (L) and to trace the MPP at PV array. In detailed basic representation is given in the figure 7 generally it had certain topologies of buck-boost, boost, buck, and cuck, etc… Now the circuit is implemented a system by using the boost chopper circuit.
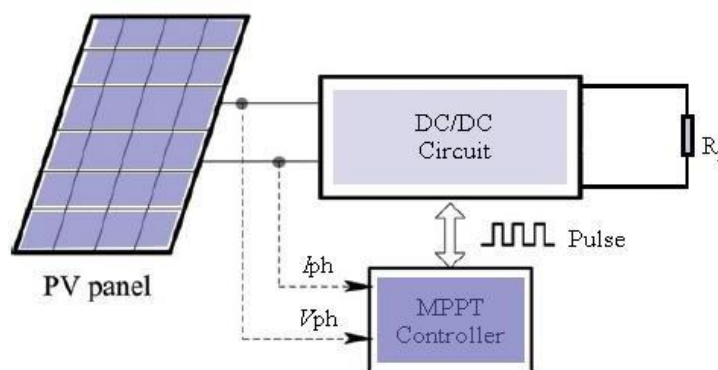
Figure: 3.4 Schematic Diagram Representation of MPPT Controller.

In this controller design part, power MOSFET is for the power switch of the converter. The freewheeling diode is of a rapid switching sort and if we deeply analyze the converter circuit to thwart the core saturations while the ferrite-core is wounded by the inductor L with perfect air gaps

which valor occurred by DC current element value. C1 and C2 are input-output capacitors correspondingly; V_{ph} is voltage and I_{ph} as current of the PV board.

The MPPT controller is combination of 3 sections which are discussed as follows:

Circuits Interfacing

The interfacing of circuits with the comparison of the signal conditioners and sensors which are associated to the micro-controller A-D controller is illustrated in the figure: 9 less than the out voltage of the panel will be sampled by using the Allen Bradley (AB) voltage& current sensor VSM75A &CSM075A, than augmented to the controller by using in service amplifier to the A/D converter of AVR microcontroller.

IC Driver

To generate gate signal for driving the power MOSFET, directly it will be taken from the Ardunio board with using the additional devices which is the great advantage compared to the previous methods and designs.
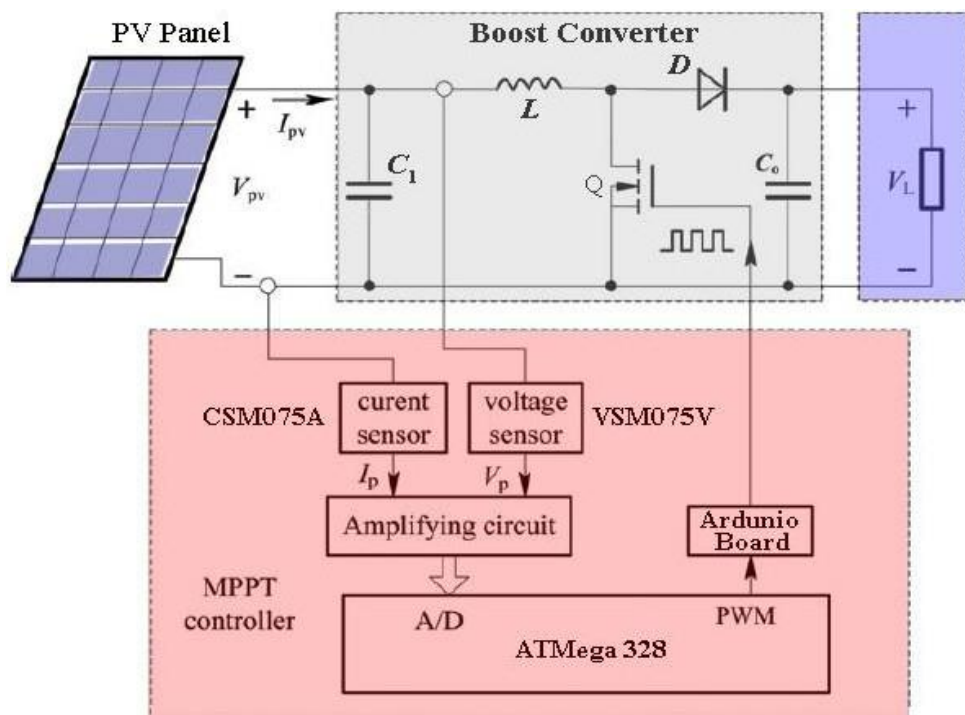
Figure: 3.5 Schematic Diagram of MPPT Controller.

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AT MEGA 328

The ATmega328 is a single-chip microcontroller created by Atmel in the megaAVR family (later Microchip Technology acquired Atmel in 2016). It has a modified Harvard architecture 8-bit RISC processor core. Atmega328 microcontroller is used in basic Arduino boards, i.e., Arduino Uno, Arduino Pro Mini and Arduino Nano.

```
PCINT14/RESET) PC6  [ 1      28 ]  PC5 (ADC5/SCL/PCINT13)
  (PCINT16/RXD) PD0  [ 2      27 ]  PC4 (ADC4/SDA/PCINT12)
  (PCINT17/TXD) PD1  [ 3      26 ]  PC3 (ADC3/PCINT11)
 (PCINT18/INT0) PD2  [ 4      25 ]  PC2 (ADC2/PCINT10)
(PCINT19/OC2B/INT1) PD3 [ 5   24 ]  PC1 (ADC1/PCINT9)
 (PCINT20/XCK/T0) PD4 [ 6     23 ]  PC0 (ADC0/PCINT8)
               Vcc  [ 7ATmega 22 ] GND
               GND  [ 8 28PDIP 21 ] AREF
(PCINT6/XTAL1/TOSC1) PB6 [ 9  20 ]  AVCC
(PCINT7/XTAL2/TOSC2) PB7 [ 10 19 ]  PB5 (SCK/PCINT5)
 (PCINT21/OC0B/T1) PD5 [ 11  18 ]  PB4 (MISO/PCINT4)
(PCINT22/OC0A/AIN0) PD6 [ 12 17 ]  PB3 (MOSI/OC2A/PCINT3)
  (PCINT23/AIN1) PD7 [ 13   16 ]  PB2 (SS/OC1B/PCINT2)
(PCINT0/CLKO/ICP1) PB0 [ 14  15 ]  PB1 (OC1A/PCINT1)
```

Figure: 3.6 Pin diagram.

Introduction to ATmega328

- ATmega328 is an 8-bit, 28-Pin AVR Microcontroller, manufactured by Microchip, follows RISC Architecture and has a flash-type program memory of 32KB.

- Atmega328 is the microcontroller, used in basic Arduino boards i.e Arduino UNO, Arduino Pro Mini and Arduino Nano.

- It has an EEPROM memory of 1KB and its SRAM memory is 2KB.

- It has 8 Pins for ADC operations, which all combine to form PortA (PA0 - PA7).

- It also has 3 built-in Timers, two of them are 8 Bit timers while the third one is 16-Bit Timer.

- You must have heard of Arduino UNO, UNO is based on atmega328 Microcontroller. It's UNO's heart. :)

- It operates ranging from 3.3V to 5.5V but normally we use 5V as a standard.

- Its excellent features include cost-efficiency, low power dissipation, programming lock for security purposes, real timer counter with separate oscillator.

- It's normally used in Embedded Systems applications. You should have a look at these Real Life Examples of Embedded Systems, we can design all of them using this Microcontroller.

AVR's ATmega328

It is a single chip based micro-controller designed by the Atmel in mega AVR family, latter on modified in 2016. It contains a customized Harvard architecture with 8-bit RISC processor core.

Atmel 8-bit AVR RISC operated micro-controller consists of flash memory with read and write feature capability of 32KB ISP. 1KB EEPROM, 2KB S-RAM, 23 general purpose input-output lines, 32 general purpose working registers, 3 flexible timer/counters with parallel modes, programmable watchdog timer with internal oscillator, interior and peripheral interrupts, a byte-oriented 2-wire serial inter face, serial programmable USART, SPI serial port, 6-channel 10-bit A-D converter (8-channels in QFN/MLF and TQFP packages), and 5-software selectable power convertible modes. The scheme works between 1.8-5.5 volts. The device achieves data approaching 1 MIPS per MHz's as the internal circuit of AT Mega 328 is appeared in figure 8.
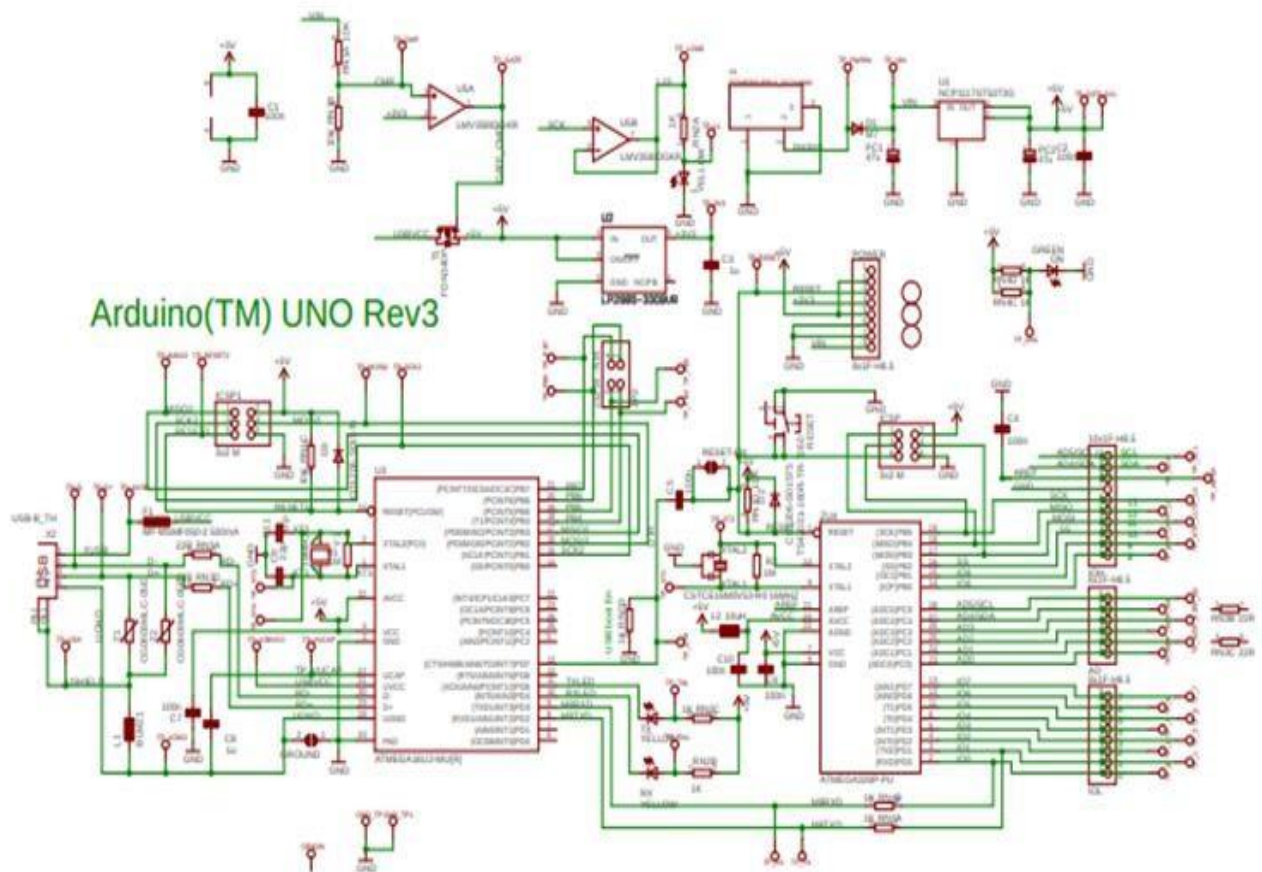
Figure: 3.7 Internal circuit architecture of ATMEGA 328.

SPCIFICATIONS

The Atmel 8-bit AVR RISC-based microcontroller combines 32 KB ISP flash memory with read-while-write capabilities, 1 KB EEPROM, 2 KB SRAM, 23 general-purpose I/O lines, 32 general-purpose working registers, 3 flexible timer/counters with compare modes, internal and external interrupts, serial programmable USART, a byte-oriented 2-wire serial interface, SPI serial port, 6-channel 10-bit A/D converter (8 channels in TQFP and QFN/MLF packages), programmable watchdog timer with internal oscillator, and 5 software-selectable power-saving modes. The device operates between 1.8 and 5.5 volts. The device achieves throughput approaching 1 MIPS/MHz.

FEATURES

Parameters	values
CPU Type	8-bit AVR
Maximum CPU speed	20MHZ
Performance	20MIPS at 20MHZ
Flash Memory	32KB
SRAM	2KB
EEPROM	1KB
Package pin count	28 OR 32
Capacitive touch sensing channels	16
Maximum input output pins	23
External interrupts	2
USB interface	NO

FAMILY

A common alternative to the ATmega328 is the "Pico Power" ATmega328P. A comprehensive list of all other members of the mega AVR series can be found on the Atmel website.

- ATmega328

- ATmega328P and ATmega328P-AUTOMOTIVE

- ATmega328PB and ATmega328PB-AUTOMOTIVE (superset of ATmega328P) - has more UART, I2C, and SPI peripherals than ATmega328P

APPLICATIONS

ATmega328 is commonly used in many projects and autonomous systems where a simple, low-powered, low-cost micro-controller is needed. Perhaps the most common implementation of this chip is on the popular Arduino development platform, namely the Arduino Uno and Arduino Nano models.

ARCHITECTURE OF ATmega328

Here Architecture is of Arduino or precisely the IC of Arduino (ATmega328p). The ATmega328/P is a low-power CMOS 8-bit microcontroller based on the **AVR** enhanced **RISC** (reduced instruction set computer) architecture. In Order to maximize performance and parallelism, the AVR uses Harvard architecture – with separate memories and buses for program and data. Instructions in the program memory are executed with a single level of pipeline. The clock is controlled by an external 16MHz Crystal Oscillator.

The basic working of CPU of ATmega328

1. The data is uploaded in serial via the port (being uploaded from the computer's Arduino IDE). The data is decoded and then the instructions are sent to instruction register and it decodes the instructions on the same clock pulse.

On the next clock pulse the next set of instructions are loaded in instruction register. In general purpose registers the registers are of 8-bit but there are 3 16-bit registers also. 8-bit registers are used to store data for normal calculations and results. 16-bit registers are used to store data of timer counter in 2 different register. Eg. X-low & X-high. They are fast, and are used to store specific hardware functions.

EEPROM stores data permanently even if the power is cut out. Programming inside a EEPROM isslow.

Interrupt Unit checks whether there is an interrupt for the execution of instruction to be executed in ISR (Interrupt Service Routine).

Serial Peripheral Interface (SPI) is an interface bus commonly used to send data between microcontrollers and small peripherals such as Camera, Display, SD cards, etc. It uses separate clock and data lines, along with a select line to choose the device you wish to talk to. Watchdog timer is used to detect and recover from MCU malfunctioning.

Analog comparator compares the input values on the positive and negative pin, when the value of positive pin is higher the output is set**.** Status and control is used to control the flow of execution of commands by checking other blocks inside the CPU at regular intervals.

ALU (Arithmetic and Logical unit) The high performance AVR ALU operates in direct connection with all the 32 general purpose working registers. Within a single clock cycle, arithmetic operations b/w general purpose registers are executed. The ALU operations are divided into 3 main categories – arithmetic, logical and bit-function.

I/O pins The digital inputs and outputs (digital I/O) on the Arduino are what allow you to connect the Arduino sensors, actuators, and other ICs. Learning how to use them will allow you to use the Arduino to do some really useful things, such as reading switch inputs, lighting indicators, and controlling relay outputs.
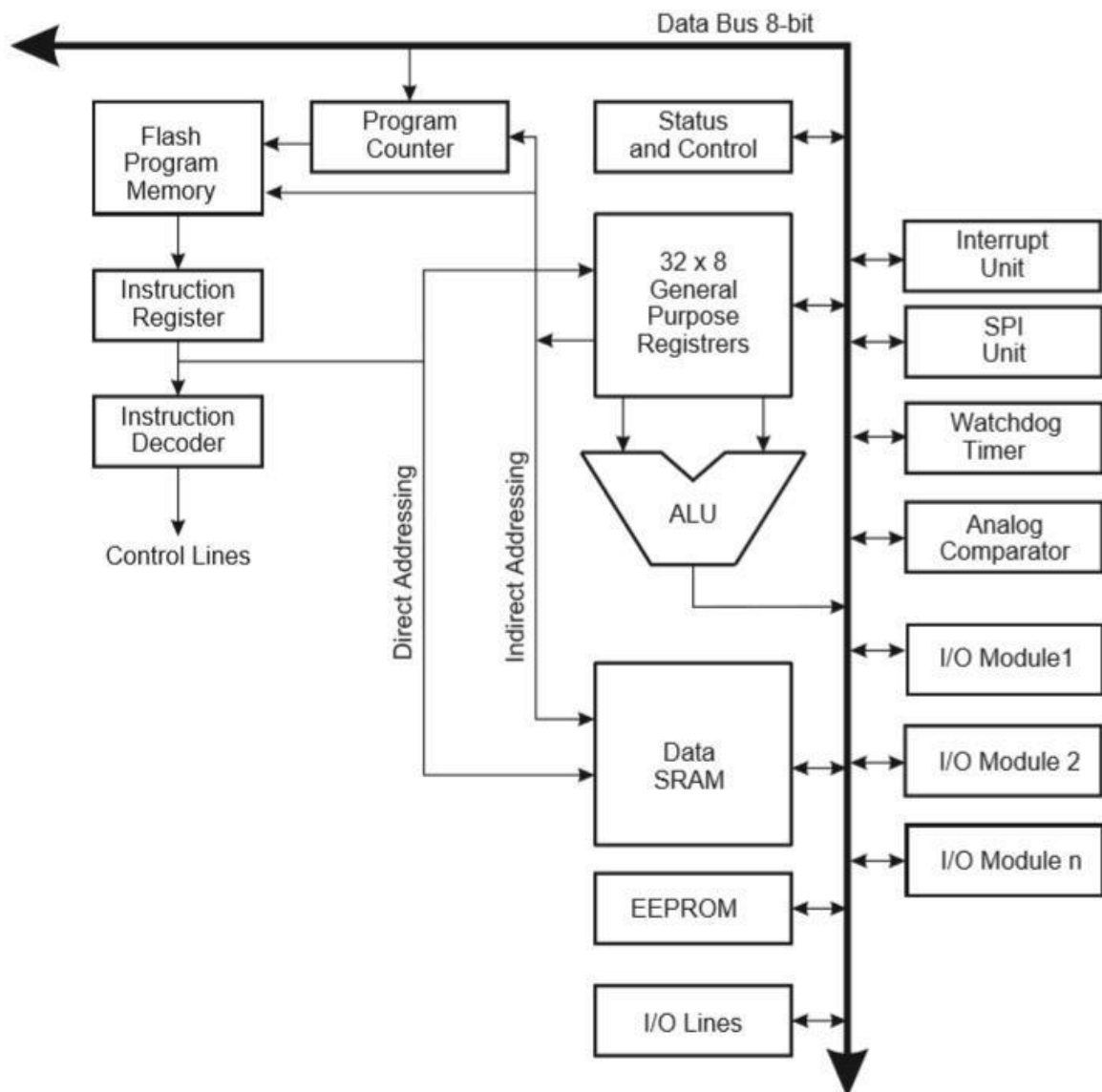
Figure: 3.8 Architecture of ATmega328.

CHAPTER-4

PULSE WIDTH MODULATION

TECHNIQUES

4.1. PULSE WIDTH MODULATION

Pulse-width modulation (PWM), or pulse-duration modulation (PDM), is a method of reducing the average power delivered by an electrical signal, by effectively chopping it up into discrete parts. The average value of voltage (and current) fed to the load is controlled by turning the switch between supply and load on and off at a fast rate. The longer the switch is on compared to the off periods, the higher the total power supplied to the load. Along with maximum power point tracking (MPPT), it is one of the primary methods of reducing the output of solar panels to that which can be utilized by a battery.[1] PWM is particularly suited for running inertial loads such as motors, which are not as easily affected by this discrete switching, because their inertia causes them to react slowly. The PWM switching frequency has to be high enough not to affect the load, which is to say that the resultant waveform perceived by the load must be as smooth as possible.

The rate (or frequency) at which the power supply must switch can vary greatly depending on load and application. For example, switching has to be done several times a minute in an electric stove; 100 or 120 Hz (double of the utility frequency) in a lamp dimmer; between a few kilohertz (kHz) and tens of kHz for a motor drive; and well into the tens or hundreds of kHz in audio amplifiers and computer power supplies. The main advantage of PWM is that power loss in the switching devices is very low. When a switch is off there is practically no current, and when it is on and power is being transferred to the load, there is almost no voltage drop across the switch. Power loss, being the product of voltage and current, is thus in both cases close to zero. PWM also works well with digital controls, which, because of their on/off nature, can easily set the needed duty cycle. PWM has also been used in certain communication systems where its duty cycle has been used to convey information over a communications channel.

In electronics, many modern microcontrollers (MCUs) integrate PWM controllers exposed to external pins as peripheral devices under firmware control by means of internal programming interfaces. These are commonly used for direct current (DC) motor control in robotics and other applications.
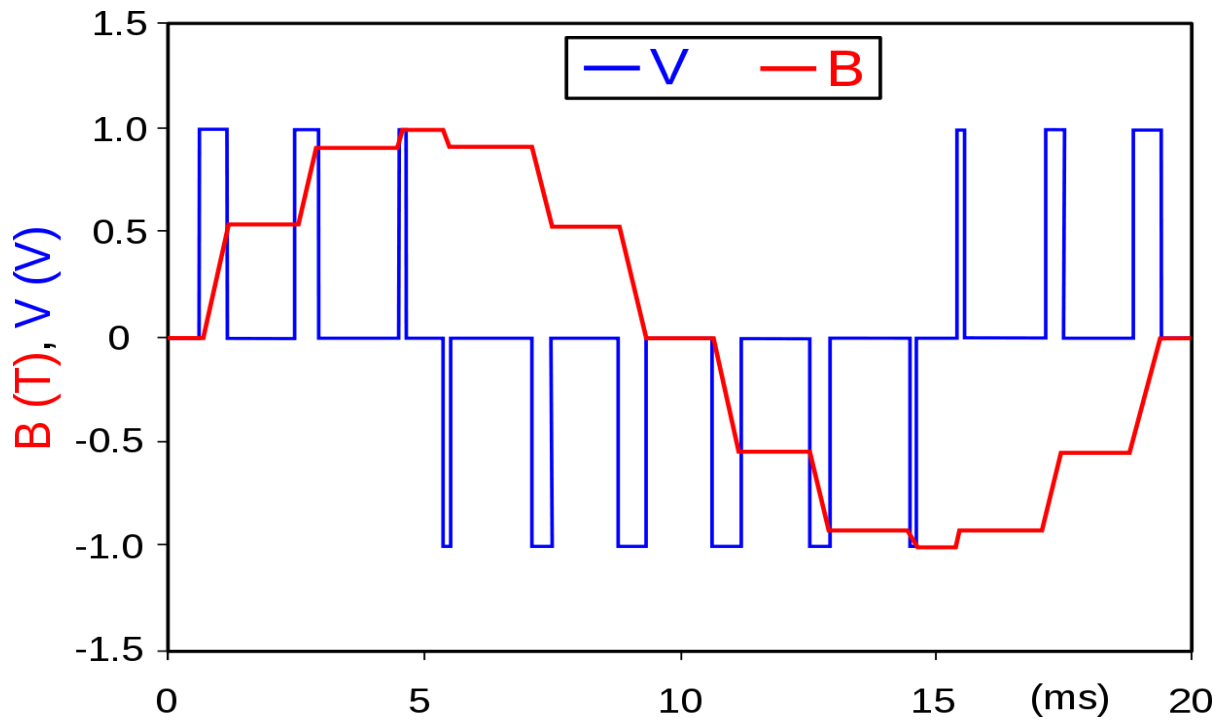
Figure: 4.1 Pulse Width Modulations.

An example of PWM in an idealized inductor driven by a voltage source modulated as a series of pulses, resulting in a sine-like current in the inductor. The rectangular voltage pulses nonetheless result in a more and more smooth current waveform, as switching frequency increases. Note that the current waveform is the integral of the voltage waveform.

PRICNIPLE

Pulse-width modulation uses a rectangular pulse wave whose pulse width is modulated resulting in the variation of the average value of the waveform. If we consider a pulse waveform f(t), with period T, low value y_{min}, a high value y_{max} and a duty cycle D (see figure:4.2), The average value of the waveform is given by:

$$y = 1/T \int_0^{\square} \square(\square)\square\square$$

As f(t) is a pulse wave, its value is y_{max} for $0 \leq t \leq D.T$ and y_{min} for $D.T \leq t \leq T$. The above expression then becomes:
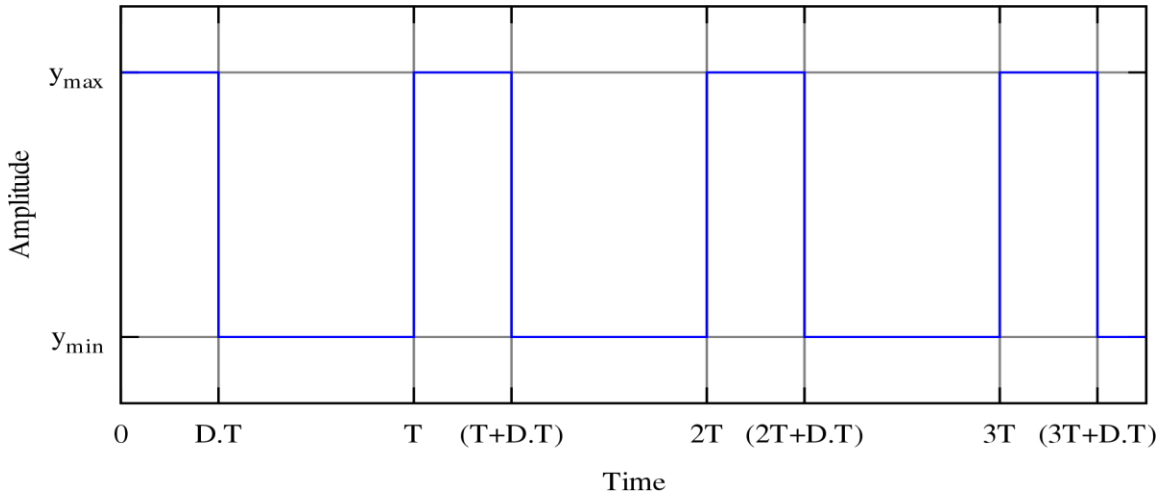
Figure: 4.2 A pulse wave showing the definitions of y_{max} y_{min} and D.

$$y = 1/T \ (\int_0^{\square\square} Ymax \ \square\square \ + \ \int_{\square\square}^{\square} Ymin \ \square\square)$$

$$= 1/T(D.T \ y_{max} + T(1-D) \ y_{min})$$

$$= D. \ y_{max} + (1-D) \ y_{min}$$

This latter expression can be fairly simplified in many cases where $y_{min} = 0$ as $y = D. \ y_{max}$. From this, the average value of the signal (y) is directly dependent on the duty cycle D.
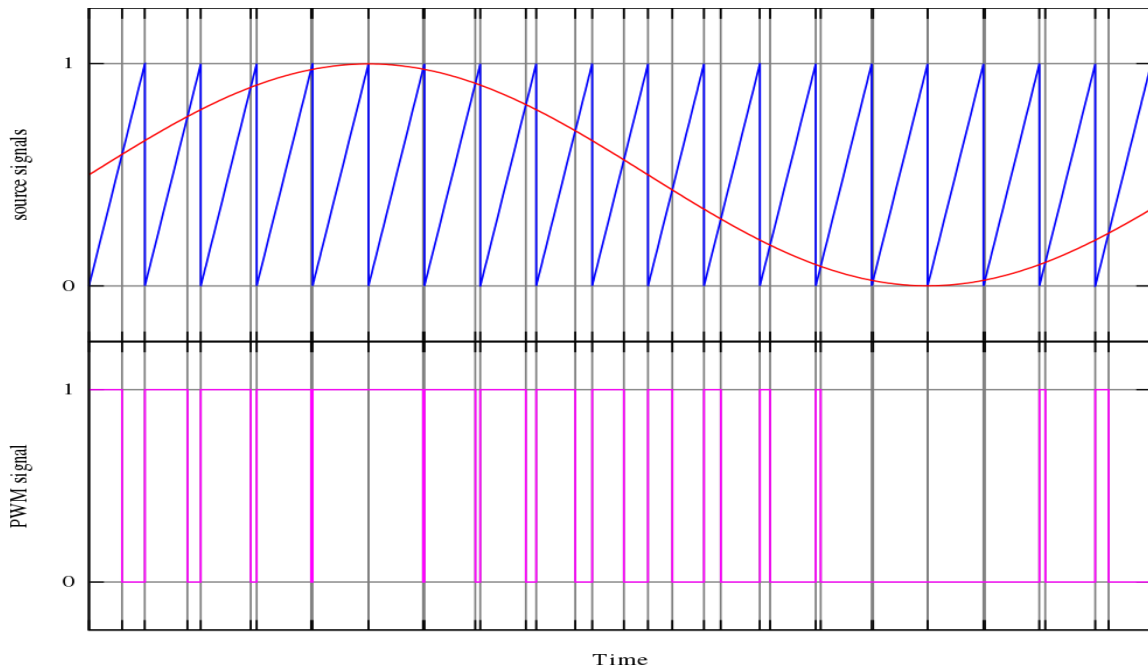
Figure: 4.3 A simple method to generate the pwm pulse train corresponding to a given signal is the interceptive PWM.

The simplest way to generate a PWM signal is the interceptive method, which requires only a saw tooth or a triangle waveform (easily generated using a simple oscillator) and a comparator. When the value of the reference signal (the red sine wave in figure) is more than the modulation waveform (blue), the PWM signal (magenta) is in the high state, otherwise it is in the low state.

DELTA MODULATION

In the use of delta modulation for PWM control, the output signal is integrated, and the result is compared with limits, which correspond to a Reference signal offset by a constant. Every time the integral of the output signal reaches one of the limits, the PWM signal changes state. Figure 4.4
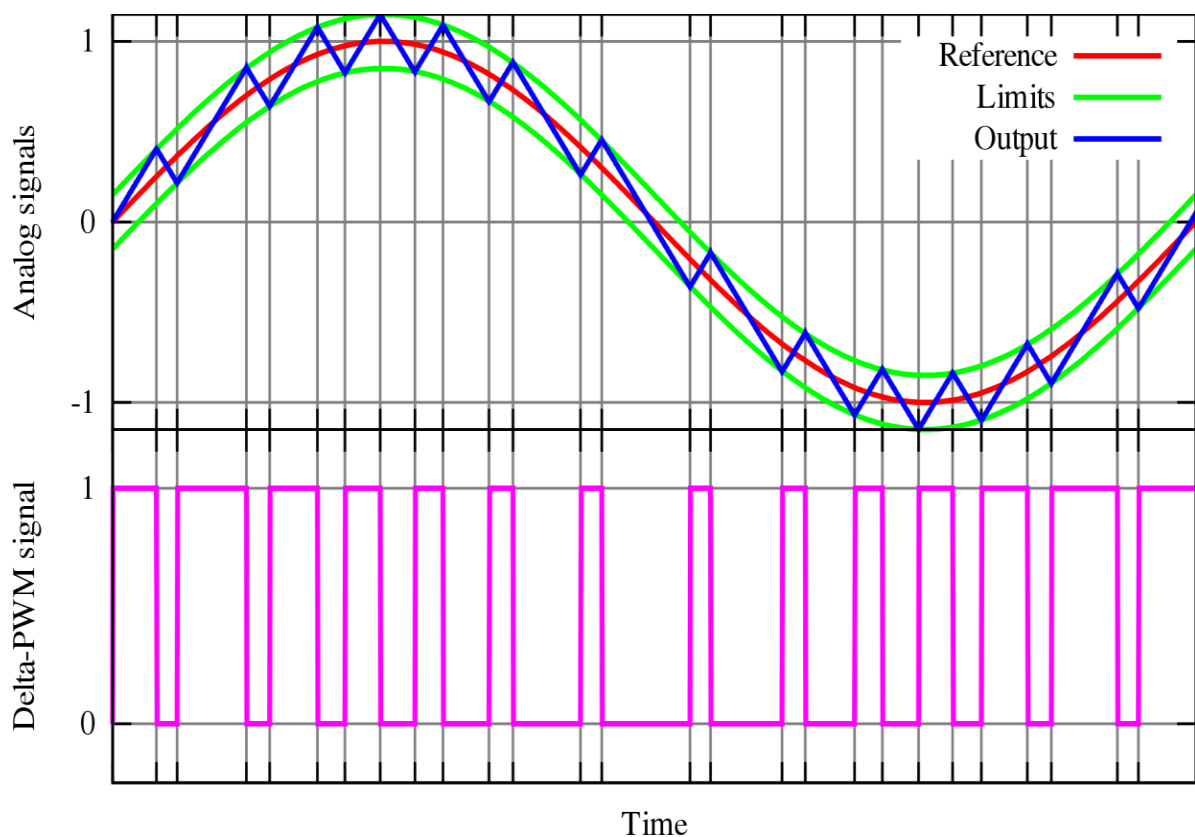
Figure: 4.4 Principle of the delta PWM.

The output signal (blue) is compared with the limits (green). These limits corresponding to the reference signal (red). Offset by a given value. Every time the output signal (blue) reaches one of thr limits, the PWM signal changes state.

DELTA-SIGMA **MODULATION**

In delta-sigma modulation as a PWM control method, the output signal is subtracted from a reference signal to form an error signal. This error is integrated, and when the integral of the error exceeds the limits, the output changes state. Figure
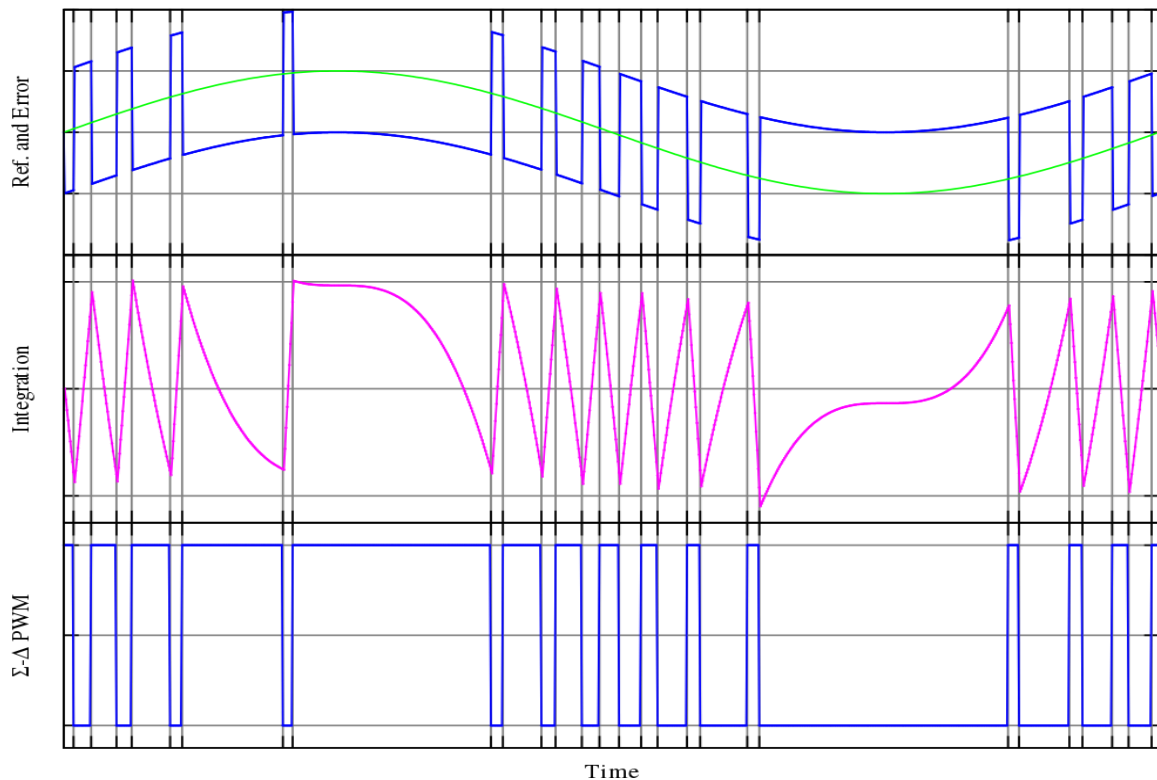
Figure: 4.5 Principle of the sigma – delta PWM.

The top green waveform is the reference signal, on which the output signal (PWM, in the bottom plot) is subscribed to from the error signal (blue, in top plot). This error is integrated (middle plot), and when the integral of the error exceeds the limits(red lines). The output changes state.

SPACE VECTOR MODULATION

Space vector modulation is a PWM control algorithm for multi-phase AC generation, in which the reference signal is sampled regularly; after each sample, non-zero active switching vectors adjacent to the reference vector and one or more of the zero switching vectors are selected for the appropriate fraction of the sampling period in order to synthesize the reference signal as the average of the used vectors.

DIRECT TORQUE CONTROL (DTC)

Direct torque control is a method used to control AC motors. It is closely related with the delta modulation (see above). Motor torque and magnetic flux are estimated and these are controlled to stay within their hysteresis bands by turning on a new combination of the device's semiconductor switches each time either signal tries to deviate out of its band.

Time proportioning

Many digital circuits can generate PWM signals (e.g., many microcontrollers have PWM outputs). They normally use a counter that increments periodically (it is connected directly or indirectly to the clock of the circuit) and is reset at the end of every period of the PWM. When the counter value is more than the reference value, the PWM output changes state from high to low (or low to high). This technique is referred to as time proportioning, particularly as time-proportioning control – which proportion of a fixed cycle time is spent in the high state.

The incremented and periodically reset counter is the discrete version of the intersecting method's sawtooth. The analog comparator of the intersecting method becomes a simple integer comparison between the current counter value and the digital (possibly digitized) reference value. The duty cycle can only be varied in discrete steps, as a function of the counter resolution. However, a high-resolution counter can provide quite satisfactory performance.

SPECTRUM

The resulting spectra (of the three cases) are similar, and each contains a dc component—a base sideband containing the modulating signal and phase modulated carriers at each harmonic of the frequency of the pulse. The amplitudes of the harmonic groups are restricted by a $\sin x / x$ envelope (sinc function) and extend to infinity. The infinite bandwidth is caused by the nonlinear operation of the pulse-width modulator. In consequence, a digital PWM suffers from aliasing distortion that significantly reduce its applicability for modern communications system. By limiting the bandwidth of the PWM kernel, aliasing effects can be avoided.

On the contrary, the delta modulation is a random process that produces continuous spectrum without distinct harmonics.

PWM SAMPLING THEOREM

The process of PWM conversion is non-linear and it is generally supposed that low pass filter signal recovery is imperfect for PWM. The PWM sampling theorem[7] shows that PWM conversion can be perfect. The theorem states that "Any bandlimited baseband signal within ±0.637 can be represented

by a pulsewidth modulation (PWM) waveform with unit amplitude. The number of pulses in the waveform is equal to the number of Nyquist samples and the peak constraint is independent of whether the waveform is two-level or three-level."

Nyquist-Shannon Sampling Theorem: "If you have a signal that is perfectly band limited to a bandwidth of f_0 then you can collect all the information there is in that signal by sampling it at discrete times, as long as your sample rate is greater than $2f_0$.

PWM TECHNIQUES

Single pulse width modulation technique

Used for single-phase circuits. Changing the width of the pulse to control the on-time or to control the gate signal of a transistor so that the output voltage of the inverter can be controlled. By changing the width or by changing the width of the courier signal we can definitely change the on-time of the transistor. As we vary the time of the transistor we can vary the inverter output voltage. So, if the width of the gate pulse that we are getting as an output or comparator after pulse width modulation is the width of the output voltage will be getting is d.

Third harmonic injection pulse width modulation

The third harmonic voltage is not present on the phase voltages and the line to line for a three-phase load with a neutral point which is of floating-point type. Hence, it does not causes any distortion on the phase voltages. By adding a third harmonic signal in a low-frequency sinusoidal reference signal, we can get the amplitude increase in output voltage waveform.

Multiple pulse width modulation

Multiple pulse width modulation consists of multiple numbers of pulses per half cycle of the output voltage. Each pulse can be varied by the carrier signal. The frequency of the triangular wave is greater than that used in single pulse width modulation and it decides the number of gating signals per half cycle. By using multiple pulses, the harmonic content can be reduced. The frequency decides the number of pulses per half cycle. The output voltage can be controlled by controlling the modulation index.

Sinusoidal pulse width modulation

It indicates that the generation of outputs of the pulse width modulation with a sine wave as the modulating signal. The switching time of a PWM signal can be obtained by comparing a reference sinusoidal wave with a triangular wave of high frequency. This type of pulse width modulation is widely used in industrial applications. The RMS value of the output voltage can be varied by varying the modulation index. This technique improves the distortion factor and eliminates all harmonics less than or equal to 2p-1. By using a filter we can easily remove the higher-order harmonics.

Hysteresis band pulse width modulation

In this technique, the output is free to oscillate within the predefined error band known as the hysteresis band. The switching frequency of power devices is not fixed constantly and will change depending upon the magnitude and frequency of the reference signal. The main benefit of this control scheme is its ability to respond rapidly to load and line transients.

Space vector pulse width modulation

Space vector PW modulation (SVPWM) is an algorithm for the control of pulse width modulation (PWM). It is employed for the creation of alternating current (AC) waveforms; it is most commonly to drive 3 phase AC powered motors at varying speeds from DC using multiple class-D amplifiers. The harmonic present at the output is decreased and hence this vector modulation method offers an optimal output current or voltage.

CONVENTIONAL MULTILEVEL INVERTER

Based on modulating signals

Multilevel SPWM techniques can also be classified based on the nature of modulating signal as given below:

Pure sinusoidal PWM

It is the most widely accepted PWM technique which compares pure sinusoidal voltage signal with the triangular carrier wave to generate control pulses as shown in Fig.13
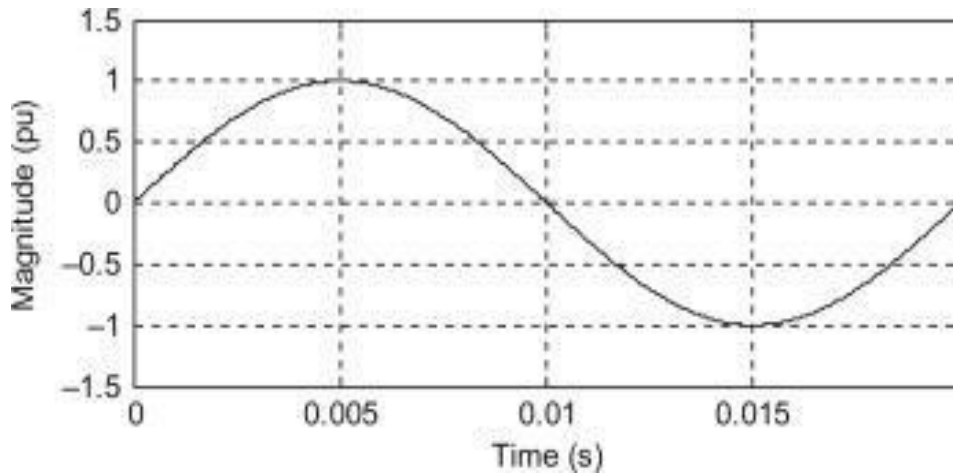
Figure: 4.6 Modulating signal with pure sinusoidal PWM technique.

Third harmonic injection PWM

By adding the third harmonic component to the fundamental component, the gain of the modulator can be increased. The amount of gain increase depends on magnitude of third harmonic content. It is observed that injecting 17% of third harmonics into reference modulating wave yield approximately 15% increase in gain over the pure SPWM technique before going into over-modulation as shown in Fig.
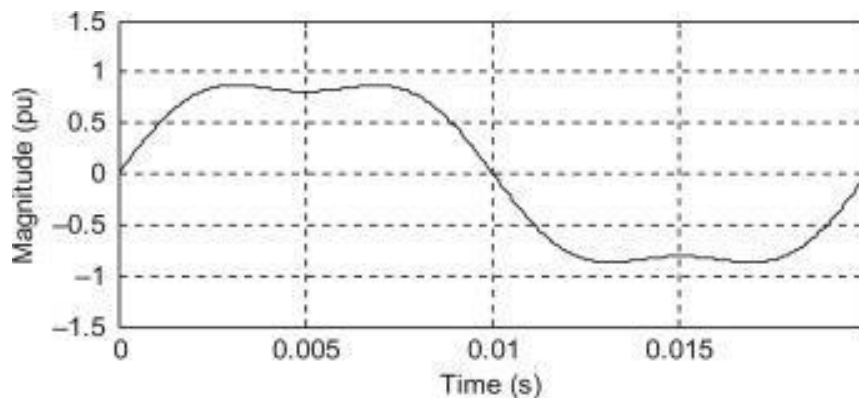
Figure: 4.7 Modulating signal with third harmonic injection sinusoidal PWM technique.

Control pulse generation in switching frequency optimal SPWM technique

The concept of SFO SPWM technique was proposed by Steinke [13]. Fig. 3.20(A) and (B) shows the carrier signals and modulating wave for conventional SPWM and SFO-SPWM technique for five-level inverter with amplitude modulation index $m_f=21$ and frequency modulation index $m_a=0.8$. It clearly shows that the intersection points of carrier signals and modulating signals are different for

each case. Thus by appropriate selection of carrier signals and off-set signals, inverter switching losses can be controlled.
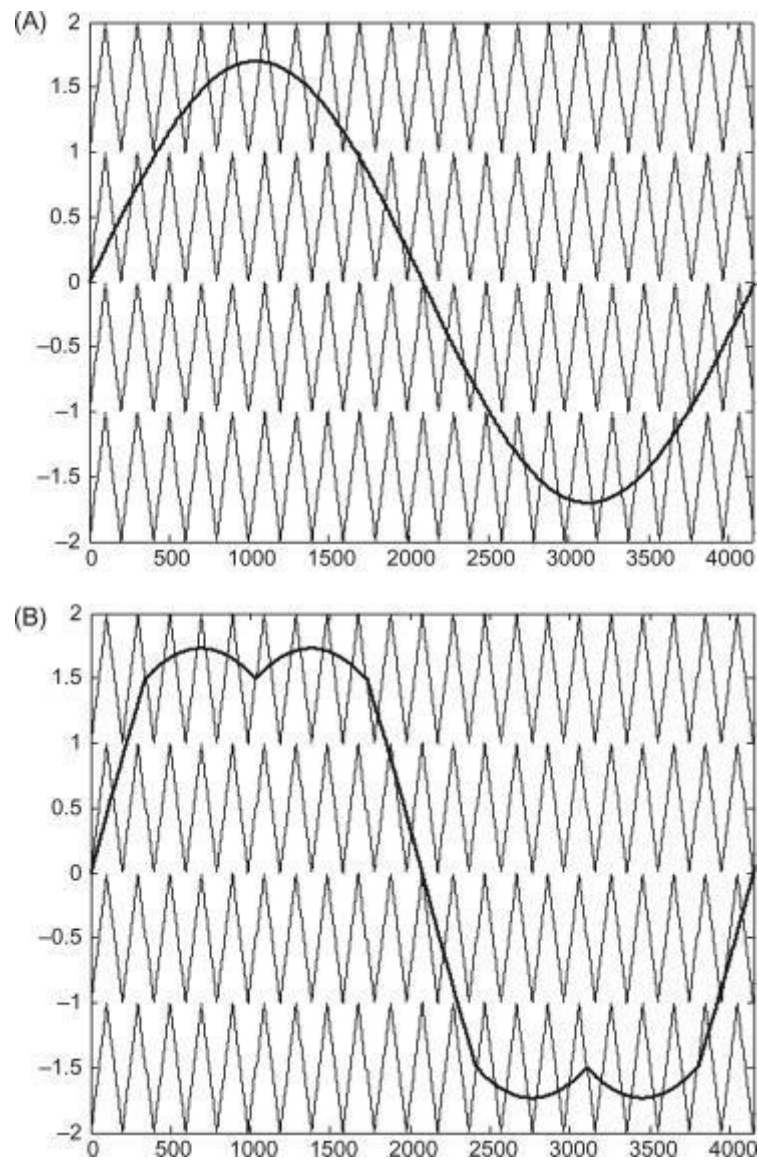
Figure: 4.8 Multilevel carrier-based (A) SPWM and (B) SFO-SPWM, showing carrier signals and modulating signals for five-level inverter.

CHAPTER-5

IMPLEMENTAION OF SIMULINK MODELS

5.1 SIMULATION RESULTS & PONDERING

In this study, we are considering the 4 solar cells with voltage rating of 3volt each which are connected in series which assigned to boost converter which gives 123V at the output through the converter. Assurance of maximum power tracking, while the solar cell of each had open circuit voltage of 3 volts as Voc and (irradiance used for the measurement is 1000W/m^2,module temperature of 25°C, AM = 1.5),inductance of the boost converter 100μH. The input capacitance C_1 as 1000 microfarads and the resistor value of 100Ω. In this context, the anticipated organize technique is functional PV system to track the MPP. In while time likewise to the above design the PWM specified by the controller of MPPT whilst the equipped changes occurs. On the behalf of the unreliable the PWM of the duty ratio, while PV array is ambitious to a novel MPP by identical the internal resistance load demand of the PV array.

For the corroboration of efficacy of the anticipated InCond MPPT control algorithm is illustrated in the figure 7, the PV power system is appeared in the figure 10 is the design modelled and simulated in the MATLAB/Simulink environment. Furthermore P&O algorithm is implemented, while the simulation is done for the P&O also with the same configuration parameters for the comparative study.
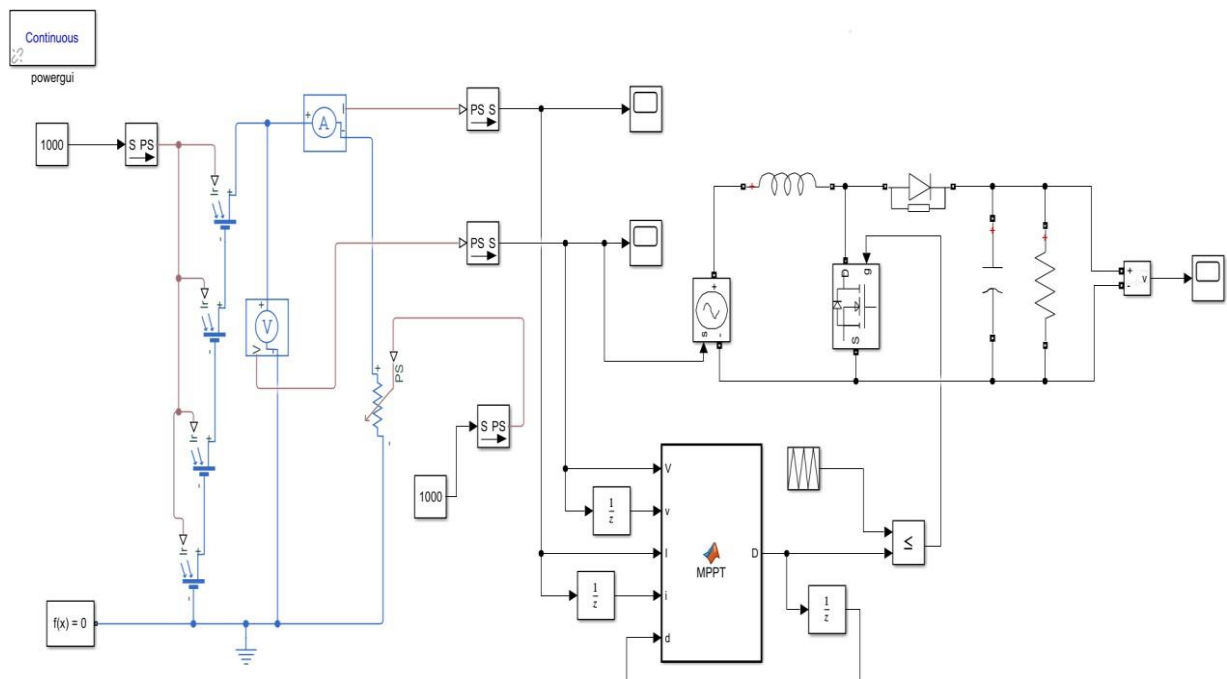
Figure: 5.1 Simulink implementation for IncCond Method.
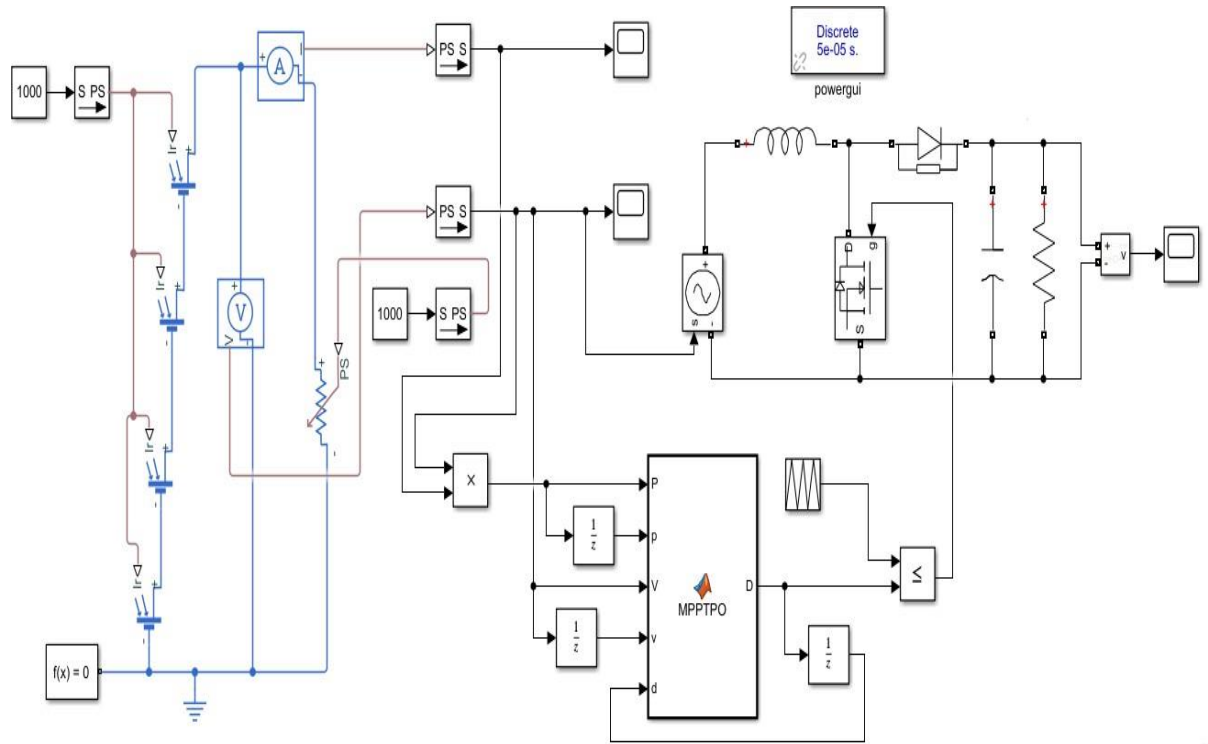
Figure: 5.2 Simulink implementation for P&O Method.

CHAPTER-6

MATLAB/SIMULINK RESULTS

6.1 RESULTS
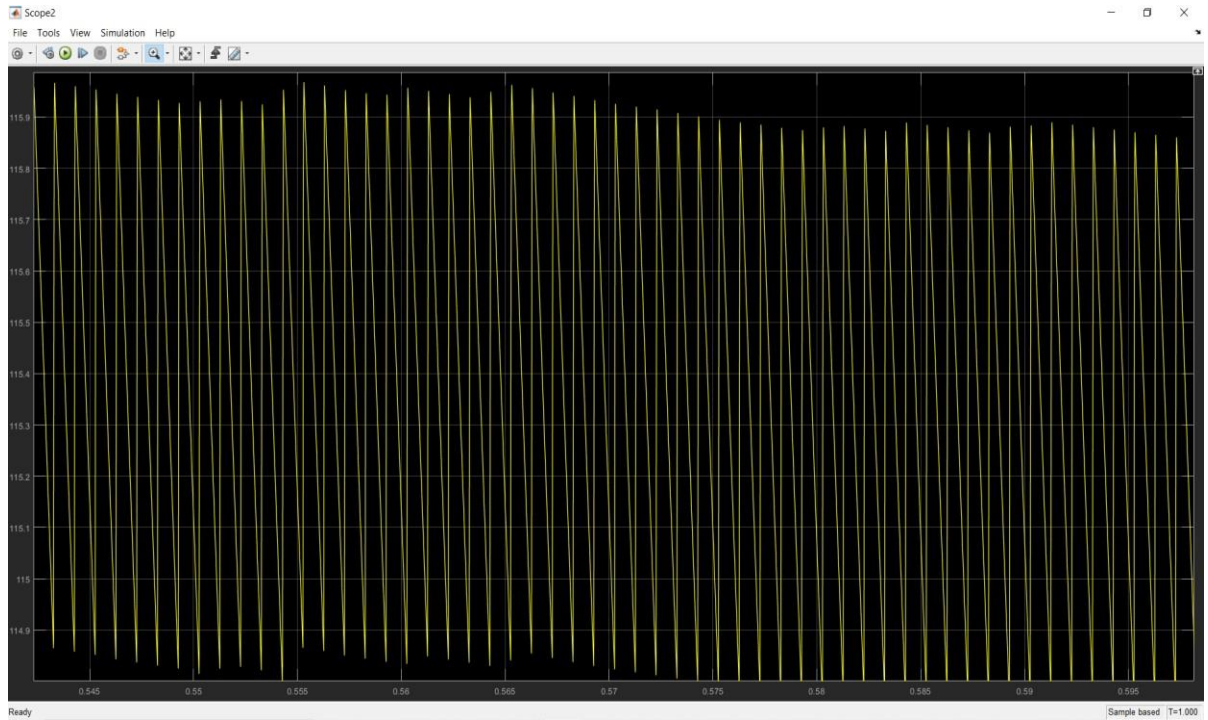
Figure: 6.1 Output for IncCond method.
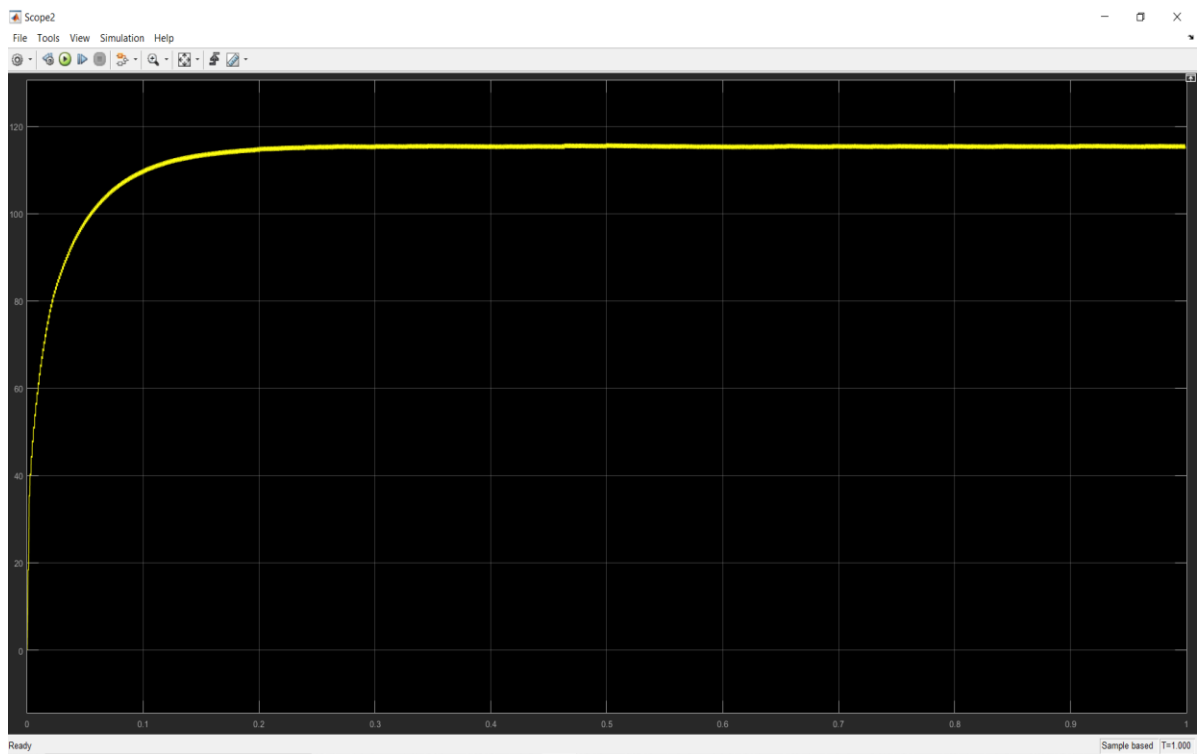
Figure: 6.2 Output for Irradiance IncCond method.
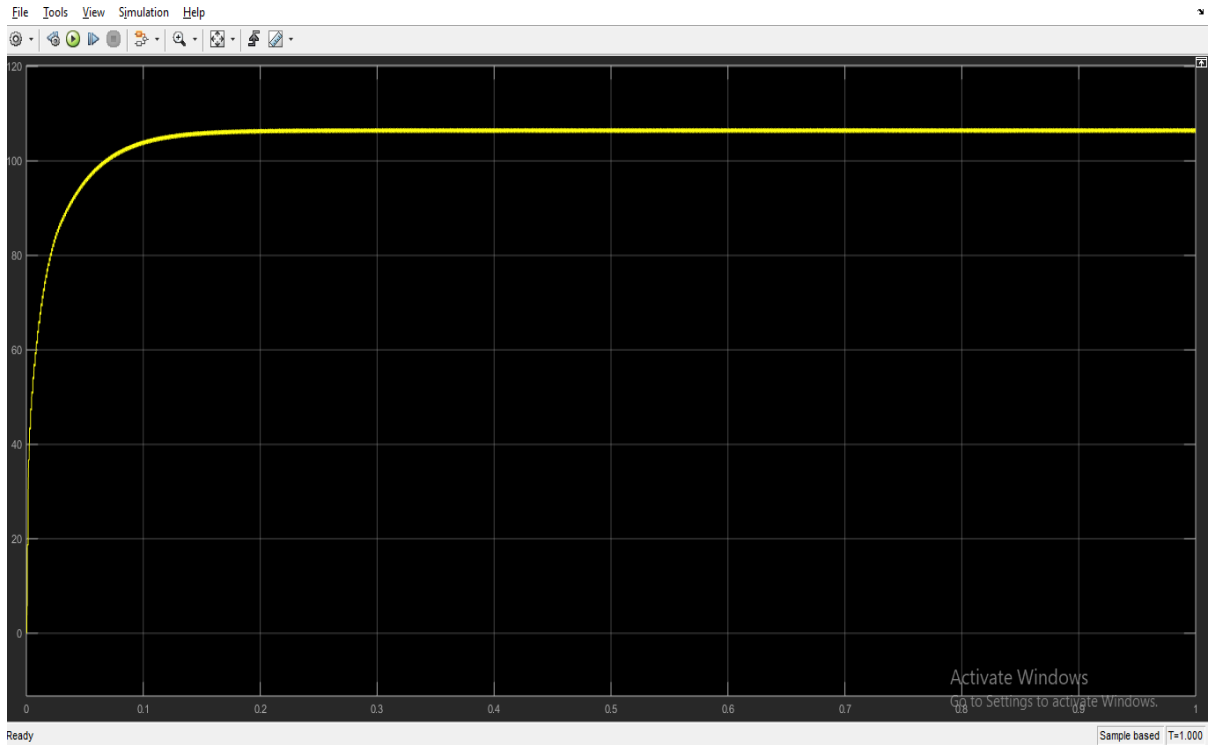
Figure: 6.3 Output for Irradiance P&O method.
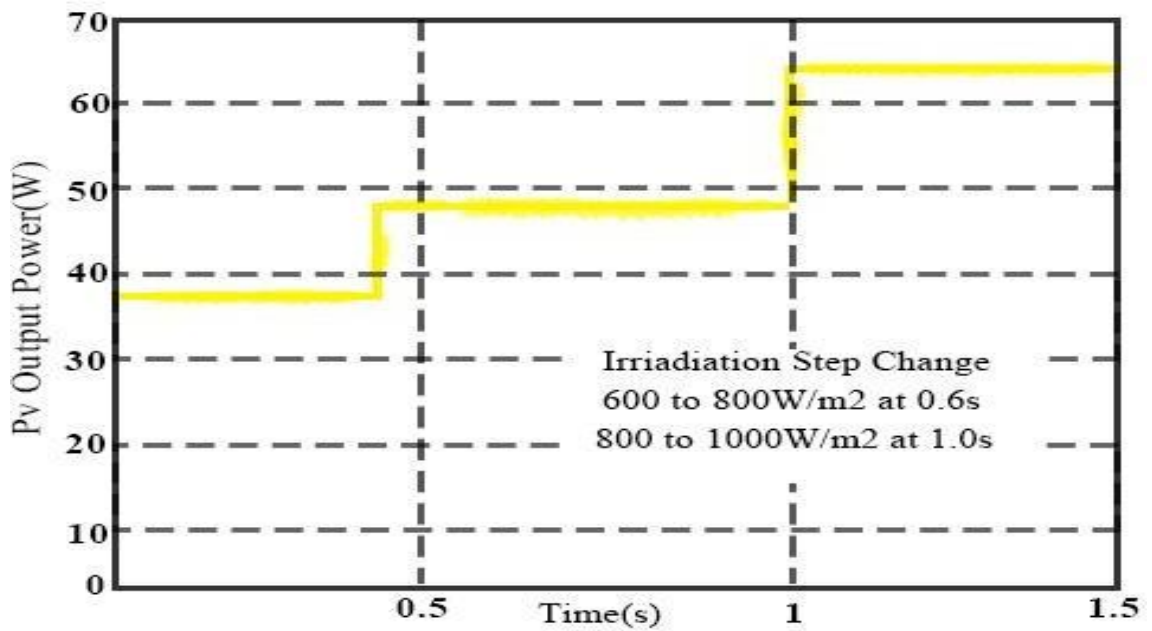
Figure: 6.4 The Power Tracking curve of the PV system.

7. CONCLUSION

Due to the discrete non-linear behaviour of solar cell, this is mandatory so as too mph manages circuit be obliged to coerce the PV component for the MPP. In this critique initially the output characteristics of the PV element and the habitual way of MPPT algorithms. As a solar MPPT controller bases on the InCond algorithm is premeditated for a PV energy system; while the MPPT regulator based on the AVR MEGA328 micro-processor, changes the duty cycle of the pulse width modulation of the boost converter circuit. As well as the results gives a great idea about the MPPT controller can trace the MPP by utilizing the InCond-methodology compare to the P&O method, has enhanced retort as well as lower oscillations underneath the hasty climatic circumstances and changes. Among all those the above advantages the most important consideration in this design is the low cost designed module with the future extension to enhance more advanced paybacks.

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ENHANCEMENT OF QUASI-SWITCHED BOOST INVERTER USING IMPROVED PWM TECHNIQUE

A project report submitted in the partial fulfillment of the

requirements for the award of degree

MASTER OF TECHNOLOGY

IN

POWER AND INDUSTRIAL DRIVES

Submitted by

M.BHARGAVI   **19U41D4202**

Under the esteemed guidance of

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2019-2021

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<u>CERTIFICATE</u>

This   is to certify that this is bonafide record of the dissertation work entitled "ENHANCEMENT OF QUASI-SWITCHED BOOST INVERTER USING IMPROVED PWM TECHNIQUE" is the work done by M.BHARGAVI (19U41D4202) submitted in partial fulfillment for the requirement for the award of '**Master of Technology (M.Tech)'** in **POWER AND INDUSTRIAL DRIVES**   from **DADI INSTITUTE OF ENGINEERING AND TECHNOLOGY** Approved by AICTE, affiliated to JNTUK, NH-16,Anakapalle ,Visakhapatnam is a record of bondified work carried out by her under my guidance and supervision for the year 2019-2021**.**

PROJECT GUIDE

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M.BHARGAVI   **(19U41D4202)**

DECLARATION

I hereby declare that the project work entitled **"Enhancement Of Quasi-Switched Boost Inverter Using Improved PWM Technique"** is being submitted to **Dadi Institute Of Engineering And Technology**, affiliated to JNTUK University, in partial fulfillment for the award of M.TECH degree in Power And Industrial Drives. The work was originally designed and executed by me under the guidance of our supervisor **Asst.Prof.D.CH.Nookesh,** and was not a duplication of work done by someone else. I hold the responsibility of the originality of the work incorporated into this thesis.

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ABSTRACT

This project presents the "Enhancement of Quasi-switched Boost Inverter by using improved PWM technique". QSBI is the combination of Boost converter and switched inverter. An improved PWM control is used for the enhancement of QSBI in order to achieve better input current with reduced ripple magnitude and increased ripple frequency. This increase in ripple frequency is accomplished without increasing the switching frequency. As compared to conventional PWMs for a given switching frequency of inverter, the z-source inductor in QSBI is of reduced in size because of increase in ripple frequency. The voltage boost in QSBI is achieved by allowing a shoot through mode operation but this restricts the maximum inverter modulation index and increases the Total Harmonic Distortions (THD) at the output. The proposed PWM maintains same boost ratio as that of conventional PWM, but with higher modulation index and lower THD at the output of QSBI. The improvement in the performance is done by introducing phase shift between the shoot through control signals and boost control signals. The results are validated by MATLAB/SIMULINK software.

Keywords: Quasi switched boost inverter(QSBI), shoot through (ST)

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CHAPTER-1

INTRODUCTION

In recent years, proliferation of electric vehicle is greatly being promoted in several countries, since transportation is one of the largest contributors to the total emissions as directed by International Panel on Climate Change. Electric vehicles are onerous due to the constraints imposed by the battery capacity, the Short Driving Range and Speed, Longer Recharge Time, non-availability of Recharge Points and many more. There are a few safety restrictions on battery voltage, like the protection against accidental contact, which is exempted for batteries with no more than 60 V. But the electric motor is designed to operate at voltages higher than 60 V, and this voltage mismatch between the battery and the electrical motor requires a two-stage conversion, with the first stage to boost the battery voltage and the second stage to invert it as a variable voltage with variable frequency. These two requirements of converters helped evolve over years the z-source inverter (ZSI), quasi z-source inverters (QZSI), and current-fed switched inverter etc., and it has presently reached to quasi switched boost inverters (QSBI). The transformations focused on several ameliorations on the basic z-source inverters like, reduced voltage stress on passive and active devices, continuous input current with high frequency, low shoot through duty ratio, high modulation index and reduced distortions at the inverter output etc. For obtaining high boost factor, shoot through states are utilized in ZSI with one or more inductors and capacitors, which makes this topology not suitable for low and medium power applications. Eventually, switched boost (SBI), quasi-switched boost (QSBI) and current-fed inverters were suggested in such applications with reduced number of passive components but with additional active

devices. However, the effect of boost factor on the shoot through duty cycle and discontinuous input current is still a trade-off in ZSI and QZSI. An upshot in overcoming the limitations of the aforementioned topologies is the quasi switched boost inverter (QSBI), which has reduced magnetics size and number, alleviated stress on the active devices and more importantly, higher boost factor with on par effects on the other parameters. There were several single phase QSBI topologies proposed in, with each one having its unique features and advantages targeting continuous input current. In this class of inverters for high boost factors, high shoot through duty ratios are to be adopted, which restricts the maximum possible modulation index for the inverter PWM. This results in higher inverter output THD. The input current profile shaping is yet another feature which has advanced from discontinuous to continuous conduction in QSBI, without additional switches and now the PWMs are centring around the reduction in the ripple current and increase in current ripple frequency so as to shrink the size of the inductor in QSBIs. This paper proposes a modification in the existing PWM control for a single phase QSBI, which exhibits improvement over the traditional PWM in terms of increased ripple frequency of input current and reduced ripple content with the boost factor maintained as that of classical PWMs and without increasing the switching losses in the inverter bridge.

1.1 Harmonics:

A harmonic of the wave is a part frequency of the signal that is an integer multiple of the fundamental frequency i.e. if the principal or fundamental frequency is f, the harmonics have the frequency of 2f, 3f, 4f…. etc. The harmonic has the property that they are all periodic at that frequency. Harmonic frequencies are equally intermittent by the width of the principle frequency and can be found by repeatedly adding that frequency.

1.1.1 Even and odd order harmonics:

Harmonics are recognized by their order, which might be even or odd, Even-odd harmonics (2, 4, 6, 8.…), which are often immaterial in industrial environment counter balance each other because of symmetry of the signal. They just happen in the presence of a DC component. Odd-order harmonics (3, 5,7 ,9……), however, are much of the time experienced on the electrical system.

Note that most by far of harmonic currents found in a distribution network are Odd-order harmonics (3rd, 5th, 7th, etc....). Secondly, as a general rule, the sources of the harmonics currents in a distribution network are the loads in operation inside that facility. Curiously, these are often possible the types of loads that are the touchiest to distribution
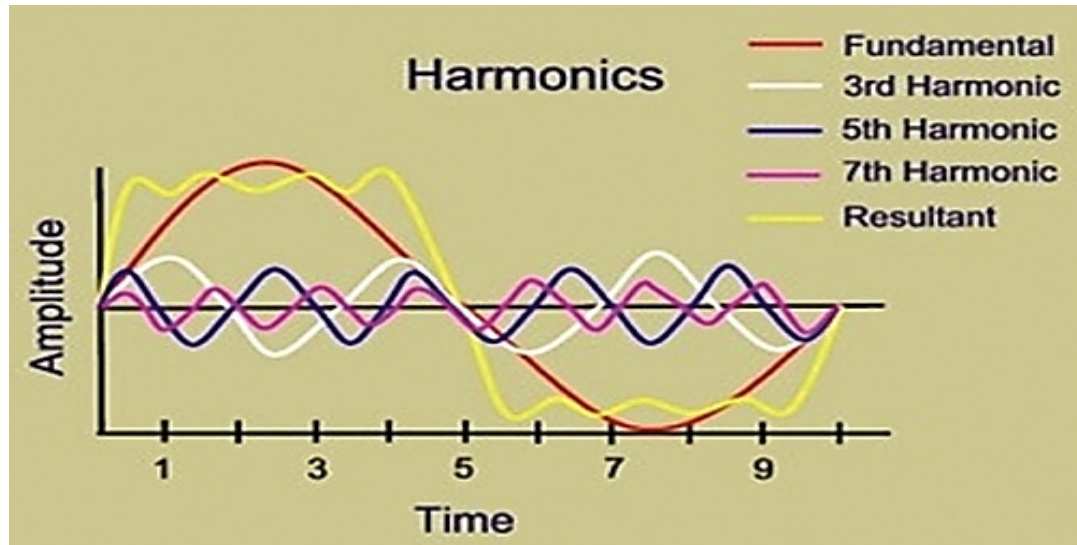
in the current as well as voltage

Fig.1.1: Resultant waveform due to harmonics

1.1.2 Triplen Harmonics:

The triple harmonics are characterized as the odd products of the 3rd harmonics (ex. 3rd, 9th, 15th, 21st etc.). Triple harmonics are of specific concern since they are zero sequence harmonics, not at all like the principle, which is positive sequence. The consequence of this fact is that the magnitude of these currents on the 3 phases are additive in the neutral. This larger than can present fire hazard.

These currents can also circulate in the transformer causing significant overheating there too. Single-phase power supplies for equipment such as electronic ballasts and PC's are the most significant source of triple harmonics.

Causes:

In a normal alternating current power system, the voltage varies sinusoidal at aspecific frequency, usually 50 or 60 hertz. When a linear electrical load is connected to

the system, it draws a sinusoidal current at the same frequency as the voltage (through usually not in phase with the voltage).

When a nonlinear load, such as a rectifier, is connected to the system, it draws a current that is not necessarily sinusoidal. The current wave form can become quite complex depending on the type of load and its interaction with other components of the system. Regardless of how complex the current waveform becomes, as described through Fourier series analysis, it is possible be decompose it into a series of simple sinusoids, which start at the power system fundamental frequency and occur at integer multiples of the fundamental frequency. Further examples of non-linear loads include common office equipment such as computers and printers, fluorescent lighting, battery chargers and also adjustable speed drives.

Harmonics are present in all most all power systems. Fundamentally one needs to control harmonics only when they become a problem. There are three common causes of harmonic problems:

1. The source of harmonics current is too great.
2. The path in which the currents flow is too long(electrically), resulting in high voltage distortion or telephone interface.
3. The response of the system magnifies one or more harmonics to a greater degree that can be tolerated.

Effects:

One of the major effect of harmonics is to increase the current in the system. This is particularly the case for the third harmonic, which causes a sharp increase in the zero-sequence current, and therefore increases the current in the neutral conductor. This effect can require special consideration in the design of an electrical equipment can suffer effects from the harmonics on the power system. The presence of harmonics disturbs the other load connected the terminals on the same voltage source, even when they are linear. Indeed, these loads may no longer be supplied in conditions complying with the voltage references required.

Other possible consequences included:

1) Heating of the neutral conductor: currents with triple harmonics (3rd order and multiples of 3) are added together in neutral conductor, leading to a neutral current which is often 120% to 130% of phase currents.

2) The simulation use for capacitive and inductive devices in distributive networks results in parallel or series resonance manifested by vary high or very low impedance values respectively. The variations in impedance modify the current and voltage in the distribution network.

1. Interference on phone and communication systems.
2. Untimely main circuit breaker tripping due to over currents.
3. Higher RMS current values then those required for the load's energy needs.
4. Overheating of installations (transformers,cables, etc) due toskin effect.
5. Voltage resonance on a system composed of capacitors designed to raise the displacement power factor.
6. Increased maintenance of equipment and machinery.

1.2 Need for harmonic compensation:

The implementation of active filter in this modern electronic age has become an increasingly essential element to the power network. With the advancement technology since the early 80's and significant trends of power electronic devices among consumers and industry, utilities are continually pressured in providing a quality and reliable supply. Power electronic devices such as computer, printers and most other office equipment all create harmonics. These types of devices are commonly classified collectively as "nonlinear loads". Nonlinear loads create harmonics by drawing current in abrupt short pulses rather than in a smooth sinusoidal manner.

The major issues associated with the supply of harmonics to a nonlinear load are serve overheating and insulation damage. Increased operating temperature of generators and transformers degrade the insulation materials of it's windings. If this heating were continued to the point at which insulation fails, a flashover may occur should it be combined with leakage current from its conductors. This would permanently damage the device and results in loss of generation causing widespread blackouts.

One solution to this foreseeable problem is to install active filter for each nonlinear load in the power system network. Although presently uneconomical, the installation of

active filters proves indispensable for solving power quality problems in distribution networks such as harmonic current compensation, reactive current compensation, voltage sag compensation, voltage flicker compensation and negative phase sequence current compensation. Ultimately, this would ensure a polluted free system with increased reliability and quality.

The objective of this is to understand the modelling and analysis of shunt active power filter. In doing so, the accuracy of current compensation for current harmonics found at a nonlinear load, by the P-Q theory control techniques is supported and also substantiates the reliability and effectiveness of this model for integration into a power system network.

The aim of the system simulation is to verify the active filter effectiveness for a nonlinear load. In simulation, total harmonic distortion measurements are undertaken along with variety of waveforms and the results are justified accordingly.

1.3 Total Harmonic Distortion (THD):

The total harmonic distortion or THD, of a signal is a measurement of the harmonic distortion present and is defined as the ratio of the sum of the powers of all harmonic components to the power of the fundamental frequency. THD is use to characterize the linearity of audio systems and the power quality of electric power system. Distortion factor is a closely related term, sometimes used as a synonym.

In audio system, lower distortion means the component in the loud speaker, amplifier or microphone or other equipment produce a more accurate reproduction of an audio recording.

In radio communications, lower THD means pure signal emission without causing interferences to other electronic devices. Moreover, the problem of distorted and not eco-friendly radio emission appears to be also very important in the contest of spectrum sharing and spectrum sensing.

In power systems, lower THD means reduction in peak currents, heating, emissions and core loss in motors.

$$\text{THD}_{\mathbf{F}} = \frac{\sqrt{V_2^2 + V_3^2 + V_4^2 + \cdots}}{V_1}$$

1.4 Measurement of Total Harmonic Distortion:

The distortion of a waveform relative to a pure sine wave can be measured either by using a THD analyser to analyse the output wave into its constituent harmonics and noting the amplitude of each relative to the fundamental or by cancelling out the fundamental with a notch filter and measuring the remaining signal, which will be total aggregate harmonic distortion plus noise.

Given a sine wave generator of very low inherent distortion, it can be used as input to amplification equipment, whose distortion at different frequencies and signal levels can be measured by examining the output waveforms.

There is electronic equipment both to generate sine waves and to measure distortion, but a general-purpose digital computer equipped with a sound card can carry out harmonic analysis with suitable software. Different software can be used to generate sine waves, but the inherent distortion may be to high for measurement of very low distortion amplifiers.
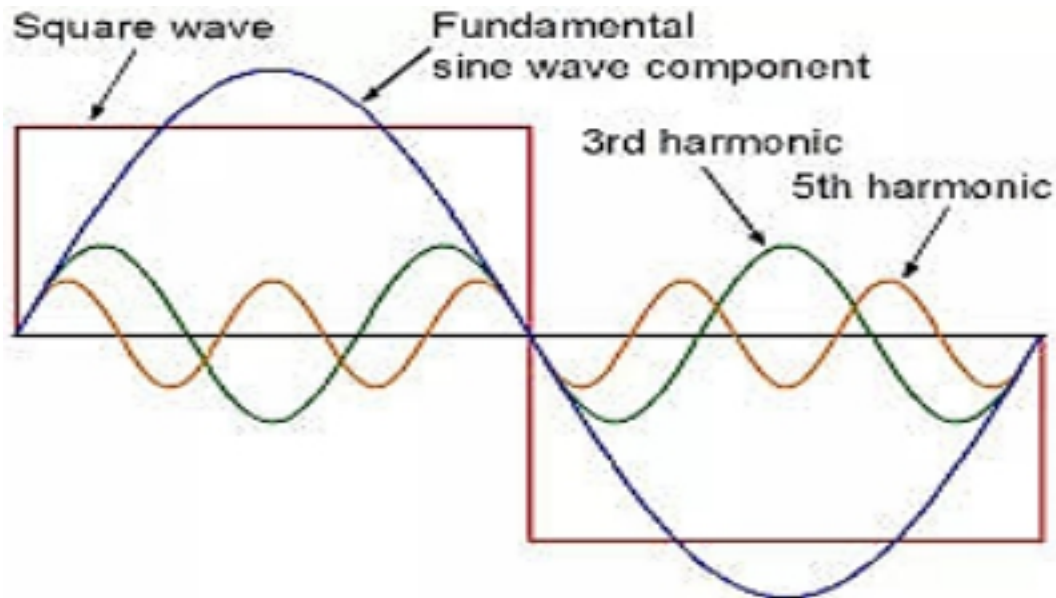
Fig: 1.2: Sine wave consists of different harmonics

CHAPTER-2

CONVERTERS

2.1 INVERTERS:

2.1.1Introduction:

An Inverter is a power electronic device that converts direct current (DC) toalternating current (AC) at the required frequency and voltage output. It is not the same thing as an alternator, which converts mechanical energy (e.g. movement) into alternating current.

Direct current is created by devices such as batteries and solar panels. When connected, an inverter allows these devices to provide electric power for small household devices. The inverter does this through a complex process of electrical adjustment. From this process, AC electric power is produced. This form of electricity can be used to power an electric light, a microwave oven, or some other electric machine.

An inverter usually also increases the voltage. In order to increase the voltage, the current must be decreased, so an inverter will use a lot of current on the DC side when only a small amount is being used on the AC side.

Inverters are made in many different sizes. They can be as small as 150 watts, or as large as 1 megawatt (1 million watts). Smaller inverters often plug into a car's cigarette lighter socket and provide 120 or 240 volt AC power from the car's 12 volt supply.

The earliest inverters consisted of a DC motor connected mechanically to an AC generator. A later design often used with vacuum tube car radios consisted of a rapidly switching relay. Modern inverters are based on MOSFET or IGBT transistors.

2.1.2 Classification of Inverter:

Inverter can be classified into many types based on output, source, type of load etc. Below is the complete classification of the inverter circuits:

(I) According to the Output Characteristic

1. Square Wave Inverter
2. Sine Wave Inverter
3. Modified Sine Wave Inverter

(II) According to the Source of Inverter

1. Current Source Inverter
2. Voltage Source Inverter

(III) According to the Type of Load

1. Single Phase Inverter

   A. Half Bridge Inverter
   B. Full Bridge Inverter

2. Three Phase Inverter

(IV) According to different PWM Technique

1. Simple Pulse Width Modulation (SPWM)
2. Multiple Pulse Width Modulation (MPWM)
3. Sinusoidal Pulse Width Modulation (SPWM)
4. Modified sinusoidal Pulse Width Modulation (MSPWM)

(V) According to Number of Output Level

1. Regular Two-Level Inverter
2. Multi-Level Inverter

(VI) According to the network

    1. Z-Source Inverter Network

    2. E Z-Source Inverter Network

    3. T Z-Source Inverter Network

(I) According to the Output Characteristic:

According to the output characteristic of an inverter, there can be three different types of inverters.

1) Square wave inverter:

The output waveform of the voltage for this inverter is a square wave. This type of inverter is least used among all other types of inverter because all appliances are designed for sine wave supply. If we supply square wave to sine wave based appliance, it may get damaged or losses are very high. The cost of this inverter is very low but the application is very rare. It can be used in simple tools with a universal motor.

2) Sine wave:

The output waveform of the voltage is a sine wave and it gives us a very similar output to the utility supply. This is the major advantage of this inverter because all the appliances we are using, are designed for the sine wave. So, this is the perfect output and gives guarantee that equipment will work properly. This type of inverters is more expensive but widely used in residential and commercial applications.

3) Modified sine wave:

The construction of this type of inverter is complex than simple square wave inverter but easier compared to the pure sine wave inverter. The output of this inverter is neither pure sine wave nor the square wave. The output of such inverter is the some of two square waves. The output waveform is not exactly sine wave but it resembles the shape of a sine wave.
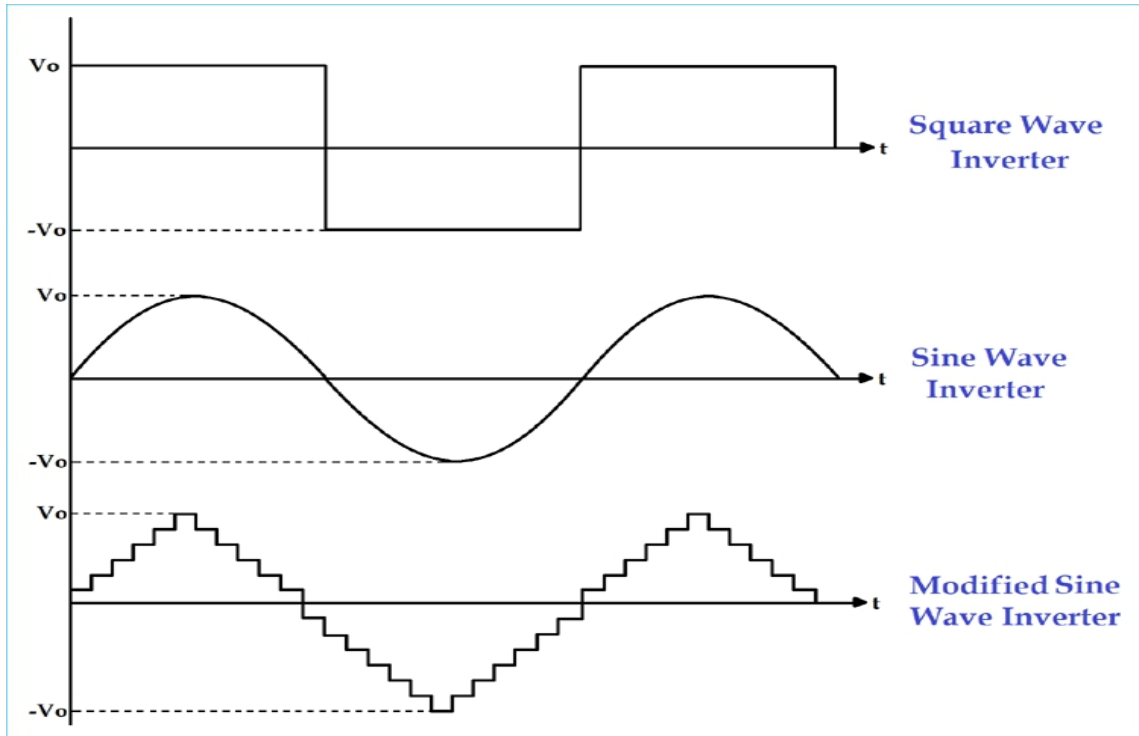
Fig:2.1 output characteristics

(II) According to the Source of the Inverter:

1) Current Source Inverter:

A current source inverter is supplied with a variable current from a DC source that has high impedance. The resulting current waves are not influenced by the load.

2) Voltage Source Inverter:

The voltage source inverter has stiff DC source voltage that is the DC voltage has limited or zero impedance at the inverter input terminal.

(III) According to the Type of Load:

1)Single phase inverter:

Generally, residential and commercial load uses single phase power. The single-phase inverter is used for this type of application. The single-phase inverter is further divided into two parts;

A) Single Phase Half-bridge Inverter

B) Single Phase Full-bridge Inverter

A) Single Phase Half bridge Inverter:

This type of inverter consists of two thyristors and two diodes and connection is as shown in below figure:2.2.
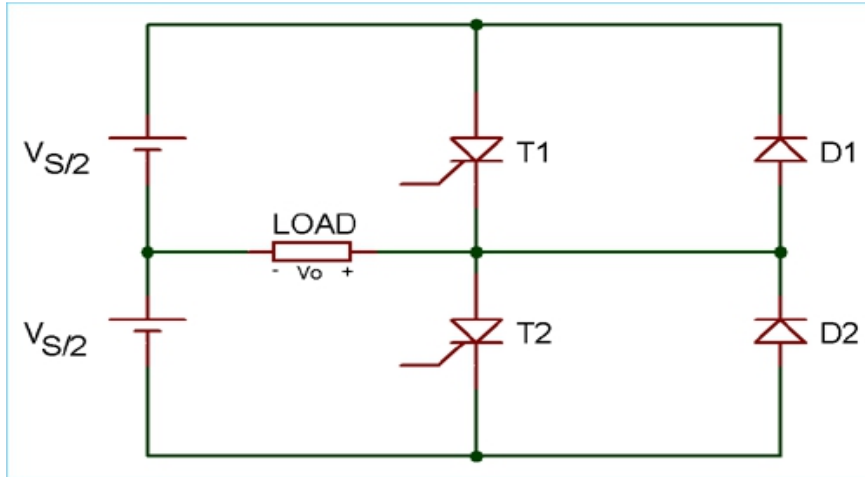
Fig: 2.2 single phase half bridge inverter

In this case, total DC voltage is Vs and divided into two equal parts Vs/2. Time for one cycle is T sec.

For half cycle of 0 <t <T/2, thyristor T1 conducts. The load voltage is Vs/2 due to the upper voltage source Vs/2.

For the second half cycle of T/2 <t <T, thyristor T1 is commutated and T2 conducts. During this period, the load voltage is -Vs/2 due to the lower source Vs/2.

$$V_0 = \frac{V_S}{2}.$$
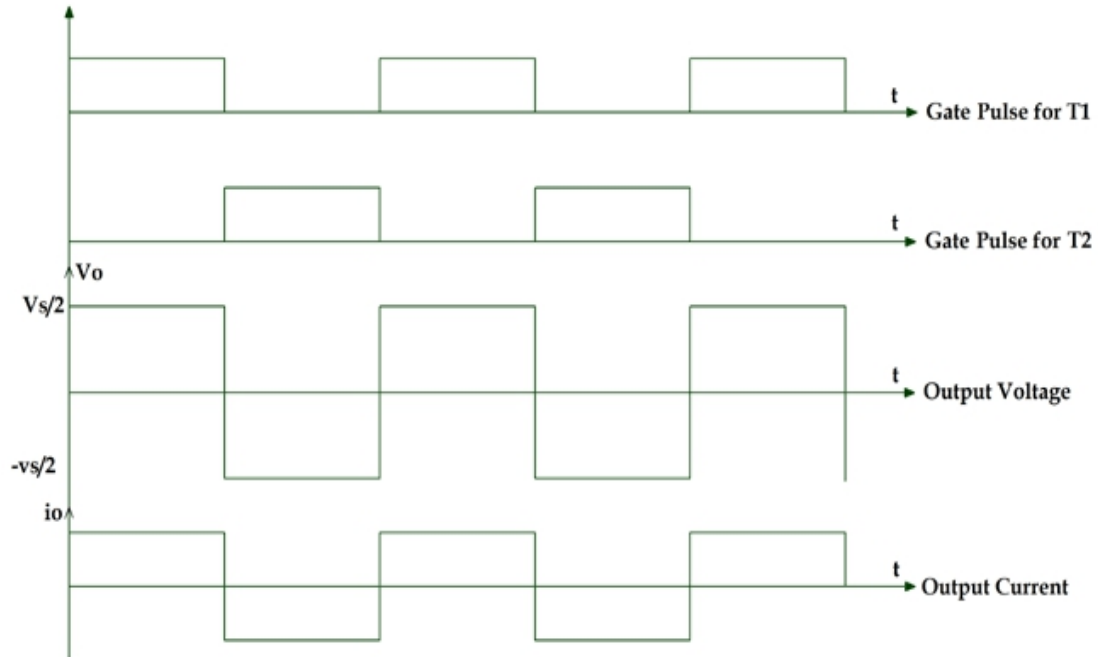
Fig:2.3 wave forms of single phase half bridge inverter

By this operation, we can get alternating voltage waveform with 1/T Hz frequency and Vs/2 peak amplitude. The output waveform is a square wave. It will be passed through the filter and remove unwanted harmonics which give us pure sine waveform. The frequency of the waveform can be controlled by the ON time (Ton) and OFF time (Toff) of the thyristor.

The magnitude of the output voltage is half of the supply voltage and source utilization period is 50%. This is a disadvantage of half bridge inverter and solution of this is full bridge inverter.

B) Single Phase Full-bridge Inverter:

In this type of inverter, four thyristors and four diodes are used. The circuit diagram of single-phase full bridge is as shown in below figure:2.4.
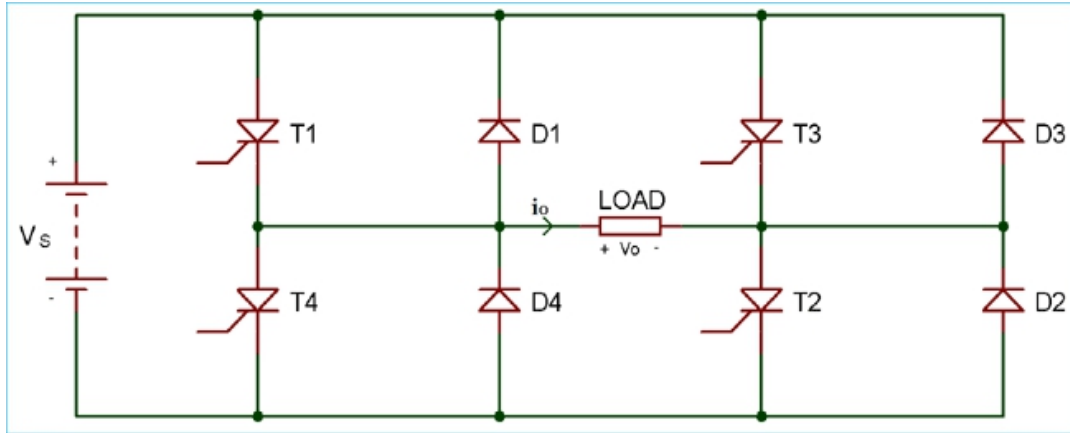
Fig:2.4 single phase full bridge inverter

At a time two thyristors T1 and T2 conduct for first half cycle $0 < t < T/2$. During this period, the load voltage is Vs which is similar to the DC supply voltage.

For second half cycle $T/2 < t < T$, two thyristors T3 and T4 conducts. The load voltage during this period is -Vs.
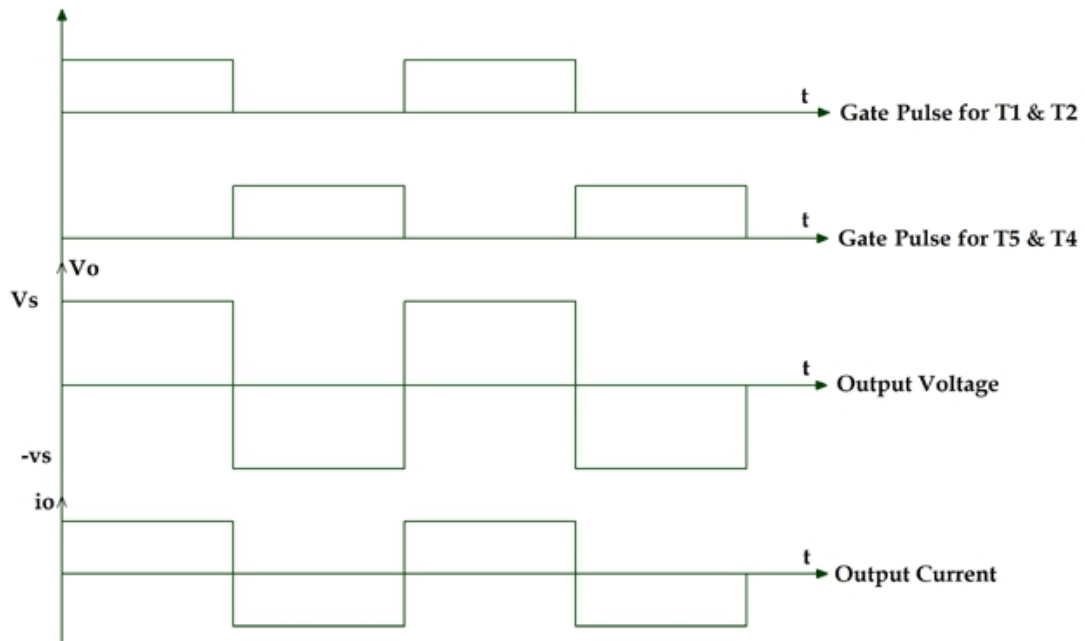
Fig:2.5 wave forms of single phase full bridge inverter

Here we can get AC output voltage same as DC supply voltage and the source utilization factor is 100%. The output voltage waveform is square waveform and the filters are used to convert it into a sine wave.

If all thyristors conduct at the same time or in a pair of (T1 and T3) or (T2 and T4) then the source will be short-circuited. The diodes are connected in the circuit as feedback diode because it is used for the energy feedback to the DC source.

If we compare full bridge inverter with half bridge inverter, for the given DC supply voltage load, output voltage is two times and output is power is four times in full bridge inverter.

2) Three Phase Bridge Inverter:

In case of industrial load, three phase ac supply is used and for this, we have to use a three-phase inverter. In this type of inverter, six thyristors and six diodes are used and they are connected as shown in below figure:2.6.
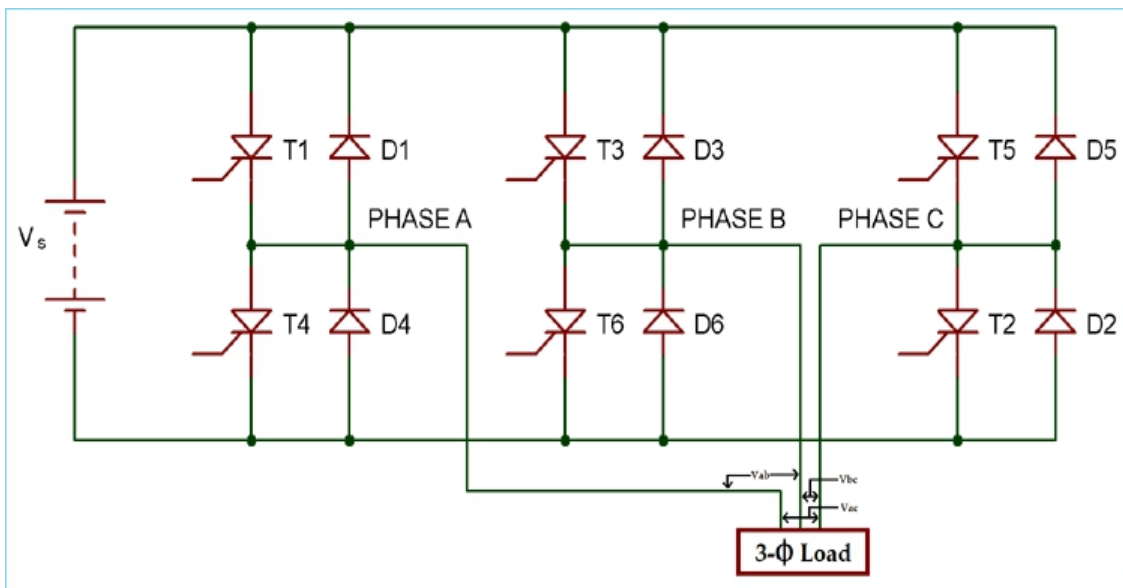
Fig:2.6 three phase bridge inverter

(IV) Classification According to Control Technique:

The output of the inverter is square wave signal and this signal is not used for the load. Pulse width modulation (PWM) technique is used to control AC output voltage. This control is obtained by the controlling of ON and OFF period of switches. In PWM technique two signals are used; one is reference signal and second is triangular carrier signal. The gate pulse for switches is generated by comparing these two signals. There are different types of PWM techniques.

1) Single Pulse Width modulation (single PWM):

For every half cycle, the only pulse is available in this control technique. The reference signal is square wave signal and the carrier signal is triangular wave signal. The gate pulse for the switches is generated by comparing the reference signal and carrier signal. The frequency of output voltage is controlled by the frequency of the reference signal. The amplitude of the reference signal is A_r and the amplitude of the carrier signal is A_c, then the modulation index can be defined as A_r/A_c. The main drawback of this technique is high harmonic content.
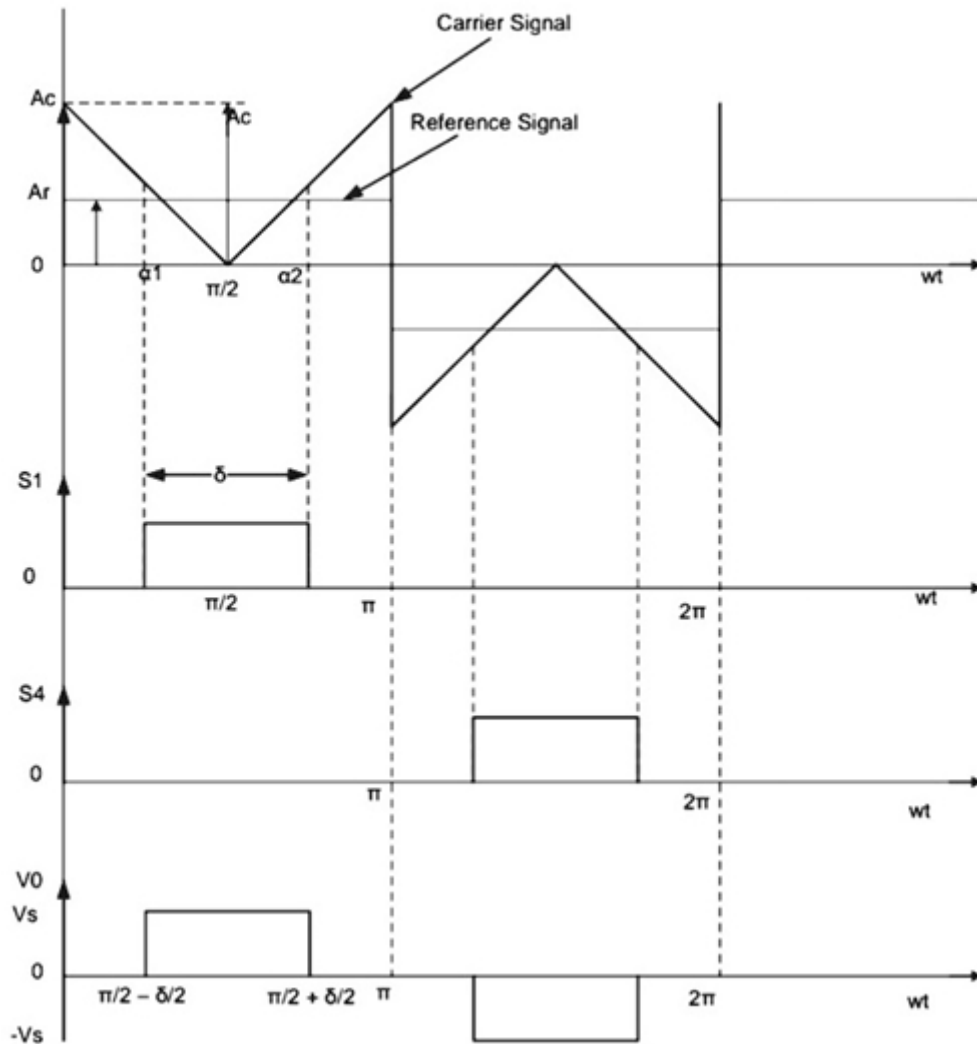
Fig:2.7 single phase PWM

2) Multiple Pulse Width Modulation (MPWM):

The drawback of single pulse width modulation technique is solved by multiple PWM. In this technique, instead of one pulse, several pulses are used in each half cycle

of the output voltage. The gate is generated by comparing the reference signal and carrier signal. The output frequency is controlled by controlling the frequency of the carrier signal. The modulation index is used to control the output voltage.

The number of pulses per half cycle = $f_c/ (2*f_0)$

Where f_c = frequency of carrier signal

f_0 = frequency of output signal
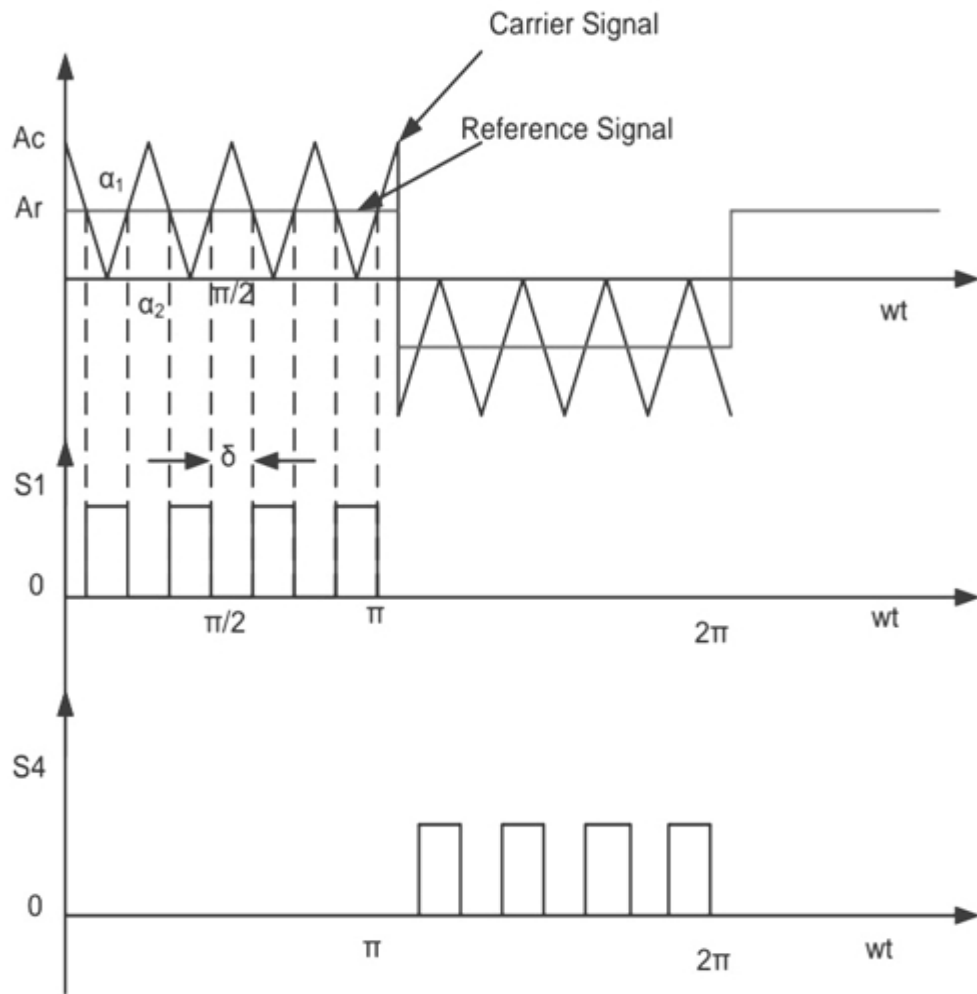
Fig:2.8 multiple PWM

3) Sinusoidal Pulse Width Modulation (SPWM):

This control technique is widely used in industrial applications. In above both methods, the reference signal is a square wave signal. But in this method, the reference

26

signal is a sine wave signal. The gate pulse for the switches is generated by comparing the sine wave reference signal with the triangular carrier wave. The width of each pulse varies with variation of amplitude of the sine wave. The frequency of output waveform is the same as the frequency of the reference signal. The output voltage is a sine wave and the RMS voltage can be controlled by modulation index. Waveforms are as shown in below figure:2.9.
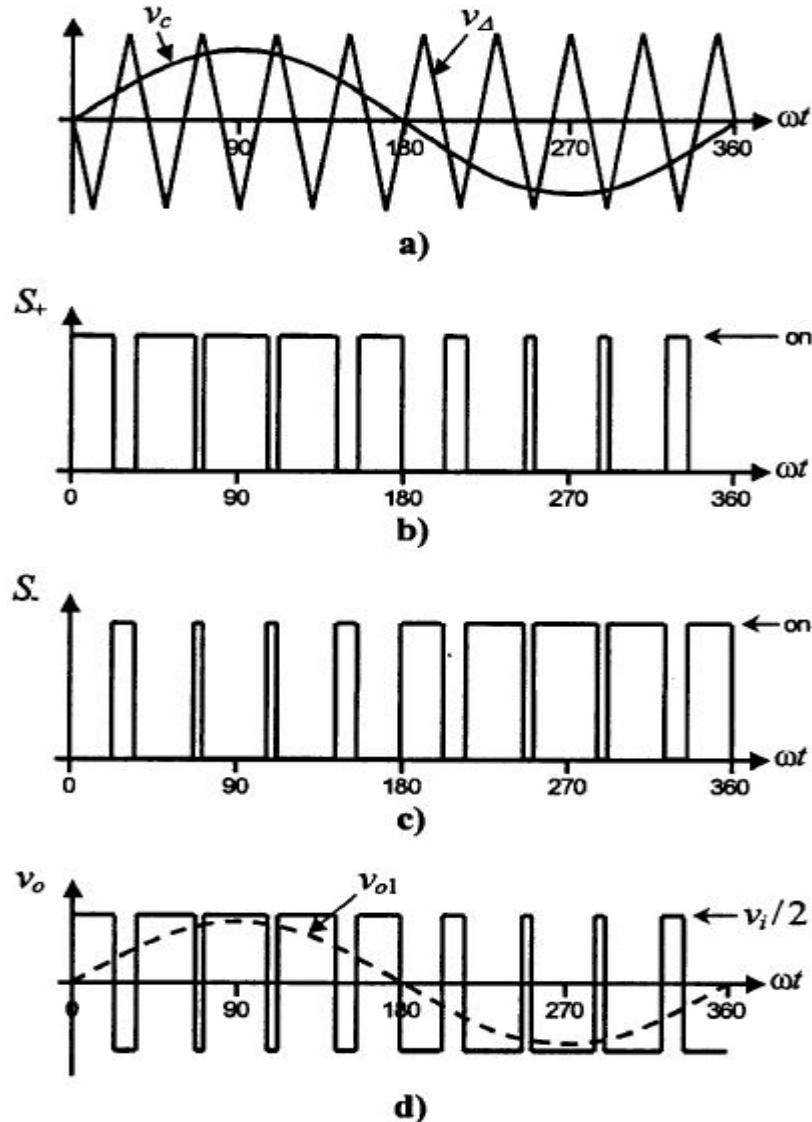
Fig:2.9 sinusoidal PWM

4) Modified Sinusoidal Pulse Width Modulation (MSPWM):

Due to the characteristic of sine wave, the pulse width of the wave cannot be changed with variation in the modulation index in SPWM technique. That is the reason,

MSPWN technique is introduced. In this technique, the carrier signal is applied during the first and last 60-degree interval of each half cycle. In this way, its harmonic characteristic is improved. The main advantage of this technique is increased fundamental component, reduced number of switching power devices and decreased switching loss. The waveform is as shown in below figure:2.10.
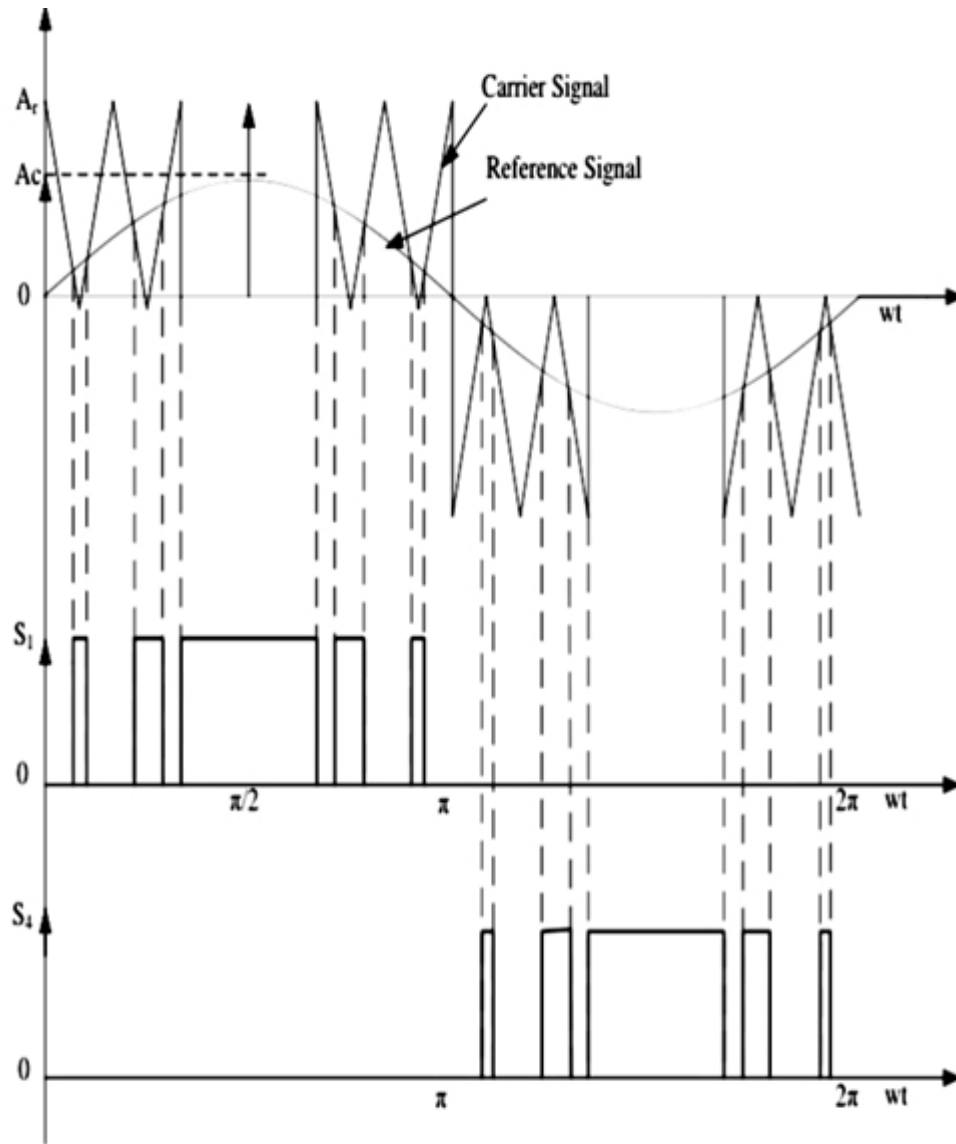
Fig:2.10 Modified Sinusoidal PWM

(V) According to the Number of Levels at the Output:

1)Regular two-level Inverter:

These inverters have only voltage levels at the output which are positive peak voltage and negative peak voltage. Sometimes, having a zero-voltage level is also known as a two-level inverter.

2) Multilevel Inverters:

These inverters can have multiple voltage levels at the output. The multi-level inverter is divided into four parts.

- Flying capacitor Inverter

- Diode-clamped Inverter

- Hybrid Inverter

- Cascade H-type Inverter

Every inverter has its own design for operation, here we have explained these inverter briefly to get an basic ideas about them.

(VI) According to the network:

1)Z-Source inverter network

The Z-source converter (ZSC) is a new topology in power conversion, which has unique features that can overcome the limitations of VSI and CSI. Figure: 2.11 shows the ZSC implemented as a three-phase DC/AC converter (inverter). Although DC /AC conversion is the most common application of the Z-source topology. It can also be applied to AC/DC & AC/AC power conversions. The X-shape impedance is the Z source network which is composed of two split inductors and two capacitors to provide a coupling between the DC source and the inverter bridge. The Z-source inverter (ZSI) has the unique back-boost capability which ideally gives an output voltage range from zero to infinity regardless of the input voltage.
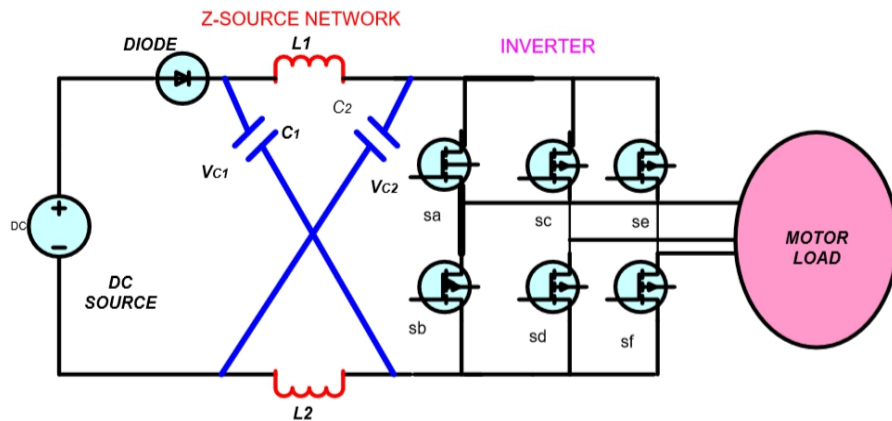
Fig:2.11 ZSC implemented as a three-phase inverter (ZSI)

2)EZ-Source inverter network:

The voltage-type EZ-source inverter show in Figure 2.12 has its DC sources embedded within the X shaped LC impedance network with its inductive elements L1 and L2 respectively, used for filtering the currents drawn from the two DC sources without using any external LC filter. Quite obviously, the immediate disadvantage shown in Figure 2.12 is that two DC sources of Vdc/2, instead of the single DC source shown in Figure 2.11 are needed for the EZ-source inverter.
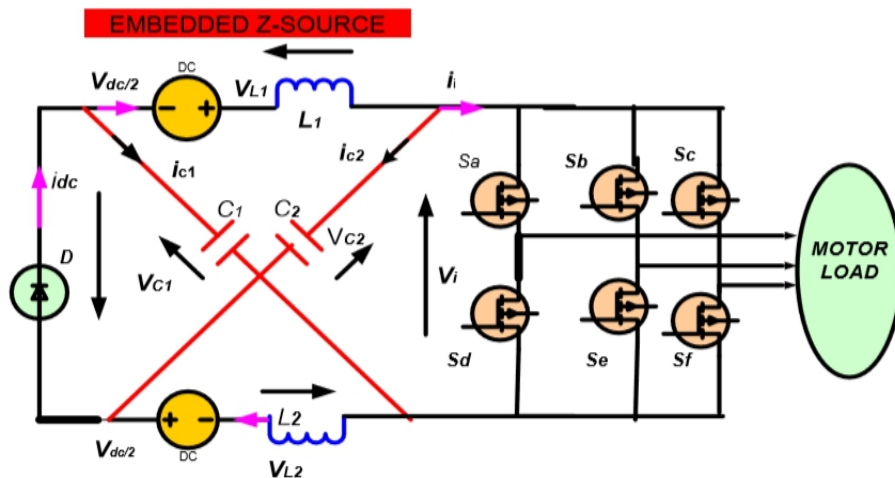
Fig: 2.12 EZSI implemented as a three-phase inverter (EZSI)

3)TZ-Source inverter network:

In the trans-Z-source inverters, high gain is obtained by increasing their common transformer turns ratio γTZ, which is in agreement with classical transformer theories. Depending on the eventual voltage gain demanded, the raised γTZ might at times be excessive for realization. Because of this, T-Z-source inverters shown in Figure 2.13 are proposed for wind energy conversion. The proposed inverters use the same components as the trans-Z-source inverters, but with different transformer placement. This difference causes the T-Z-source gain to be raised by lowering, and not increasing, the transformer turns ratio γTZ. The general structure of three phase T- Z-source inverter is shown in Figure 2.13. It basically has an impedance network that couple the converter main circuit to be power source. This addition of impedance network introduce a unique feature that cannot be used for the traditional three phase voltage source inverter and three phase current source inverter. The limitations for the traditional inverter are being solved in the TZ-source inverter. The TZ-source also can be used for all DC-DC, AC-AC, AC-DC and DC-AC power combination.
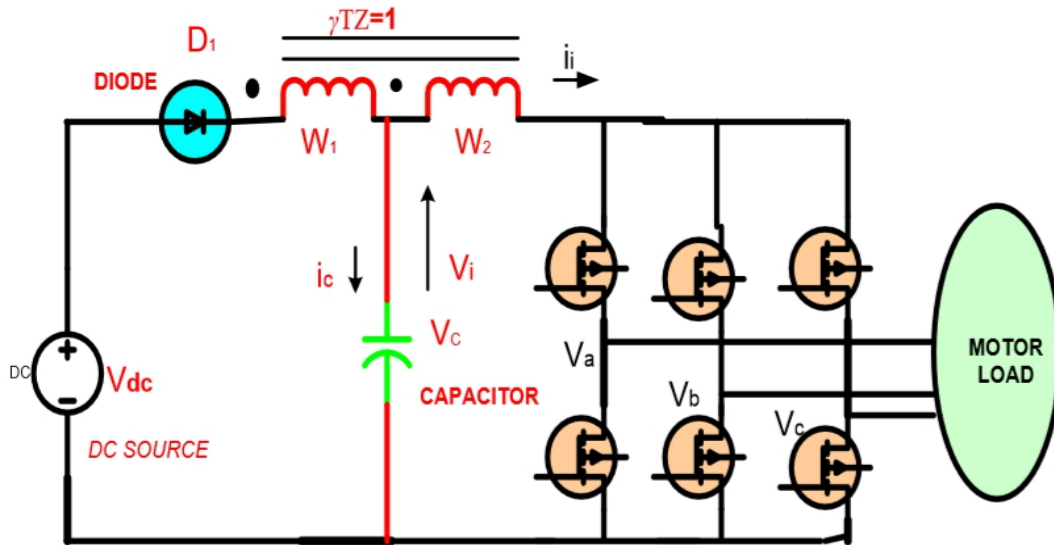
Fig:2.13 General structure of TZ-source inverter

2.2 DC-DC CONVERTER:

2.2.1 Introduction:

DC –DC converters are power electronic circuits that convert a dc voltage to a different voltage level. There are different types of conversion method such as electronic, linear, switched mode, magnetic, capacitive. The circuits described in this report are classified as switched mode DC-DC converters. These are electronic devices that are used whenever change of DC electrical power from one voltage level to another is needed. Generically speaking the use of a switch or switches for the purpose of power conversion can be regarded as an SMPS. From now onwards whenever we mention DC-DC converters we shall address them with respect to SMPS. A few applications of interest of DC-DC converters are where 5V DC on a personal computer motherboard must be stepped down to 3V, 2V or less for one of the latest CPU chips; where 1.5V from a single cell must be stepped up to 5V or more, to operate electronic circuitry. In all of these applications, we want to change the DC energy from one voltage level to another, while wasting as little as possible in the process. In other words, we want to perform the conversion with the highest possible efficiency. DC-DC Converters are needed because unlike AC, DC can't simply be stepped up or down using a transformer. In many ways, a DC-DC converter is the DC equivalent of a transformer. They essentially just change the input energy into a different impedance level. So whatever the output voltage level, the output power all comes from the input; there is no energy manufactured inside the converter. Quite the contrary, in fact some is inevitably used up by the converter circuitry and components, in doing their job.

2.2.2 Applications of DC-DC Converters:

1. Dc converters can be used in regenerative braking of dc motors to return energy back into the supply and this feature results in energy savings for transportation system with frequent stops. As for example :

a) Traction motor control in electric automobiles.

b) Trolley cars.

c) Marine Hoists.

d) Forklift trucks.

e) Mine Haulers

2. Also used in DC voltage regulators and also are used in conjunction with an inductor to generate a dc current source especially for the current source inverter.

2.2.3 Types of DC-DC Converter: There different kinds of DC-DC converters. A variety of the converter names are included here:

1. The BUCK converter

2. The BOOST converter

3. The BUCK-BOOST converter

4. The CUK converter

5. The Fly-back converter

6. The Forward Converter

7. The Push-pull Converter

8. The Full Bridge Converter

9. The Half Bridge Converter

10. Current Fed converter

11. Multiple output converters

Study of DC-DC Converters There are a variety of DC-DC converters are possible. But from the list of the converters only the first four of the converters are to be described which are basically of non-isolated input output terminals.

1)The Buck Converter:

The buck converter is a commonly used in circuits that steps down the voltage level from the input voltage according to the requirement. It has the advantages of

simplicity and low cost. Figure: 2.14 shows a buck converter the operation of the Buck converters start with a switch that is open (so no current flow through any part of circuit) When the switch is closed, the current flows through the inductor, slowly at first, but building up over time. When the switch is closed the inductor pulls current through the diode, and this means the voltage at the inductors "output" is lower than it first was. This is the very basic principle of operation of buck circuit.
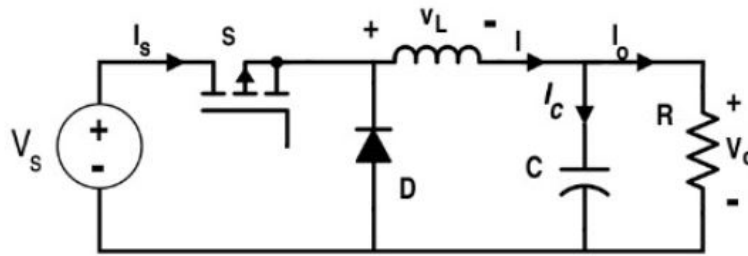
FIG: 2.14 Buck Converter

Analysis of the buck converter begins by making these assumptions:

1. The circuit is operating in the steady state.

2. The inductor current is continuous.

3. The capacitor is very large, and the output voltage is held constant at voltage Vo. This restriction will be relaxed later to show the effects of finite capacitance.

4. The switching period is T, the switch is closed for time DT and open for time (1-D)T.

5. The components are ideal.

2) The Boost converter:

A boost converter (step-up converter) is a power converter with an output DC voltage greater than its input DC voltage. It is a class of switching mode power supply (SMPS) containing at least two semi-conductors switches (a diode and a transistor) and at least one energy storage element. Filters made of capacitors (sometimes in combination with inductors) are normally added to the output of the converter to reduce output voltage ripple. A boost converter is sometimes called a step-up converter since it "steps up" the

source voltage. Since power (P = VI) must be conserved, the output current is lower than the source current.

The boost converter has the same components as the buck converter, but this converter produces an output voltage greater than the source."Boost" converters start their voltage conversion with a current flowing through the inductor (switch is closed). Then they close the switch leaving the current no other path to go than through a diode (functions as one way valve) The current then wants to slow really fast and the only way it can do this is by increasing it's voltage (akin to pressure) at the end that connects to the diode, and switch. If the voltage is high enough it opens the diode, and one through the diode, the current can't flow back. This is the very basic concept of boost converter.

Circuit analysis

Analysis of the boost converter begins by making these assumptions:

➢ The circuit is operating in the steady state.
➢ The inductor current is continuous (always positive).
➢ The capacitor is very large, and the output voltage is held constant at voltage Vo. This restriction will be relaxed later to show the effects of finite capacitance.
➢ The switching period is T, the switch is closed for time DT and open for time (1-D)T.
➢ The components are ideal

Operating principle:

The key principle that drives the boost converter is the tendency of an inductor to resist changes in current. When being charged it acts as a load and absorbs energy (somewhat like a resistor); when being discharged it acts as an energy source (somewhat like a battery). The voltage it produces during the discharge phase is related to the rate of change of current, and not to the original charging voltage, thus allowing different   input   and output   voltages.
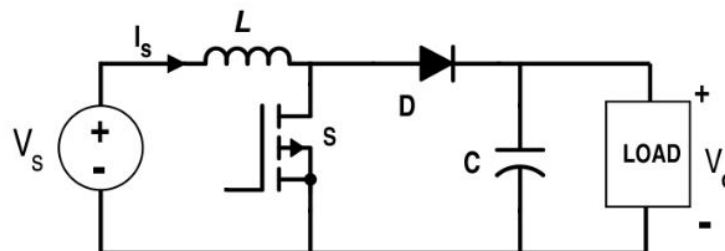
Fig:2.15Boost Converter Schematic
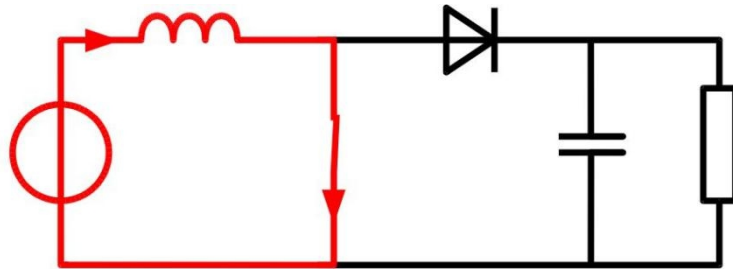
Fig: 2.16 SWITCH ON
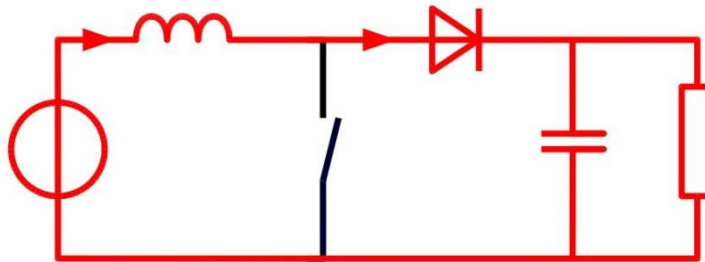
Fig: 2.17 SWITCH OFF

The basic principle of a Boost converter consists of 2 distinct states as shown in fig-(2.16&2.17):

▪ In the On-state, the switch S(fig:2.16) is closed, resulting in an increase in the inductor current;

▪ In the Off-state, the switch s (fig:2.17) is open and the only path offered to inductor current is through the fly back diode D, the capacitor C and the load R. These results in transferring the energy accumulated during the On-state into the capacitor.

▪ The input current is the same as the inductor current. So it is not discontinuous as in the buck circuit and the requirements on the input filter are relaxed compared to a buck converts.

3) Buck-Boostconverter:

Another basic switched mode converter is the buck-boost converter. The output of the buck-boost converter can be either higher or lower than the input voltage. Assumption made about the operation of this circuit is same as it was for the previous converter circuits.
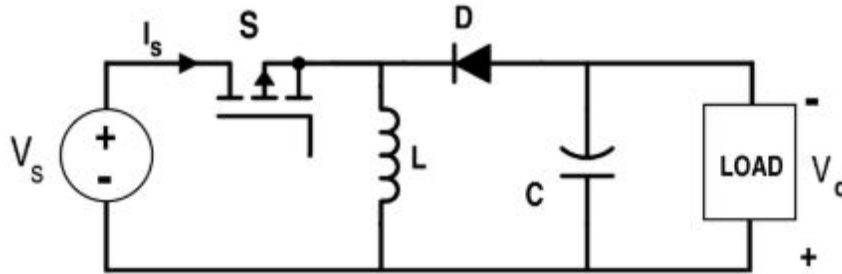
Fig:2.18 Schematic Of Buck-Boost Converter
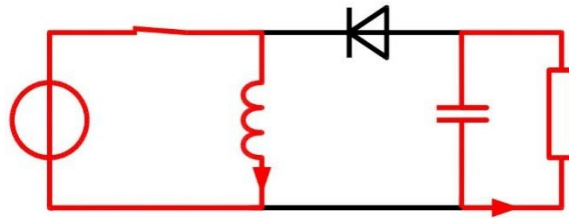
Fig:2.19 SWITCH ON
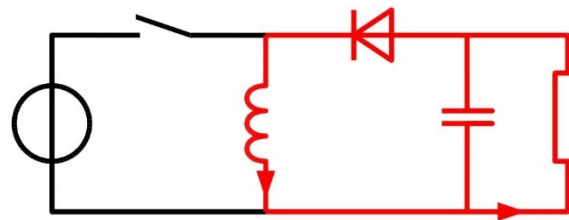
Fig:2.20 SWITCH OFF

Figure 2.18: The two operating states of a buck–boost converter: When the switch is turned-on, the input voltage source supplies current to the inductor, and the capacitor supplies current to the resistor (output load).When the switch is opened, the inductor supplies current to the load via the diode D.

The basic principle of the buck–boost converter is fairly simple (Figure 2.18):

while in the On-state fig (2.19), the input voltage source is directly connected to the inductor (L). This results in accumulating energy in L. In this stage, the capacitor supplies energy to the output load.

while in the Off-state fig(2.20), the inductor is connected to the output load and capacitor, so energy is transferred from L to C and R. Compared to the buck and boost converters, the characteristics of the buck–boost converter are mainly:

Polarity of the output voltage is opposite to that of the input;

The output voltage can vary continuously from 0 to (for an ideal converter). The output voltage ranges for a buck and a boost converter are respectively 0 to and to .The circuit has two main mode of operations. They are described below.

2.2.4 Switching Consideration of DC-DC Converters:

 The converter switch can be implemented by using

 a) Thyristor.

 b) Power bipolar junction transistor (BJT).

 c) Power Metal Oxide Semiconductor Field Effect Transistor (MOSFET).

d) Gate Turn Off Thyristor (GTO).

e) Insulated Gate Bipolar Transistor (IGBT).

　　　　Practical devices have a finite voltage drop ranging from 0.5V to 2V but during the calculations for the sake of simplicity of the understanding, these switches are considered lossless.

1) Thyristor:

　　　This device is also referred to as a PNPN structure or Thyristor. Such device can in principle be made using any semiconductor. However, silicon thyristors are the most common thyristors. The advantage of the structure is that it provides a high power handling capability, high blocking voltage and high gain with a very low on-state resistance.

The Thyristor has a lower on-state voltage than the Darlington pair and typically requires an even smaller turn- on current, which only needs to be applied temporarily because of the internal positive feedback between the two transistors of the equivalent circuit.

This latter property is also the main disadvantage of the Thyristor: since the device latches into the on-state once sufficient gate current is supplied, the device can't be turned off by removing the gate current. Instead one has to disconnect the power supply to turn off the device. Further since both transistors are in saturation in the on state, a significant amount of minority carriers are accumulated in the base region of each transistor.

These minority carriers must be removed prior to reconnecting the power supply since these carriers would temporarily lead to a base current in each device and trigger the turn-on of the Thyristor. Finally, one has to slowly ramp up the power supply voltage to avoid the so called dv/dt effect. Since a rapid increase of the applied voltage with time causes a displacement current proportional to the capacitance of the junctions, this displacement current could again provide a temporary base current in Q1 and Q2, which is large enough to trigger the Thyristor.

2) Metal oxide semiconductor field effect transistor:

Power MOSFETs (Metal Oxide Semiconductor Field Effect Transistor) are the most commonly used power devices due to their low gate drive power, fast switching speed and superior paralleling capability. Most power MOSFETs feature a vertical structure with Source and Drain on opposite sides of the wafer in order to support higher current and voltage. Figure 1a and 1b show the basic device structures of Trench and Planar MOSFETs respectively. Trench MOSFETs are mainly used for ¡200V voltage rating due to their higher channel density and thus lower on-resistance. Planar MOSFETs are good for higher voltage ratings since on- resistance is dominated by epilayer resistance and high cell density is not beneficial. The basic MOSFET operation is the same for both structures. Unless specified, the N-channel trench MOSFET is discussed in this application note. The MOSFET capacitances are non-linear as well as a function of the dc bias voltage. All the MOSFET capacitances come from a series combination of a

bias independent oxide capacitance and a bias dependent depletion (Silicon) capacitance. The decrease in capacitances with VDS comes from the decrease in depletion capacitance as the voltage increases and the depletion region widens. The power MOSFET gate presents an impedance like an RC network to its gate drive. The equivalent R is referred to as the gate resistance Rg. The gate resistance is caused by the finite resistance of the Poly silicon gate conductors, and the metal and contact structures that route the gate signal to the pad for connection to external package leads.

3)Bipolar junction transistors:

The main difference is that the active area of the device is distinctly higher, resulting in a much higher current handling capability. Power BJTs also have a thick and low-doped collector region. Such collector regions result in a large blocking voltage. Extremely low doping densities are used to obtain blocking voltages as large as 3000 V.

As a result, one finds that the structure needs to be redesigned to

a) effectively manage the power dissipation and
b) avoid the Kirk effect.

The power dissipation is managed by minimizing the power dissipation and spreading the resulting heat dissipation onto a large area. The Kirk effect is normally avoided by increasing the collector doping density. However, for devices with a very high blocking voltage, this may not be an option. Power BJTs therefore are operated at rather low current density. Since the lower current density reduces the power dissipation per unit area and eliminates the Kirk effect. Large currents are obtained by making a large area device. Silicon BJTs dominate the power device market, in part because of the low cost of large area silicon devices and the high thermal conductivity of silicon compared to Ga. As Silicon carbide (SiC) has been hailed as the perfect material for high-power BJTs. The higher thermal conductivity and breakdown field compared to silicon give it a clear performance advantage. The high saturation velocity also shifts the onset of the Kirk effect to higher current densities. The proliferation of its use will heavily depend on the material cost and quality of the SiC wafers.

4) Insulated gate bipolar transistor:

The Insulated Gate Bipolar Transistor also called an IGBT for short, is something of a cross between a conventional Bipolar Junction Transistor, (BJT) and a Field Effect Transistor, (MOSFET) making it ideal as a semiconductor switching device. The IGBT transistor takes the best parts of these two types of transistors, the high input impedance and high switching speeds of a MOSFET with the low saturation voltage of a bipolar transistor, and combines them together to produce another type of transistor switching device that is capable of handling large collector-emitter currents with virtually zero gate current drive.

Fig.2.21.Typical IGBT

The Insulated Gate Bipolar Transistor, (IGBT) uses the insulated gate (hence the first part of its name) technology of the MOSFET with the output performance characteristics of a conventional bipolar transistor, (hence the second part of its name). The result of this hybrid combination is that the "IGBT Transistor" has the output switching and conduction characteristics of a bipolar transistor but is voltage-controlled like a MOSFET. IGBTs are mainly used in power electronics applications, such as inverters, converters and power supplies, were the demands of the solid state switching device are not fully met by power bipolars and power MOSFETs. High-current and high-voltage bipolars are available, but their switching speeds are slow, while power MOSFETs may have high switching speeds, but high-voltage and high-current devices are expensive and hard to achieve.

The advantage gained by the insulated gate bipolar transistor device over a BJT or MOSFET is that it offers greater power gain than the bipolar type together with the higher voltage operation and lower input losses of the MOSFET. In effect it is an FET integrated with a bipolar transistor in a form of Darlington configuration as shown in fig (2.22).
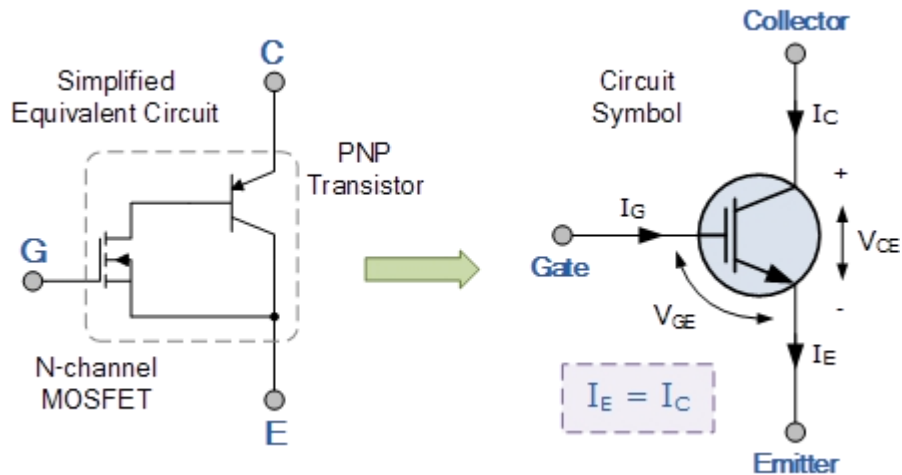
Fig.2.22.Diagram of Insulated Gate Bipolar Transistor

We can see that the insulated gate bipolar transistor is a three terminal, trans conductance device that combines an insulated gate N-channel MOSFET input with a PNP bipolar transistor output connected in a type of Darlington configuration. As a result the terminals are labelled as: Collector, Emitter and Gate. Two of its terminals (C-E) are associated with a conductance path and the third terminal (G) associated with its control. The amount of amplification achieved by the insulated gate bipolar transistor is a ratio between its output signal and its input signal. For a conventional bipolar junction transistor, (BJT) the amount of gain is approximately equal to the ratio of the output current to the input current, called Beta. For a metal oxide semiconductor field effect transistor or MOSFET, there is no input current as the gate is isolated from the main current carrying channel. Therefore, an FET's gain is equal to the ratio of output current change to input voltage change, making it a trans conductance device and this is also true of the IGBT. Then we can treat the IGBT as a power BJT whose base current is provided by a MOSFET.

The Insulated Gate Bipolar Transistor can be used in small signal amplifier circuits in much the same way as the BJT or MOSFET type transistors. But as the IGBT combines the low conduction loss of a BJT with the high switching speed of a power MOSFET an optimal solid state switch exists which is ideal for use in power electronics applications. Also, the IGBT has a much lower "on-state" resistance, R_{ON} than an equivalent MOSFET. This means that the I^2R drop across the bipolar output structure for

a given switching current is much lower. The forward blocking operation of the IGBT transistor is identical to a power MOSFET. When used as static controlled switch, the insulated gate bipolar transistor has voltage and current ratings similar to that of the bipolar transistor. However, the presence of an isolated gate in an IGBT makes it a lot simpler to drive than the BJT as much less drive power is needed.

An insulated gate bipolar transistor is simply turned "ON" or "OFF" by activating and deactivating its Gate terminal. A constant positive voltage input signal across the Gate and the Emitter will keep the device in its "ON" state, while removal of the input signal will cause it to turn "OFF" in much the same way as a bipolar transistor or MOSFET.

IGBT characteristics:
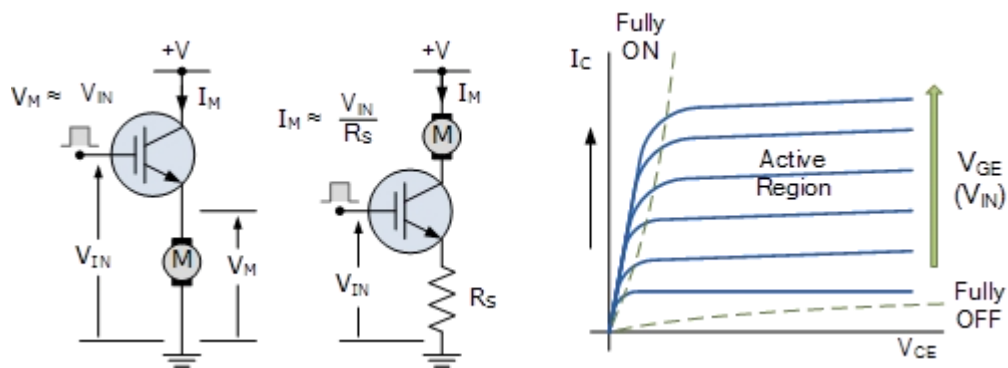
Fig.2.23 IGBT Characteristics

Because the IGBT is a voltage-controlled device, it only requires a small voltage on the Gate to maintain conduction through the device unlike BJT's which require that the Base current is continuously supplied in a sufficient enough quantity to maintain saturation. Also the IGBT is a unidirectional device, meaning it can only switch current in the "forward direction", that is from Collector to Emitter unlike MOSFET's which have bi-directional current switching capabilities (controlled in the forward direction and uncontrolled in the reverse direction).The principal of operation and Gate drive circuits for the insulated gate bipolar transistor are very similar to that of the N-channel power MOSFET. The basic difference is that the resistance offered by the main conducting channel when current flows through the device in its "ON" state is very much smaller in

the IGBT. Because of this, the current ratings are much higher when compared with an equivalent power MOSFET.

The main advantages of using the Insulated Gate Bipolar Transistor over other types of transistor devices are its high voltage capability, low ON-resistance, ease of drive, relatively fast switching speeds and combined with zero gate drive current makes it a good choice for moderate speed, high voltage applications such as in pulse-width modulated (PWM), variable speed control, switch-mode power supplies or solar powered DC-AC inverter and frequency converter applications operating in the hundreds of kilohertz range.

CHAPTER 3

QUASI-SWITCHED BOOST INVERTERS

3.1: INTRODUCTION:

In traditional voltage source inverters the DC source voltage cannot be higher than the peak AC output voltage. When low input voltages such as solar photo voltaic and fuel cells are used to obtain a high AC output voltage, hence an additional boost DC-DC converter, with two stage DC-DC-AC power conversion, is inserted in front of the inverter bridge. The two stages of power conversion i.e. boosting and inverting performed in one circuit that circuit is called quasi switched boost inverter.

Similar to the conventional ZSI and SBI, the QSBIs have extra shoot-through zero states, besides the traditional active state, and two zero states in the single-phase topology. Thus, the operating principles of the QSBIs are similar to those of the classical ZSI and SBI.

Like the quasi impedance source inverter has the main features of continuous input current, boosting the voltage with single stage conversion and shoot through immunity.

3.2 EMBEDDED TYPE QUASI SWITCHED BOOST INVERTER:

3.2.1 Steady State Circuit Analysis:

An embedded type QSBI is shown in Fig3.1. This circuit has equal number of components to that of SBI, but provides higher boost voltage and, most importantly,
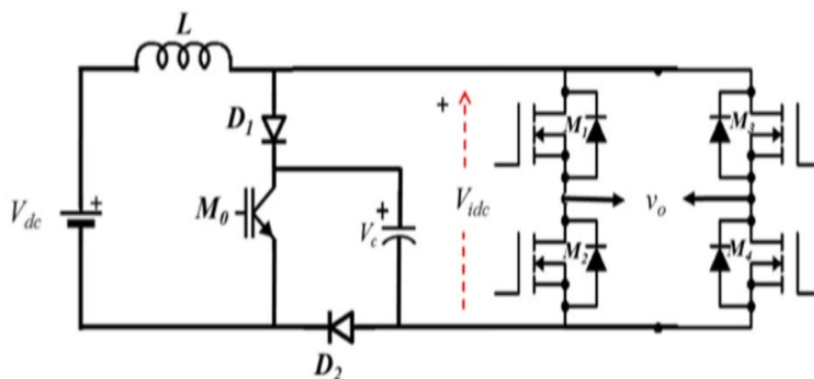
Fig: 3.1 Embedded type QSBI

operates with continuous input current. It has a Z-source network at the dc side with one or more active devices to achieve continuous input current. The placement of the inductance in series with the input dc source makes the source current continuous. At the same time, it is worth noting that the capacitor voltage stress is the same as compared to the SBI and is equal to the dc link voltage, which reaches high values at high boost conditions. There are two operating states possible for QSBI viz. Shoot Through (ST) and Non-Shoot Through (NST) states. The number of NST and ST states depends on the type of PWM strategy used in the converter. Operation of the embedded QSBI with basic PWM has one NST and one ST conditions, and can be explained using the equivalent circuits under these two operating states as shown in Fig. 3.2. The ST state can be initiated by turning on switches M_0, M_1 and M_2 together with a duty ratio $D = T_0/T$ where T_0 is the duration of the shoot through switching period T.

(a)   (b)
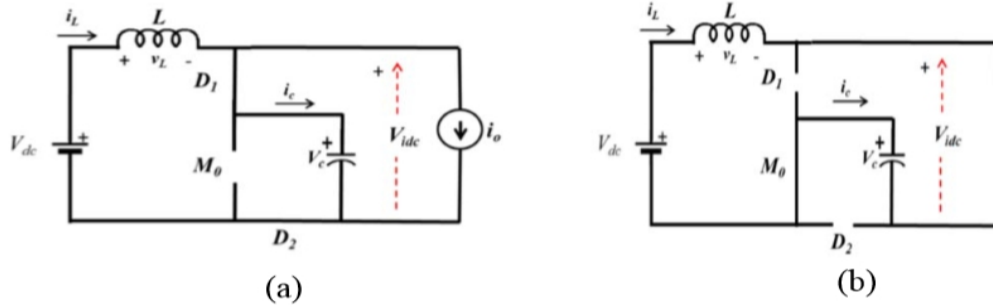
Fig: 3.2 Equivalent circuit of QSBI during (a) non-shoot through state (b) shoot through state.

Under steady state, observing the voltage across inductor in NST and ST states will yield,

$$L\frac{di_L}{dt} = V_{dc} - V_c \qquad\qquad \text{in NST} \qquad\qquad (1)$$

$$L\frac{di_L}{dt} = V_{dc} + V_c \qquad\qquad \text{inST} \qquad (2)$$

where, V_{dc} is the input dc voltage of the QSBI, V_c the Z-source Capacitor voltage, i_L is the source current or the Z-source inductor current and L is the inductance in the Z-

source network. By applying voltage-second balance for inductor over the switching period, the capacitor voltage in terms of input dc voltage is expressed as,

$$V_C = \frac{1}{1-2D} V_{dc} \tag{3}$$

The DC link voltage or the inverter input voltage V_{idc} is found to be the same as that of the capacitor voltage and expressed as,

$$V_{idc} = V_c = \frac{1}{1-2D} V_{dc} \tag{4}$$

Thus, the boost factor 'B', which is the ratio between the dc link voltage to the dc source voltage is deduced as,

$$B = \frac{V_{idc}}{V_{dc}} = \frac{1}{1-2D} \tag{5}$$

3.2.2 Basic PWM method for QSBI:

Generation of control signals for the basic PWM for a QSBI is shown in Fig. 3.3 With the shoot through signals the resulting Z-source inductor current in shown in Fig.3.4.
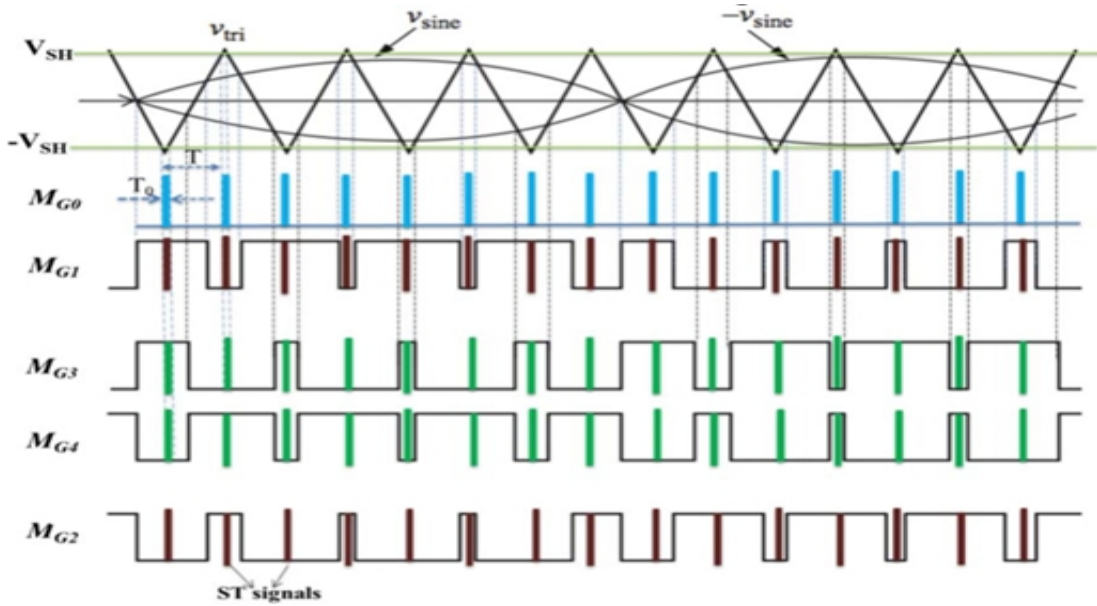
Fig: 3.3 shoot through signals and control signals of M_0.
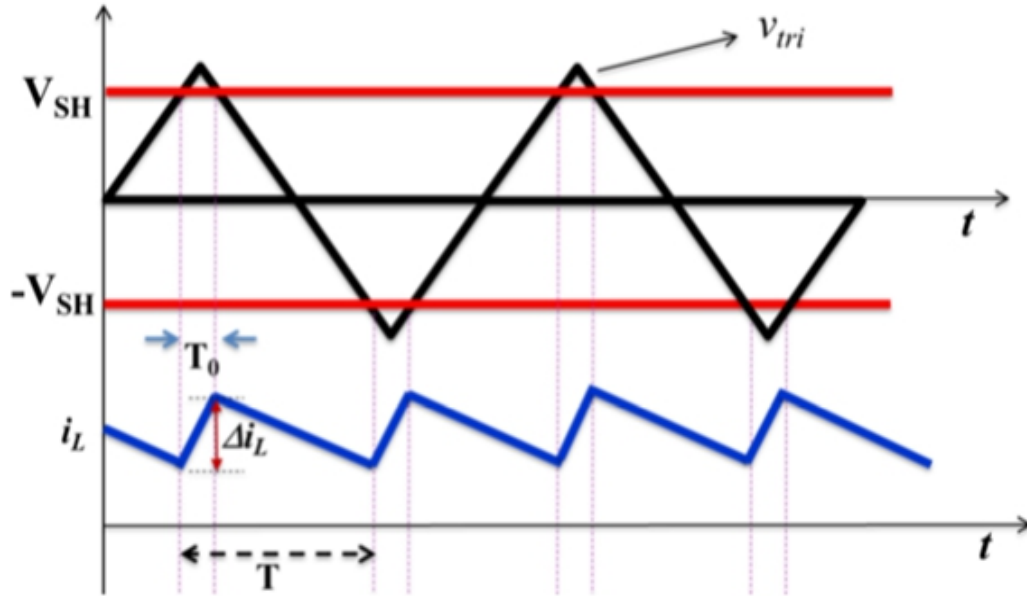
Fig: 3.4 z-source inductor current.

MG$_1$ to MG$_4$ are the gating signals of inverter bridge switches from M$_1$ to M$_4$, which are obtained from Unipolar PWM logic by comparing a triangular wave at switching frequency f$_{tri}$ with two 180° phase shifted sine waves at the required.

Fundamental frequency of the inverter f$_o$. The magnitude of sine and triangle waveform is v$_{sine}$ and v$_{tri}$respectively. The shoot through control signals for the Z-impedance network switch M_O and the inverter switches are generated by comparing the same triangular signal with two constant voltages V$_{SH}$ and $-$V$_{SH}$, such that,

$$D = \frac{T_0}{T} - \frac{|V_{SH}|}{\widehat{V_{tri}}} \tag{6}$$

This eventually results a shoot through control signal M_{G0} at frequency 2f$_{tri}$ as depicted in Fig.3a. Logic circuits are used to superimpose the shoot through signals with that of the inverter PWM signals. The same effect of doubling the shoot through control frequency can be obtained by comparing V$_{SH}$ with a unipolar triangular waveform at two times the inverter switching frequency f$_{tri}$. The output voltage of a unipolar PWM inverter for an input voltage of V$_{idc}$ can be expressed as,

$$\widehat{V_0} = m_a V_{idc} \tag{7}$$

where, m_a is the amplitude modulation index of the PWM inverter and $\widehat{V_0}$ is the peak inverter output voltage. The amplitude modulation index can be expresses in terms of the control circuit quantities as v_{sin}/v_{tri} . This method of PWM is referred as simple boost control method, in which, there exists a restriction imposed by the shoot through duty ratio on the inverter modulation index. The maximum inverter modulation index is now restricted to (1-D), which implies that the larger the duty ratios, the higher the boost ratios, but lower the modulation index will be. This low modulation index eventually results in a higher THD at the inverter output. When the QSBI is switched with this basic PWM method, the inductor current ripple will be at two times the inverter switching frequency and the peak to peak inductor current ripple depends on the boost ratio and the value of L as per equations (1) and (2). When high boost ratios are required, the inductor current ripple will be reaching higher values, which demands a larger inductance for the same switching frequency. If the size of inductor is to be reduced without compromising on the ripple content, then the inverter switching frequency has to be increased which will lead to higher switching loss in the inverter. The proposed PWM aims at achieving the dual task of increasing the frequency of the inductor current ripple without increasing the inverter switching frequency, leading to a more efficient converter system.

3.2.3. PROPOSED PWM METHOD FOR QSBI:

In the basic PWM for QSBI, the shoot through control signals of M_0 is integrated into the control signals of inverter switches. This synchronized switching will result the energy exchange between the z-source components to happen during the shoot through states. This synchronized switching results in an increased loss of the active devices. From the basic principles, the switches in the inverter bridge are to be controlled to produce a near sinusoidal output voltage whereas switch M_0 is controlled to introduce the necessary boost. As there is an independency between these two control tasks, these two switching can be decoupled. Such decoupling will make the input current alone to have higher switching frequency without actually increasing the inverter switching frequency.

The proposed PWM method for QSBI aims to establish such a decoupling between the switching of M_0 and the inverter switches $M_1 - M_4$ by introducing a phase shift between these two control signals. This phase shift will make the charge/discharge cycles

shorter compared to the earlier PWM method, thereby doubling the input inductor ripple frequency. However, this phase shift will revise the working of QSBI of Fig.3.1 because of the introduction of an additional NST state.

1)Description of the proposed PWM:

The proposed PWM uses multiple control voltage levels for generating the switching signals for M_0 and shoot through separately as depicted in Fig. 3.5. The shoot trough signals for the inverter switches are generated by comparing the triangle wave of frequency f_{tri} with the voltage level V_{SH} and - V_{SH} with the following logic: when $V_{tri}>$ V_{SH} or $V_{tri}< -V_{SH}$, shoot through pulses will be generated. The control signal for the Z source switch M_0 is generated by comparing the triangle wave with two other derived voltage levels $(1-V_{SH})$ and $-(1-V_{SH})$ with the following logic: when $(1-V_{SH})>V_{tri}< -(1-V_{SH})$, gating pulse for M_0 will be generated. Thus, there are two independent control signals generated one for the shoot through and one for the input switch M_0 which are phase shifted by an angle ϕ. This phase shift varies upon the choice of V_{SH}. Because of this phase shift, the circuit operation swerves from that of the basic PWM operation in terms of the number of cycles of the inductor and capacitor charge/discharge. It can be seen that there are two complete on and off time durations for the inductor within the triangular period, which is two times as that in the basic PWM. This eventually doubles the inductor current ripple frequency and further reduces the ripple magnitude to half that of the basic PWM. Ultimately, the ripple frequency of the inductor current is now at four times the inverter switching frequency. This doubling effect is accomplished without increasing the inverter frequency and its losses. The number of NST states now becomes two, while the ST state remains the same as that of the basic PWM.
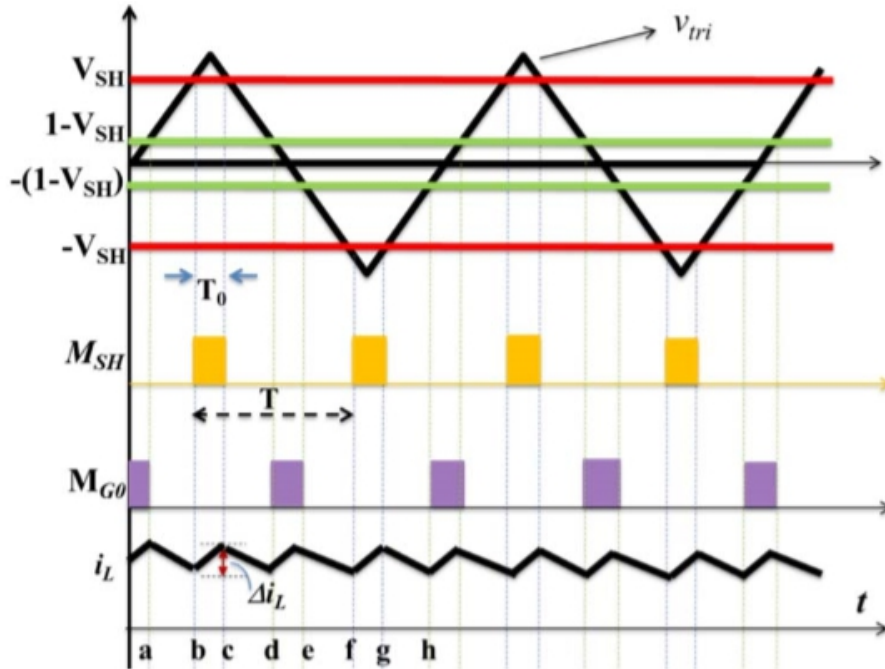
Fig. 3.5Proposed PWM technique

2)Analysis of the proposed PWM:

From Fig. 3.5, the NST duration can be identified as c-f, however, the circuit will enter into a different NST operating condition during d-e because of the turn on of M_0, which introduces an additional NST mode of operation. The equivalent circuit of the QSBI with the proposed PWM is depicted in Fig. 5 with three operating states instead of two as in the basic PWM. The NST state during 'd' to 'e' is presented in Fig. 3.6(a) during which the switch M_0 is turned on and makes the inductor store energy and the V_{idc} is maintained by the capacitor which is discharging and the inverter is in its non-zero state. The equivalent circuit for the durations c-d and e-f remains the same as in the basic PWM   as depicted in Fig. 3.6 (b) wherein the inductor delivers the stored energy to the load through the inverter, the capacitor is charging and the dc link voltage is taken care of by V_c; this state persists in two continuous-time slots with a total duration of (1-2D) T. The shoot through state is presented in Fig. 3.6 (c) and the inverter bridge arm shorts the input dc source across the Z-source inductor L thus making the inductor store energy.
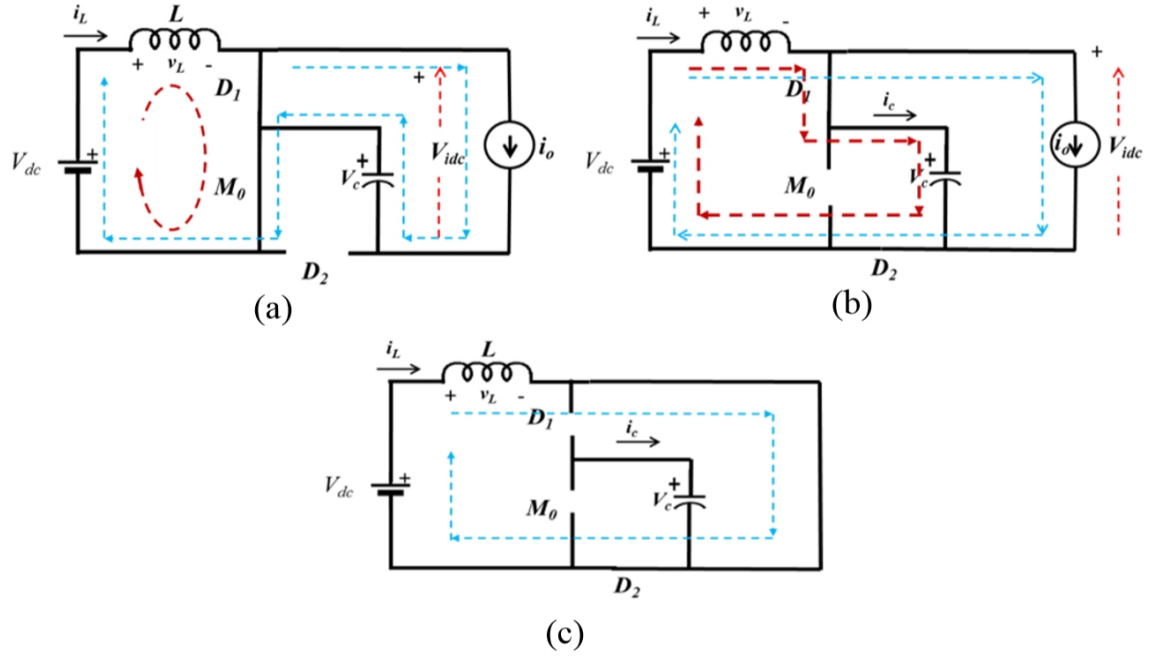
Fig:3.6 : Equivalent circuit of QSBI with the proposed PWM technique (a) operation during 'd' to 'e' NST state, (b) operation during NST state between c-d and e-f (c) operation during ST state between b-c.

The equations pertaining to these three modes of operations are expressed as,

$$L\frac{di_L}{dt} = V_{dc} \qquad\qquad \text{NST d to e} \qquad\qquad (8)$$

$$L\frac{di_L}{dt} = V_{dc}\text{-}V_c \qquad\qquad \text{NST c to d} \qquad\qquad (9)$$

$$L\frac{di_L}{dt} = V_{dc} \qquad\qquad \text{NST d to e} \qquad\qquad (10)$$

From the volt-second balance the dc link voltage V_{idc} can be derived as,

$$V_{idc} = \frac{V_{dc}}{1-2D} = V_c \qquad\qquad (11)$$

The dc-link voltage is observed to remain constant as in case of the basic PWM for QSBI. The further analysis is extended to quantify the capacitor ripple voltage and the inductor ripple current with the proposed PWM scheme. From (8) to (10) it is possible to express the inductor current ripple as,

$$\Delta i_L = \frac{V_{dc}\,dt}{L} = \frac{V_{dc}D}{L}\frac{T}{2} = \frac{V_{dc}D}{2\,f_{tri}L} \qquad\qquad (12)$$

The peak-peak ripple in the inductor current is just half of its value at a frequency twice that of f_{tri} when compared to the basic PWM, because in equation (12) the time period of operation of M_0 is half the triangle period or twice the triangle frequency. Similarly, the capacitor voltage ripple can be obtained by deriving the capacitor charge-second balance equations for the two NST states as,

$$C\frac{dv_c}{dt} = - I_0 \qquad\qquad \text{NST d to e} \qquad\qquad (13)$$

$$C\frac{dv_c}{dt} = I - I_0 \qquad\qquad \text{NST c to d} \qquad\qquad (14)$$

$$\Delta v_c = \frac{I_0}{C} dt = \frac{I_0}{C} D\frac{T}{2} = \frac{I_0 D}{2Cf_{tri}} \qquad\qquad (15)$$

From equation (15), it is evident that the capacitor voltage ripple is also reduced to half when compared to the basic PWM with the ripple frequency of capacitor voltage doubled.

CHAPTER -4

INTRODUCTION TO MATLAB

4.1 WHAT IS MATLAB?

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include:

- Math and computation
- Algorithm development
- Modelling, simulation, and prototyping
- Data analysis, exploration, and visualization
- Scientific and engineering graphics
- Application development, including Graphical User Interface building

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows you to solve many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar no interactive language such as C or FORTRAN.

The name MATLAB stands for matrix laboratory. MATLAB was originally written to provide easy access to matrix software developed by the LINPACK and EISPACK projects, which together represent the state-of-the-art in software for matrix computation.

MATLAB has evolved over a period of years with input from many users. In university environment, it is the standard instructional tool for introductory and advanced courses in mathematics, engineering, and science. In industry, MATLAB is the tool of choice for high-productivity research, development, and analysis.

MATLAB features a family of application-specific solutions called toolboxes. Very important to most users of MATLAB, toolboxes allow you to *learn* and *apply* specialized technology. Toolboxes are comprehensive collections of MATLAB functions (M-files) that extend the MATLAB environment to solve particular classes of problems. Areas in

which toolboxes are available include signal processing, control systems, neural networks, fuzzy logic, wavelets, simulation, and many others.

4.2 PARTS IN MATLAB:

The MATLAB system consists of five main parts:

4.2.1 The MATLAB Language:

This is a high-level matrix/array language with control flow statements, functions, data structures, input/output, and object-oriented programming features. It allows both "programming in the small" to rapidly create quick and dirty throw-away programs, and "programming in the large" to create complete large and complex application programs.

4.2.2 The MATLAB Working Environment:

This is the set of tools and facilities that you work with as the MATLAB user or programmer. It includes facilities for managing the variables in your workspace and importing and exporting data. It also includes tools for developing, managing, debugging, and profiling M-files, MATLAB's applications.

4.2.3 Handle Graphics:

This is the MATLAB graphics system. It includes high-level commands for two-dimensional and three-dimensional data visualization, image processing, animation, and presentation graphics. It also includes low-level commands that allow you to fully customize the appearance of graphics as well as to build complete Graphical User Interfaces on your MATLAB applications.

4.2.4 The MATLAB Mathematical Function Library:

This is a vast collection of computational algorithms ranging from elementary functions like sum, sine, cosine, and complex arithmetic, to more sophisticated functions like matrix inverse, matrix Eigen values, Bessel functions, and fast Fourier transforms.

4.2.5 The MATLAB Application Program Interface (API):

This is a library that allows you to write C and Fortran programs that interact with MATLAB. It include facilities for calling routines from MATLAB (dynamic linking), calling MATLAB as a computational engine, and for reading and writing MAT-files.

4.3 MATLAB-SIMULINK:

- Commonly Used Blocks

- Logic and Bit Operations

- Sinks

- Sources

Simulink contains a large number of blocks from which models can be built. These blocks are arranged in Block Libraries which are accessed in the Simulink library browser window shown below

Each icon in the main Simulink window can be double clicked to bring up the corresponding block library. Blocks in each library can then be dragged into a model window to build a model.
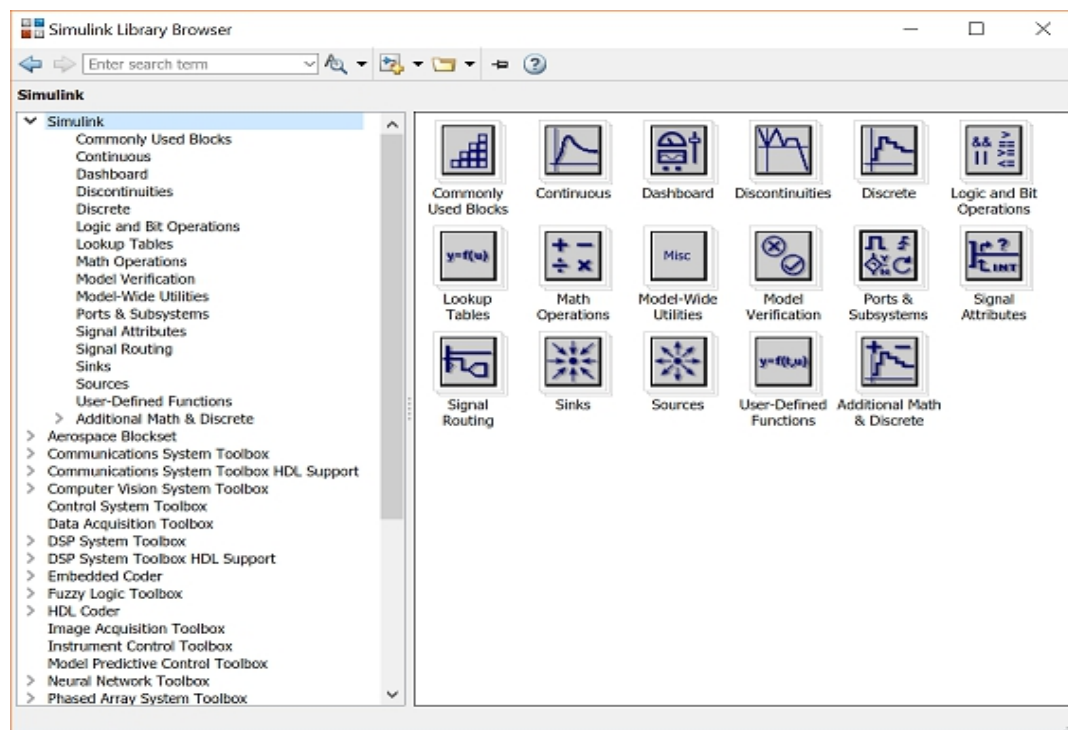
4.3.1 Commonly used blocks:

Commonly Used Blocks are used to list a lot of blocks which are usually used. Double-click on the Commonly Used Blocks icon in the main Simulink window to bring up the Commonly Used window.
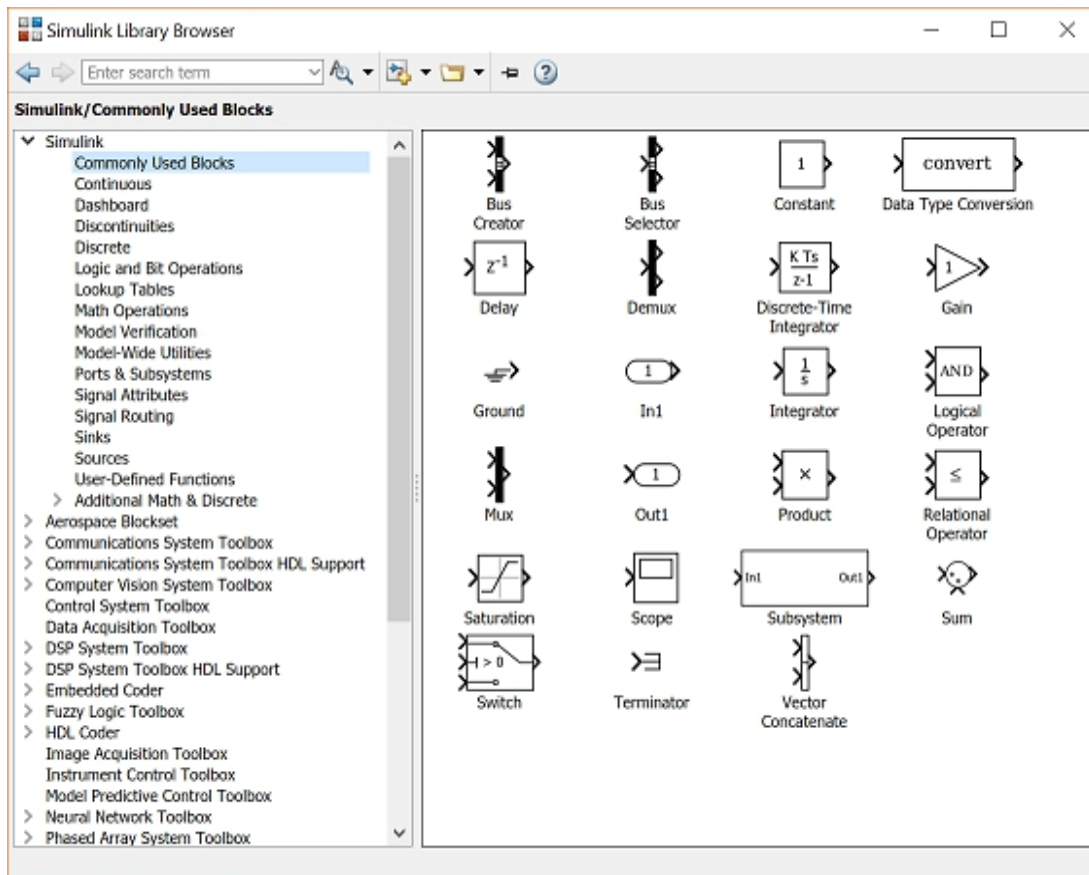
Constant:

The Constant block generates a real or complex constant value. The constant output value isdisplayed in the middle of the block, with a default value of 1.

In order to examine these blocks, create a new model window (select New from the File menu in the Simulink window or hit Ctrl+N).

Data Type Conversion :

The Data Type Conversion block converts an input signal of any Simulink data type to the data type you specify for the Output data type parameter. The input can be any real- or complex-valued signal.

Delay:

The Delay block delays an input u according to the Delay length parameter, which you specify on the dialog box, or a delay length that a signal supplies to the input port. This block is equivalent to the z-1 discrete-time operator.

Demux, **Mux:**

The Mux (Multiplexer) block is used to combine two or more scalar signals into a single vector signal. Similarly, a Demux (Demultiplexer) block breaks a vector signal into scalar signal components. The number of vector components must be specified in each case.

Discrete-Time Integrator:

This is the discrete time approximation of a continuous-time integrator. The approximation method can be specified as well as the initial condition and saturation limits.

From :

The From block accepts a signal from a corresponding Goto block, then passes it as output. The data type of the output is the same as that of the input from the Goto block. From and Goto blocks allow you to pass a signal from one block to another without actually connecting them. To associate a Goto block with a From block, enter the Goto block's tag in the Goto Tag parameter.

A From block can receive its signal from only one Goto block, although a Goto block can pass its signal to more than one From block.

This figure shows that using a Goto block and a From block is equivalent to connecting the blocks to which those blocks are connected. In the model at the left, Block1 passes a signal to Block2. That model is equivalent to the model at the right, which connects Block1 to the Goto block, passes that signal to the From block, then on to Block2.
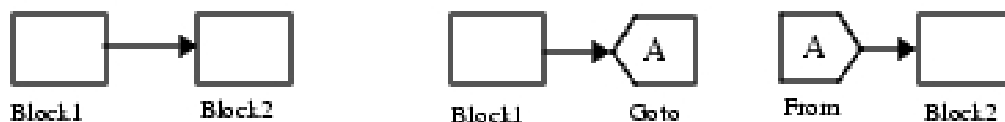
The visibility of a Goto block tag determines the From blocks that can receive its signal. For more information, see Goto and Goto Tag Visibility. The block indicates the visibility of the Goto block tag:

➢ A local tag name is enclosed in brackets ([]).

➢ A scoped tag name is enclosed in braces ({}).

➢ A global tag name appears without additional characters.

Gain :

The Gain block multiplies the input by a constant value (gain). The input and the gain can each be a scalar, vector, or matrix.

Gain

You specify the value of the gain in the Gain parameter. The Multiplication parameter lets you specify element-wise or matrix multiplication. For matrix multiplication, this parameter also lets you indicate the order of the multiplicands.

The gain is converted from doubles to the data specified in the block mask offline using round-to-nearest and saturation. The input and gain are then multiplied, and the result is converted to the output data type using the specified rounding and overflow modes.

Ground:

The Ground block connects to blocks whose input ports do not connect to other blocks.

Goto :
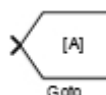
Goto

The Goto block passes its input to its corresponding From blocks. The input can be a real- or complex-valued signal or vector of any data type. From and Goto blocks allow you to pass a signal from one block to another without actually connecting them.

A Goto block can pass its input signal to more than one From block, although a From block can receive a signal from only one Goto block. The input to that Goto block is passed to the From blocks associated with it as though the blocks were physically connected. Goto blocks and From blocks are matched by the use of Goto tags.

The Tag Visibility parameter determines whether the location of From blocks that access the signal is limited:

• local, the default, means that From and Goto blocks using the same tag must be in the same subsystem. A local tag name is enclosed in brackets ([]).

• scoped means that From and Goto blocks using the same tag must be in the same subsystem or at any level in the model hierarchy below the Goto Tag Visibility block that does not entail crossing a nonvirtual subsystem boundary, i.e., the boundary of an atomic, conditionally executed, or function-call subsystem or a model reference. A scoped tag name is enclosed in braces ({}).

• global means that From and Goto blocks using the same tag can be anywhere in the model except in locations that span non virtual subsystem boundaries.

The rule that From-Goto block connections cannot cross nonvirtual subsystem boundaries has the following exception. A Goto block connected to a state port in one conditionally executed subsystem is visible to a From block inside another conditionally executed subsystem. For more information about conditionally executed subsystems.

Integrator:

The output of the Integrator is the integral of the input. An initial condition can be specified, as well as saturation limits. This block is very useful for modelling system in modelling system in Simulink.

4.3.2 Logical Operators:

The Logical Operator block performs the specified logical operation on its inputs. An input value is TRUE (1) if it is nonzero and FALSE (0) if it is zero.

Out1:

Outport blocks are the links from a system to a destination outside the system.

Product :

By default, the Product block outputs the result of multiplying two inputs: two scalars, a scalar and a nonscalar, or two nonscalars that have the same dimensions.

The default parameter values that specify this behavior are:
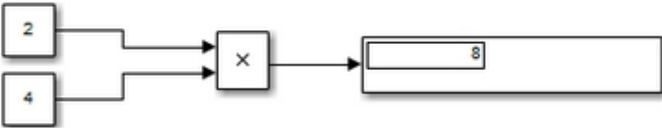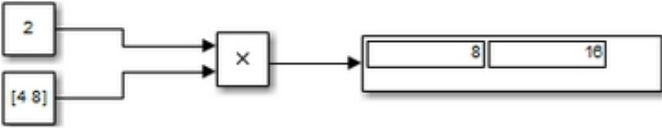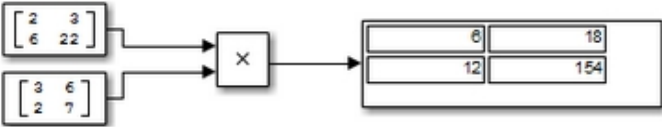
Multiplication: Element-wise(.*)

Number of inputs: 2

Setting non-default values for either of these parameters can change a Product block to function as a Divide block or a Product of Elements block. See the documentation of those two blocks for more information.

If all you need is to multiply two inputs to create an output, you can use the Product block with default parameter values. If you need additional capabilities, see Product Block Capabilities.

The following table shows the output of the Product block for example inputs usingdefault block parameter values.

Inputs and Behavior	Example
Scalar X Scalar Output the product of the two inputs.	
Scalar X Nonscalar Output a nonscalar having the same dimensions as the input nonscalar. Each element of the output nonscalar is the product of the input scalar and the corresponding element of the input nonscalar.	
Nonscalar X Nonscalar Output a nonscalar having the same dimensions as the inputs. Each element of the output is the product of corresponding elements of the inputs.	

Relational Operator:

By default, the Relational Operator block compares two inputs using the Relational operator parameter that you specify. The first input corresponds to the top input port and the second input to the bottom input port.

Scope and Floating Scope :

The Scope block displays inputs signals with respect to simulation time.

Scope

- **Scope window** - If a Scope window is closed at the start of a simulation, scope data is still written to the connected Scope. As a result, if you open a Scope after a simulation, the Scope window displays the input signal or signals.
- **Plotting signals** - If the input signal is continuous, the Scope draws a point-to-point plot. If the signal is discrete, the Scope draws a stair-step plot.
- **Time step values** -The Scope block only displays major time step values. The scope displays additional interpolated points between major time steps if specified by the refine parameter.
- **Multiple y-axes (graphs)** - A Scope window can display multiple y-axes (graphs) with one graph per input port. All of the y-axes have a common time range on the x-axis. The Scope block allows you to adjust the amount of time and the range of input values displayed. You can modify the Scope parameter values during a simulation.
- **Data type support** -The Scope block accepts real (not complex) signals of any data type that Simulink® supports, including fixed-point and enumerated data types. The Scope block also accepts homogeneous vectors. For more information, see Data Types Supported by Simulink in the Simulink documentation.

Subsystem, Atomic Subsystem, Non virtual Subsystem, Code Reuse Subsystem:
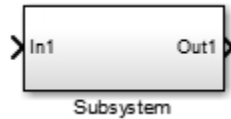
A subsystem block contains a subset of blocks or code within an overall model or system. The subsystem block can represent a virtual subsystem or a non virtual subsystem.

In non virtual subsystems, you can control when the contents of the subsystem are evaluated. Non virtual subsystems are executed as a single unit (atomic execution). You can create conditionally executed non virtual subsystems that execute only when a transition occurs on a triggering, function-call, action, or enabling input (see Conditional Subsystems).

A subsystem is virtual if the block is neither conditionally executed nor atomic.

If only addition of all inputs is required, then a numeric parameter value equal to the number of inputs can be supplied instead of "+" characters.

If only one input port is required, a single "+" or "-" collapses the element via the specified operation.

The Sum block first converts the input data type(s) to its accumulator data type, then performs the specified operations. The block converts the result to its output data type using the specified rounding and overflow modes.

An Atomic Subsystem block is a subsystem block in which Treat as atomic unit is selected by default.

A Cod e Reuse Subsystem block is a subsystem block in which Treat as atomic unit is selected and Function packaging is set to Reusable function, specifying the function code generation format for the subsystem. (see Function packaging for details).

To create a subsystem, do one of the following:

Copy a subsystem block from the Ports & Subsystems library into your model. Then add blocks to the subsystem by opening the subsystem block and copying blocks into it.

Select all blocks and lines that make up the subsystem, and select Diagram > Subsystem & Model Reference > Create Subsystem from Selection. Simulink® replaces

the blocks with a subsystem block, along with the necessary Inport and Outport blocks to reflect signals entering and leaving the subsystem.

The number of input ports drawn on the subsystem block's icon corresponds to the number of Inport blocks in the subsystem. Similarly, the number of output ports drawn on the block corresponds to the number of Outport blocks in the subsystem.

The subsystem block supports signal label propagation through subsystem Inport and Outport blocks.

Sum, Add, Subtract, Sum of Elements :

The Sum block performs addition or subtraction on its inputs. This block can add or subtract scalar, vector, or matrix inputs. It can also collapse the elements of a signal.

You specify the operations of the block with the List of signs parameter. Plus (+), minus (-), and spacer (|) characters indicate the operations to be performed on the inputs.

If there are two or more inputs, then the number of + and - characters must equal the number of inputs. For example, "+-+" requires three inputs and configures the block to subtract the second (middle) input from the first (top) input, and then add the third (bottom) input.

All non-scalar inputs must have the same dimensions. Scalar inputs will be expanded to have the same dimensions as the other inputs.

A spacer character creates extra space between ports on the block's icon.

For a round Sum block, the first input port is the port closest to the 12 o'clock position going in a counter clockwise direction around the block. Similarly, other input ports appear in counter clockwise order around the block.

Switch:

The Switch block passes through the first input or the third input based on the value of the second input. The first and third inputs are called data inputs. The second input is called the control input.

4.3.3 Sinks:

Sink Blocks are used to display or output signals. Double-click on the Sinks icon in the main Simulink window to bring up the Sinks window.
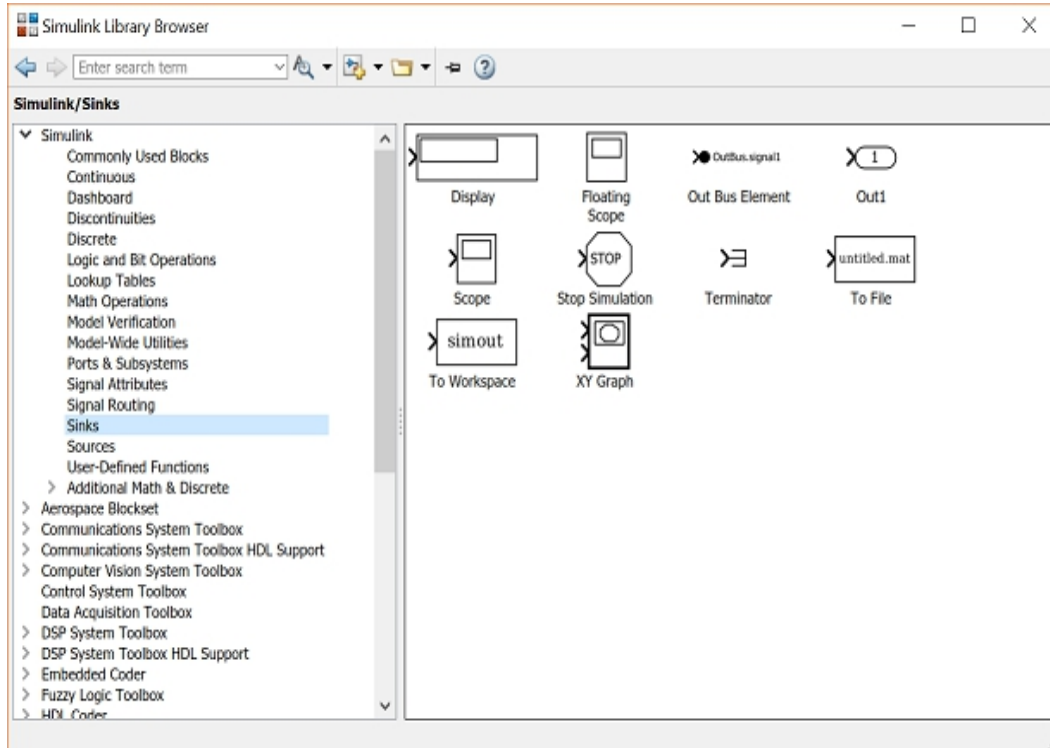
Notice that all of the sink blocks have inputs and no outputs. Most have a single input.

Display:

The Display Sink Block is a digital readout of a signal at the current simulation time.

Stop Simulation:

This is a special control block which is triggered to stop the current simulation when its input is non-zero.

To File:

The To File Sink Block saves a signal to a .mat file in the same way that the From File Source Block reads from a file. The sampling time can be specified, but is not necessary.

To Workspace:

The To Workspace Sink Block stores a signal in a specified workspace variable. Unlike the To File Sink Block, the time is not saved in the variable, and must be stored separately.

XY Graph:

The XY Graph Sink Block plots one signal against another. It is useful for phase-plane plots, etc.

4.3.4 Sources:

Source Blocks are used to generate signals. Double-click on the Sources icon in the main Simulink window to bring up the Sources window.
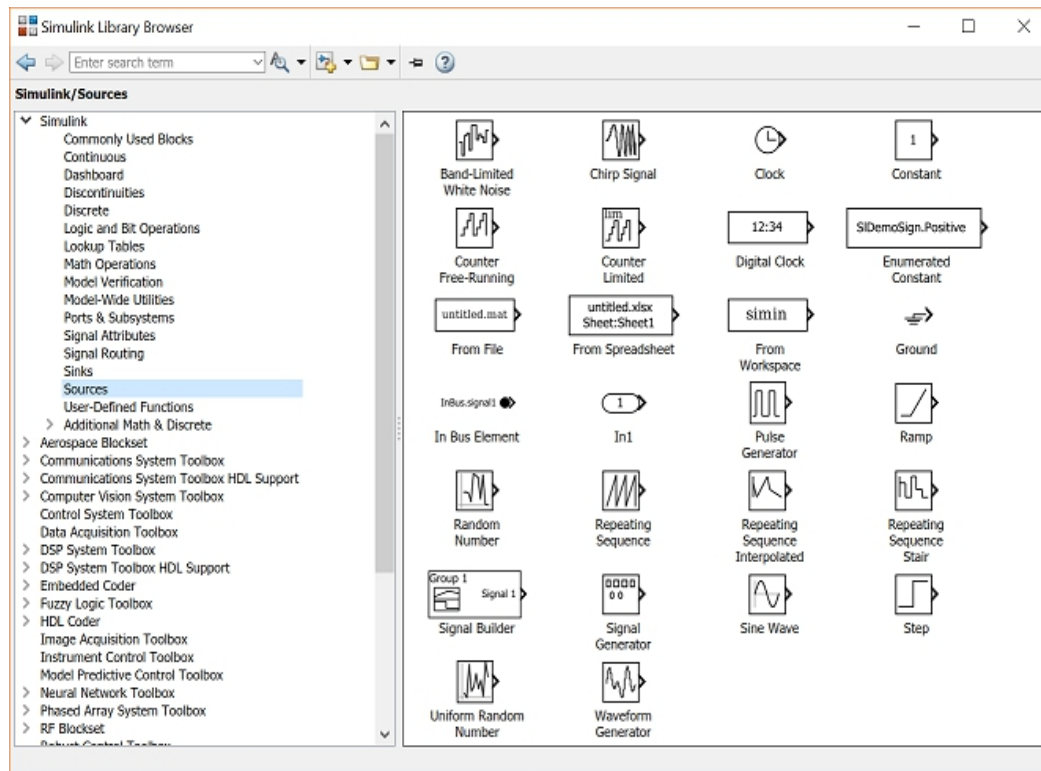
Notice that all of the source blocks have a single output and no inputs. While parameters in each of these blocks in the library can be modified by double-clicking the block, it is best to not modify the blocks until they have been copied into a model window.

Pulse Generator:

The Pulse Generator Source Block generates a pulse train of varying duty cycle. The signal switches between 0 and the specified value starting at a particular time. The Period, Duty Cycle, Amplitude, and Start Time can be specified.

Ramp:

The Ramp Source Block generates a signal which is initially constant and begins to increase (or decrease) at a constant rate at a specified time. The slope, start time, and initial output can be specified.

Waveform Generator:

The Waveform Generator block outputs waveforms based on signal notations that are entered in the Waveform Definition table.

Signal Generator:

The Signal Generator Source Block is a general-purpose source which encompasses some of the other blocks' functions. It generates periodic waveforms such as sine, square, and sawtooth waves as well as a random signal. Drag this block from the Sources window to your model window.

Sine Wave:

The Sine Wave Source Block generates a sinusoidal signal. The Amplitude and Frequency can be specified, as well as the Phase (unlike the Signal Generator). There is a fourth parameter, the Sample Time, which can be used to force the Sine Wave Source to operate in discrete-time mode.

Step :

The Step block provides a step between two definable levels at a specified time. If the simulation time is less than the Step time parameter value, the block's output is the Initial value parameter value. For simulation time greater than or equal to the Step time, the output is the Final value parameter value.

Step

The numeric block parameters must be of the same dimensions after scalar expansion. If the Interpret vector parameters as 1-D option is off, the block outputs a signal of the same dimensions and dimensionality as the parameters. If the Interpret vector parameters as 1-D option is on and the numeric parameters are row or column vectors (that is, single row or column 2-D arrays), the block outputs a vector (1-D array) signal. Otherwise, the block outputs a signal of the same dimensionality and dimensions as the parameters.

CHAPTER-5

SIMULATION DIAGRAMS AND RESULT ANALYSIS

Simulink Diagram of Quasi switched boost inverter (QSBI):
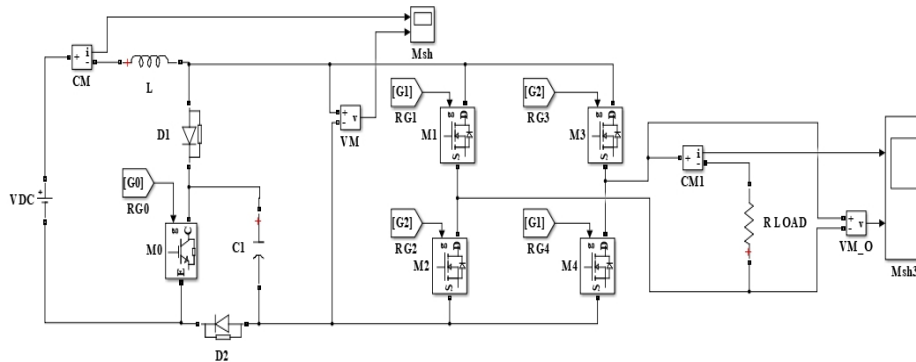
Fig:5.1 Simulink Diagram of QSBI

Simulink Diagram of Basic PWM Technique:
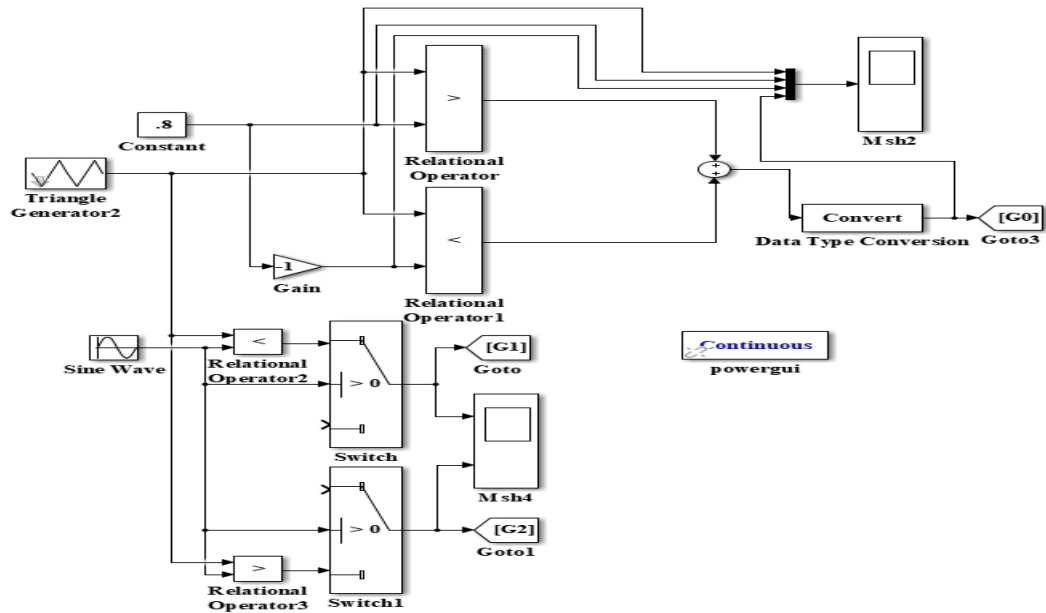
Fig:
5.2 Simulink Diagram of basic PWM Technique

Simulink Diagram of Proposed PWM:
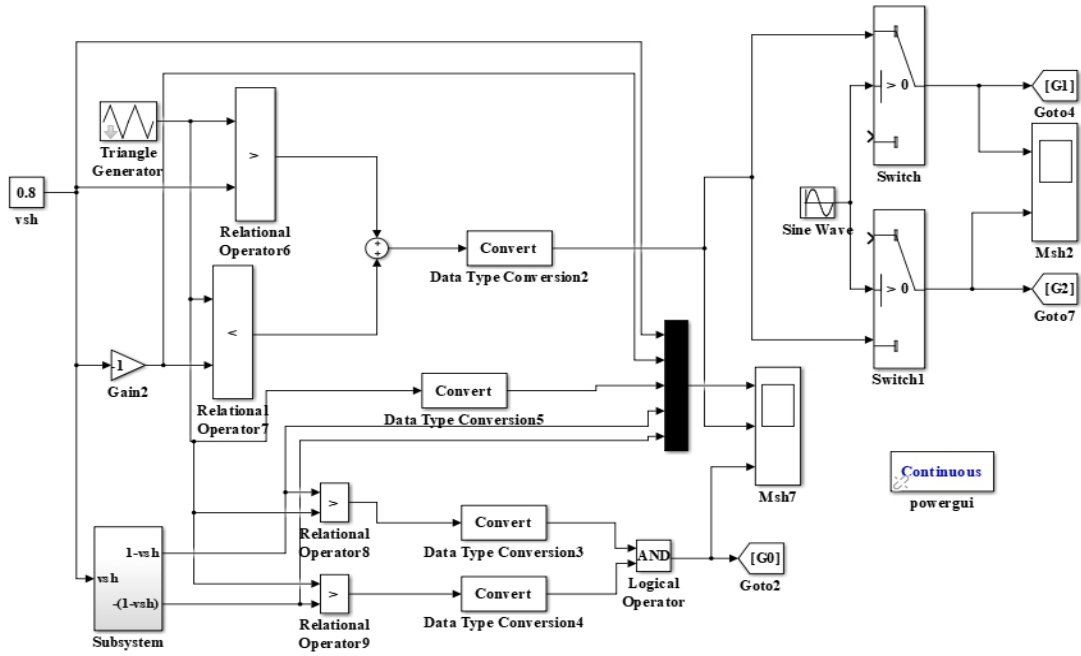
Fig:5.3 Simulink Diagram of proposed PWM Technique

Simulink Diagram of Subsystem of proposed PWM:
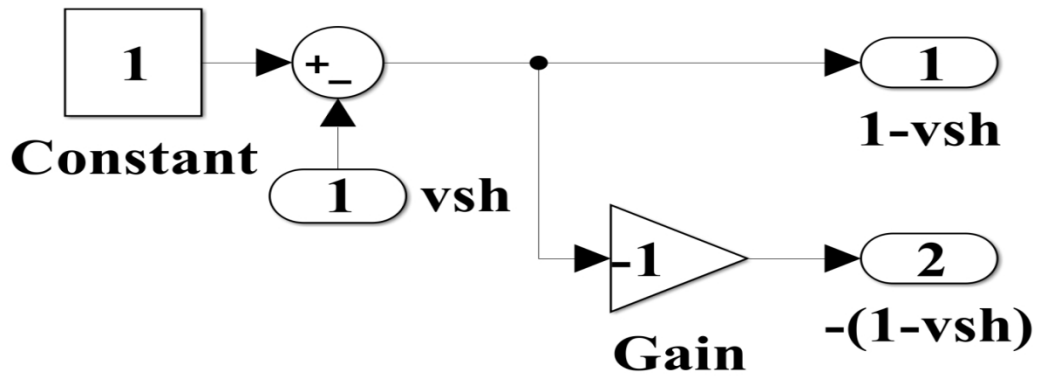
Fig: 5.4 Subsystem of proposed PWM

Simulation Results Basic PWM Technique:

(a)

(b)

(c)

(d)
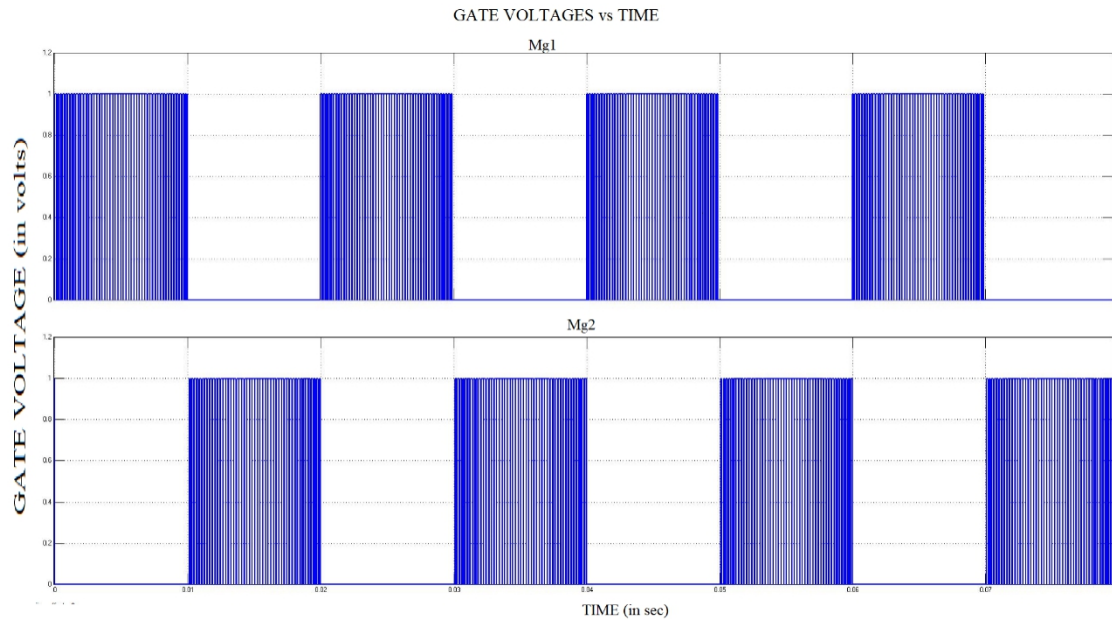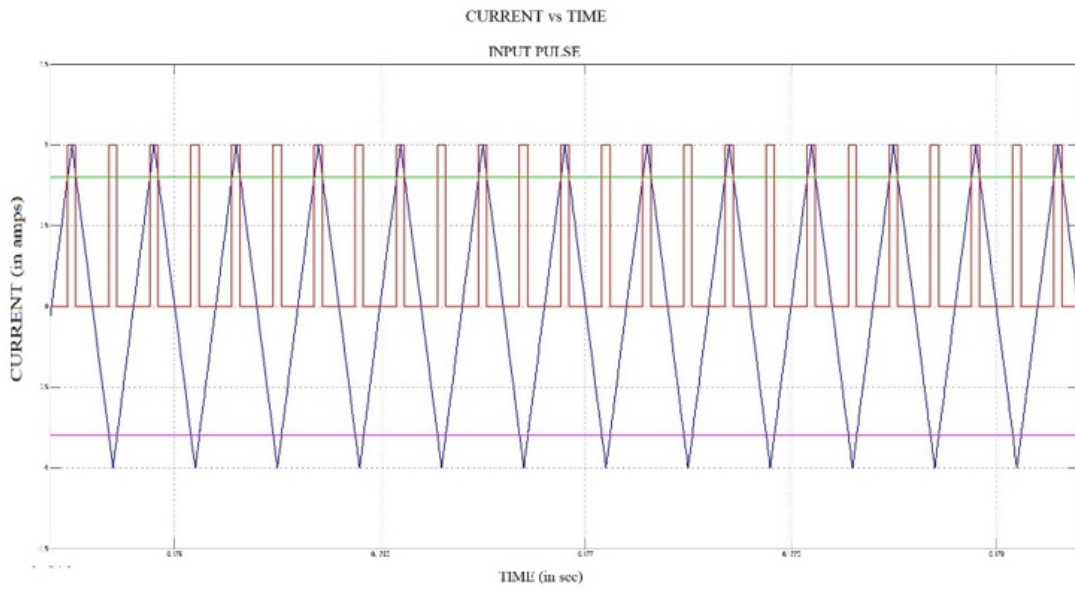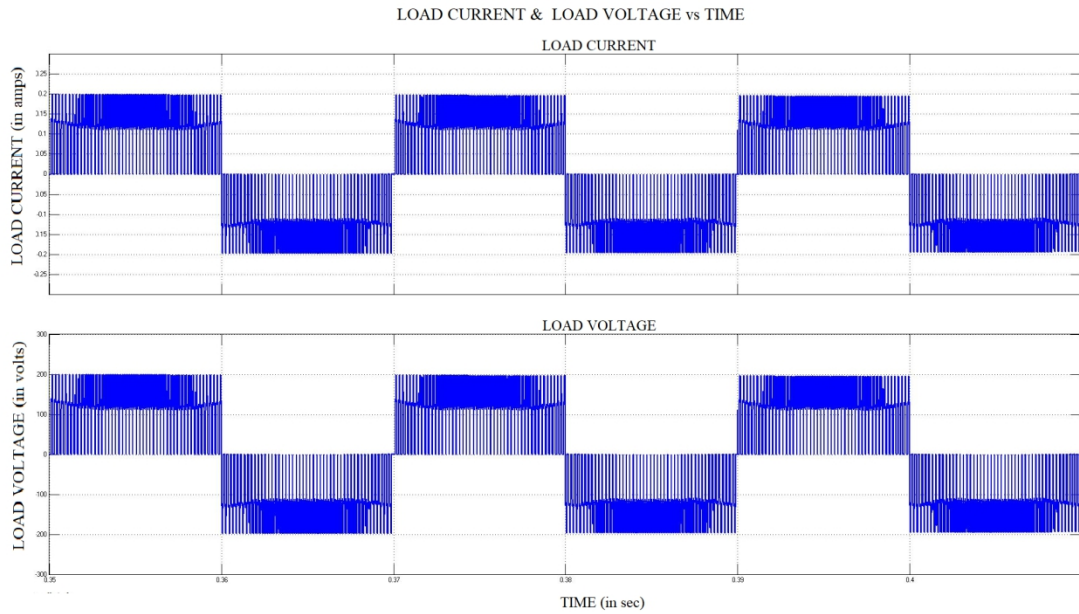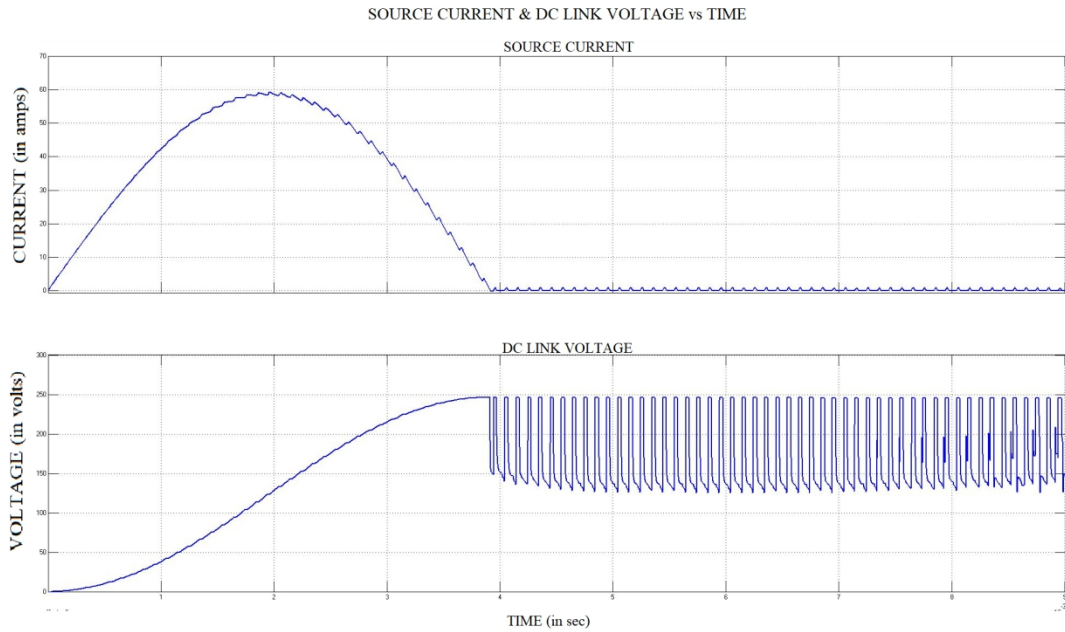
Fig:5.5 Waveforms of QSBI with the basic PWM (a) Gate voltages, (b) Input pulse, (c)DC link voltage & Source current , (d) Output current & voltage.

Simulation Results of Basic PWM Techniqueat modulation index = 0.8 :
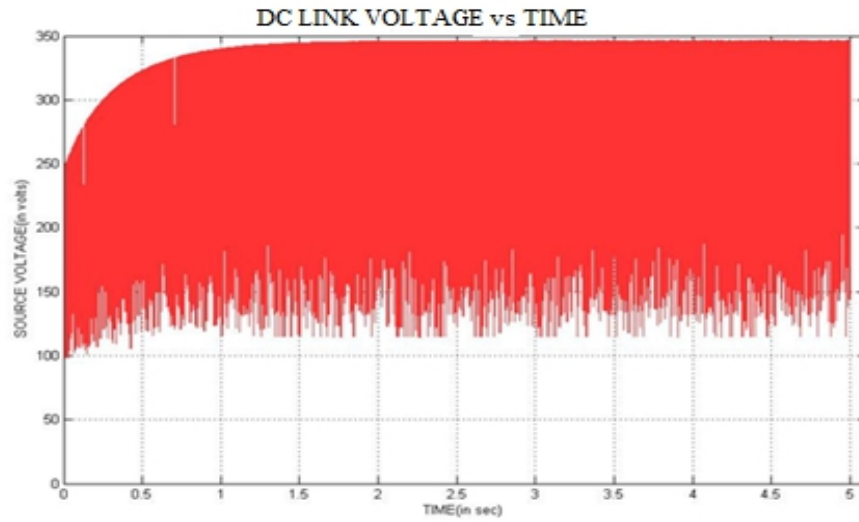
(a)
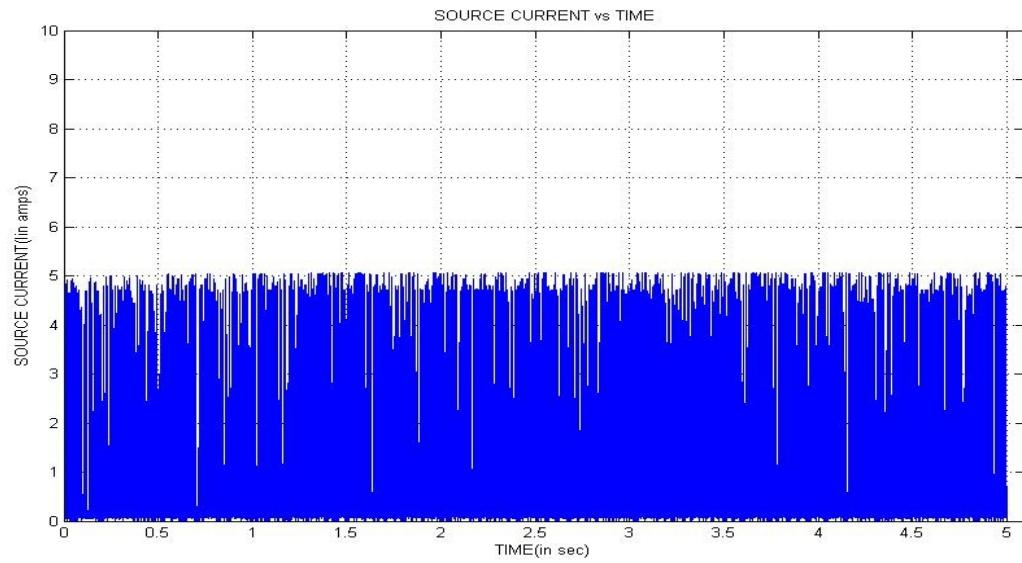
(b)
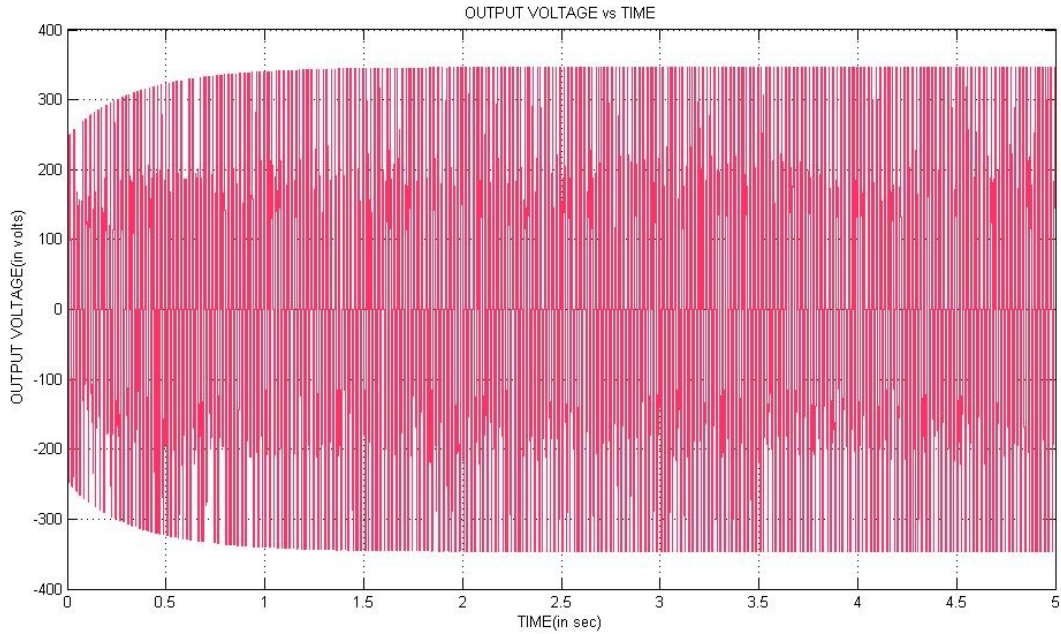
(c)
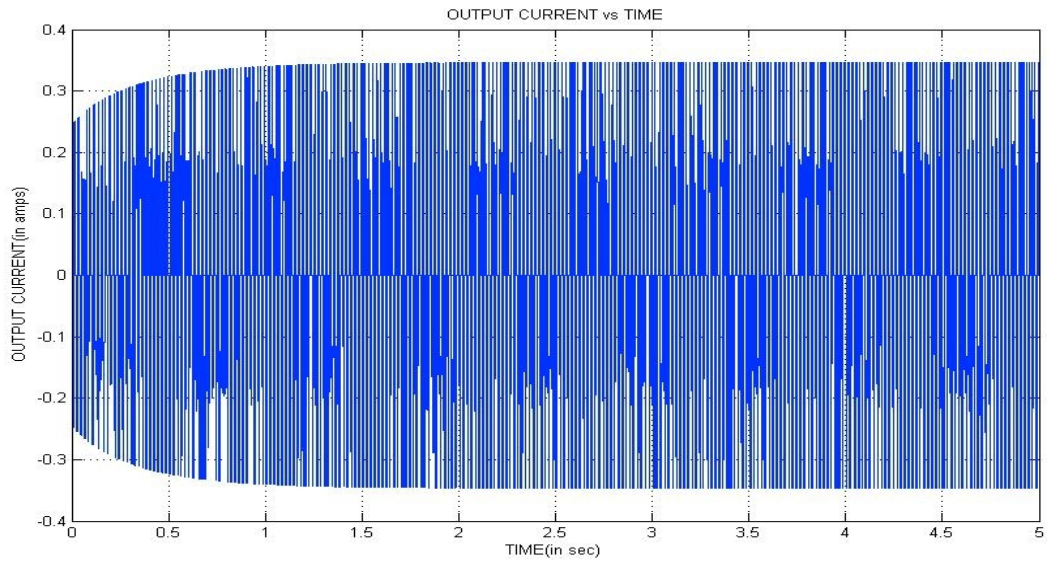
(d)

Fig:5.6 Waveforms of QSBI with the basic PWM at modulation index = 0.8 (a)
DC link voltage, (b) Source current , (c) Output voltage, (d) Output current.

Simulation Results of Basic PWM Technique at modulation index =
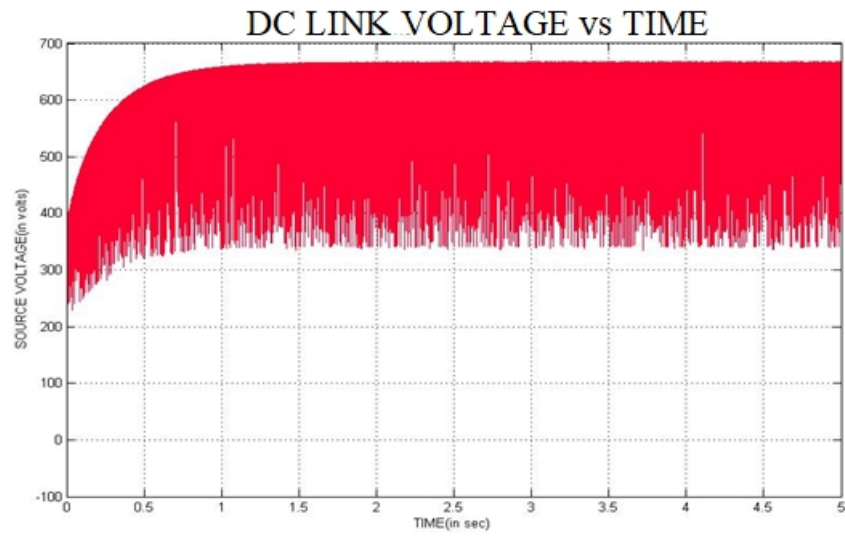
0.5

(a)
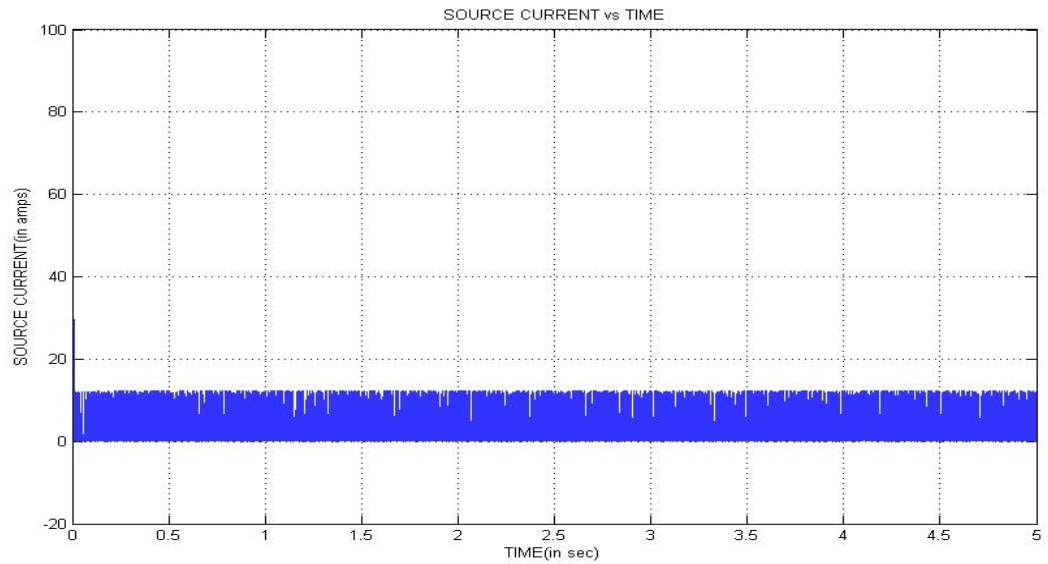
(b)
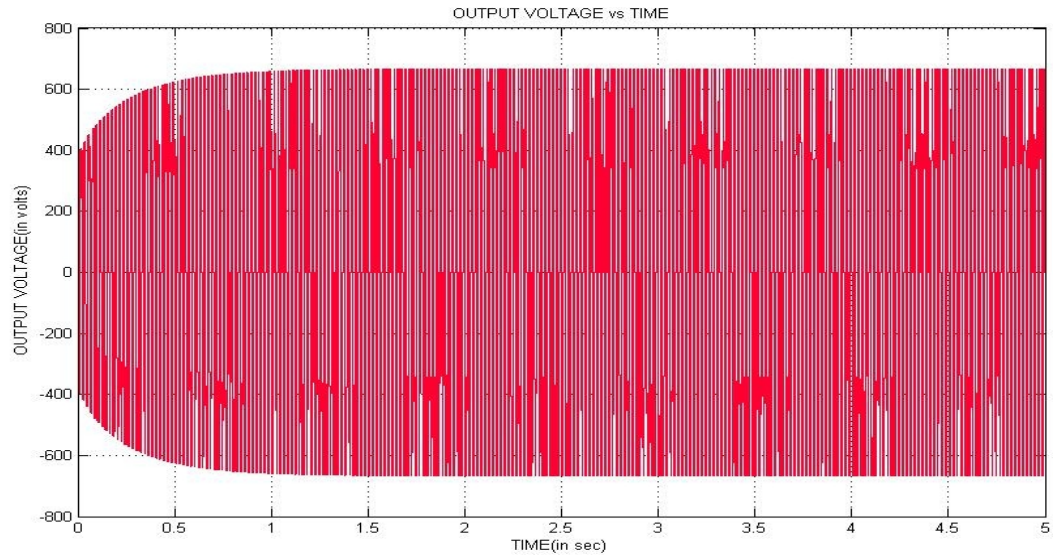
(c)
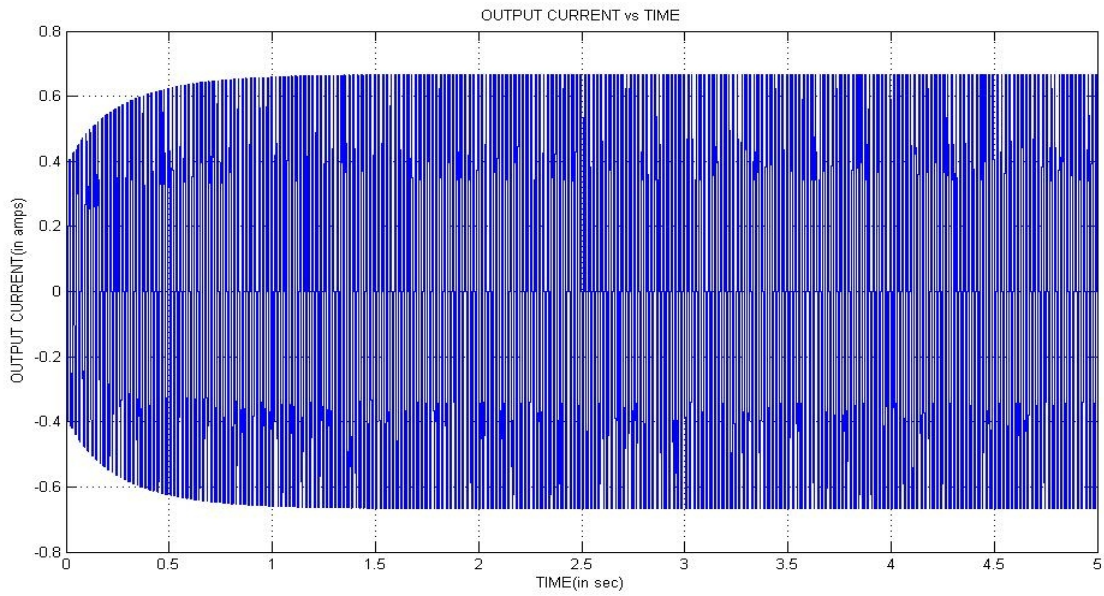
(d)

Fig:5.7 Waveforms of QSBI with the basic PWM at modulation index = 0.5 (a) DC link
voltage, (b) Source current , (c) Output voltage, (d) Output current.

Simulation Results of Basic PWM Technique at modulation index =
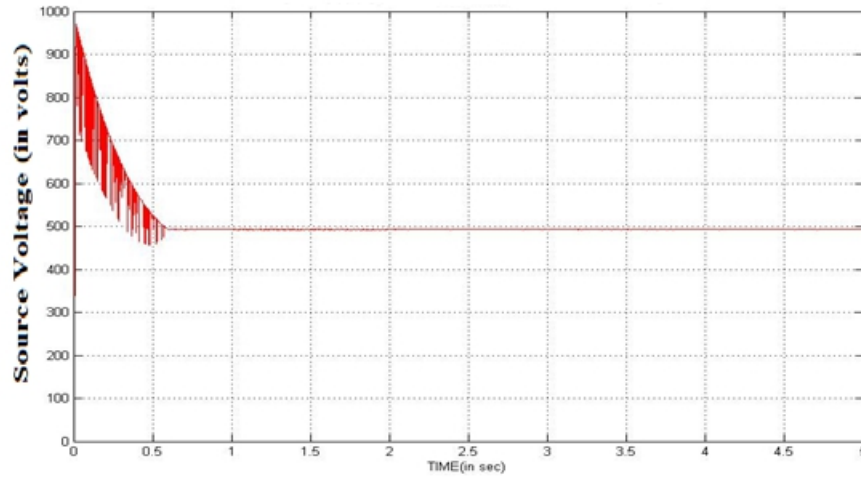
0.2:

(a)
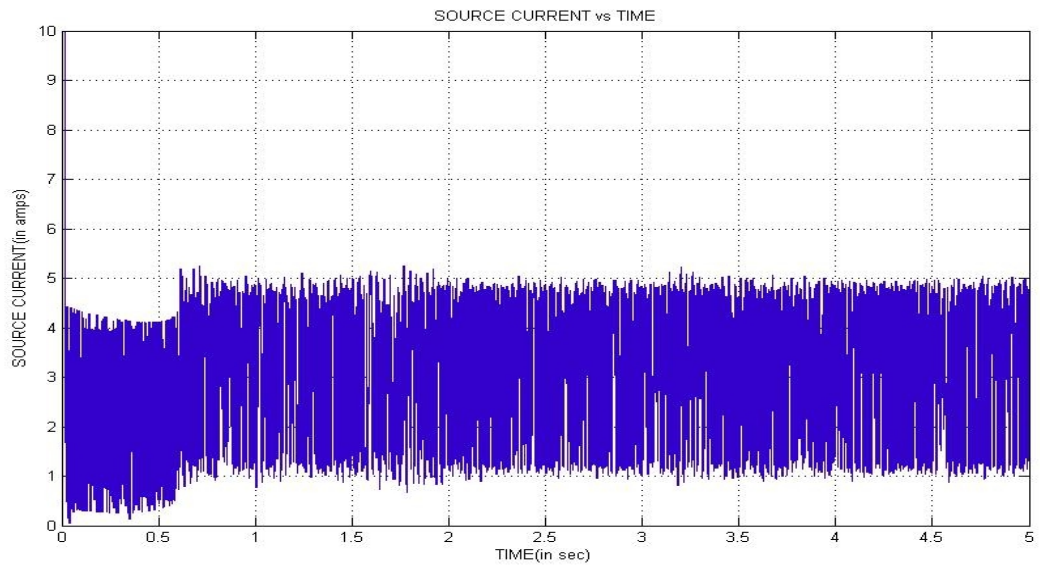
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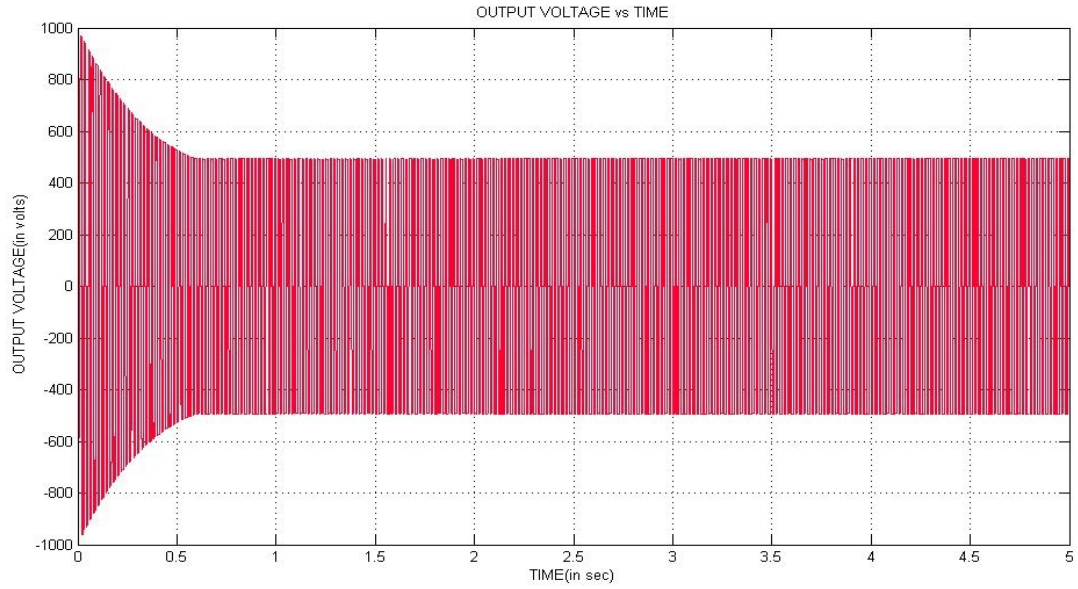
(c)
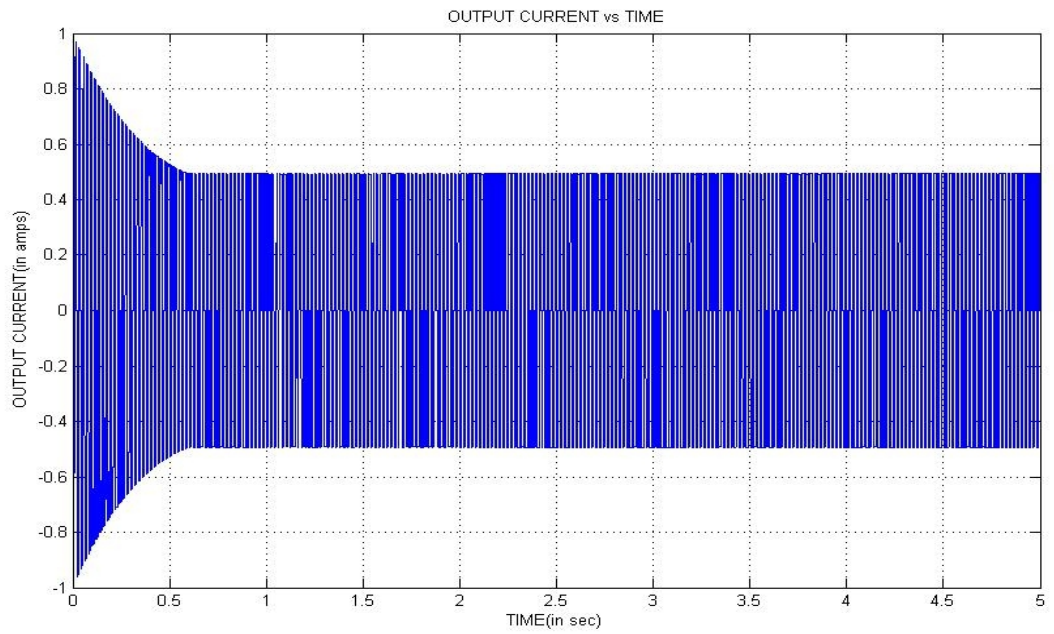
(d)

Fig:5.8 Waveforms of QSBI with the basic PWM at modulation index = 0.2

(a) DC link voltage, (b) Source current , (c) Output voltage, (d) Output current.

Simulation results of proposed PWM :

GATE VOLTAGES vs TIME

(a)

GATE VOLTAGE vs TIME

(b)

(c)

(d)
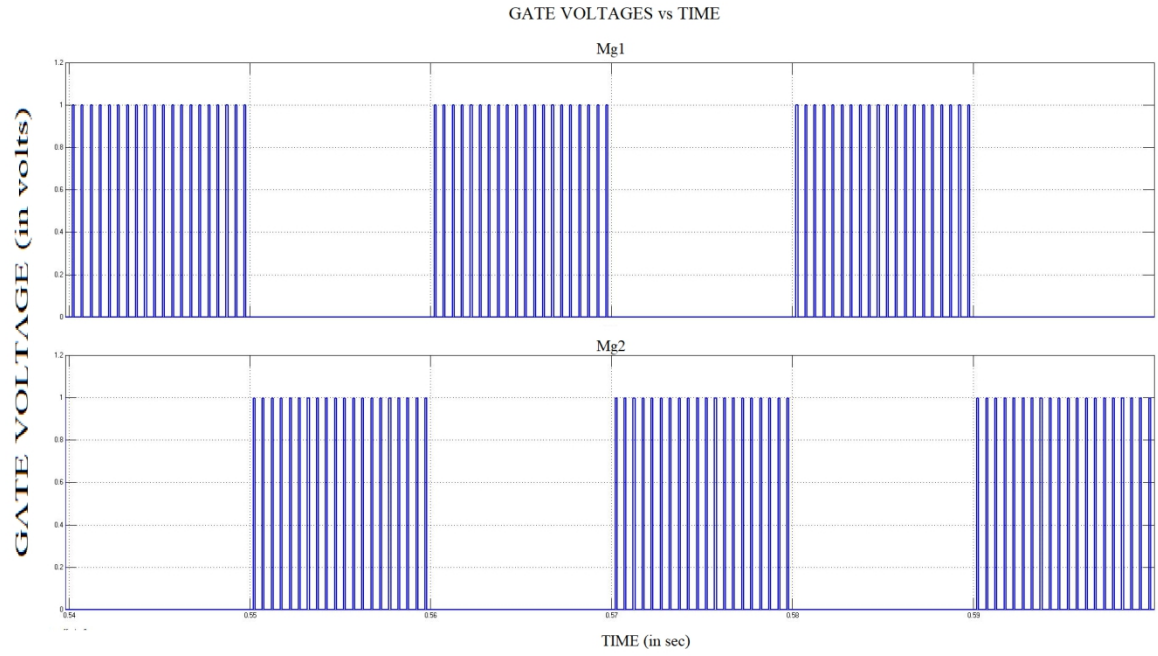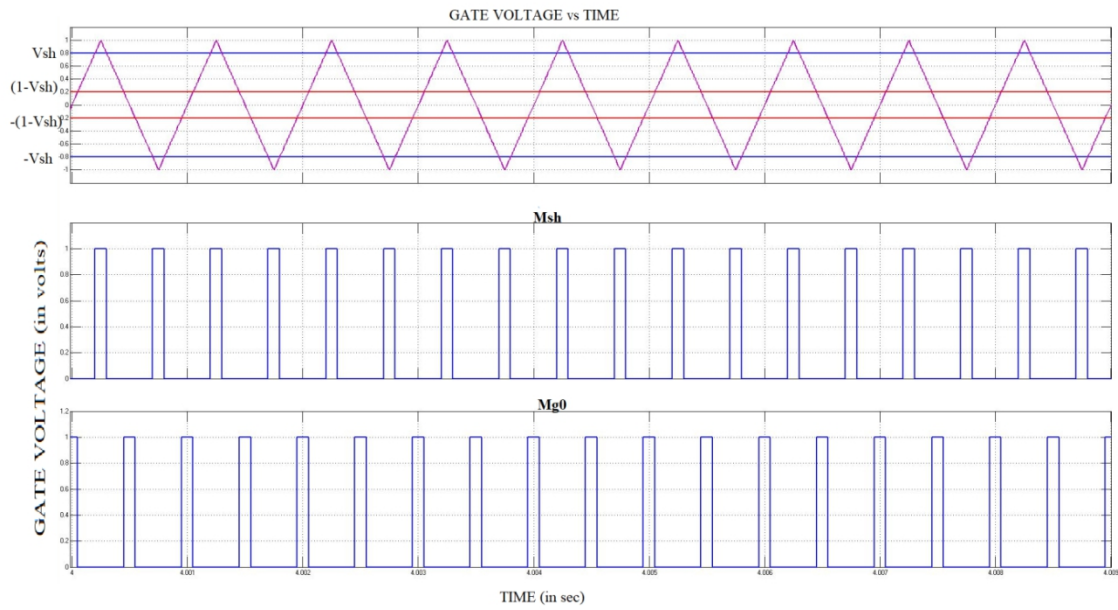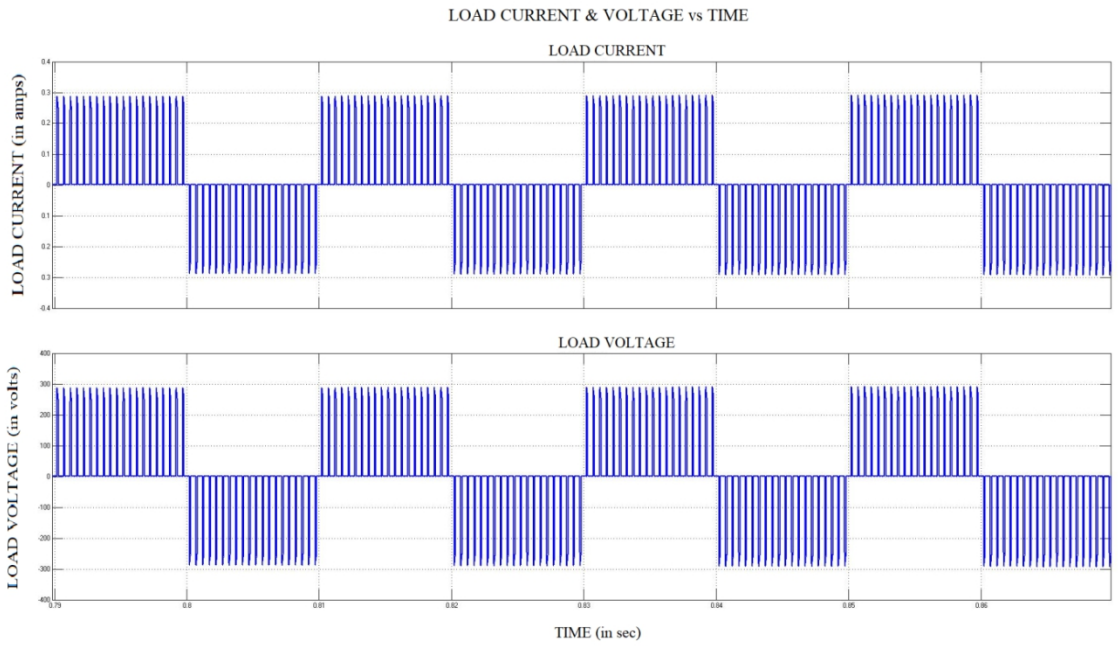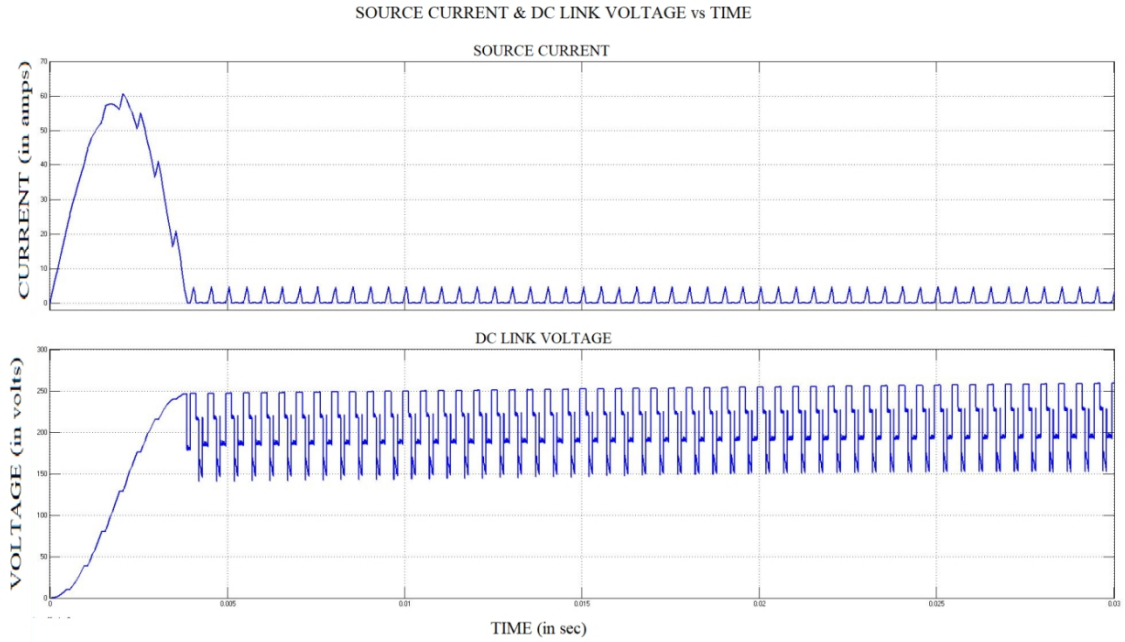
Fig:5.9 Waveforms of QSBI with the basic PWM (a) Gate voltages, (b)Input pulse, (c)
DC link voltage & current , (d) Output current & voltage.

Simulation Results of Proposed PWM Technique at modulation index =
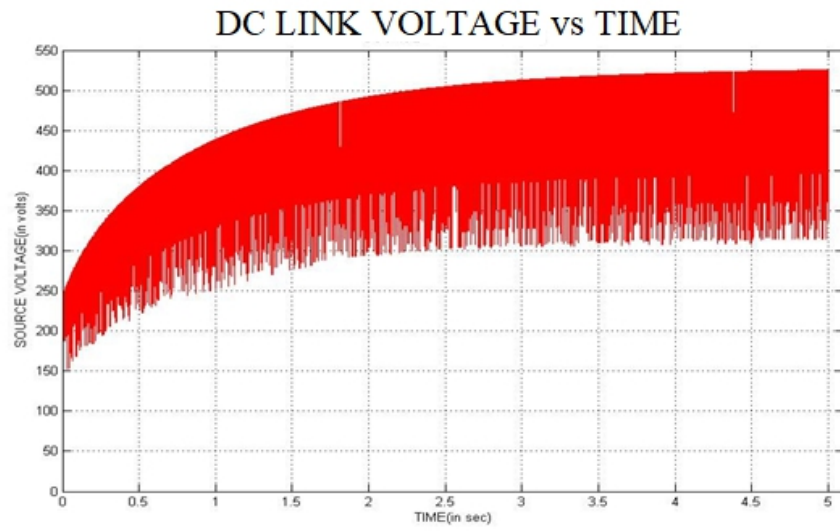
0.8 :

(a)
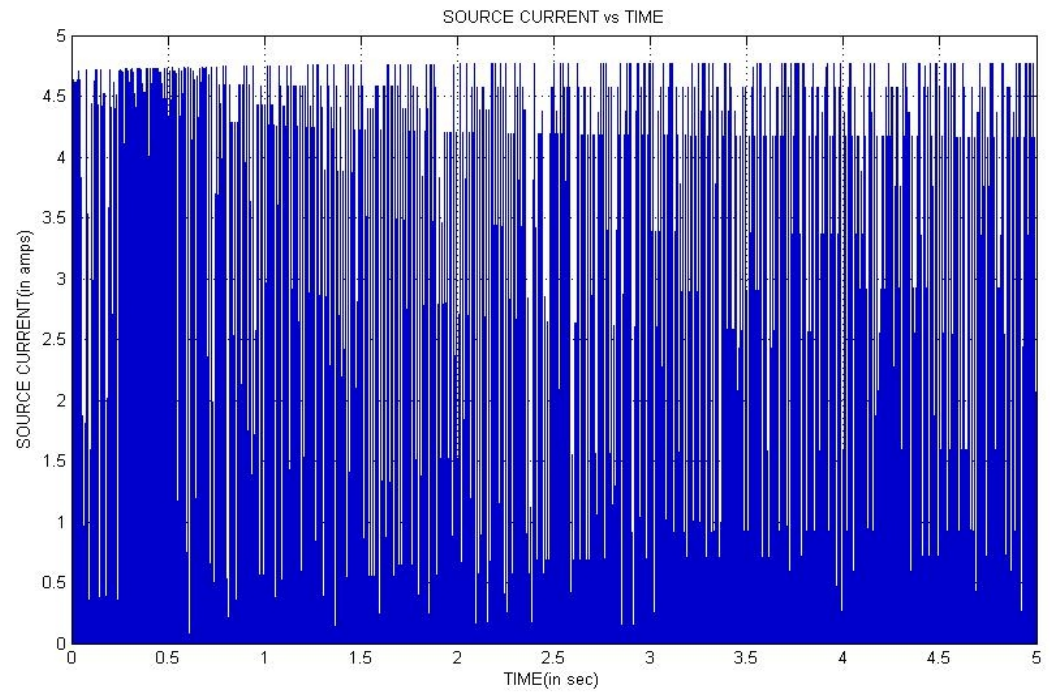
(b)
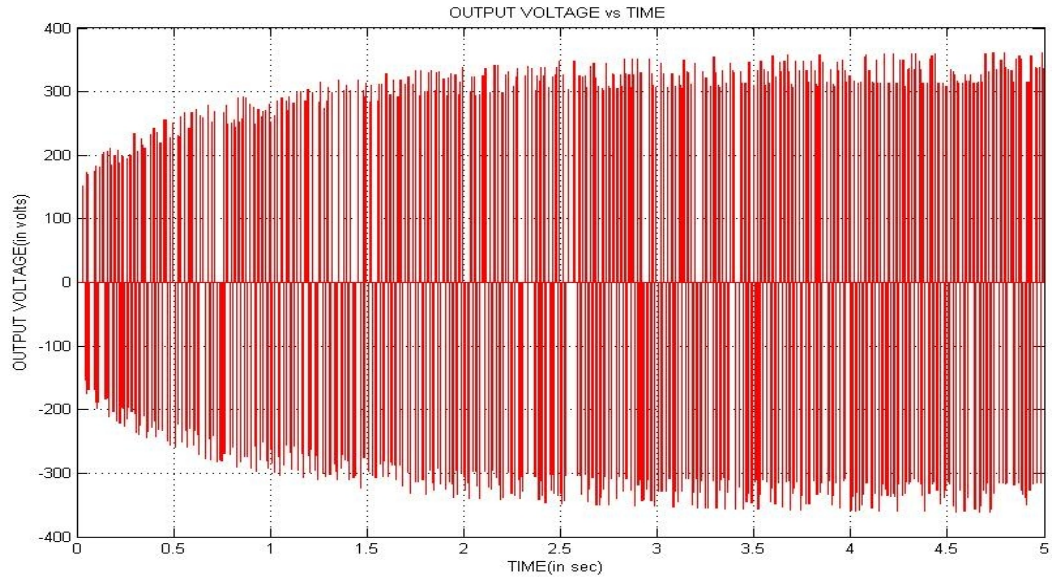
(c)
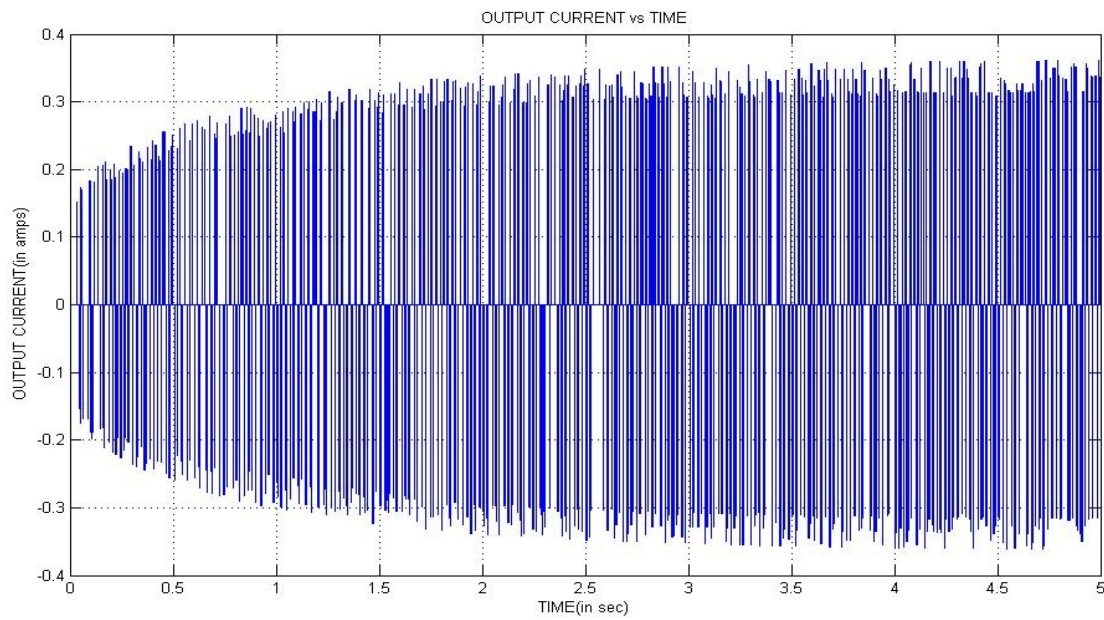
(d)

Fig:5.10 Waveforms of QSBI with the proposed PWM with at Modulation index =0.8

(a) DC link voltage, (b) Source current , (c) Output voltage, (d) Output current.

Simulation Results of Proposed PWM Technique at modulation index =
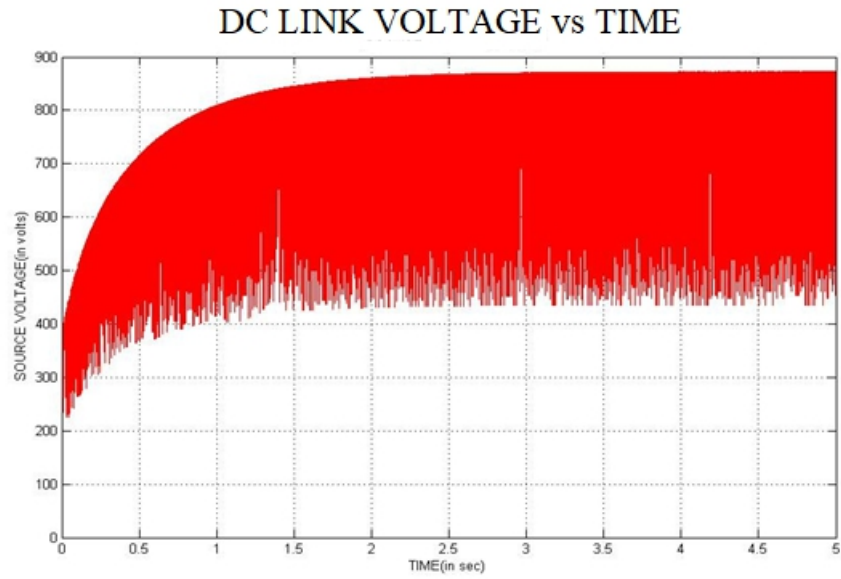
0.5 :

(a)
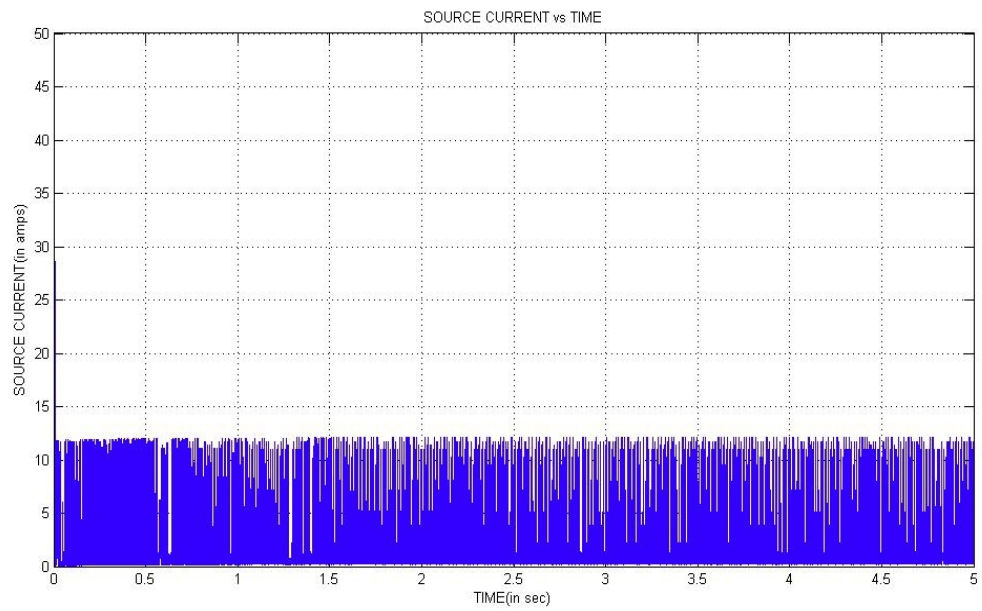
(b)
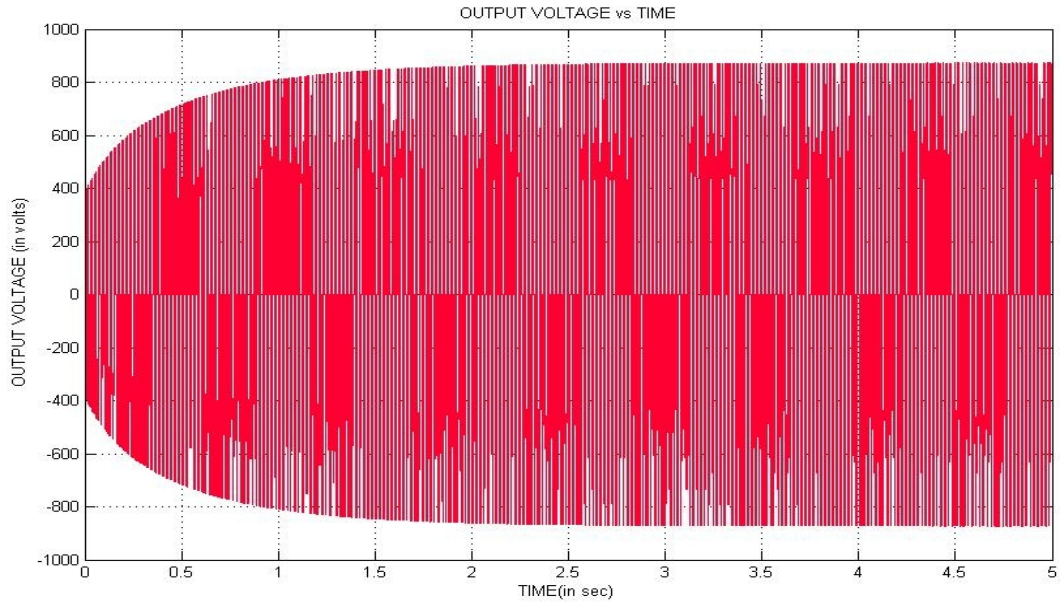
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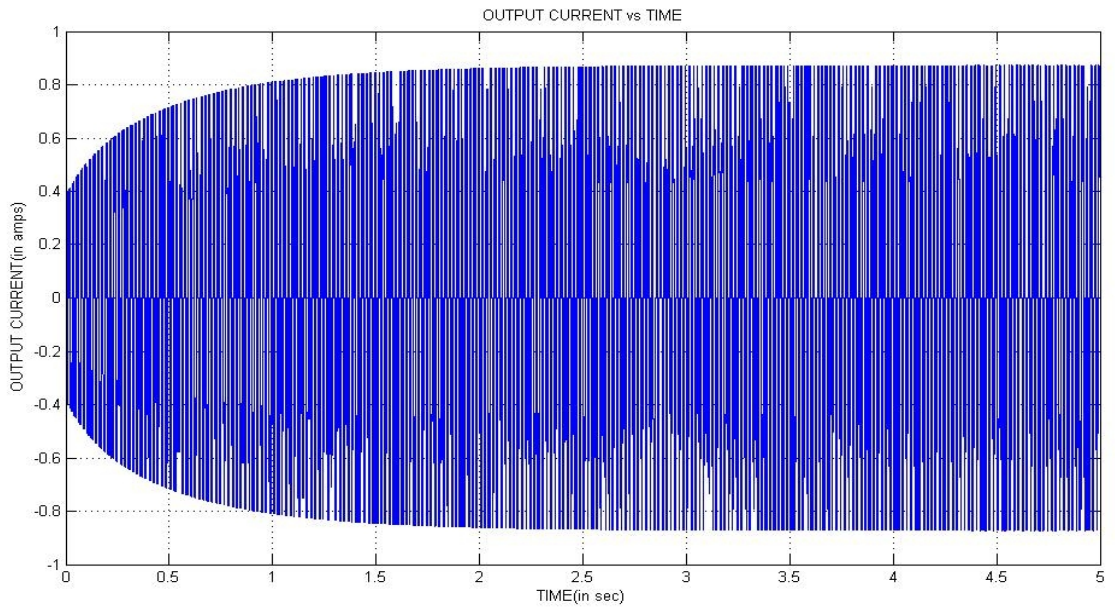
(d)

Fig:5.11 Waveforms of QSBI with the proposed PWM at Modulation index = 0.5

(a) DC link voltage, (b) Source current , (c) Output voltage, (d) Output current.

Simulation Results of Proposed PWM Technique at modulation index =
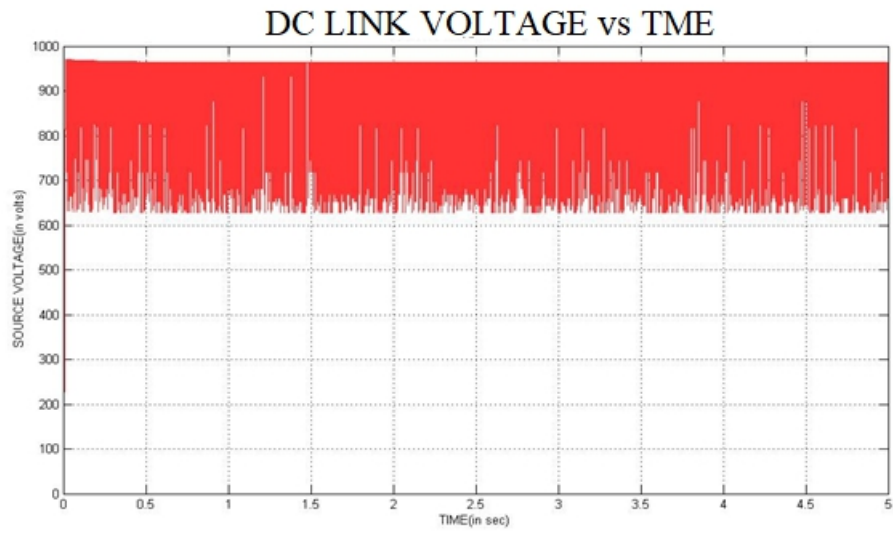
0.2 :

(a)
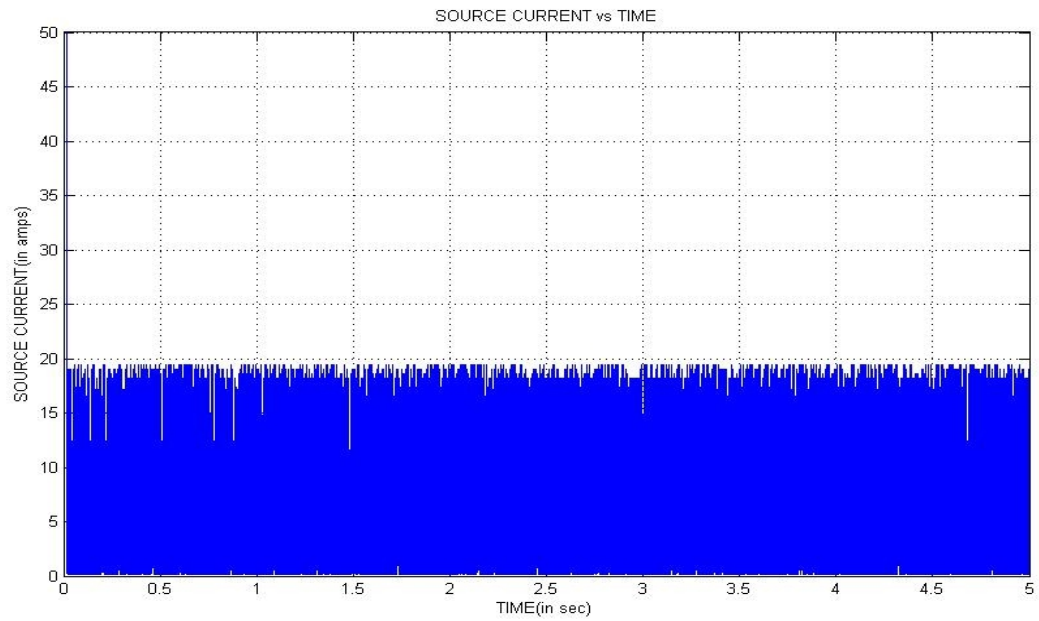
(b)
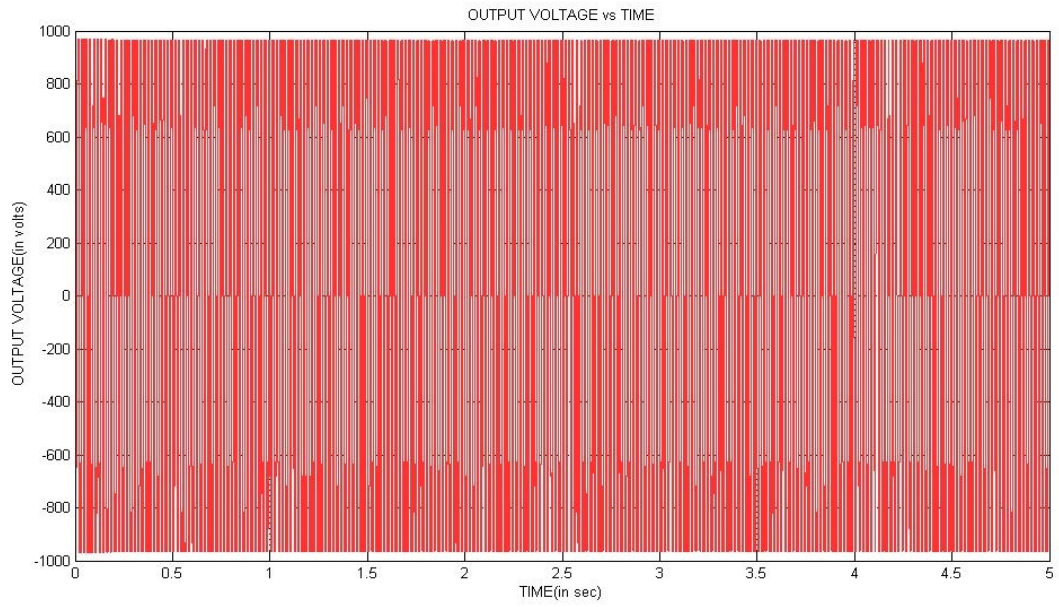
(c)
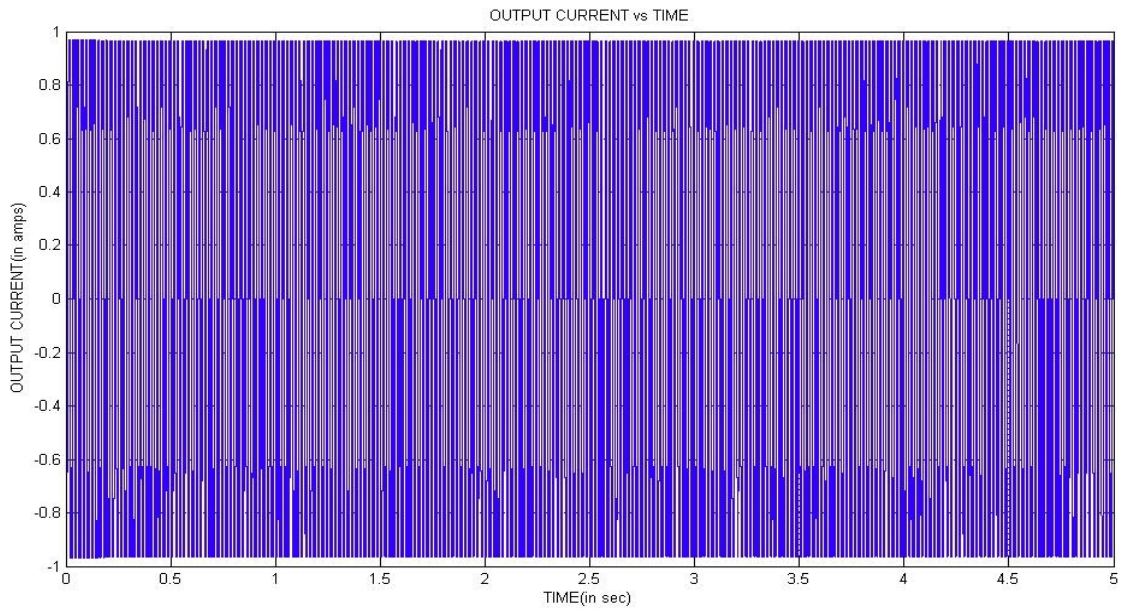
(d)

Fig:5.12 Waveforms of QSBI with the proposed PWM at Modulation index =0.2

(a) DC link voltage, (b) Source current , (c) Output voltage, (d) Output current.

THD Analysis:

Fast Fourier Transform (FFT) of Quasi Switched Boost Inverter(QSBI):
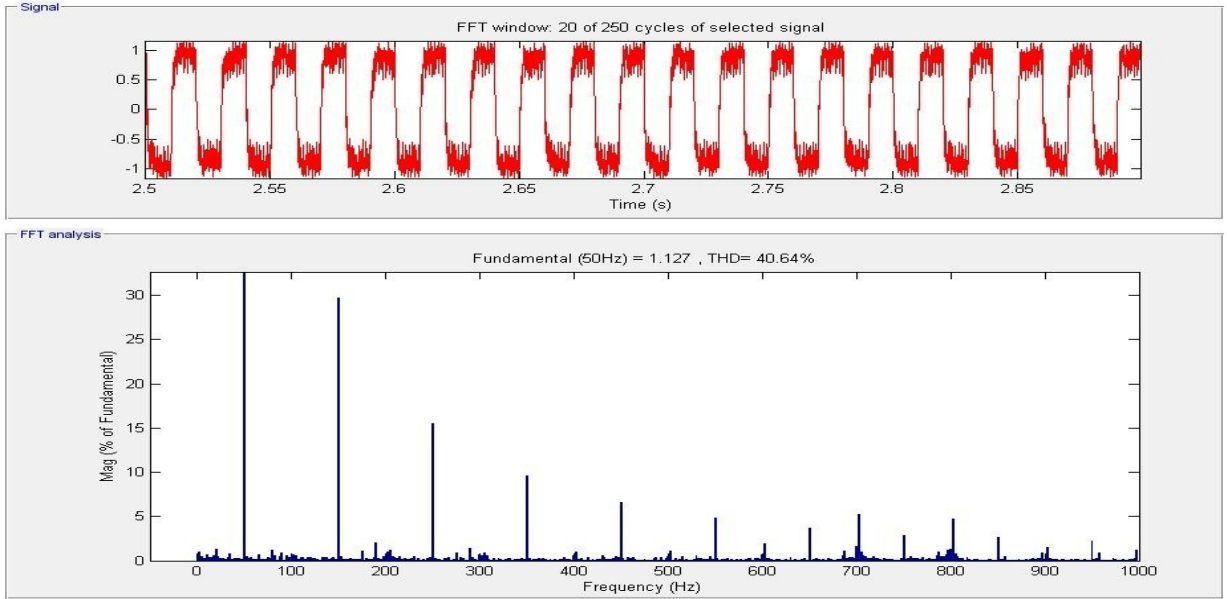
(b)
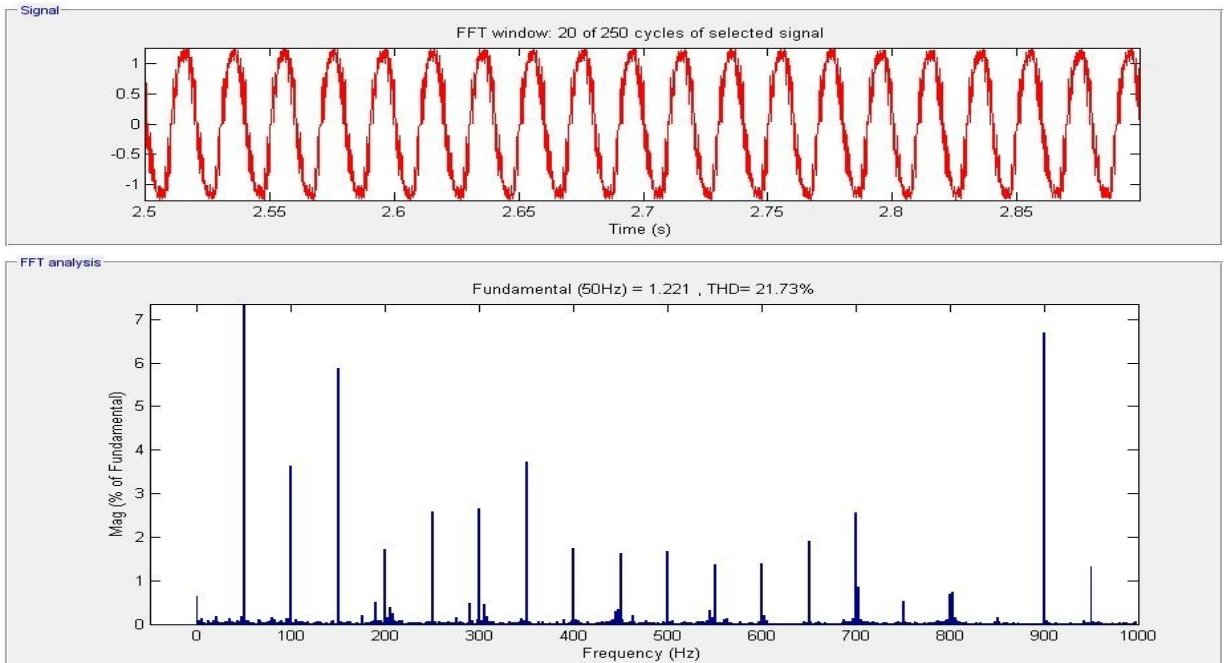
(a)

Fig: FFT analysis of Quasi Switched boost Inverter(QSBI) at modulation index=0.2

(b).proposed method (a).conventional method

CONCLUSION& FUTURE SCOPE

CONCLUSION:

Achieving an inverter output RMS voltage greater than the dc input voltage is attempted for several years through voltage boost concepts with the help of Z-networks. Such converters suffer either due to discontinuous input current or bulky inductors. This paper presented one such existing inverter, which has an inherent boost feature, but with an attempt to modify the QSBI with conventional PWM, has achieved further improvements over the existing methods. Thus the Quasi Switched Boost Inverter (QSBI), with the proposed PWM Technique exhibited a continuous input current with a reduced ripple magnitude and quadrupled inductor current ripple frequency despite the use of a smaller inductor. The trade-off between the modulation index and the boost ratio in ZSIs and QZSIs is eluded due to the additional ST and NST modes of operations introduced due to the proposed PWM. The inverter switching losses are contained as that of the basic PWM for QSBIs by keeping the inverter switching frequency unaltered considering the improvements on the dc side. The response of the proposed PWM remained consistent across various operating conditions. Thus, this PWM is an endowment for the performance enhancement of QSBIs.

FUTURE SCOPE:

Electrical vehicles are expected to be the major share-holder in future transportation works. Henceefficient and reliable power electronics interface is required. Several power electronics converters have been presented in the study to independently address the issues like high efficiency, reliability, low cost, minimum number of components and less power loss, but no single circuity is available which can collectively address these issues. Future research is required to develop a circuity which can provide a good match between instantaneously changing source and variable loads.

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DESIGN AND ANALYSIS OF BIDIRECTIONAL BATTERY CHARGER FOR ELECTRIC VEHICLE

Submitted in partial fulfillment of the requirements for award of the degree of

MASTER OF TECHNOLOGY

IN

POWER INDUSTRIAL DRIVES

Submitted by

M.HEMALATHA   **19U41D4203**

Under the Esteemed Guidance of
Mrs. K. ALFONI JOSE
Assistant Professor, Dept. of EEE

DADI INSTITUTE OF ENGINEERING & TECHNOLOGY

(Approved by A.I.C.T.E, New Delhi & Affiliated to JNTU Kakinada)

NAAC ACCREDITED INSTITUTE

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NH-16, Anakapalle – 531002, Visakhapatnam, A.P.

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CERTIFICATE

This is to certify that the project work entitled "DESIGN AND ANALYSIS OF BIDIRECTIONAL BATTERY CHARGER FOR ELECTRIC VEHICLE" has been carried out by M.HEMA LATHA (19U41D4203) submitted in the partial fulfillment of the requirement for the award of the degree of MASTER OF TECHOLOGY for POWER AND INDUSTRAL DRIVES during the academic year 2019-2021.

Mrs. K. ALFONI JOSE   **Mr. A. KRISHNA NAG MTech, (PID)**

(ASSISTANT PROFESSOR)   **(ASSOCIATE PROFESSOR)**

(PROJECT GUIDE)   (HEAD OF THE DEPARTMENT)

EXTERNAL EXAMINER

DECLARATION

I hereby declare that the dissertation entitled "DESIGN AND ANALYSIS OF BIDIRECTIONAL BATTERY CHARGER FOR ELECTRIC VEHICLE" was carried out and written by me under the guidance of Mrs. k. ALFONI JOSE, Assistant Professor, Department of Electrical and Electronics Engineering, Dadi Institute of Engineering & Technology. This work has not been previously formed the basis for the award of any degree of diploma or certificate nor has been submitted elsewhere for the award of any degree or diploma.

BY

M.HEMALATHA   (19U41D4203)

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I also consider it as our privilege to express our gratitude in thanking **Sri.Dr.CH.NARASIMHAM,** Principal, for providing us this opportunity to complete the project work.

With great solemnity and sincerity, we offer our profuse thanks to **Sri DADI RATNAKAR**, Secretary and Correspondent, for providing all the resources that greatly helped the project work to get successfully completed. I sincerely thank all the members of the staffin the department of EEE for their sustained help in our pursuit. We also thank all those who contributed directly or indirectly in successfully carrying out this work.

M.HEMA LATHA   **(19U41D4203)**

ABSTRACT

The increase in the electric vehicle mobility has encouraged the growth of vehicle to grid technology. The vehicle to grid technology allows bidirectional power flow between the battery of electric vehicle and grid. This allows peak load shaving, load leveling voltage regulation and improvement of power system stability. In this project we developed on-board bidirectional battery charger for Electric Vehicles (EVs) targeting Grid-to-Vehicle (G2V), Vehicle-to-Grid (V2G), and Vehicle-to-Home (V2H) technologies. During the G2V operation mode batteries are charged from the power grid with sinusoidal current and unitary power factor. During the V2G operation mode the energy stored in the batteries can be delivered back to the power grid contributing to the power system stability. In the V2H operation mode the energy stored in the batteries can be used to supply home loads during power outages, or to supply loads in places without connection to the power grid. Along the paper the hardware topology of the bidirectional battery charger is presented. Some considerations about the sizing of the AC side passive filter are considered to improve the performance in the three operation modes. The adopted topology and computer simulations and validated by experimental results achieved.

Keywords—Bidirectional Battery Charger; Grid-to-Vehicle (G2V); Vehicle-to-Grid (V2G);
Vehicle-to-Home (V2H)

LIST OF CONTENTS

1 INTRODUCTION

1.1 INTRODUCTION

Electric Vehicles (EVs), represents a new concept in the transports sector around the world. Consequently, the interest in technologies for EVs has significantly increased in the last years, resulting in several scientific publications concerning this subject. It is expected that the market share of EVs will exponentially grow comprising 24% of the U.S. light vehicle fleet in 2030, representing 64% light vehicle sales in this year. In this context, the EVs battery charging process (Grid-to-Vehicle, G2V) must be regulated to preserve the power quality in the power grids. Nevertheless, with the proliferation of EVs a considerable amount of energy will be stored in their batteries, arising the opportunity of the energy flow in opposite sense (Vehicle-to-Grid, V2G).In the future smart grids, the interactivity with the EVs will be one of the key technologies, contributing to the power grid autonomous operation. Nowadays, several projects related with smart grids are under development around the world. Regarding this new approach, especially in homes equipped with charging points for EVs, besides the G2V and V2G operation modes the EVs can also operates as voltage source capable to feed the home loads. This technology, begins to be denominated in the literature as Vehicle-to-Home (V2H). As example of this new approach, Nissan presented the "LEAF-to-Home" system. This is a technology that uses energy from the Nissan Leaf batteries to supply the home loads through the "EV Power Station" unit. Effectively, smart homes with energy management and efficiency solutions will be the first step to the smart grid evolution. However, solutions like the "LEAF-to-Home" only allows deliver the stored energy in the batteries back to the home in the place where the equipment is installed. In this paper is proposed an on-board battery charger that enables the V2H operation mode in the place where the EV is parked. This battery charger allows receive energy from the power grid (G2V), and deliver back to the power grid part of the stored energy in the batteries (V2G), or provide energy to any load connected to the EV (V2H), in an isolated island mode. In this sequence of ideas, the EVs can bring benefits to the home

energy management, especially to feed priority loads during power outages and other emergencies. From the point of view of the power grid, EVs can bring benefits to ancillary services, compensation of the renewable energy sources intermittency (providing both backup, storage and load-shift).

These new approaches are more relevant when looking that private vehicles are parked on average 93-96% of their lifetime, and most of the vehicles are at home between 8 pm and 7 am. The concept of the on-board bidirectional charger with V2G and V2H technologies is introduces. When the EV is connected to the power grid the energy can flow to or from the EV batteries (G2V and V2G).

In the absence of power grid or power outages, the EV can operate as voltages source to feed the desired loads. The system is not intended for a real-time energy backup, but has an auxiliary energy storage system. Thus, the transitions between the modes can be seamless.

The electric vehicle has become more competitive when compared to the conventional internal combustion engine vehicle due to lower carbon dioxide emission and raising fossil fuels.However, the EV id not widely adopted into the market due to some limitations such as high vehicle cost, limited charging infrastructure and limited all electric drive.EV battery can be utilized as energy storage this potential has led to the new vehicle to grid(V2G) concept. Apart from charging EV batteries V2G allows interaction between the EV owners and power utility. In future smart grids the interactive with the electric vehicles will be the keytechnologies contributing to the power grid autonomous operation. Regarding this newapproach especially in home equipped with charging points for EV besides grid to vehicle. And vehicle to grid operation the EV can also operate as voltage source capable to feedthe home loads.

This technology begins to be denominated as vehicle to home.Effectively smart homes with energy management and efficiency solutions willbe the first step to smart grid evolution. This battery charger allows receive energy fromthe power grid (G2V) and deliver back to the power grid part the stored energy in thebatteries (V2G) or provide energy to any load connected to

electric vehicle (V2H) in anisolated modeThe concept of the on-board bidirectional charger with V2G and V2H technologies.When EV is connected to the power grid the energy can flow to or from the EV batteries. in the absence of the power grid or power outages the EV can operate as a voltagesources to feed the desired loads. The system is not intended for a real time energybackup but has an auxiliary energy storage system thus the transitions between themodes can be seamless. An EV is a shortened acronym for an electric vehicle. EVs are vehiclesthat are either partially or fully powered on electric power. Electric vehicles have low running costs as they have fewer moving parts for maintaining and also very environmentally friendly as they use little or no fossil fuels (petrol or diesel).

1.2 BATTERY CHARGER FOR VEHICLE

There are two main types of chargers used for vehicles:

- To recharge a fuel vehicle's starter battery, where a modular charger is used; typically an 3-stage charger.
- To recharge an electric vehicle (EV) battery pack; see Charging station.

  Chargers for car batteries come in varying ratings. Chargers that are rated up to two amperes may be used to maintain charge on parked vehicle batteries or for small batteries on garden tractors or similar equipment. A motorist may keep a charger rated a few amperes to ten or fifteen amperes for maintenance of automobile batteries or to recharge a vehicle battery that has accidentally discharged. Service stations and commercial garages will have a large charger to fully charge a battery in an hour or two; often these chargers can briefly source the hundreds of amperes required to crank an internal combustion engine starter.

1.3 ELECTRIC VEHICLE BATTERIES

Electric vehicle battery chargers (ECS) come in a variety of brands and characteristics. These chargers vary from 1 kW to 7.5 kW maximum charge rate. Some use algorithm charge curves, others use constant voltage,

constant current. Some are programmable by the end user through a CAN port, some have dials for maximum voltage and amperage, some are preset to specified battery pack voltage, amp-hour and chemistry. Prices range from $400 to $4500.

A 10 amp-hour battery could take 15 hours to reach a fully charged state from a fully discharged condition with a 1amp charger as it would require roughly 1.5 times the battery's capacity.

Public EV charging stations provide 6 kW (host power of 208 to 240 VAC off a 4amp circuit).

6 kW will recharge an EV roughly 6 times faster than 1 kW overnight charging.

Rapid charging results in even faster recharge times and is limited only by available AC power, battery type, and the type of charging system.

Onboard EV chargers (change AC power to DC power to recharge the EV's pack) can be:

- Isolated: they make no physical connection between the A/C electrical mains and the batteries being charged. These typically employ some form of inductive connection between the grid and a charging vehicle. Some isolated chargers may be used in parallel. This allows for an increased charge current and reduced charging times. The battery has a maximum current rating that cannot be exceeded
- Non-isolated: the battery charger has a direct electrical connection to the A/C outlet's wiring. Non-isolated chargers cannot be used in parallel.

Power-factor correction (PFC) chargers can more closely approach the maximum current the plug can deliver, shortening charging time.

2 ELECTRIC VEHICLE

2.1 INTRODUCTION

An electric vehicle (EV) is a vehicle that uses one or more electric motors or traction motors for propulsion. An electric vehicle may be powered through a collector system by electricity from off-vehicle sources, or may be self-contained with a battery, solar panels, fuel cells or an electric generator to convert fuel to electricity.[1] EVs include, but are not limited to, road and rail vehicles, surface and underwater vessels, electric aircraft and electric spacecraft.

EVs first came into existence in the mid-19th century, when electricity was among the preferred methods for motor vehicle propulsion, providing a level of comfort and ease of operation that could not be achieved by the gasoline cars of the time. Modern internal combustion engines have been

the dominant propulsion method for motor vehicles for almost 100 years, but electric power has remained commonplace in other vehicle types, such as trains and smaller vehicles of all types.

2.2 EVOLUTION OF ELECTRIC VEHICLE

Electric Vehicles actually have their origin in the 1800s. The first American electric car was developed by William Morrison in 1891. His six-passenger wagon reached a top speed of 14 mph. (While this may seem slow, in 1899 the land speed record was set by an EV at 66 mph.) Morrison's invention was considered the first practical example of an EV, and it spurred interest in electric Transport.

Commonly, the term EV is used to refer to an electric car. In the 21st century, EVs have seen a resurgence due to technological developments, and an increased focus on renewable energy and the potential reduction of transportation's impact on climate change and other environmental issues. Project Drawdown describes electric vehicles as one of the 100 best contemporary solutions for addressing climate change.

Interest in EVs made a bit of a resurgence in the 1960s and 1970s, but it wasn't until the early 1990s that a more substantial push for driving electric was realized. This surge was mainly driven by regulations and legislation, such as the California Air Resources Board, which pushed for more fuel-efficient and emissions-free vehicles. In 1996, General Motors (GM) developed the first mass-produced battery-electric car, the EV1. The EV1 had a range of approximately 60 miles and a top speed of 80 mph. By 2002, though, GM discontinued it. The California Air Resources Board mandate had been weakened, and GM viewed electric transportation as an unprofitable sector of the market.

The availability of a range of electric vehicle models across multiple segments and consumer price points is a key factor for the broader adoption of electric vehicles. There is a clear link between electric vehicle model availability and uptake15. The top electric vehicle markets had noticeably more electric vehicle models available than other markets. The state could refer to the following indicators while investigating the availability of electric vehicle technologies. The total number of available electric models.
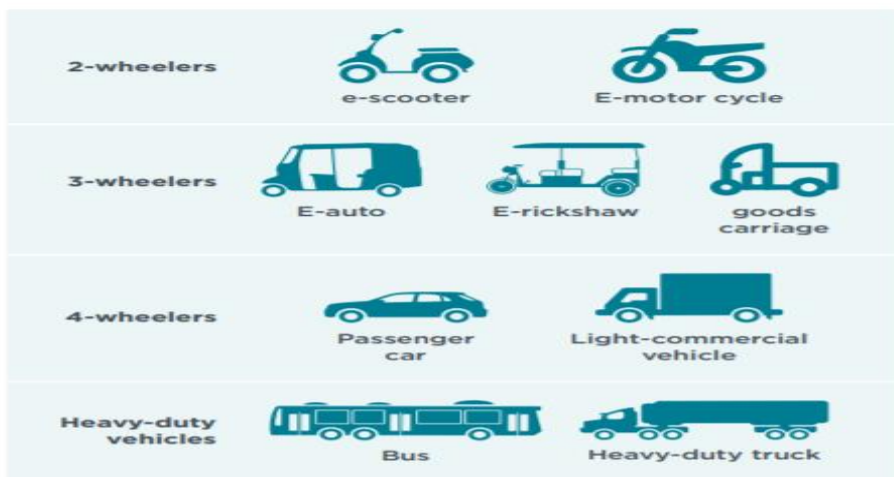
2.3 NEED OF THE ELECTRIC VEHICLE (EV)

There are many reasons why people are moving to Electric Vehicles (EV) to get them to the places they need to be. These include:

• EVs are fun to drive because they are fast and smooth.

• Many studies show that the emissions from burning fossil fuels such as gasoline produce harmful greenhouse gases. EV's produce no smelly fumes or harmful greenhouse gases.

• EVs are innovative and cool.

• EVs only cost approximately $360 a year to operate compared to $3600 for a gasoline vehicle.

• EVs are a smart and convenient choice.
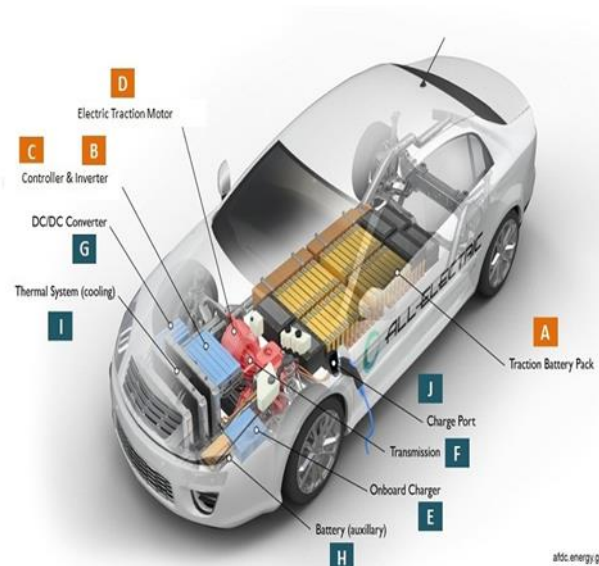
2.4 PARTS OF ELECTRIC VEHICLE

• MAIN PARTS OF ELECTRIC VEHICLE

1. ELECTRICAL TRCTION MOTOR'
2. CONTROLLER AND INVERTER
3. DC/DC CONVERTER
4. THERMAL SYSTEM
5. TRACTION BATTERY PACK

6. CHARGE PORT
7. TRANSMISSION
8. ONBOARD CHARGER
9. BATTERY

2.4.1 ELECTICAL TRACTION MOTOR

A **traction motor** is an electric motor used for propulsion of a vehicle, such as locomotives, electric or hydrogen vehicles, elevators or electric multiple unit.
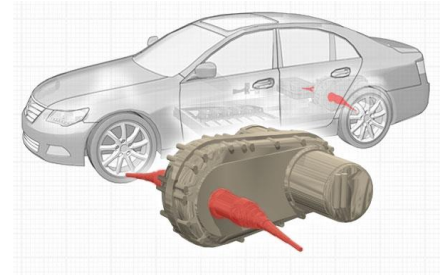
Traction motors are used in electrically powered rail vehicles (electric multiple units) and other electric vehicles including electric milk floats, elevators, roller coasters, conveyors, and trolleybuses, as well as vehicles with electrical transmission systems (Diesel-electric Locomotives, electric hybrid vehicles), and battery electric vehicles.

2.4.2 CONTROLLER AND INVERTER

Converters

A device that increases or decreases the voltage (AC or DC) of a power source depending on application. A converter that increases voltage is

called a step-up converter and a converter that decreases voltage is called a step-down converter. In EVs/HEVs step-up and step-down converters are combined into one unit. An application of a step-up converter is converting EV/HEV battery voltage (typically 180-300 volts) to about 650 volts to power the traction motor. An advantage of using a converter to increase voltage from the battery is a smaller and less expensive battery may be used while still utilizing an efficient high voltage motor. An application of a step-down inverter would be decreasing the high voltage direct current (DC 180-300 volts) from the HEV/EV battery to low voltage (12-14 volts) DC that can be used to charge the 12-volt auxiliary battery and operate light load devices such as lighting, radio, and windows.

Inverters

Converts direct current (DC) from the battery to alternating current (AC) to be used by other devices such as the traction motor and coolant pump. Existing conventional vehicle inverters operate off of low voltage and are limited to low power (limits of alternator supply) – 12 or 24 VDC.

- Less than 6 kW "Electrified" vehicles – battery electric, hybrid electric and fuel cell electric - operate at higher DC bus voltage and have higher power capacity
- 48 to 800 VDC
- 10 to 200 kW on board

2.4.3 THERMAL SYSTEM

Air cooling uses the principle of convection to transfer heat away from the battery pack.As air runs over the surface, it will carry away the heat emitted by the pack. Air cooling is simple and easy, but not very efficient and relatively crude compared to liquid cooling. Air cooling is used in earlier versions of electric cars, such as the [Nissan Leaf.](#) As electric cars are now being used more commonly, safety issues have arisen with purely air-cooled battery packs, particularly in hot climates. Other car

manufacturers, such as Tesla, insist that liquid cooling is the safest method. Liquid coolants have higher heat conductivity and heat capacity (ability to store heat in the form of energy in its bonds) than air, therefore performs very effectively and own advantages like compact structure and ease of arrangement. Out of these options, liquid coolants will deliver the best performance for maintaining a battery pack in the correct temperature range and uniformity. Liquid cooling systems have their own share of safety issues related to leaking and disposal, as glycol can be dangerous for the environment if handled improperly. These systems are currently used by Tesla, Jaguar, and BMW, to name a few.
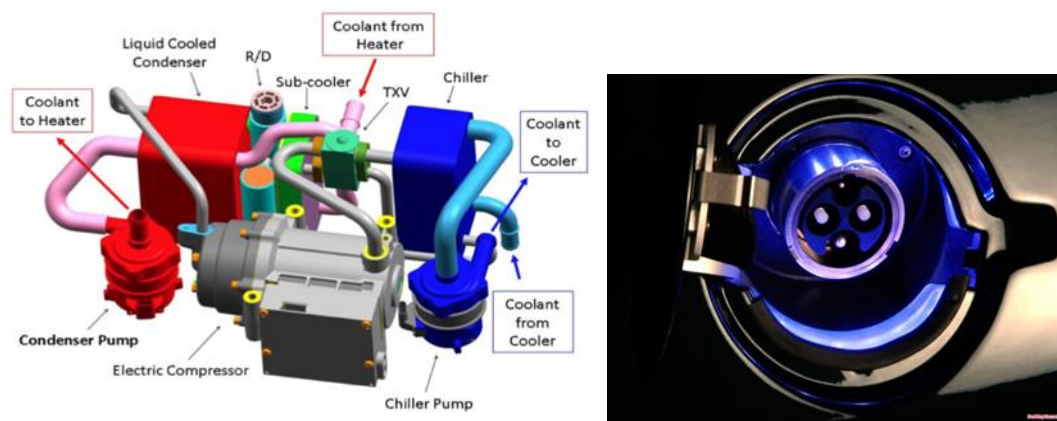
2.4.4 CHARGE PORT

Charge ports on electric cars are similar to the fuel tank filler openings on gasoline and diesel   cars in that the fuel or energy is transferred into the vehicle through anopening thatis typically concealed by a small door or flap.

- A typical electric car (60kWh battery) takes just under 8 hours to charge from empty-to-full with a 7kW charging point.
- Most drivers top up charge rather than waiting for their battery to recharge from empty-to-full.

- For many electric cars, you can add up to 100 miles of range in ~35 minutes with a 50kW rapid charger.
- The bigger your car's battery and the slower the charging point, the longer it takes to charge from empty to full.

2.4.5 ON BOARD CHARGER

The on-board charger (OBC) is the system built into the car to recharge the high voltage battery from the AC grid while the vehicle is parking. Higher driving ranges of the plug-in hybrid (PHEV) and battery electric (BEV) vehicles are realized by increasing the battery capacity and the energy efficiency of the electric components. The used battery voltage classes tend to become standardized at approx. 450 V with a trend towards higher voltages, as this supports faster charging times and enables lighter cabling within the vehicle. Discrete high voltage components are widely used for OBC (on-board charger) applications, as price pressure increasingly displaces module-based solutions. The trend towards fast charging also impacts on the power range demanded from OBC topologies, therefore new designs trend towards 11 kW or even up to 22 kW. This development, paired with a demand for high efficiency and power density at low system cost, is a strong driver for the usage of three-phase solutions. Today typically there is a unidirectional power flow from the grid to the battery, but there is also bidirectional use cased like a battery to load or battery to grid.
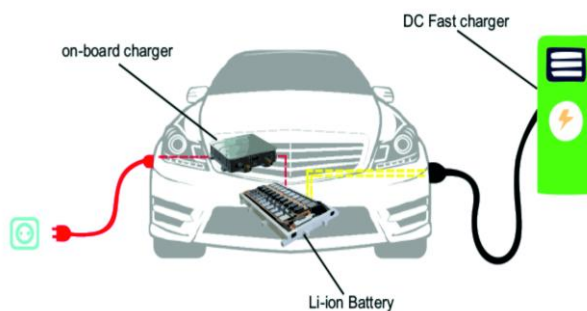
2.4.6 BATTERIES

An electric-vehicle battery (EVB, also known as a traction battery) is a battery used to power the electric motors of a battery electric vehicle (BEV) or hybrid electric vehicle (HEV). These batteries are usually rechargeable (secondary) batteries, and are typically lithium-ion batteries. These batteries are specifically designed for a high ampere-hour (or kilowatt-hour) capacity.

Lithium ion (Li-ion) batteries are now considered to be the standard for modern battery electric vehicles. There are many types of Li-ion batteries that each have different characteristics, but vehicle manufactures are focused variants that have excellent longevity. Compared to other mature battery technologies, Li-ion offers many benefits. For example, it has excellent specific energy (140 Wh/kg) and energy density, making it ideal for battery electric vehicles. Li-ion batteries are also excellent in retaining energy, with a self-discharge rate (5% per month) that anorder of magnitude lower than NiMH batteries.

However, Li-ion batteries also have some drawbacks as well. Comparatively, Li-ion batteries have been a very expensive battery technology. There are also major safety concerns regarding the overcharging and overheating of these batteries. Li-ion can experience a thermal runaway, which can trigger vehicle fires or explosions. There had been serval instances where the Tesla Model S, which utilized Li-ion batteries, had infamously caught on fire due to issues with fluctuating

charging or damage to the battery. However, great efforts have been made to help improve the safety of vehicles that use Li-ion batteries.

2.5 ADVANTAGES OF ELECTRIC VEHICLE

1. Simplicity in design. No issues of balancing of rotating and reciprocating masses as compared to IC Engines.

2. Electric vehicles have good power (induction motor) to weight ratio.

3. Instant torque right away from 0 to the maximum limit. Peak torque at zero rpm. The moving power is immense.

4. Regenerative braking is main part of electric vehicles in India.

5. Typically, no requirement of transmission.

6. EV has no tailpipe. Hence no pollution.

7. Silent operation as compared to a conventional vehicle.

8. Efficiency is about 3 times higher than IC Engine vehicles.

9. Cheaper to use and maintain.

10. No or Less use of Carburetor in Vehicles.

2.6 DISADVANTAGES OF ELECTRIC VEHICLE

1. If the battery is faulty/ has problems/ needs to be replaced. An EV battery is very expensive than a conventional one. It can be a problem for Electric Vehicles in India

2. Battery charging may take at-least an hour, whereas full tank petrol can be filled within 5 minutes.

3. Above all, Electric cars are expensive to buy.

4. The operation of electric carsarewidely based on location. The main problem is charging station which provides electricity in emergency case. It's not readily available at all the place like petrol pump which comes at-least every 5, 10 or 15 km – that is, of course, attributed to the underdeveloped infrastructure.

5. Electric vehicle may have shorter range than Internal combustion

engine car. As said electric vehicle of same segment may have a range of 200-250 km. Whereas Internal combustion engine car may have a range of approx. 600-700 km (with full tank).

3 BIDIRECTIONAL BATTERY CHARGER TOPOLOGY

3.1 INTRODUCTION

In simple terms, bidirectional charging allows us to not only charge the batteries of electric vehicles but to also take energy from car batteries and push it back to the power grid to help balance momentary spikes in electricity demand.

Bidirectional charging is powered by vehicle-to-grid (or V2G) technology. V2G allows us to communicate with the energy system to help stabilize the power grid through demand response services.

Bidirectional charging and vehicle-to-grid are often used as synonyms, even though technically bidirectional charging refers to two-way charging, while V2G is the technology that allows the one-way flow of energy from the car battery back to the grid.

EV charging that goes two ways. Whilst with unidirectional (one-way) EV chargers, electricity flows from the electric grid into the electric vehicle, with bidirectional (two-way) EV chargers, electricity can flow both ways.

3.2 UNIDIRECTIONAL BATTERY CHARGER

The unidirectional battery charging means the flow of the charge in only one direction i.e either from the Grid to Vehicle(G2V) or from the Vehicle to grid(V2G).

Unidirectional V2G is especially attractive because it requires little if any additional infrastructure other than communication between the EV and an aggregator The unidirectional v2g refer to the single power flow from the power grid to the EV the unidirectional v2g needs the participation of grid operation to control and limit charging time location and power flow during EV charging event.

3.2.1 GRID TO VEHICLE

The basic concept of vehicle-to-grid power is that EDVs provide power to the grid while they are parked.

The EDV can be a battery-electric vehicle, hybrid, or a fuel cell vehicle connected to the grid. Each vehicle must have three required elements for V2G.

A power connection to the grid for electrical energy flow. Control or logical connection necessary for communication with grid operators Precision metering on-board the vehicle.
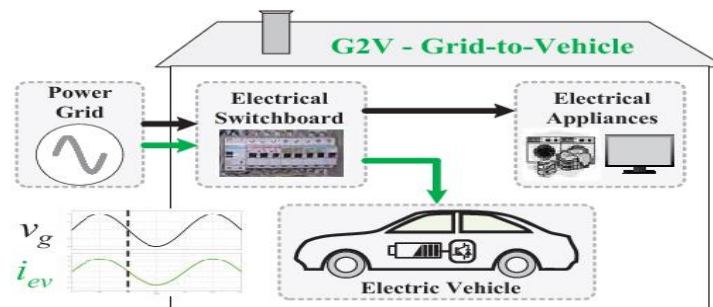
In the G2V operation mode this converter operates as buck converter to control the current and voltage during the current and voltage batteries charging stages, respectively.

During this operation mode the full-bridge AC-DC bidirectional converter operates as active rectifier with sinusoidal current and unitary power factor. The reversible DC-DC converter operates as buck converter.

The DC link voltage is always higher than the traction batteries voltage and for this reason during the G2V operation mode the reversible DC-DC converter operates as buck converter. In order to perform the batteries charging process, most of the battery's manufacturers recommend two charging stages: constant current followed by constant voltage. The first stage consists in charging the batteries with constant current until the voltage reaches the recommended maximum voltage, and in the second stage the voltage is maintained constant until the current consumed by the batteries falls to a residual value

3.2.2 ADVANTAGES OF GRID TO VEHICLE OPERATION

- Consumers may profit from the use of electric vehicles (EV's) because electricity is cheaper than petrol for equivalent distances traveled.

3.3 BIDIERCTIONAL BATTERY CHARGER

The proposed bi-directional, capacitor less EV charger consists of grid type capacitor, resonant bi-directional converter, grid selector, load and battery. The grid type capacitor acts like a grid which stores power and also supplies power whenever needed. It is connected to a bi-directional DC-DC converter, which reduces the switching losses, thereby improves the efficiency of the proposed system. The grid selector plays an important role in the proposed system. The grid selector performs two modes of operation, like Vehicle to Grid (V2G)and Grid to Vehicle (G2V). It acts like a switch and performs the operations of various modes depending on the power requirement of various components. The home appliances are considered as load. The use of the battery is to store energy and supply power to the home appliances when needed.
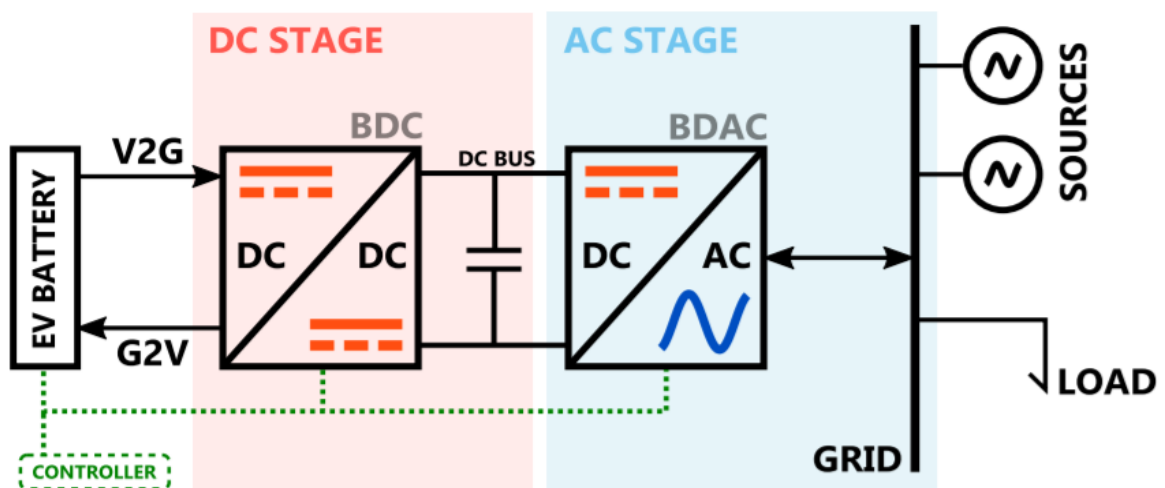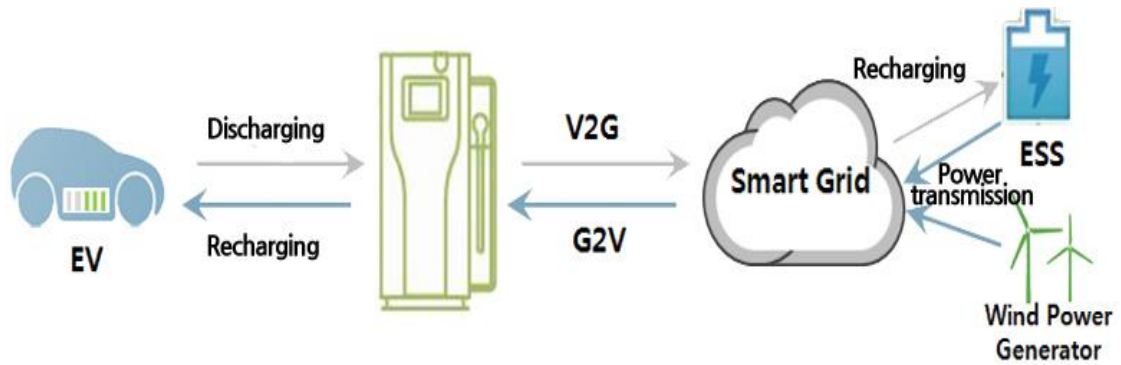
3.3.1 VEHICLE TO GRID

V2G stands for "vehicle to grid" and is a technology that enables energy to be pushed back to the power grid from the battery of an electric car. With electric vehicle-to-grid technology—also known as car-to-grid—a car battery can be charged and discharged based on different signals — such as energy production or consumption nearby.

Unidirectional V2G refers to the single directional power flow from the power grid to the EV. Unidirectional V2G needs the participation of grid operators to control and limit the charging time, location and power flow during EV charging event [9]. A new electricity policy with different energy rates can be introduced to encourage the off-peak charging and to avoid the on-peak charging. Implementation of this policy requires less investment cost. Moreover, unidirectional V2G will not introduce extra stress on the battery and can prolong the battery lifespan. The unidirectional V2G also has simple operation, low investment cost and highly available as conventional battery chargers can be adopted for the application of this technology.

The full-bridge AC-DC bidirectional converter operates as inverter with sinusoidal current and unitary power factor, and the reversible DC-DC converter operates as a boost converter.
As in the G2V operation mode, in the V2G mode the full-bridge AC-DC bidirectional converter must be synchronized with the power grid fundamental

voltage. As aforementioned the synchronization is obtained through a single-phase α-β PLL in α-β coordinates. The active power to be delivered to the power grid is established as external input parameter received from a serial communication port in order to enable the collaborative integration of the EV in a smart grid context. Therefore, the control algorithm employed in the V2G operation mode is similar to the one used in the G2V operation mode. Aiming to synthesize the reference current correspondent to the active power to be delivered it was also used a predictive current control. In order to the full-bridge AC-DC bidirectional converter deliver back to the power grid the energy stored in the traction batteries; the DC link voltage must be slightly greater than the peak value of the power grid voltage. For such intent, the reversible DC-DC converter has to operate as a boost converter, once the traction batteries voltage is smaller than the required to the DC link voltage.

3.3.2 ADVANTAGES OF VEHICLE TO GRID OPERATION

- A bidirectional V2G charger has the similar benefits as unidirectional V2G charger, as well as can achieve load leveling, peak load shaving, reactive power support, active power regulation and harmonic filtering.
- Bidirectional V2G concept can provide more system flexibility to power utility and offer significant financial benefits to EV owner.
- Bidirectional V2G technology brings flexibility to control and manage the operation of power system.

- Energy market can trade and optimize their balance.

- Network operators can optimize investments & stabilize the grid.

3.3.3 DISADVANTAGES OF VEHICLE TO GRID OPERATION

- However, there are some impediments and challenges during the transition of V2G implementation.

- One of the barriers is the battery degradation issue.

- V2G operation requires frequent charging and discharging the EV battery but the rechargeable EV battery has limited charge and discharge lifecycle.

- Apart from that, other impediments of V2G implementation are the need for intensive communication between power grid and EV, power system reinforcement, high investment of V2G facilities and social obstacles.

- These barriers can be resolved by well-planned V2G strategy, infrastructure and standards.

3.3.4 THE BENEFITS OF BIDERCTIONAL CHARGING

Firstly, bidirectional charging is a great way to locally manage momentary spikes in electricity consumption. Instead of having to invest a ton of money in replacing a real estate property's electricity system to prepare for managing heavier loads, electric cars can be used as temporary energy reserves.

Secondly, the power grid and the planet both benefit from V2G, as the technology makes it possible to reserve renewable energy and pull it back into use exactly when it's needed. Because the production of solar and wind energy is extremely unpredictable, without V2G, a lot of renewable energy would go to waste. Thirdly, if environmental consciousness isn't enough of a motivation for consumers, taking part in bidirectional charging is likely to become a cost-effective EV charging method. By agreeing to use their vehicles as flexible energy containment reserves, consumers will most likely be able to enjoy lower charging prices.

4 DEVELOPMENTOF BI-DIRECTIONAL CHARGER

4.1 BATTERY MODELING

Since the most widely used batteries for electric vehicles are lithium-ion (Li-Ion) and nickel-metal hydride (Ni-MH), From the perspective of power grid, an EV is viewed as a load during charging and as a source during discharging. An appropriate battery model is necessary to accurately represent the characteristics of an EV battery. Likewise, a state of charge (SOC) must be implemented in the controls to select between the two scenarios. The electric circuit-based model is best due to its capability to represent the electric characteristics of a battery. The controlled voltage source is described by an equation developed by Shepherd. This equation describes the electrochemical behavior of a battery in terms of SOC, terminal voltage, open circuit voltage, internal resistance and discharge current.

The state of charge (SOC) of a cell denotes the capacity that is currently available as a function of the rated capacity. The value of the SOC varies between 0% and 100%. If the SOC is 100%, then the cell is said to be fully charged, whereas a SOC of 0% indicates that the cell is completely discharged.

The electrical battery model is able to calculate the SOC of a lithium-Ion battery by:

$$SOC = 100 \ (1 - it/Q) \qquad \text{Where i - current}$$

, t =time ,Q =quantity of charge
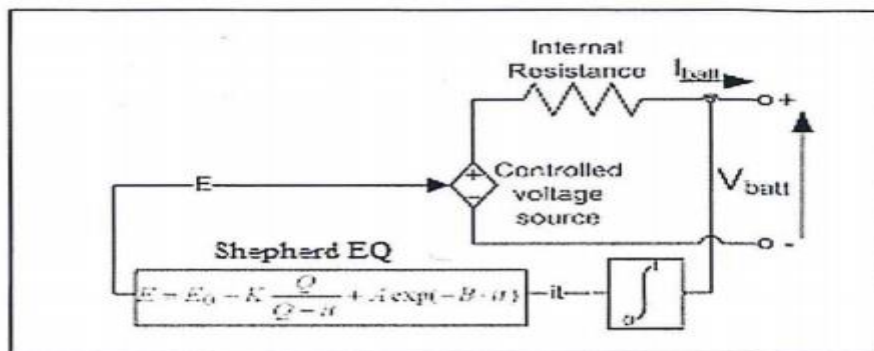
4.2 OPERATION OF BIDIRECTIONAL CHARGER

The presented battery charger is composed by two power converters that share a DC link. One is to interface the power grid and the other is to interface the traction batteries. In order to interface the power grid is used a full-bridge AC-DC bidirectional converter. This converter can operate as active rectifier with sinusoidal current and unitary power factor during the G2V operation mode. During the V2G and V2H operation modes this power converter operates as inverter. In the V2G mode the converter operates as controlled current source to inject the required power in the power grids. In order to interface the batteries is used a reversible DC-DC converter. In the G2V operation mode this converter operates as buck converter to control the current and voltage during the current and voltage batteries charging stages, respectively.
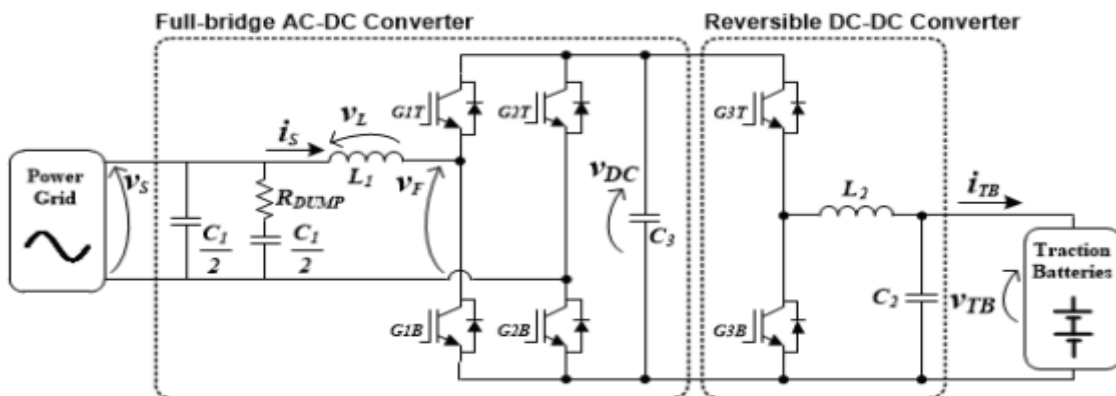
During V2G and V2H the converter operates as boost converter to elevate the batteries voltage to an adequate DC link voltage aiming to guarantee the proper operation of the full-bridge AC-DC bidirectional converter. The complete electric diagram of the bidirectional battery charger is presented in Fig. 2. Although using two bidirectional converters, the required hardware is equivalent to a controlled three leg IGBT bridge.

4.3 AC-DC BIDIRECTIONAL CONVERTER OPERATION

The bidirectional AC-DC converter consists of six IGBT- Diode switches (S 1 -S 6), which is connected with three phase AC voltage supply through series filter inductance (Ls) and resistance (Rs). A DC capacitor (C dc) is connected across DC voltage bus to keep the voltage (V dc) constant. The bidirectional AC-DC converter operates in two modes. The first mode is rectifier mode, in which the bidirectional AC-DC converter operates as a frontend rectifier and allows power transfer from the three-phase AC voltage end to the DC voltage bus. The second mode is inverter mode, where the power flows from DC voltage bus to three-phase AC voltage end and the converter acts as a voltage source inverter.
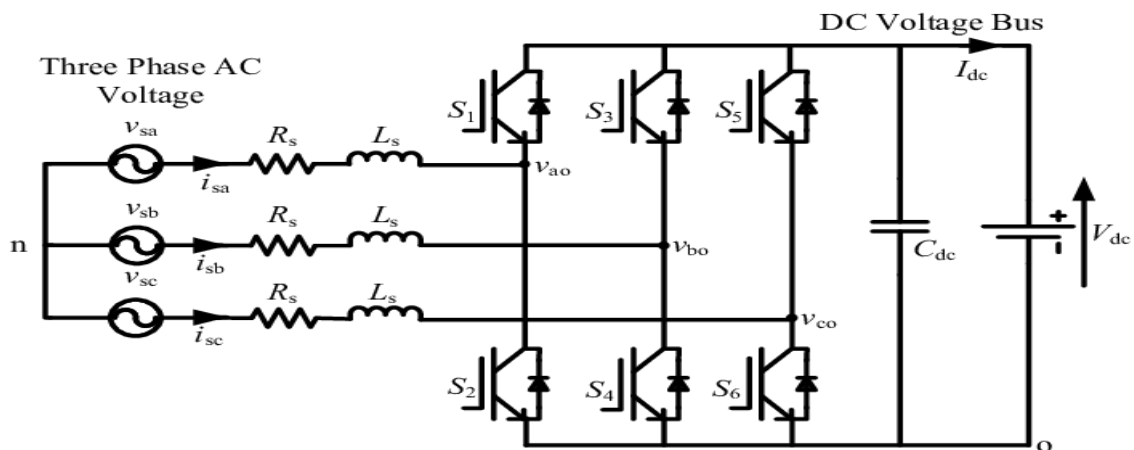
The AC/DC converter consists of a power factor correction (PFC) which converts input AC voltage into DC voltage, an H-bridge circuit which converts the DC voltage into high-frequency AC voltage, a high-frequency transformer which regulates transformation and insulation, and a circuit which rectifies and smooths high-frequency AC voltage. This circuit diagram has two problems. One is that the coil parts, such as the transformer and the choke coil, contribute to an increase in the volume and weight of the AC/DC converter. Generally, an AC/DC converter has higher output power than that of a DC/DC converter for driving auxiliaries, and accordingly AC/DC converter's coil parts occupy a larger

space. As the AC/DC converter is also equipped with a reactor for the PFC, the coil parts alone weigh as much as 20-30% of the total weight of the AC/DC converter.

4.4 DC-DC BIDIRECTIONAL CONVERTER OPERATION

This type of converter nowadays is mainly used in electric vehicles. It is also called a Half-Bridge DC-DC converter. When the Buck and the boost converters are connected in antiparallel across each other with the resulting circuit is primarily having the same structure as the basic Boost and Buck structure but with the combined feature of bidirectional power flow is called Bi directional dc-dc converter. It works in both directions.
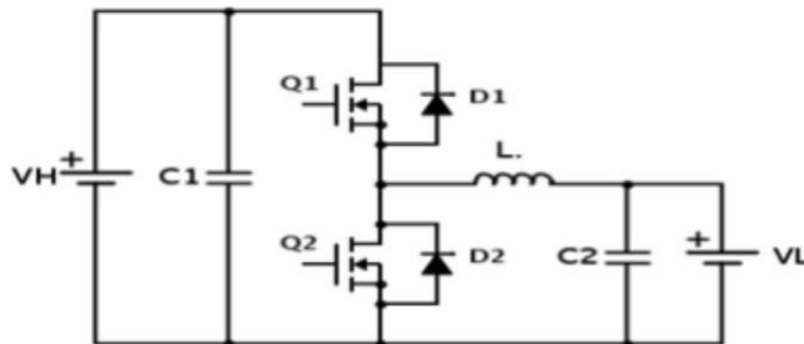
The above circuit can work in buck or boost mode depending on the switching of the MOSFETS Q1 and Q2. The switches Q1 or Q2 in sequence with the anti-parallel diodes D1 or D2 (acting as a freewheeling diode) respectively, which makes the circuit step up or step down the voltage connected across them. The bidirectional operation of the above circuit can be described in the below two modes as follows:

Mode 1 (Boost Mode): In this mode switch Q2 and diode D1 begin into conduction depending on the duty cycle whereas the switch Q1 and diode D2 are off all the time. This mode can moreover be divided into two intervals depending on the conduction on the switch Q1 and diode D2.

Mode 2 (Buck Mode): In this mode switch Q1 and diode D2 begin into conduction depending on the duty cycle whereas the switch Q2 and diode D1 are off all the time. This mode can moreover be divided into two intervals depending on the conduction on the switch Q2 and diode D1.

Interval 1 (Q2-on, D2-off; Q1-off, D2-Off): In this mode, Q1 is on and Q2 is off. The greater voltage battery will charge the inductor and the o/p capacitor will get charged by battery.

Interval 2 (Q1-off, D1-off; Q2-off, D2-on): In this mode, Q2 and Q1 both are off. Again, as the inductor current cannot change instantaneously, it gets discharged via the freewheeling diode D2. The voltage across the load is stepped down as correlated to the input voltage.

A comparison between the features of the non-isolated bidirectional topologies have been explained below:

01. During step-up mode, in the buck-boost bidirectional converter the RMS value of the current in the inductor and the power switches is greater by an amount equivalent to the output current as compared to the buck-boost cascade bidirectional converter. Furthermore, the capacitor RMS current also excels in the former case by an amount of the 1/3rd of the output current. Hence in the bidirectional buck-boost converter the power switches, inductor, and the capacitor work under more thermal and electrical stresses as compared to the buck-boost cascade converter following in greater power loss and also creating the saturation of the inductor core. Also, as the stress on the MOSFET and the diode is higher, the buck-boost bidirectional converter needs power devices with larger device ratings. Higher RMS currents also result in greater conduction losses and thus reducing the overall efficiency of the buck-boost bidirectional converter.

02. However, the no of devices needed by the cascade buck-boost converter is double the number of devices in the buck-boost bidirectional converter. This problem can be resolved by using the Half-Bridge Bidirectional DC-DC Converter. It has the same no devices as the buck-boost bidirectional

converter and can be used instead of the buck-boost cascade bidirectional converter for the applications that need the boost operation only in 1 direction and the buck in the other direction.

03. The main benefits of the half-bridge bi-directional converter as correlated to the bi-directional buck converter is that it only needs one inductor instead of two and that too half the value of the latter, as well as the power switches ratings needed for the half-bridge bidirectional converter, is very lower as compared to the buck converter. Also, the efficiency of the half-bridge converter is higher than the buck converter because of the lower inductor current and hence lower conduction as well as lower switching losses.

4.5 CONTROLLER OF AC/DC CONVERTER

The controller of the rectifier is Proportional Integral type. A linking dual proportional integral
Controllers for AC current regulation and DC bus voltage, the method of phase locked loop is giving reference for AC current control.
A Phase-locked loop is a control system that generates an output signal whose phase is related to the phase of an input signal.

4.6 CONTROLLER OF DC/AC CONVERTER

During the reverse process, the DC is converted to AC. The controller used is PI-based controller. Those PWM signal were given to the IGBT to control the flow of voltage in the charger. The PLL is also used provide reference of DC current. The booster was used in the circuit to improve steady flow of the voltage and current. This operation will only use when the mode is change to the inverter mode. The requirement of the frequency of both AC to DC and DC to AC are more or less same. The generated frequency is feed into the IGBT and rectifier.

4.7 BATTERY MANAGEMENT SYSTEM (BMS)

Electric vehicles run on rechargeable battery packs that are made of multiple cell modules arranged in a series and parallel. These battery packs produce

several hundred volts of electricity. Various functions inside the car are dependent on them. That is why it becomes a critical component of the vehicle that requires constant monitoring and control.

The main function of BMS is to ensure that the battery is protected and any operation out of its safety limit is prevented. It monitors the battery pack's state of charge (SOC) along with the state of health. BMS also manages the battery optimization via cell balancing that improves the life of the battery in the long run. The BMS will also monitor voltage, different temperature parameters, and coolant flow.

5 INTRODUCTION TO MATLAB

5.1 WHAT IS MATLAB?

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include:

- Math and computation
- Algorithm development
- Modeling, simulation, and prototyping
- Data analysis, exploration, and visualization
- Scientific and engineering graphics
- Application development, including Graphical User Interface building

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows you to solve many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar no interactive language such as C or FORTRAN.

The name MATLAB stands for matrix laboratory. MATLAB was originally written to provide easy access to matrix software developed by the LINPACK and EISPACK projects, which together represent the state-of-the-art in software for matrix computation.

MATLAB has evolved over a period of years with input from many users. In university environments, it is the standard instructional tool for introductory and advanced courses in mathematics, engineering, and science. In industry, MATLAB is the tool of choice for high-productivity research, development, and analysis.

MATLAB features a family of application-specific solutions called toolboxes. Very important to most users of MATLAB, toolboxes allow you to *learn* and *apply* specialized technology. Toolboxes are comprehensive collections of MATLAB functions (M-files) that extend the MATLAB environment to solve particular classes of problems. Areas in which toolboxes are available include signal processing, control systems, neural

networks, fuzzy logic, wavelets, simulation, and many others.

5.2 CHAPTERS IN MATLAB

The MATLAB system consists of five main parts:

5.2.1 The MATLAB language

This is a high-level matrix/array language with control flow statements, functions, data structures, input/output, and object-oriented programming features. It allows both "programming in the small" to rapidly create quick and dirty throw-away programs, and "programming in the large" to create complete large and complex application programs.

5.2.2 The MATLAB Working Environment

This is the set of tools and facilities that you work with as the MATLAB user or programmer. It includes facilities for managing the variables in your workspace and importing and exporting data. It also includes tools for developing, managing, debugging, and profiling M-files, MATLAB's applications.

5.2.3 Handle Graphics

This is the MATLAB graphics system. It includes high-level commands for two-dimensional and three-dimensional data visualization, image processing, animation, and presentation graphics. It also includes low-level commands that allow you to fully customize the appearance of graphics as well as to build complete Graphical User Interfaces on your MATLAB applications.

5.2.4 The MATLAB mathematical function library

This is a vast collection of computational algorithms ranging from elementary functions like sum, sine, cosine, and complex arithmetic, to more sophisticated functions like matrix inverse, matrix Eigen values, Bessel functions, and fast Fourier transforms.

5.2.5 The MATLAB Application Program Interface (API)

This is a library that allows you to write C and FORTRAN programs that interact with MATLAB. It includes facilities for calling routines from MATLAB (dynamic linking), calling MATLAB as a computational engine, and for reading and writing MAT-files.

5.3 MATLAB-SIMULINK

1.Commonly Used Blocks

2.Sinks

3.Sources

Simulink contains a large number of blocks from which models can be built. These blocks are arranged in Block Libraries which are accessed in the Simulink library browser window shown below.

Each icon in the main Simulink window can be double clicked to bring up the corresponding block library. Blocks in library can then be dragged into a model window to build a model.
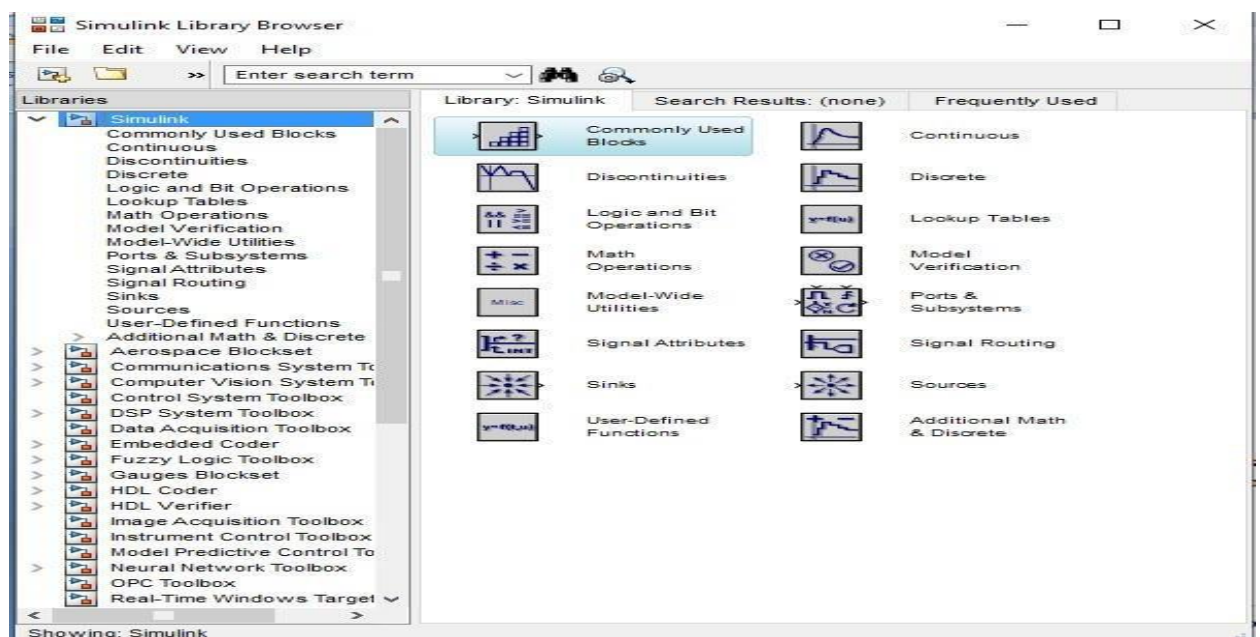
4.3.1 Commonly used blocks

Commonly Used Blocks are used to list a lot of blocks which are usually used. Double-click on the Commonly Used Blocks icon in the main Simulink window to bring up the Commonly Used window
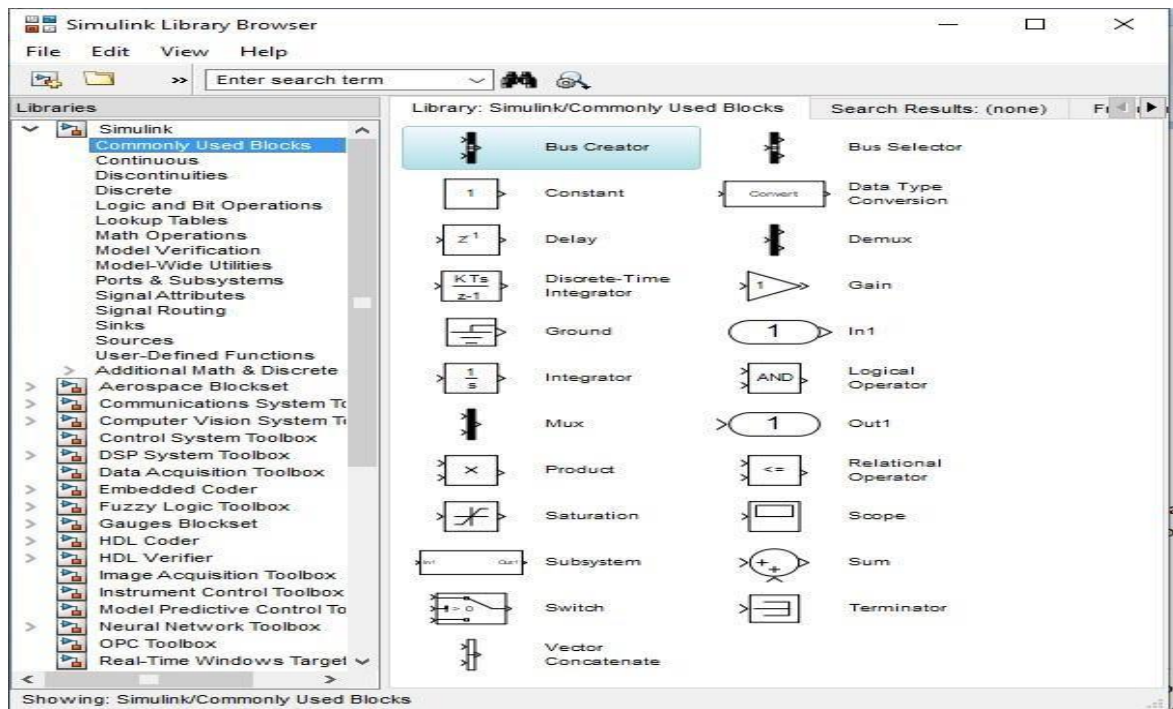
5.4 SIMULINK BLOCKS USED IN THE SIMULATION

5.4.1. Three-Phase Source

Purpose: Implement three-phase source with internal R-L impedance

Description: The Three-Phase Source block implements a balanced three-phase voltage source with internal R-L impedance. The three voltage sources are connected in Y with a neutral connection that can be internally grounded or made accessible. You can specify the source internal resistance and inductance either directly by entering R and L values or indirectly by

specifying the source inductive short-circuit level and X/R ratio.

5.4.2 In port
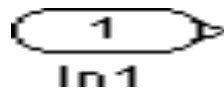
Purpose: Provide a link to an external input and for linearization.

Description: In ports are the links from the outside world into a system. Inside a subsystem block, there is an in port corresponding to each input port on the block. A signal that arrives at an input port on a subsystem block flows out of the corresponding in port within that block. The imports within a subsystem block must be numbered consecutively, starting with 1.

5.4.3 out port
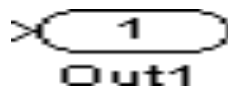
Purpose: provide a link to an external output and for linearization.

Description: The Out Port block provides a mechanism for labeling a system's outputs. In a subsystem, output ports correspond to outputs on the subsystem block.

5.4.4 Subsystem
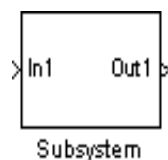
Purpose: Group blocks into a subsystem

Description: Subsystem blocks represent one system within another system. Any set of blocks and lines can be converted to a Subsystem block

with the Group command on the options menu. The Group command removes all selected objects from the active window and replaces them within a Subsystem block. This new block, when opened, redisplays all of the grouped objectives.

To create a subsystem, do one of the following:

- Copy a subsystem block from the Ports & Subsystems library into your model. Then add blocks to the subsystem by opening the subsystem block and copying blocks into it.

- Select all blocks and lines that make up the subsystem and select Diagram > Subsystem & Model Reference > Create Subsystem from Selection. Simulink® replaces the blocks with a subsystem block, along with the necessary Inport and Outport blocks to reflect signals entering and leaving the subsystem.

- The number of input ports drawn on the subsystem block's icon corresponds to the number of Inport blocks in the subsystem. Similarly, the number of output ports drawn on the block corresponds to the number of Outport blocks in the subsystem.

- The subsystem block supports signal label propagation through subsystem In port and output blocks.

5.4.5 Gain

Purpose: Multiply its input by a constant.
Description: The Gain block implements Y=KU, where Y is the output, U is the input, and K is the
specified gain. The Gain block displays scalar gain data entered as variable or a constant. The block

displays the text as it appears in the dialog box.

5.4.6 Scope

Scope

Purpose: Display signals during simulation**.**

Description: While the simulation is running, the Scope block displays the output of the block driving it. Opening a scope block produces a scope window. The title of this window matches the name of the block.

5.4.7 Voltage Measurement
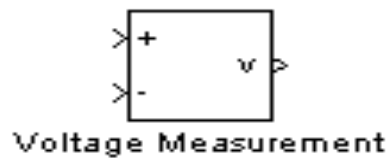
Voltage Measurement

Purpose: Measure a voltage in a circuit

Description: The Voltage Measurement block is used to measure the instantaneous voltage between two electric nodes. The output is a Simulink signal that can be used by other Simulink blocks.

5.4.8 Breaker

3-Phase Breaker
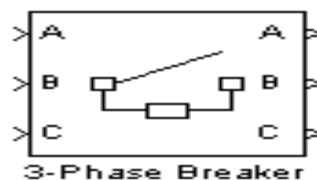
Purpose: Implement a circuit breaker opening at current zero crossing

Description: The Breaker block implements a circuit breaker that is controlled by a Simulink signal applied on its second input. The control signal must be 0 or 1, 0 for open and 1 for closed. The arc extinction process is simulated by opening the breaker when the current passes through zero (first current zero-crossing following the transition of the Simulink control input from 1 to 0). When the breaker is closed, it behaves as a series RL circuit. The R and L values can be set as small as necessary in order to be negligible compared with external components (typical values Ron=10m?, Lon=10μH). When the breaker is open, it has infinite impedance. If the breaker's initial state is set to 1 (closed), initializes all the states of the linear circuit and breaker initial current so that the simulation starts in steady-state.

5.4.9 Bus bar
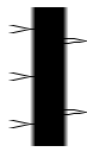
Purpose: Implement a labeled network node
Description: The Bus Bar block is used to interconnect components. It allows multiple Electrical
block outputs and inputs to be connected together.

5.4.10 Current Measurement
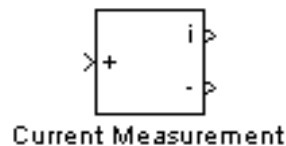
Current Measurement

Purpose: Measure a current in a circuit
Description: The Current Measurement block is used to measure the instantaneous current flowing in any electrical block or connection line.

The first output provides a Simulink signal that can be used by other Simulink blocks.

5.4.11 Constant
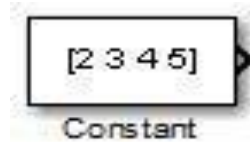
Constant

Description: The Constant block generates a real or complex constant value. The constant output value is displayed in the middle of the block, with a default value of 1. In order to examine these blocks, create a new model window (select New from the File menu in the Simulink window or hit Ctr1+N)

5.4.12 PID Controller
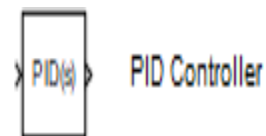
PID Controller

Purpose: Continuous-time or discrete-time PID controller

Description: The PID Controller block output is a weighted sum of the input signal, the integral of the input signal, and the derivative of the input signal. The weights are the proportional, integral, and derivative gain parameters. A first-order pole filters the derivative action.

5.4.13. POWER GUI:

Continuous

powergui

Description: The Power gui block allows you to choose one of the following methods to solve your circuit continuous, which uses a variable step solver from Simulink Ideal Switching continuous di securitization of the electrical system for a solution at fixed time steps pharos solution the Powergui block is necessary for simulation of any Simulink model containing Sim Power System blocks. It is used to store the equivalent Simulink circuit that represents the state-space equations of the model.

5.4.14 Display

Description: The Display block shows the value of the input data. You can specify the frequency of the display. For numeric input data, you can also specify the format of display.

If the block input is an array, you can resize the block vertically or horizontally to show more than just the first element. If the block input is a vector, the block sequentially adds display fields from left to right and top to bottom. The block displays as many values as possible. A black triangle indicates that the block is not displaying all input array elements.

The Display block shows the first 200 elements of a vector signal and the first 20 rows and 10 columns of a matrix signal.

5.4.15 From
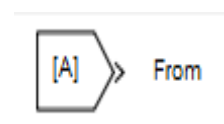
Description: The From block accepts a signal from a corresponding Goto block, then passes it as output. The data type of the output is the same as that of the input from the Goto block. From and Goto blocks allow you

to pass a signal from one block to another without actually connecting them. To associate a Goto block with a From block, enter the Goto block's tag in the Goto Tag parameter

5.4.16 GOTO
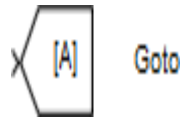
Description: The Go to block passes its input to its corresponding From blocks. The input can be a real- or complex-valued signal or vector of any data type. From and Go to blocks allow you to pass a signal from one block to another without actually connecting them.A Go to block can pass its input signal to more than one From block, although a From block can receive a signal from only one Go to block. The input to that Go to block is passed to the From blocks associated with it as though the blocks were physically connected. Go to blocks and From blocks are matched by the use of Go to tags.

5.4.17 MUX, DEMUX

Description: The Mux (Multiplexer) block is used to combine two or more scalar signals into a single Vector signal. Similarly, a Demux (Demultiplexer) block breaks a vector signal into scalar signal components. The number of vector components must be specified in each case.

5.4.18 MOSFET:
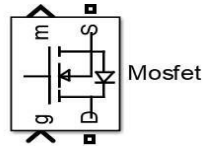
Description: The MOSFET block implements a macro model of the real MOSFET device. It does not take into account either the geometry of the device or the complex physical processes. Depending on the value of the inductance Lon, the MOSFET is modeled either as a current source (Lon > 0) or as a variable topology circuit (Lon = 0). The MOSFET block cannot be connected in series with an inductor, a current source, or an open circuit, unless its snubber circuit is in use.

Use the Powergui block to specify either continuous simulation or discretization of your electrical circuit containing MOSFET blocks. When using a continuous model, the ode23tb solver with a relative tolerance of 1e-4 is recommended for best accuracy and simulation speed.

5.4.19 Resistor:

Description: The Resistor block models a linear resistor, described with the following equation: V=IR Connections + and – are conserving electrical ports corresponding to the positive and negative terminals of the resistor, respectively. By convention, the voltage across the resistor is given by V(+) – V(–), and the sign of the current is positive when flowing through the device from the positive to the negative terminal. This convention ensures that the power absorbed by a resistor is always positive.

5.4.20 Inductor

Inductor

Description: The Inductor block models a linear inductor, described with the following equation:

V=Ldi/dt

The Series resistance and Parallel conductance parameters represent small parasitic effects. The series resistance can be used to represent the DC winding resistance or the resistance due to the skin effect. Simulation of some circuits may require the presence of a small parallel conductance. For more information, see Modeling Best Practices.

Connections + and – are conserving electrical ports corresponding to the positive and negative terminals of the inductor, respectively. The current is positive if it flows from positive to negative, and the voltage across the inductor is equal to the difference between the voltage at the positive and the negative terminal, V(+) – V(–).

5.4.21. Capacitor

Capacitor

Description: The Capacitor block models a linear capacitor, described with the following equation:

I=cdv/dt

The Series resistance and Parallel conductance parameters represent small parasitic effects. The parallel conductance directly across the capacitor can be used to model dielectric losses, or equivalently leakage

current per volt. The series resistance can be used to represent component effective series resistance (ESR) or connection resistance. Simulation of some circuits may require the presence of the small series resistance.

Connections + and – are conserving electrical ports corresponding to the positive and negative terminals of the capacitor, respectively. The current is positive if it flows from positive to negative, and the voltage across the capacitor is equal to the difference between the voltage at the positive and the negative terminal, V(+) – V(–).

5.4.22 Three-Phase Series RLC Load
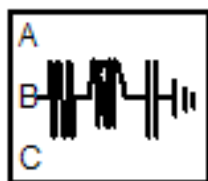
Description: The Three-Phase Series RLC Load block implements a three-phase balanced load as a series combination of RLC elements. At the specified frequency, the load exhibits constant impedance. The active and reactive powers absorbed by the load are proportional to the square of the applied voltage.

5.5 ANALYSIS OF BIDIRECTIONAL CHARGER

With reference to the simulation results, the measured battery current is able to follow the reference battery current throughout the simulation process. This shows that the design and analysis of bidirectional battery charger has successfully controlled the direction and magnitude of current flow.

Mode of operation	SOC	VOLTAGE	CURRENT
G2V(Grid to vehicle mode	60%(increasing)	249.4 V	-22 A
V2G(Vehicle to Grid mode)	60%(decreasing)	247.2V	24.72 A

5.6 SIMULINK BLOCK DIAGRAM OF BIDIRECTIONAL ELECTRIC CHARGER
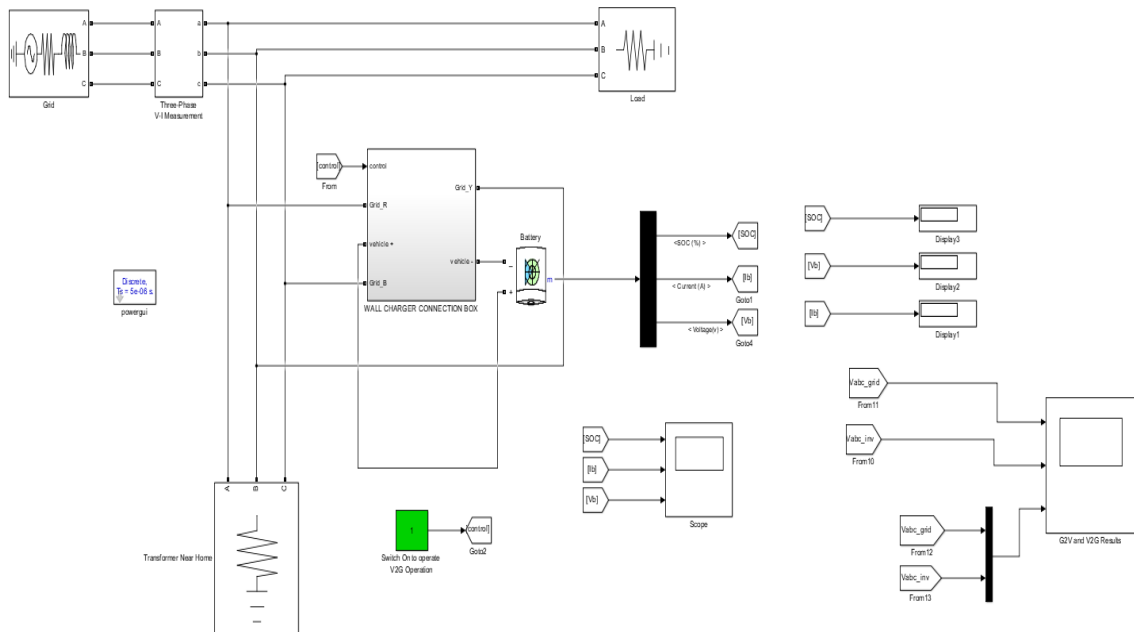
Fig: Simulink model of Bidirectional electric charger
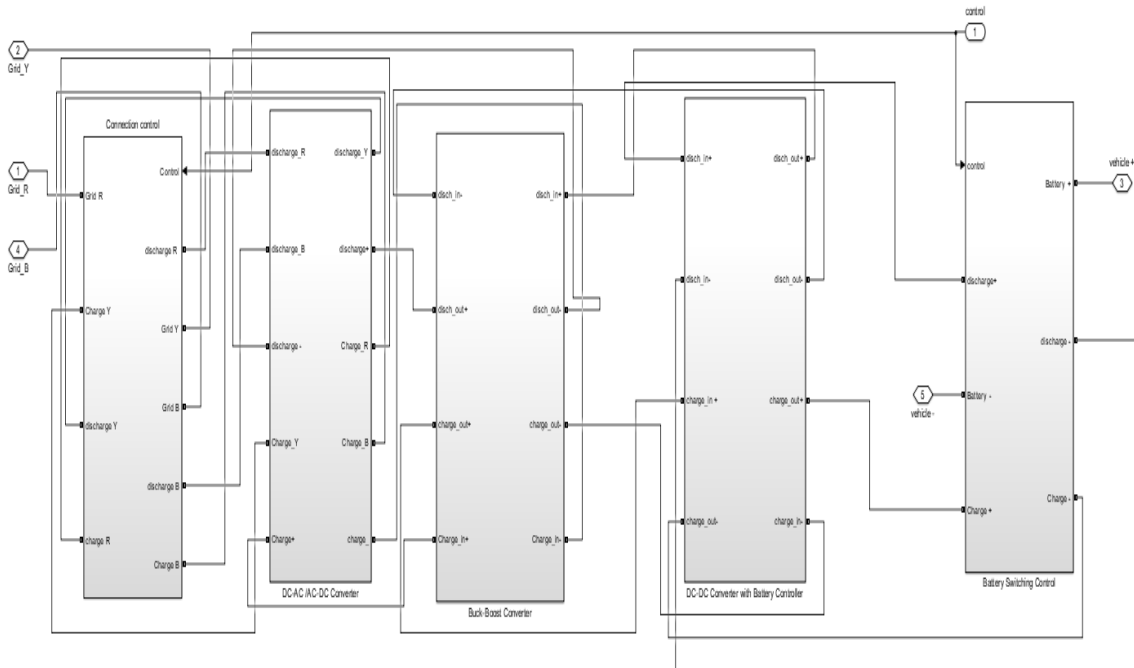
Fig: Proposed internal subsystem of wall charger connection box
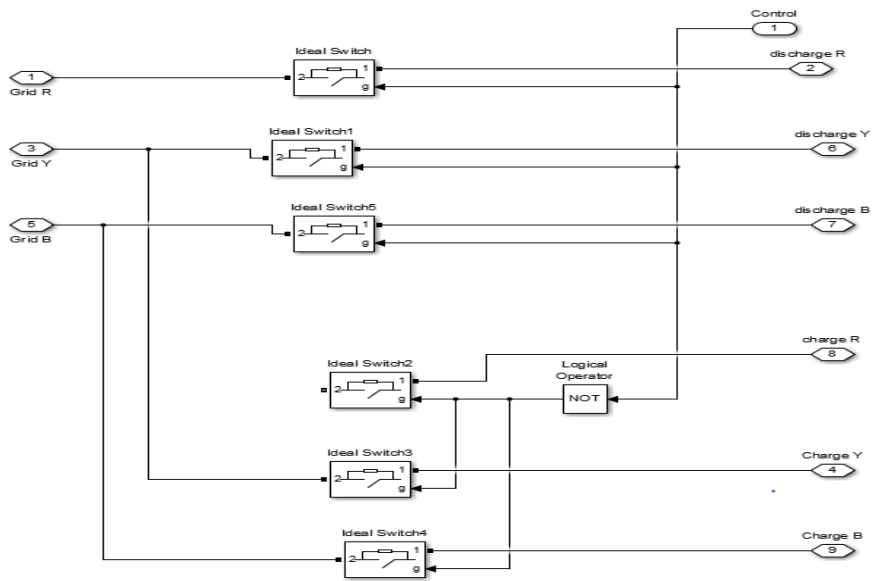
Fig: proposed Simulink model of connection control
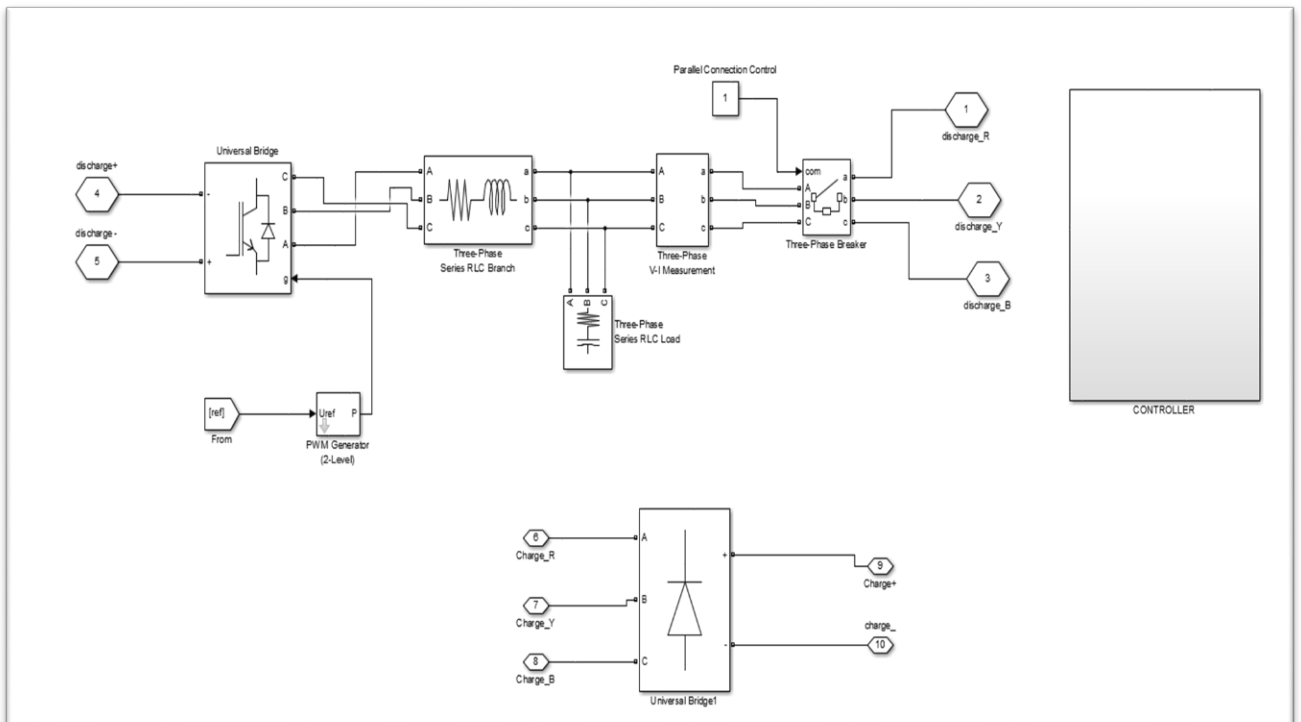
Fig: proposed Simulink model of AC/DC converter with controller circuit
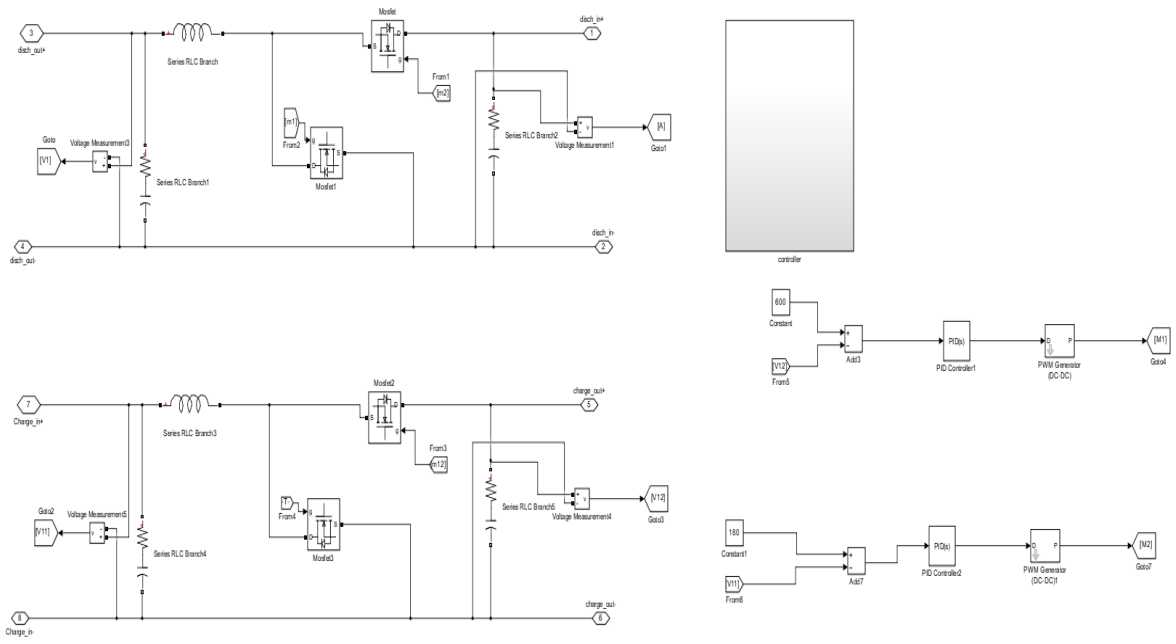
Fig: proposed Simulink model of Buck-Boost converter with controller circuit
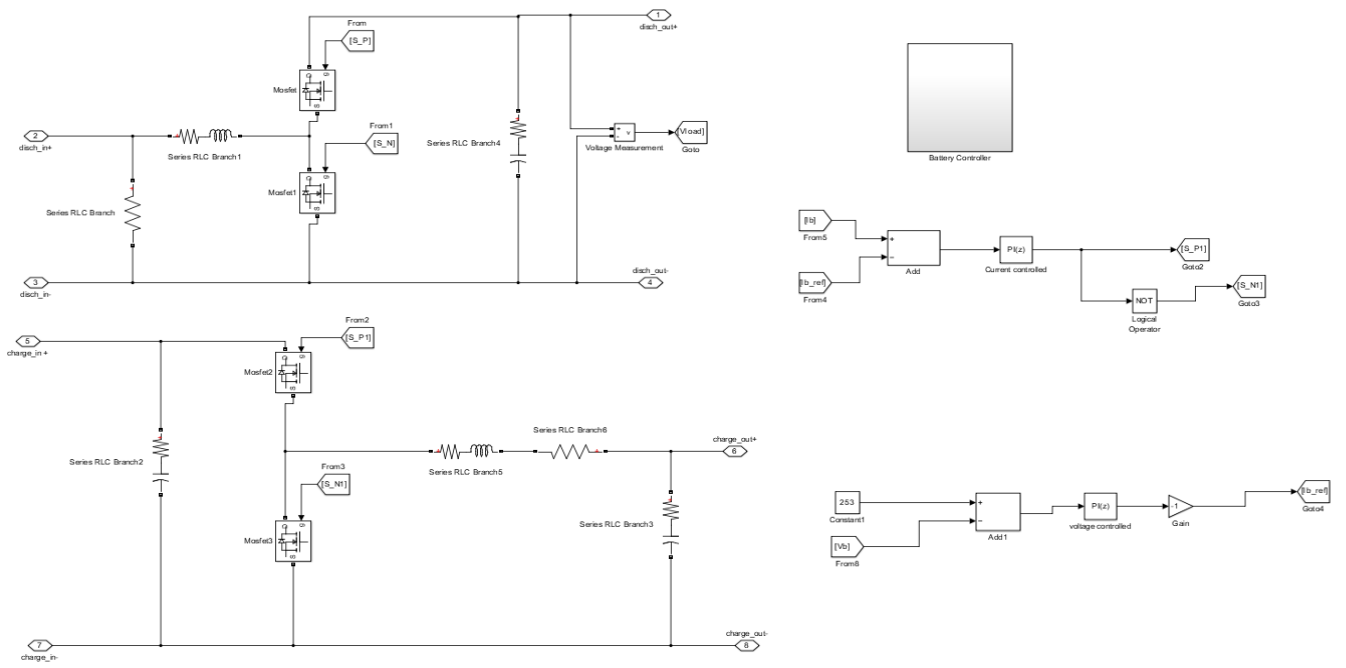
Fig: proposedSimulink model of DC-DC converter with battery controller

44
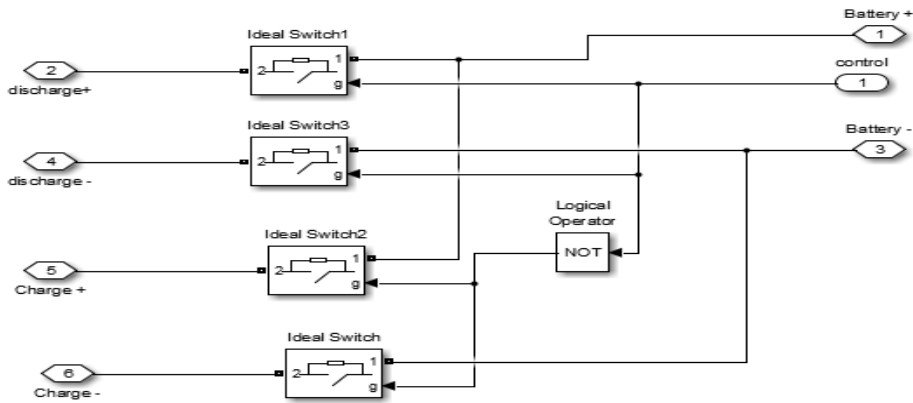
Fig: proposed Simulink model of connection control

5.7 SIMULATION RESULT AND DISCUSSIONS

Normal EV charger works uni-directionally having electricity flow from Grid to Vehicle only, but in bi-directional charger both Grid to Vehicle and Vehicle to Grid operations can perform.

With Bi-directional Charger topology, two operations can be performed according to the electricity flow direction.

     1)Grid to Vehicle flow(G2V)

     2)Vehicle to Grid flow (V2G)

G2V flow allows charging your EV when you need to charge the EV battery bank.

V2G operation allows selling electricity from EV battery bank to Grid when you have more than enough charge.

Simulation is conducted to test the performance of the proposed bidirectional controller under, Grid to vehicle and Vehicle to grid operation. The battery initial SOC is set to 50 percent. This value is chosen to ensure that the battery is able to receive or supply power when necessary.

Initially, the simulation requires some times to start up and stabilize. This procedure takes around 1 minute.

5.6.1. Grid to Vehicle

During this operation the virtual switch is in 0 position .It is like normal

electric vehicle operation. The battery is charged and it is utilized for movement of vehicle.

To operate in G2V (Grid to Vehicle) mode switch has to be set to 0.

a) SOC gradually increasing from point 58 because we have to set the initial state of charge to 60%

b) Current = -22 A to -28 A (Negative value referring that the battery is charging state)

c) Grid voltage (Vgrid)will be positive and 249 V (+_3V) and Inverter voltage (V_inv) have to be '0' but there is a likage voltage is flowing on of (0.2-0.5) but if we observe the 3rd waveform combination, the V_inv is at 0.

d) V_inv can be made 0, by substituting the perfect filter circuit value after rectification process.
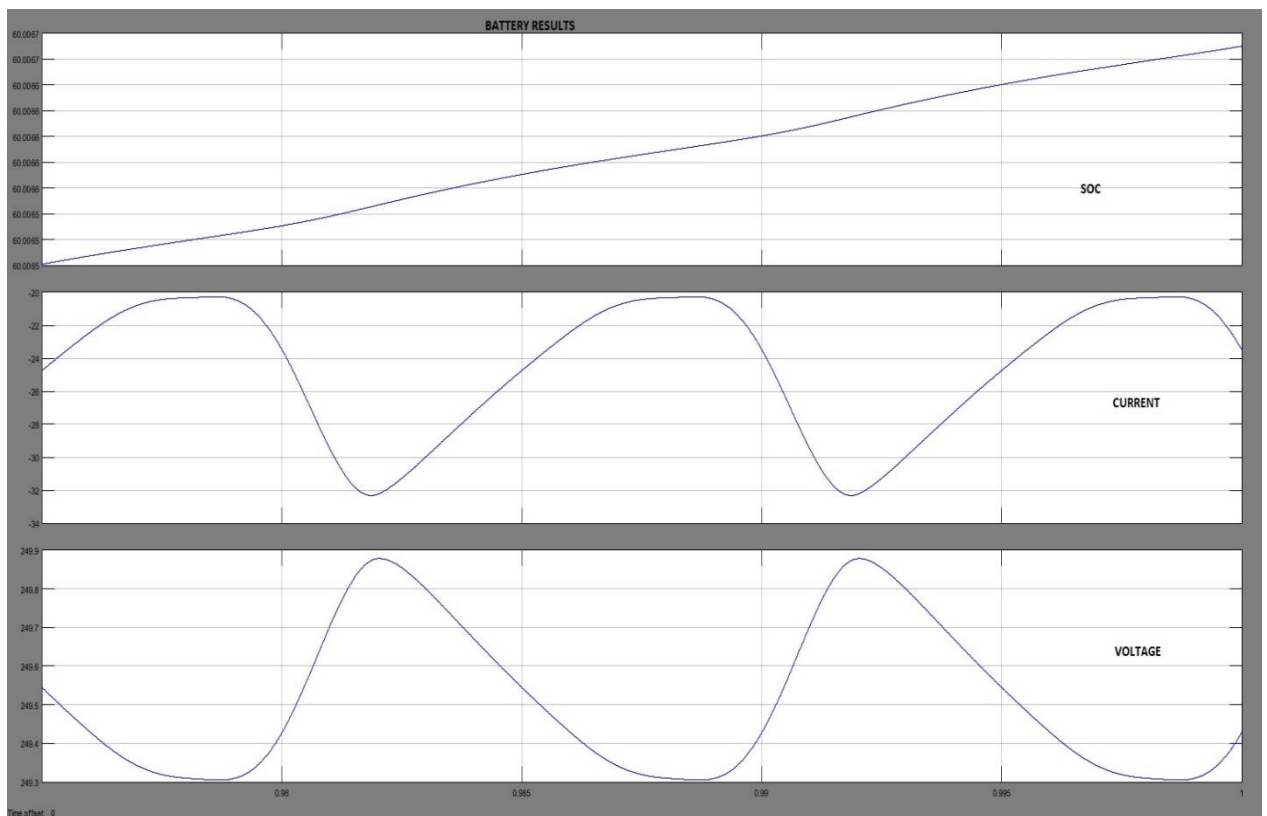
Fig: Simulation Battery graph for Grid to Vehicle Operation
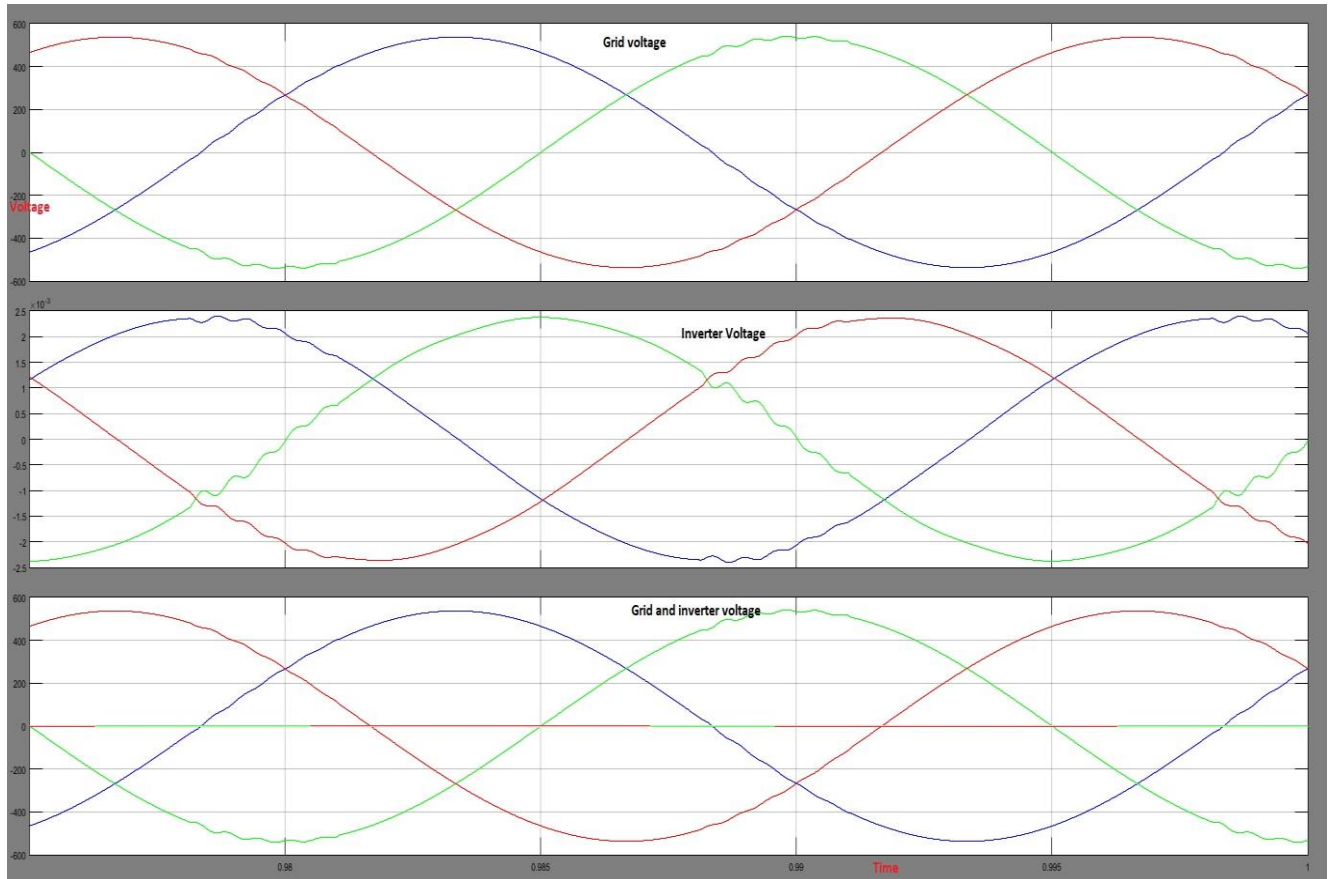
Fig: Simulation Voltage graph for Grid to Vehicle Operation

5.6.2 V2G

To Activate the V2G operation there is virtual switch in the car mobile application, (ex, Tesla mobile application), by turning on that switch, V2G operation can be activated.

Assume that switch, with a green block in our simulation.

By turning it on (i.e., 1), V2G operation will start.

During V2G operation, SOC will decrease and battery current and battery voltage will be positive.

To operate in V2G mode the switch has to be set to 1.

a) SOC gradually decreasing from point 58 because we have to set the initial state of charge to 60%

b) Current = 22 A to 28 A (Positive value referring that the battery is discharging and been utilized by grid, motor, home or Emergency Purposes)

c) Voltage =249(+_3V)

d) V_grid and V _inv need to synchronous because we are sending back the power to grid so, the voltage magnitude should be equal and need to be in Phase. (Similar concept when we try to perform two transformers in parallel, we need to check for the synchronous between them)
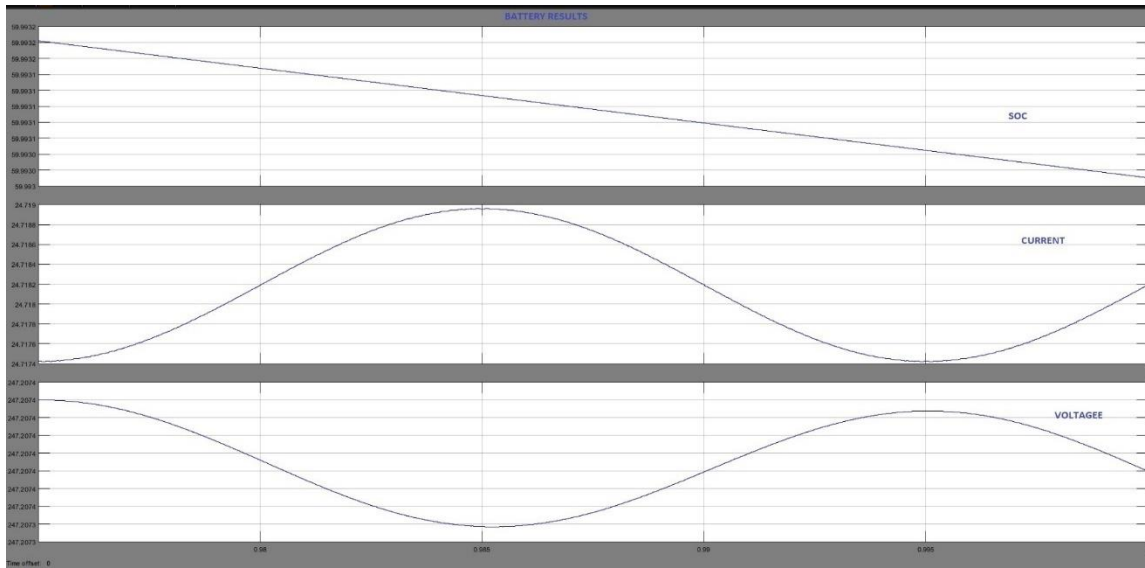
Fig: Simulation Battery graph for Vehicle to Grid Operation
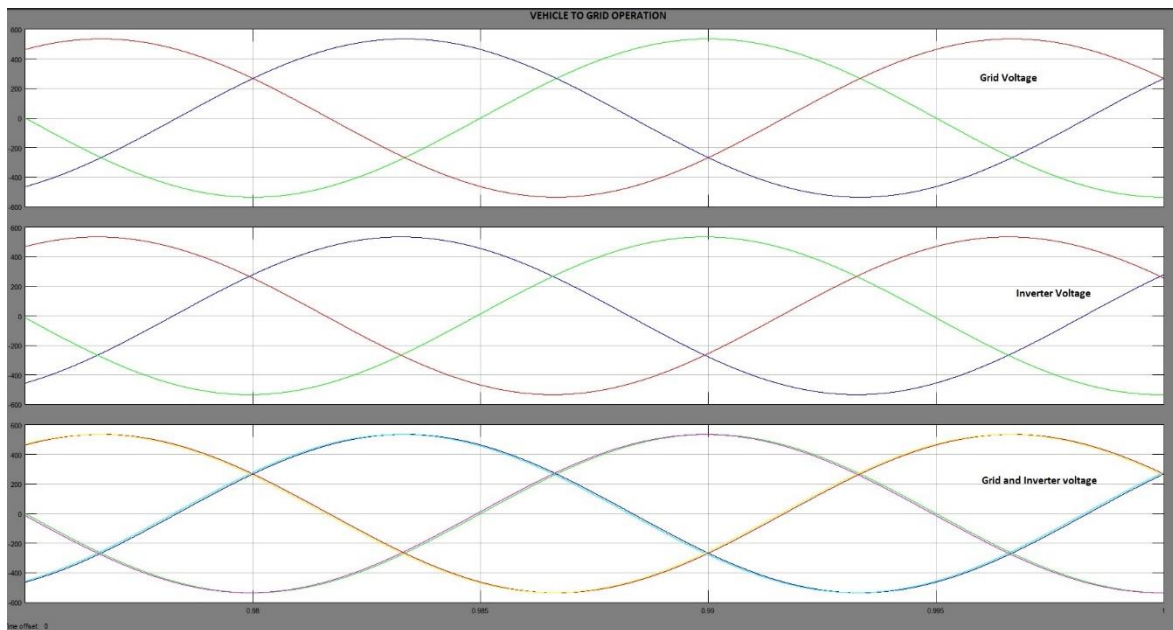
Fig: Simulation Voltage graph for Vehicle to Grid Operation

6 CONCLUSIONS AND FUTURE WORK

This project presents the development of an on-board bidirectional battery charger for Electric Vehicles (EVs) capable of work in the operating modes Grid-to-Vehicle (G2V), Vehicle-to-Grid (V2G) which consist in important technologies for targeting the future smart grids scenario. The hardware topology and the control algorithms of the presented battery charger are validated through computer simulations, using the MATLAB software, and also through experimental results, achieved with a developed laboratory prototype. Since this work only intends to validate the topology and the control algorithms, the developed prototype that supports this work is intentionally oversized. The experimental results obtained with the three operation modes (G2V, V2G) are in accordance with the expected, validating the viability of the proposed topology.

Bidirectional technology (allowing electricity to flow into and out of EVs) has only just become advanced enough for more people to use it. As the tech gets better with time, so will its potentialities. As an EV owner, you only stand to gain by going for a bidirectional charger. From making extra income by selling energy back to the grid to becoming energy self-sufficient – going bidirectional comes with clear pay-offs.

The bidirectional charger is developed which is to be used for the V2G and G2V power flow. It means a charging and discharging with one unit are possible, with the design proposed. It operate in constant current, constant voltage battery charging methods are happen in unit power factor changing. The operating parameters can be adjusted by varying the control signal from the controller. This design allows the charging and discharging operation at the different power level.

After high efficiency is maintained, plan to introduce varying passive components for a wide range of EV battery voltages before beginning the physical design. At which point I plan to create a program with a user interface which will monitor, initiate, and cease power transmission.

7 REFERNCES

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SOLAR POWERED BLDC MOTOR WITH HCC FED WATER PUMPING SYSTEM FOR IRRIGATION

A Project Report

Submitted in partial fulfillment of the requirements for award of the degree

MASTER OF TECHNOLOGY
In
POWER & INDUSTRIAL DRIVES

Submitted by

S.SAI KUMAR
(19U41D4204)

Under the Esteemed Guidance of
Mr.J.DELEEP KUMAR, M.Tech

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DADI INSTITUTE OF ENGINEERING & TECHNOLOGY

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2019 – 2021

CERTIFICATE

This is to certify that the project work entitled **"SOLAR POWERED BLDC MOTOR WITH HCC FED WATER PUMPING SYSTEM FOR IRRIGATION"** has been carried out by **S.SAI KUMAR (19U41D4204)** submitted in the partial fulfillment of the requirement for the award of the degree of **MASTER OF TECHOLOGY** in **POWER & INDUSTRIAL DRIVES** during the academic year 2020-2021.

Mr.J.DELEEP KUMAR, M.Tech   **Mr.A.Krishna Nag** M,Tech., (Ph.D)

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PROJECT GUIDE   HEAD OF THE DEPARTMENT

EXTERNAL EXAMINER

DECLARATION

I hereby declare that the dissertation entitled **"SOLAR POWERED BLDC MOTOR WITH HCC FED WATER PUMPING SYSTEM FOR IRRIGATION"** was carried out and written by me under the guidance of **Mr.J.DELEEP KUMAR,** for the award of the degree **MASTER OF TECHNOLOGY** in **POWER & INDUSTRIAL DRIVES**. I further declare that this dissertation has not been submitted elsewhere for the award of any diploma or degree in any university.

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I would like to express my sincere gratitude to **Mr. J.DELEEP KUMAR,** Associate Professor, Department of EEE for his valuable guidance, whole hearted cooperation under unfailing inspiration throughout the project, his suggestions and constant encouragement has given a right direction towards learning.

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ABSTRACT

This project deals with the BLDC motor drive powered from solar photovoltaic system with HCC fed water pumping system for irrigation. BLDC motor is preferred over other brush-based motors for its unique features like high efficiency, high torque and simple structure with low noise. By using conventional control strategies torque ripples are present, By introducing Hysteresis Current Control (HCC) torque ripple can be minimised. As solar power is abundant and available at any place so the solar photovoltaic (SPV) array system is considered as the source. The modified incremental conductance maximum power point technique is used because of its advantage of providing soft starting to BLDC motor.

KEY WORDS:

BLDC motor, solar photovoltaic (SPV) system, Hysteresis   Current Control (HCC), Modified Incremental conductance MPPT technique, DC-DC converter.

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LIST OF ABBREVIATIONS

Acronym	Abbreviation
PV	Photo Voltaic
MPPT	Maximum Power Point Tracking
P&O	Perturb And Observe
HC	Hill Climbing
IC	Integrated Circuit
DC	Direct Current
SMPS	Switch Mode Power Supply
HEV	Hybrid Electric Vehicles
BLDC	Brush Less Dc Motor
EMF	Electric Magnetic Field
PMSM	Permanent Magnet Synchronous Motor
PWM	Pulse Width Modulation
ESC	Electronic Speed Controller
BEMF	Back Electromotive Force
EMI	Electromagnetic Interface
VSI	Voltage Source Invertor
CSI	Current Source Invertor
UPS	Uninterruptible Power Supply
HCC	Hysteresis Current Control
IGBT	Insulated Gate Bipolar Transistor

LIST OF TABLES

CHAPTER-1
SOLAR PHOTO VOLTAIC SYSTEM

1.1 INTRODUCTION

The obvious choice of a clean energy source, which is abundant and could provide security for the future enlargement and growth, is the Sun's energy. Solar is an everlasting, renewable energy source. It is a clean energy source, no potential damage to the environment. It is a very large source of energy. The power from the sun intercepted by the earth is about 1.8×10^{11} MW. The adverse of the conventional energy sources can be overcome by making use of the sun's energy with added advantages. There is a wealth of solar energy throughout the world, which can be easily converted into electrical energy using Photovoltaic. Electricity generation via photovoltaic cells is a very attractive renewable energy source. Its advantages include relatively low complexity supporting structural requirements, less weight, though systems may outspread over wide areas, free and sustainable fuel source and noiseless operation due to the absence of huge rotating machines or engine parts other than slow sun tracking mechanisms.

Standalone applications of PV energy are quite predominant. PV electricity has the maximum applicable utilities in areas like water pumping, domestic appliances, fans, enhancing usage of electricity in rural locations where the unavailability of grid connection, air conditioning, etc. is yet to be implemented. However, in many poor, arid and rural areas is placed too far away from the existing grid lines. Installation of new transformers, long transmission lines and other protection devices is very expensive. Solar PV system was installed at those places. Photovoltaic energy has gaining popularity and a lot of focuses in recent years because it is an environment friendly energy source and sustainable compared to conventional energy sources.

1.2 SOLAR PV TECHNOLOGY

PV power generation employs solar panels, composed of a number of solar cells. PV cells are semiconductor devices that convert radiant energy directly into electricity. In simple terms, when sunlight strikes a cell, a

certain portion of its energy is absorbed within the semiconductor material. The absorbed energy knocks electrons loose, allowing them to flow freely under the influence of electric fields. The most common PV technology uses solar cells made of semiconductor materials, such as silicon or germanium, dosed with small amounts of impurities, typically metals or metalloids.

Solar PV cells have inbuilt electric fields that force the free electrons to flow in a certain direction. Metal contacts on the top and bottom of the PV cell, enable the cell to circulate the current in the external circuit. This current, together with the cell's voltage (which is a result of its in-built electric fields), defines the power (or wattage) that a solar cell can produce. There are different types of solar PV cells. However, the most common and commercially available types are the mono crystalline, polycrystalline and amorphous cells.

The conversion efficiencies of the solar cells manufactured by the various technologies are given below:

1. Mono crystalline – 13% to 25%
2. Polycrystalline – 10% to 20%
3. Amorphous cells – 6% to 13%

Silicon PV cells typically produce only about 0.5 V and hence anumber of cells need to be connected in a series, in order to get the required voltage level. A PV string is formed by arranging a number of PV modules in series. A PV array is a collection of PV strings. A group of PV cells connected together is called PV module. The number of modules in each string is specified according to the required voltage level of the array. The number of strings in each array is specified according to the required current rating of the array. Most PV arrays have a power diode, called the bypass diode, connected in parallel with each individual module or a number of modules. The function of this diode is to conduct the current when one or more of these modules are damaged or shaded. Another diode, called the blocking diode, is usually connected in series with each string, to prevent the reverse current flow and protect the modules. Figure 1.1 shows the PV array configuration.
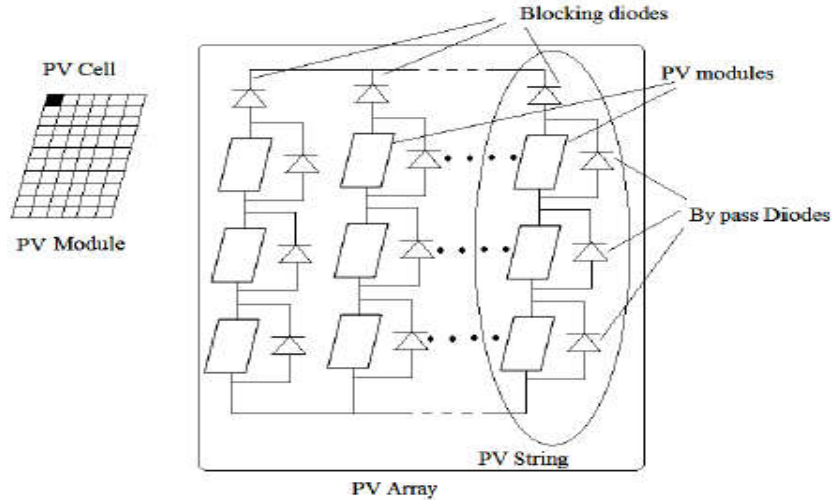
Fig1.1 PV Array Configuration

PV arrays essentially consist of a number of internal silicon based photovoltaic cells combined in series and in parallel, depending on the voltage or current requirements. Figure 1.2 shows the basic construction of a photovoltaic cell made from a P-type and N-type semiconductor material. When light penetrates through the solar cell, absorption of photons from the light occurs by means of the semiconductor atoms in which the free electrons from the N-type layer flow back to the P-type layer through an external circuit producing the electric current. A mono crystalline silicon wafer solar cell is shown in Figure 1.3
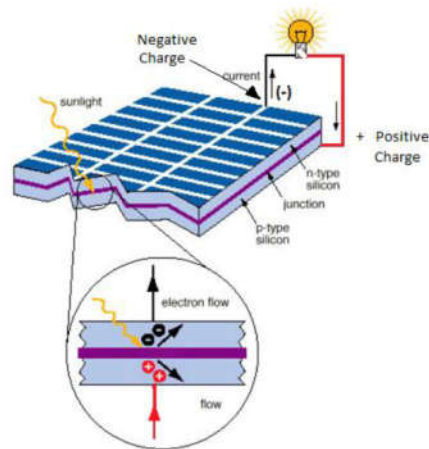
Fig1.2 Construction of PV Cell

Fig1.3 Mono crystalline silicon cell

1.2.1 Working of PV Cell

When the incident light falls on the device, the light photons of certain wavelengths are absorbed by the semiconducting material and as a result charge carriers, electrons and holes are generated. A strong electric field exists when these carriers penetrate through the junction. An electric current in the external circuit is produced when holes and electrons are separated by the electric field. This electric current, which is also called a photo current, depends on the incident photon intensity and the nature of the semiconductors that form the junction device. The basic PV circuit elements are depicted in the simple ideal equivalent circuit of Figure 1.4
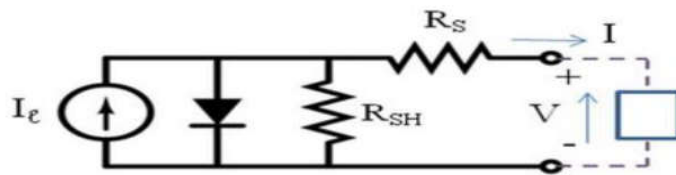
Fig1.4 Equivalent Circuit Model for a Photovoltaic Cell

A nodal current balance, with assumed current directions as shown, yields the following expression.

$$I = I_L - I_D \text{ (1.1)}$$

Where,

I = Output current

I_L = Light-generated current

I_D = Diode current or junction current

By using the Shockley equation the diode current I_d is given as

$$I = I_L - I_0 \left(e^{\frac{qv}{kt}} - 1 \right) \qquad (1.2)$$

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Where,

 I$_0$ = Saturation current of the diode

q = Elementary charge 1.6×10^{-19} Coulombs

K = Constant value

 T = Cell temperature in Kelvin

V = Measured cell voltage that is either produced or applied

$$I = I_l - I_o \left(e^{\frac{q(v+IR_S)}{\eta.k.T}} - 1 \right) - \frac{v+IR_S}{R_{sh}} \quad (1.3)$$

1.3 CHARACTERISTICS OF A PV MODULE

The current and power outputs of photovoltaic modules are approximately proportional to solar irradiation and the ambient temperature. At a given intensity, a module's output current and operating voltages are determined by the characteristics of the load. In order to determine the characteristics of the PV module, the Power vs. Voltage (P-V) and Current vs. Voltage (I-V) curves must be constructed. Three parameters, namely, Open Circuit voltage (Voc), Short circuit current (*Isc*), and Maximum Power Point (*Vmp*, *Imp*), given by the manufacturer of the PV module, are used for the prediction of the PV characteristics of solar PV module. The Typical P-V and I–V characteristics of a PV cell are shown in Figure 1.5 There is a unique Maximum Power Point (MPP) on the P–V curve, at which the PV cell generates the maximum power. This point is known as the maximum power point (Vmpp, Impp). The value of the maximum powers depends on the environmental factors, such as temperature and irradiation. The maximum power condition always occurs at the knee of the P-V characteristic curve.
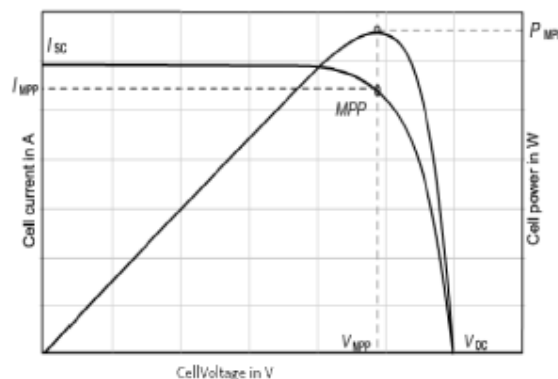
Fig1.5P-V, I-V curve of the PV cell

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1.3.1 Effect of Temperature and Irradiance
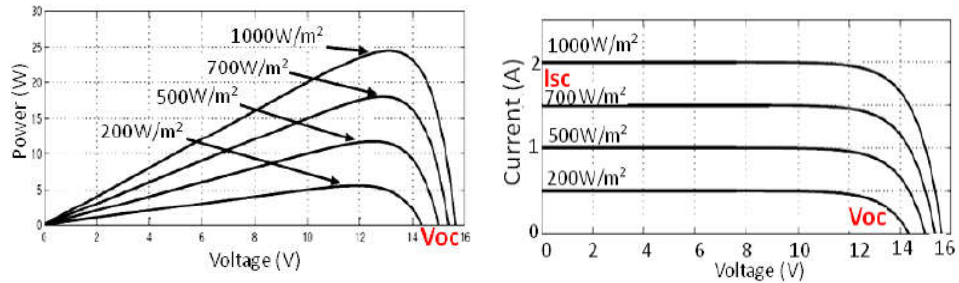
Fig1.6The P-V and I-V characteristics curve at different irradiation levels and a constant temperature (25^0 C) condition

The electric characteristics of the PV cell depend mainly on their radiance received by the cell, and the cell temperature. Figure 1.6 displays the electrical characteristics of the cell at different levels of irradiance and a constant temperature. It is clear that the change in irradiance has a strong effect on the short-circuit current (*Isc*) and output power of the cell, but negligible effect on the open-circuit voltage (*Voc*).
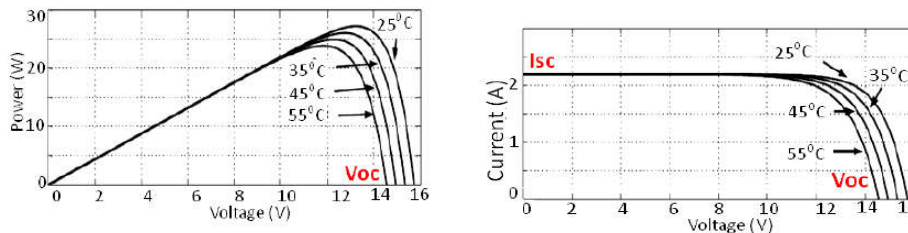
Fig 1.7 The P-V and I-V characteristics curve at different temperature Levels and a constant irradiation (1000 W/m2) condition.

On the other hand, Figure 1.7 shows that the change in temperature at a constant irradiance has a strong effect on the open-circuit voltage and output power of the cell, but negligible effect on the short-circuit current.

1.3.2 Effect of Shading
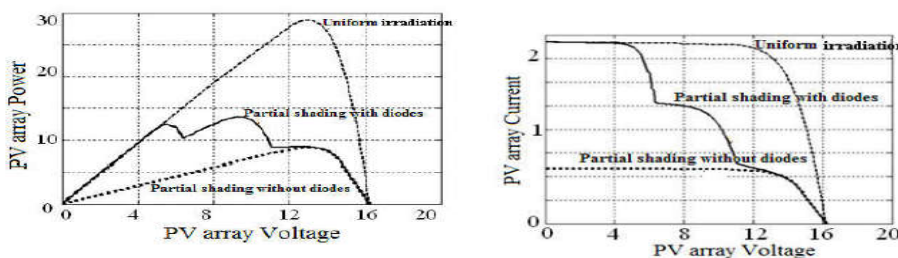
Fig 1.8 P-V, I-V curves of a PV module under various conditions.

When a part of a PV array does not receive solar irradiation due to

clouds or tree shadow, the temperature and the irradiation of the shaded modules will go down. Due to the presence of bypass and blocking diodes in the PV modules, multiple steps will be introduced in the I–V characteristics and multiple peaks in the P–V characteristics. Figure 1.8 depicts the P-V and I-V curves of a PV array with uniform irradiation and under partial shading condition, with and without the presence of bypass and blocking diodes.

1.4 MAXIMUM POWER POINT TRACKING (MPPT)

The photovoltaic (PV) cell directly converts solar energy into electricity. At a unique point on the I-V or P-V curve of a PV cell, called the Maximum Power Point (MPP), the PV system operates with the maximum efficiency and produces the maximum output power. Hence, it is essential to include a MPPT module in the PV system so that the PV arrays are able to deliver the maximum available power.

1.4.1 Conventional Control Strategies

1.4.1.1 Perturb and Observe (P&O) Method

One of the most successful and simplest methods for MPPT is the Perturb and Observe (P&O) method (Femia et al., 2004). In this approach, the controller works by perturbing the PV array output voltage and observing the effect on the output PV power. There are a number of variants of P&O algorithm which are reported in the literature. In Ying-Tung & China-Hong, (2002) the authors propose a three-point weight comparison P&O method. Here, the slope of the perturbation is decided, based on the comparison of the actual operating power with the two preceding ones. The work in Al-Amoudi & Zhang, (1998) suggests an adaptive P&O scheme, for a grid connected three-phase inverter. Initially, the perturbation is set at 10% of the open circuit voltage (VOC). Each successive perturbation is set to 50% of the preceding one, until the value of perturbation is 0.5% of the VOC. Although the method exhibits better performance, it is still not fully adaptive due to the predetermined perturbation steps. The authors in Fortunate et al, (2008) exploit the capability of the multi objective optimization technique to design the P&O based method for a single-stage inverter.

1.4.1.2 Hill climbing (HC) Method

Similar to the P&O method, Hill climbing (HC) (Weidong & Dunford, 2004) works by perturbing the PV power converter's duty cycle, and observing its impact on the PV array output power, and then deciding the new direction of the duty cycle to extract the maximum power. Even though both techniques use the same concept for optimum operating point searching, they use different ways to achieve the same method; the former uses the PV array output voltage and the latter uses the power converter duty cycle, to extract the maximum power. In the HC MPPT method, the duty cycle is changed directly without a PI controller; hence, this method is known as the direct duty cycle technique. This scheme offers a number of advantages: (1) it simplifies the tracking structure, (2) it reduces the computation time, and (3) no tuning effort is needed for the PI gains. In short, it replaces the sophisticated MPPT control with a more simplified structure while maintaining similar optimal results.

1.4.1.3 Drawbacks of P&O and HC

The major drawbacks of the P&O/HC MPPT method are, oscillations in the vicinity of the MPP, power loss, and degraded solar energy conversion efficiency. Also, the P&O approach tracks in the wrong direction under rapidly varying irradiance (Femia et al., 2004). In (Salas V et al 2005), the P&O method has been improved by using the PV panel current (IPV) as the variable for the calculation of the duty cycle (D). To overcome the disadvantages of slow convergence and oscillation around the MPP, the use of a variable perturbation size approach was proposed in (Liu and Lopes, 2004). In this approach large perturbations are applied, when the output power is far from the MPP, whereas smaller steps are adopted as the output power oscillates around the MPP. The magnitude of the variable perturbation is determined, based on the slope of the power–current curve. The determination of this slope, however, increases the complexity and cost associated with this approach.

1.4.2 Incremental Conductance Method

The idea behind the Incremental conductance method (Hohm and Ropp 2000) is to increase or decrease the reference voltage ($Vref$) value

(which is in the vicinity of the MPP voltage), based on the comparison of the instantaneous conductance with the incremental conductance. The increment size determines how fast the MPP is tracked. Fast tracking can be achieved with bigger increments, but the system might not operate exactly at the MPP and oscillate about it instead; so there is a trade-off. In (Hussein et al., 1995 & Bruendlinger et al 2006), a method is proposed that brings the operating point of the PV array close to the MPP in the first stage, and then uses the IC to exactly track the MPP in the second stage. In (Koizumi et al 2005), a linear function is used to divide the I–V plane into two areas, one containing all the possible MPPs under changing atmospheric conditions. The operating point is brought into this area, and then IC is used to reach the MPP. The main drawback associated with the IC method, is that it requires complex control circuitry

1.4.2.1 Incremental Conductance Algorithm for MPPT

The basic principle of the IC MPPT method is based on the fact that, the slope of the PV array power curve (dP_{pv}/dV_{pv}) is zero at the MPP, positive for values of the output power smaller than MPP, and negative for values of the output power greater than MPP. Eqns. 1.4 to 1.7 give the condition of the IC algorithm.

$$\frac{dP_{PV}}{dV_{PV}} = \frac{d(V_{PV} - I_{PV})}{dV_{PV}} = V_{PV} \cdot \frac{dI_{PV}}{dV_{PV}} + I_{PV} = 0 \qquad (1.4)$$

$$\frac{dP_{PV}}{dV_{PV}} > 0 \; if \; \frac{I_{PV}}{V_{PV}} > -\frac{dI_{PV}}{dV_{PV}}, \text{left of MPP} \qquad (1.5)$$

$$\frac{dP_{PV}}{dV_{PV}} = 0 \; if \; \frac{I_{PV}}{V_{PV}} = -\frac{dI_{PV}}{dV_{PV}}, \text{at MPP} \qquad (1.6)$$

$$\frac{dP_{PV}}{dV_{PV}} < 0 \; if \; \frac{I_{PV}}{V_{PV}} < -\frac{dI_{PV}}{dV_{PV}}, \text{right of MPP} \qquad (1.7)$$
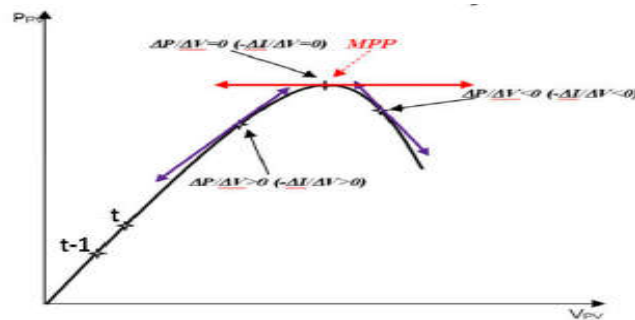
Fig 1.9 Principle of the IC algorithm

The above principle illustrated is shown in Figure 1.9. The MPP can thus be tracked, by comparing the instantaneous conductance (I_{pv}/V_{PV}) with the incremental conductance (dI_{pv}/dV_{PV}). Using the equations, the flow chart for IC algorithm is depicted in Figure 1.10.
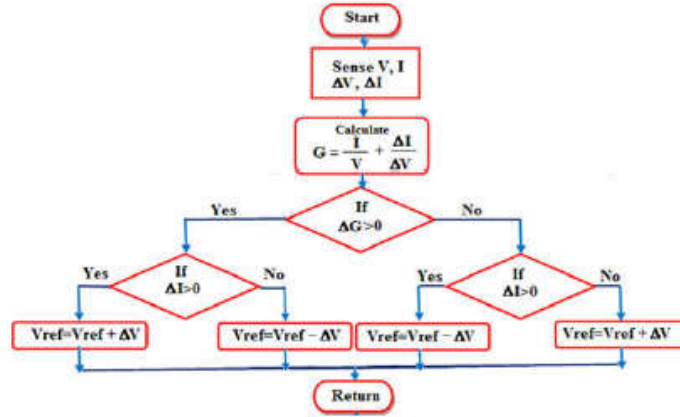
Fig 1.10 Flowchart of the IC MPPT algorithm

In this flow chart *Vref* is the reference voltage at which the PV array will be forced to operate. Initially, *Vref* is set to zero. At the MPP, *Vref* equals to *VMPP*. Once the MPP is reached, the operation of the PV array is maintained at this point unless a change in current, I, occurs as a result of a change in atmospheric conditions leading to a variation in the MPP. The algorithm, then, tracks the MPP by applying decrements or increments to *Vref*. The size of the increment or decrement determines how fast the MPP is tracked.

Under variations in the atmospheric conditions this algorithm tracks the MPP, by applying increments or decrements to *Vref*. The size of the increment or decrement value is crucial for the success of this approach. If the size is large, the algorithm finds the MPP quickly, but results in oscillations around the MPP. On the other hand, if the size is small, the oscillations around the MPP are reduced, but the rate of convergence will decrease. The maximum power point tracking (MPPT) is employed to control the input voltage and the duty cycle of the DC/DC converter in the PV system, so that the PV array delivers the maximum power. Though the IC conductance algorithm is effective in tracking the MPP without any oscillations, the algorithm may not track the MPP under rapidly varying atmospheric conditions due to its slow response.

Hence, in this work some modifications are made in the conventional

IC algorithm to speed up the MPPT process. So that it is suitable for rapidly varying atmospheric conditions, the details of which are presented in the next section.

1.4.2.2 Proposed Algorithm for MPPT

The proposed algorithm apples the principles of IC technique, with a direct duty cycle for the MPPT. The proposed method provides an optimum duty cycle to the DC-DC converter directly, without the use of a PI controller. The major drawbacks of the conventional IC MPPT method of slow convergence and the complex control circuit are eliminated by the proposed modified IC algorithm. In the modified IC algorithm, a variable step size is introduced to increase the convergence speed. To reduce its complexity the direct duty cycle is incorporated with the IC algorithm. This simplifies the tracking structure and eliminates the tuning effect needed for the PI gain.

The proposed MPPT algorithm is depicted in the flowchart shown in Figure 1.11. Initially, the values of the PV array current, voltage and power for the tth instant are measured. Next, a comparison is made between the actual conductance G(t) and the previous conductance G(t-1), to track the actual maximal power Pmax(t) and its voltage Vmax(t). If G(t) is greater than G(t-1), the actual maximum power Pmax(t) is equal to the actual power *PPV(t);* otherwise, it is equal to *PPV(t-1).* Next, the algorithm calculates the duty cycle by making a comparison, between the measured voltage Vpv(t) and the voltage at the maximum power Vmax(t). Furthermore, the step- size variation technique is used in this proposed method for duty cycle calculation. The step size is increased (about 0.1) when the slope of the P–V characteristic curve exceeds the predetermined value, e. And the step size is decreased again (about 0.01) when the slope of the P–V characteristic curve is less than the predetermined value. The step-size variation technique is applied to minimize the power loss, due to oscillations in the vicinity of the MPP, as well as to ensure a dynamic performance that is better at dealing with rapid changes in the irradiance level.
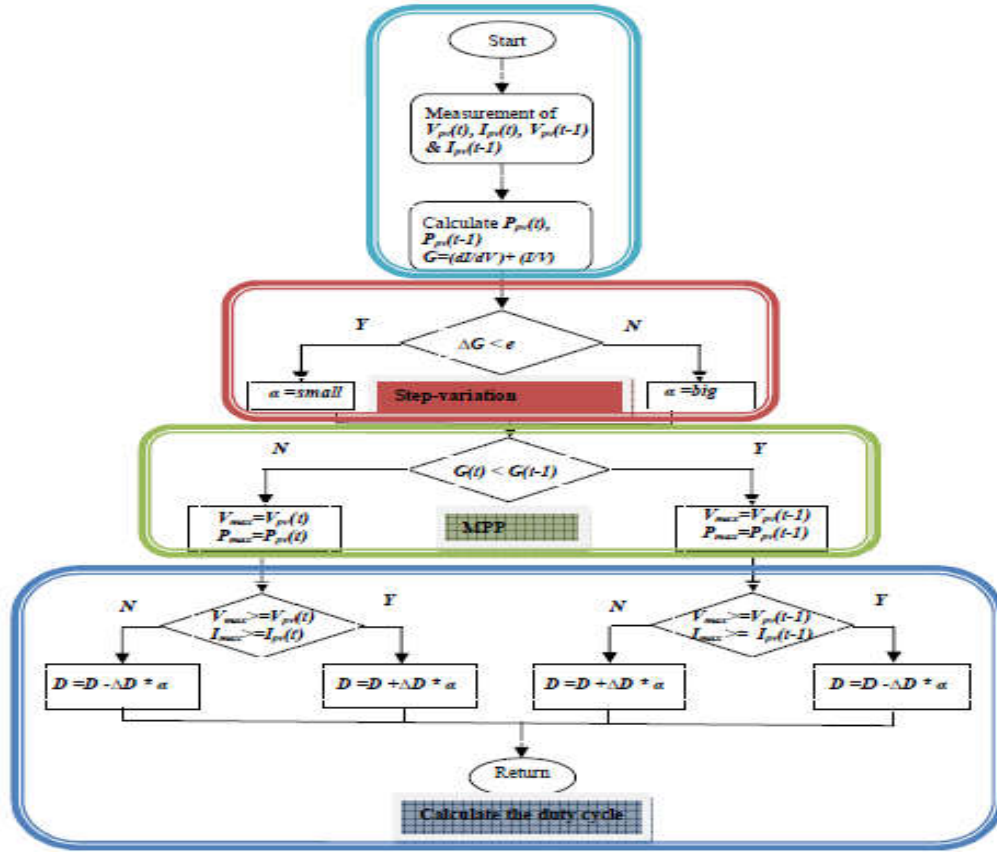
Fig 1.11Flowchart of the modified IC algorithm for rapidly varying Irradiation conditions

1.4.2.3Performance Measures

The performance of the MPPT algorithm can be measured by static and dynamic tracking efficiency; the static MPP tracking efficiency depicts the ability of the MPPT algorithm to find the MPP under uniform atmospheric conditions (i.e., solar irradiance and temperature), whereas the dynamic MPP tracking efficiency describes the ability in tracking the MPP under rapidly varying atmospheric conditions. The static MPP tracking efficiency η_{static} is defined as

$$\eta_{static} = \left(\frac{P_{out}}{P_{max}}\right) \times 100\% \qquad (1.8)$$

Where *Pout*is the averaged output power obtained under the steady state, and Pmax is the maximum available power of the PV panel under certain atmospheric conditions.

At locations where the irradiation changes rapidly due to varying atmospheric conditions, both the static and the dynamic MPP tracking efficiency have to be considered. The dynamic MPP tracking efficiency $\eta_{dynamic}$

can be defined as,

$$\eta_{dynamic} = \frac{\int_0^T V_{PV}(t) I_{PV}(t) dt}{\int_0^T P_{MAX}(t) dt} \times 100\% \qquad (1.9)$$

Where $V_{PV}(t)$ and $I_{PV}(t)$ represent the measured instantaneous voltage and current at the output of the PV panel. The $P_{MAX}(t)$ represents the available maximum power of the PV panel. T represents the time duration of the whole test sequence.

This project deals with the BLDC motor drive powered from solar photovoltaic system with HCC fed water pumping system for irrigation. BLDC motor is preferred over other brush-based motors for its unique features like high efficiency, high torque and simple structure with low noise. By using conventional control strategies torque ripples are present, by introducing Hysteresis Current Control (HCC) torque ripple can be minimized. As solar power is abundant and available at any place so the solar photovoltaic (SPV) array system is considered as the source. The modified incremental conductance maximum power point technique is used because of its advantage of providing soft starting to BLDC motor. The proposed system has been designed, modeled and simulated in MATLAB/Simulink environment.

KEYWORDS: BLDC motor, Solar photovoltaic (SPV) system, Hysteresis Current Control (HCC), Modified Incremental conductance MPPT technique, DC-DC converter.

CHAPTER-2
DC-DC CONVERTERS

2.1 INTRODUCTION

DC/DC converters/regulators form the Backbone of different portable electronic devices like cellular phones, laptops, MP3 players which are using batteries as their power supply. Portable devices usually comprise of several sub-circuits that should be supplied with different voltage levels, which are not the same as battery's voltage level which is the main supply voltage.

Employing DC/DC converters can be offered as a method to generate multiple voltage levels from a single DC supply voltage to feed the different sub-circuits in the device. This method of generating multiple voltage levels from a single battery source can reduce the device area substantially. On the other hand DC voltage provided by battery or rectifier contains high voltage ripples and it is not constant enough, thus it is not applicable for most devices. DC/DC regulators are employed to attenuate the ripples regardless of change in the load current or input voltage.

A large number of dc-dc converter circuits are known that can increase or decrease the magnitude of the dc voltage and/or invert its polarity. Figure 2.1 illustrates several commonly used dc converter circuits, along with their respective conversion ratios. In each example, the switch is realized using a power MOSFET and diode; however, other semiconductor switches such as IGBTs, BJTs, or thyristors can be substituted if desired. The first converter is the buck converter, which reduces the dc voltage and has conversion ratio $M(D) = D$.

In a similar topology known as the boost converter, the positions of the switch and inductor are interchanged. This converter produces an output voltage V that is greater in magnitude than the input voltage Vg. Its conversion ratio is $M(D) = 1/(1 - D)$.

In the buck-boost converter, the switch alternately connects the inductor across the power input and output voltages. This converter inverts the polarity of the voltage, and can either increase or decrease the voltage magnitude. The conversion ratio is $M(D) = - D/(1 - D)$.

The Cuk converter contains inductors in series with the converter

input and output ports. The switch network alternately connects a capacitor to the input and output inductors. The conversion ratio $M(D)$ is identical to that of the buck-boost converter. Hence, this converter also inverts the voltage polarity, while either increasing or decreasing the voltage magnitude.

The single-ended primary inductance converter (SEPIC) can also either increase or decrease the voltage magnitude. However, it does not invert the polarity.

The conversion ratio is $M(D) = D/(1 - D)$.
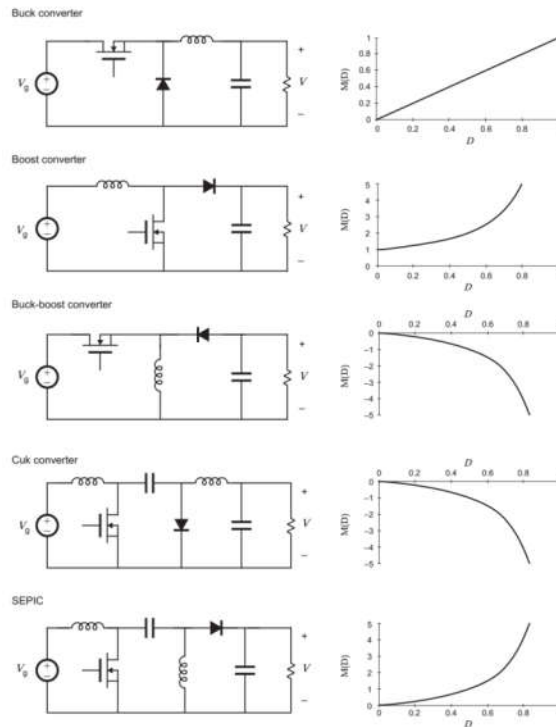
Fig 2.1 Several Basic DC-DC Converters and their DC Conversion Ratios $M(D) = V/V_g$.

2.2 BUCK CONVERTER

The buck converter is used to step an input voltage down from a higher potential to a lower potential. The input and output power ideally remains the same. The circuit usually consists of an inductor to store energy and a switch to control the power flow.

2.2.1Operating Principle
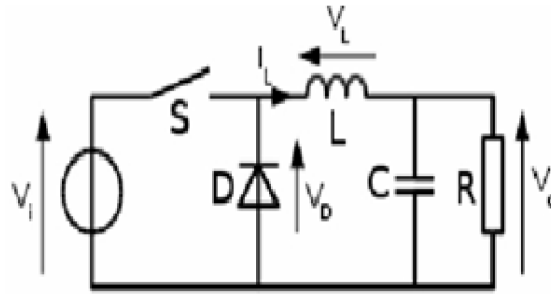
Fig. 2.2 Buck Converter

The circuit has two stages of operation

2.2.1 (A) ON State

When the switch is on the diode is open and the inductor and the load side is connected to the input and the inductor stores energy.
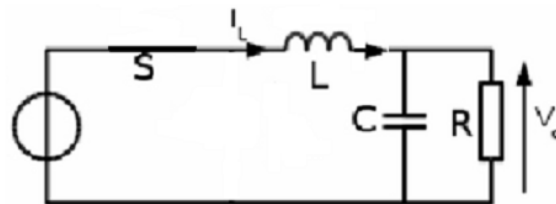
Fig. 2.3 ON State Equivalent Circuit of Buck Converter

2.2.1 (B) OFF State

The switch opens to isolate the source from the rest of the circuit, the diode becomes positive biased as the inductor changes polarity and the inductor discharges to provide energy to the load.
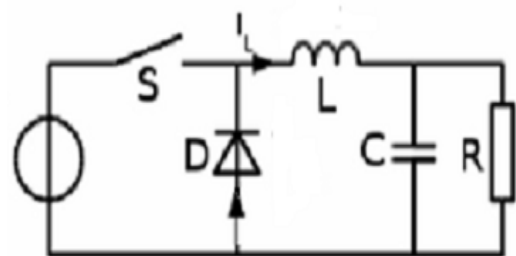
Fig. 2.4 OFF State Equivalent Circuit of Buck Converter

2.2.2 Continuous Mode
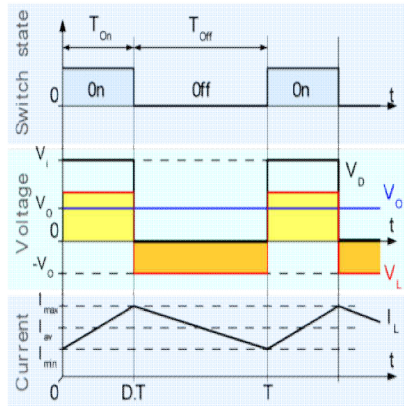
Fig. 2.5 Wave Forms of Buck Converter during Continuous Mode

2.2.3 Discontinuous Mode
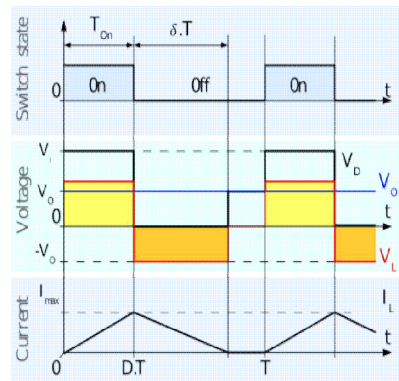
Fig. 2.6 Wave Forms of Buck Converter during Discontinuous Mode

2.3 BOOST CONVERTER

A boost converter (step-up converter) is a DC-to-DC power converter with an output voltage greater than its input voltage. It is a class of switched- mode power supply (SMPS) containing at least two semiconductor switches (a diode and a transistor) and at least one energy storage element, a capacitor, inductor, or the two in combination. Filters made of capacitors (sometimes in combination with inductors) are normally added to the output of the converter to reduce output voltage ripple.
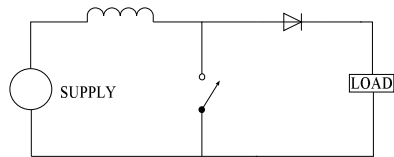
Fig: 2.7.The Basic Schematic of A Boost Converter

2.3.1 Overview

Power for the boost converter can come from any suitable DC sources, such as batteries, solar panels, rectifiers and DC generators. A process that changes one DC voltage to a different DC voltage is called DC to DC conversion. A boost converter is a DC-to-DC converter with an output voltage greater than the source voltage. A boost converter is sometimes called a step-up converter since it "steps up" the source voltage. Since power (P=VI) must be conversed, the output current is lower than the source current.

2.3.2 History

For high efficiency, the SMPS switch must turn on and off quickly and have low losses. The advent of a commercial semiconductor switch in the 1950s represented a major milestone that made SMPSs such as the boost converter possible. The major DC to DC converters were developed in the early 1960s when semiconductor switches had become available. The aero scope industry's need for small, lightweight, and efficient power converters led to the converter's rapid development.

Switched systems such as SMPS are a challenge to design since its model depends on whether a switch is opened or closed. R. D. Middle brook from Caltech in 1977 published the models for DC to DC converters used today. Middle brook averaged the circuit configurations for each switch state in a technique called state-space averaging. This simplification reduced two systems into one. The new model led to insightful design equations which helped SMPS growth.

2.3.3 Applications

Battery powered systems often stack cells in series to achieve higher voltage. However, sufficient stacking of cells is not possible in many high voltage applications due to lack of space. Boost converters can increase the

voltage and reduce the number of cells. Two battery-powered applications that use boost converters are hybrid electric vehicles (HEV) and lighting systems.

A boost converter is used as the voltage increase mechanism in the circuit known as the 'Joule thief'. This circuit topology is used with low power battery applications, and is aimed at the ability of a boost converter to 'steal' the remaining energy in a battery. This energy would otherwise be wasted since the low voltage of a nearly depleted battery makes it unusable for a normal load. This energy would otherwise remain untapped because many applications do not allow enough current to flow through a load when voltage decreases. This voltage decrease occurs as batteries become depleted, and is a characteristic of the ubiquitous alkaline battery. Since $(P = V^2/R)$ as well, and R tends to be stable, power available to the load goes down significantly as voltage decreases.

2.3.4 Operating principle

The key principle that drives the boost converter is the tendency of an inductor to resist changes in current. In a boost converter, the output voltage is always higher than the input voltage. A schematic of a boost power stage is shown in Figure 2.7. When the switch is closed, current flows through the inductor, which stores energy from the current in a magnetic field. During this time, the switch acts like a short circuit in parallel with the diode and the load, so no current flows to the right hand side of the circuit. When the switch is opened, the short circuit is removed and the load is back in play in the circuit. This represents a sudden increase in the impedance of the circuit, which, by Ohm's law will demand either a decrease in current, or an increase in voltage. The inductor will tend to resist such a sudden change in the current, which it does by acting as a voltage source in series with the input source, thus increasing the total voltage seen by the right hand side of the circuit and thereby preserving (for a brief moment) the current level that was seen when the switch was closed. This is done using the energy stored by the inductor. Over time, the energy stored in the inductor will discharge into the right hand side of the circuit, bringing the net voltage back down.

If the switch is cycled fast enough, the inductor will not discharge fully in between charging stages, and the load will always see a voltage greater than that of the input source alone when the switch is opened. Also while the switch is opened, the capacitor in parallel with the load is charged to this combined voltage. When the switch is then closed and the right hand side is shorted out from the left hand side, the capacitor is therefore able to provide the voltage and energy to the load. During this time, the blocking diode prevents the capacitor from discharging through the switch. The switch must of course be opened again fast enough to prevent the capacitor from discharging too much.

The basic principle of a Boost converter consists of 2 distinct states (see figure 2.8):

•   In the On-state, the switch S (see figure 2.9) is closed, resulting in an increase in the inductor current.

•   In the Off-state, the switch is open and the only path offered to inductor current is through the fly back diode D, the capacitor C and the load R. This result in transferring the energy accumulated during the On-state into the capacitor.

•   The input current is the same as the inductor current as can be seen in figure 2.9.So it is not discontinuous as in the buck converter and the requirements on the input filter are relaxed compared to a buck converter
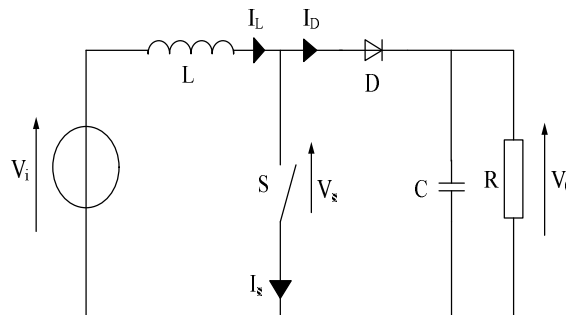
Fig 2.8 Overall Diagram of Boost Converter
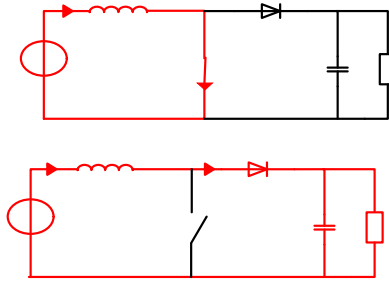
Fig 2.9 The Two Configuration of Boost Converter, Depending on The State of The Switch S

2.3.5 Continuous Mode

When a boost converter operates in continuous mode, the current through the inductor (I_L) never falls to zero. Figure 2.10 shows the typical waveforms of currents and voltages in a converter operating in this mode. The output voltage can be calculated as follows in the case of an ideal converter (i.e. using components with an ideal behavior) operating in steady conditions.
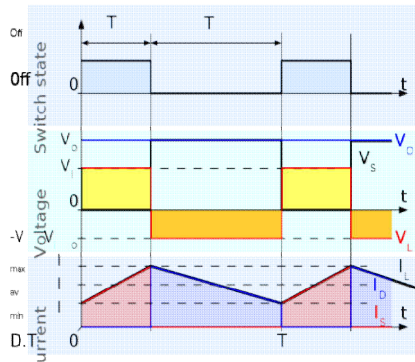
Fig. 2.10 Waveforms of Current and Voltage in a Boost Converter Operating in Continuous Mode

During the On-state, the switch S is closed, which makes the input voltage (V_i) appear across the inductor, which causes a change in current (I_L) flowing through the inductor during a time period (t) by the formula:

$$\frac{\Delta I_L}{\Delta t} = \frac{V_i}{L} \tag{2.1}$$

At the end of the On-state, the increase of I_L is therefore:

$$\Delta I_{Lon} = \frac{1}{L} \int_0^{DT} V_i dt = \frac{DT}{L} V_i \tag{2.2}$$

21

D is the duty cycle. It represents the fraction of the commutation period T during which the switch is ON. Therefore D ranges between 0 (S is never on) and 1 (S is always on).

During the Off-state, the switch S is open, so the inductor current flows through the load. If we consider zero voltage drop in the diode, and a capacitor large enough for its voltage to remain constant, the evolution of I_L is:

$$V_i - V_0 = L\frac{dI_L}{dt} \tag{2.3}$$

Therefore, the variation of I_L during the Off-period is:

$$\Delta I_{Loff} = \int_{DT}^{T} \frac{(V_i - V_0)dt}{L} = \frac{(V_i - V_0)(1-D)T}{L} \tag{2.4}$$

As we consider that the converter operates in steady-state conditions, the amount of energy stored in each of its components has to be the same at the beginning and at the end of a commutation cycle. In particular, the energy stored in the inductor is given by:

$$E = \frac{1}{2}LI_L^2 \tag{2.5}$$

So, the inductor current has to be the same at the start and end of the commutation cycle. This means the overall change in the current (the sum of the changes) is zero:

$$\Delta I_{Lon} + \Delta I_{Loff} = 0 \tag{2.6}$$

Substituting ΔI_{LON} and ΔI_{LOFF} by their expressions yields:

$$\Delta I_{Lon} + \Delta I_{Loff} = \frac{V_i DT}{L} + \frac{(V_i - V_0)(1-D)T}{L} = 0 \tag{2.7}$$

This can be written as:

$$\frac{V_0}{V_i} = \frac{1}{1-D} \tag{2.8}$$

This in turn reveals the duty cycle to be:

$$D = 1 - \frac{V_i}{V_0} \tag{2.9}$$

The above expression shows that the output voltage is always higher than the input voltage (as the duty cycle goes from 0 to 1), and that it increases with D, theoretically to infinity as D approaches 1. This is why this converter is sometimes referred to as a step-up converter.

2.3.6 Discontinuous mode
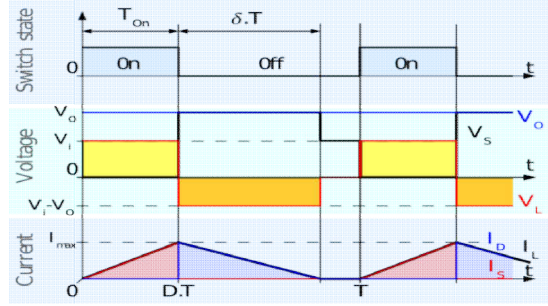
Fig.2.11Waveforms of Current and Voltage in a Boost Converter Operating in Discontinuous Mode

If the ripple amplitude of the current is too high, the inductor may be completely discharged before the end of a whole commutation cycle. This commonly occurs under light loads. In this case, the current through the inductor falls to zero during part of the period (see waveforms in figure 2.11). Although slight, the difference has a strong effect on the output voltage equation. It can be calculated as follows:

As the inductor current at the beginning of the cycle is zero, its maximum value I_{LMax} (at t=DT) is

$$I_{LMax} = \frac{V_i DT}{L} \tag{2.10}$$

During the off-period, I_L falls to zero after δT:

$$I_{LMax} + \frac{(V_i - V_0)\delta T}{L} = 0 \tag{2.11}$$

Using the two previous equations, δ is:

$$\delta = \frac{V_i D}{V_0 - V_i} \tag{2.12}$$

The load current I_o is equal to the average diode current (I_D). As can be seen on figure 2.9, the diode current is equal to the inductor current during the off-state. Therefore the output current can be written as:

$$I_0 = I_D = \frac{I_{LMax}}{2}\delta \tag{2.13}$$

Replacing I_{Lmax} and δ by their respective expressions yields:

$$I_0 = \frac{V_i DT}{2L} \cdot \frac{V_i D}{V_0 - V_i} = \frac{V_i^2 D^2 T}{2L(V_0 - V_i)} \tag{2.14}$$

Therefore, the output voltage gain can be written as follows:

$$\frac{V_0}{V_i} = 1 + \frac{V_i D^2 T}{2L I_0} \tag{2.15}$$

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Compared to the expression of the output voltage for the continuous mode, this expression is much more complicated. Furthermore, in discontinuous operation, the output voltage gain not only depends on the duty cycle, but also on the inductor value, the input voltage, the switching frequency, and the output current.

2.4 BUCK-BOOST CONVERTER

The buck-boost is a DC-DC converter that can be regulated to give an output voltage that is higher or lower than the input voltage. During normal operation of the buck-boost power stage, the switch is repeatedly turned on and off. This switching action gives rise to a train of pulses at the junction of the switch, diode and the inductor. Although the inductor L is connected to the output capacitor C only when the diode conducts, an effective L/C output filter is formed. It filters the train of pulses to produce a DC output voltage. There are two different topologies of the concept.

The output is in the reverse polarity of the input and can be regulated to be higher or lower than the input. Such a non-inverting buck boost converter may use a single inductor that is used as both the buck inductor and the boost inductor. The output is negative in polarity. The duty cycle again determines the output voltage. For duty cycle less than 0.5 the circuit acts as a boost converter.
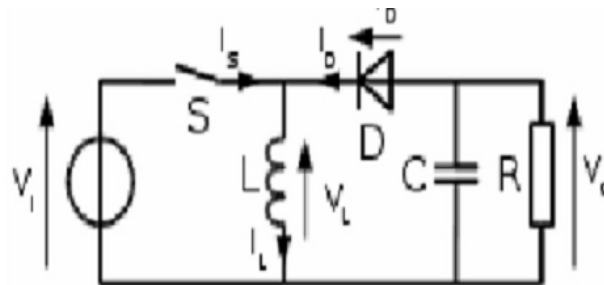
Fig. 2.12 Buck-Boost Converter

2.4.1 Operating Principle

As the inverted topology is more common to all we emphasize on the inverted topology. The operating principles are as follows:
There are two stages in which the circuit works

2.4.1 (A) ON State

When the switch is on the input and the inductor are isolated from the load side and the inductor is charged. The load receives energy from the capacitor that it accumulates during the off state.
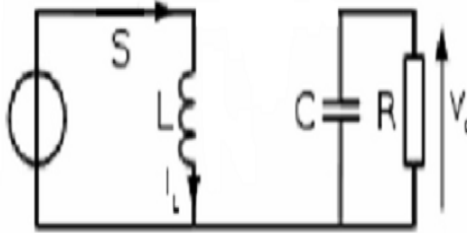
Fig. 2.13ONStage equivalent circuit of Buck-Boost converter

2.4.1 (B) OFF State

The input is isolated from the whole system and the inductor supplies energy to the output filter capacitor and the load resistor.
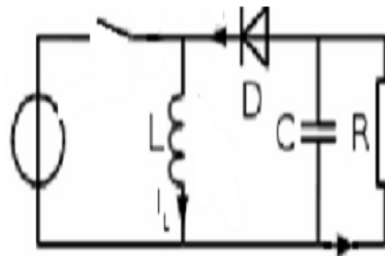
Fig. 2.14OFF Stage equivalent circuit of Buck-Boost converter

2.4.2 Continuous Mode

When a buck-boost converter operates in continuous mode, the current through the inductor (I_L) never falls to zero. Figure 2.15 shows the typical waveforms of currents and voltages in a converter operating in this mode.
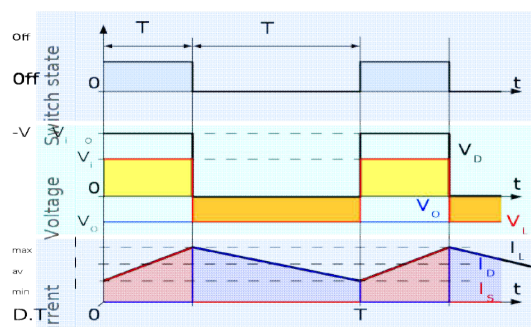
Fig.2.15 Wave Forms of Buck –Boost Converter during Continuous Mode

2.4.3 Discontinuous Mode

If the ripple amplitude of the current is too high, the inductor may be completely discharged before the end of a whole commutation cycle. This commonly occurs under light loads. In this case, the current through the inductor falls to zero during part of the period.Figure 2.16 shows the typical waveforms of currents and voltages in a converter operating in this mode.
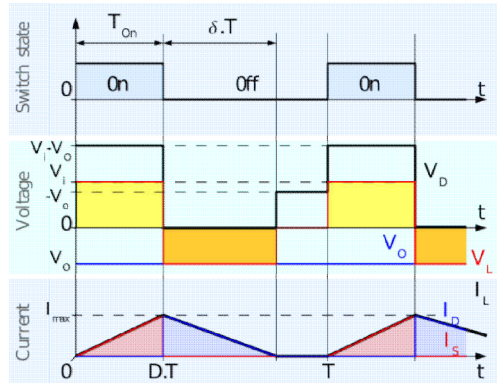
Fig.2.16 Wave Forms of Buck-Boost Converter during Discontinuous Mode

CHAPTER-3
BRUSHESS DC MOTOR

3.1 INTRODUCTION

Brushless DC (BLDC) motors are widely used in many industrial, aerospace applications and domestic appliances due to their high efficiency, excellent control accuracy and high torque to weight ratio. BLDC motor is a synchronous motor with permanent magnets on the rotor and armature windings on the stator. It is like a DC motor turned inside out, so that the field is on the rotor and the armature is on the stator.

The Brushless DC motor is basically a permanent magnet AC motor whose torque-current characteristics are similar to the DC motor. Instead of commutating the armature current using brushes and mechanical commutator, the electronic commutation system is used. Because of their brushless nature, the problems associated with the brush and the commutator arrangement like sparking and wearing out of the commutator-brush arrangement are eliminated. Due to the simplified structure, BLDC motors are more rugged than a DC motor and suitable for industrial environment. Having the armature on the stator makes the cooling of windings easy.

The winding of BLDC motor is much easier as compared to a conventional DC motor and Induction motor. Moreover it is very much possible to control the speed and the angle of motion of the rotor or both very precisely and accurately. Further, BLDC motor is compatible with the digital control systems and the motor characteristics can be controlled by digital systems.

3.2 CONSTRUCTION OF BLDC MOTOR

A BLDC motor is a permanent magnet brushless DC motor that uses position detectors and an inverter to control the armature currents. The BLDC motor is sometimes referred to as inside out DC motor because its armature is in the stator and the magnets are on the rotor and its operating characteristics resemble those of a DC motor. Instead of using mechanical commutator as in the conventional DC motor, the BLDC motor employs

electronic commutation which makes it a virtually maintenance-free motor.

There are two main types of BLDC motor: trapezoidal type and sinusoidal type. In the trapezoidal motor the back EMF induced in the stator windings has a trapezoidal shape and its phases must be supplied with quasi-square currents for ripple-free torque operation. The sinusoidal motor on the other hand has a sinusoidal shaped back EMF and requires sinusoidal phase currents for ripple-free torque operation. The shape of the back EMF is determined by the shape of the rotor magnets and the stator winding distribution.

The sinusoidal motor needs a high resolution position sensor because the rotor position must be known at every time instant for optimal operation. It also requires more complex software and hardware. The trapezoidal motor is a BLDC motor attractive alternative for most applications due to its simplicity, lower price and higher efficiency.

It has usually 4 magnets around the perimeter. The stator of the motor is composed by the electromagnets, usually 4 of them, placed in a cross pattern with 90^0 angle between them. The major advantage of the brushless motors is that, due to the fact that the rotor carries only the permanent magnets, it needs of no power at all. No connection needs to be done with the rotor, thus, no brush-commutator pair needs to be made: This feature gives the brushless motor great increment in reliability, as the brushes wear off very fast.
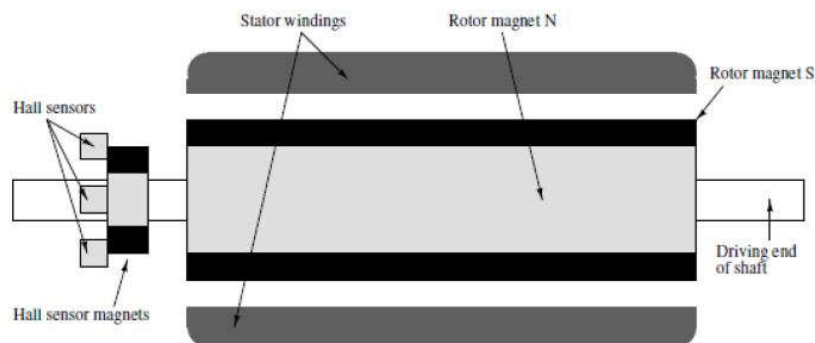
Fig 3.1 Construction of BLDC motor

BLDC motors exist in many different configurations but the three phase motor is the most common type due to its efficiency and low torque

ripple. This type of motor also offers a good compromise between precise and number of power electronic devices needed to control the stator currents. Fig 3.1 shows the construction of BLDC motor. Position detection is usually implemented using three Hall Effect sensors that detect the presence of small magnets that are attached to the motor shaft.

3.2.1 Permanent Magnets

Materials that retain magnetism are known as hard magnet materials. Various materials, such as Alnico-5, ferrites, samarium-cobalt and neodymium-iron are available as permanent magnets for use in machines. Based on the required magnetic field density in the rotor, the proper magnetic material is chosen to make the rotor. Ferrite magnets are traditionally used to make permanent magnets. As the technology advances, rare earth alloy magnets are gaining popularity. The ferrite magnets are less expensive but they have the disadvantages of low flux density for a given volume.

Rare earth magnets include Neodymium (Nd) – Iron (Fe) – Boron (B) types and Samarium (Sm) – Cobalt (Co) classes. The most commonly produced material is neodymium-iron-boron (NdFeB). This group of magnetic material provides the highest available magnetic energies of any material. NdFeB magnets allow small shapes and sizes with high magnetic fields. Super strength rare earth magnet sintered NdFeB magnets, have the characteristics of: Extreme strong Br resident induction, excellent demagnetization resistance capability, good price relative to its high magnetic properties, coating is needed for NdFeB. Both NdFeB and Sm, Co are available in sintered as well as bonded forms.

The cheapest permanent magnets are usually made from ferrite (have low coercive strength), whereas the more expensive and rare-earth type stronger ones contain Samarium-Cobalt or Neodium-Iron-Boron. Because the rare earth type magnets have a higher coercive strength, they usually withstand the demagnetization effects better than the ferrite magnets, and hence are usually preferred. The magnets are made into desired shapes, put in an appropriate jaw and then magnetized by a pulse of high current obtained from a capacitor bank. At low power ratings, especially the

fractional horsepower range, permanent magnet motors are economical. As the rating of the motor increases, the cost of permanent magnets and their manufacture becomes costlier relative to the motors in which the field is generated by applying an external source.

The smaller of the permanent magnet motors, usually in the fractional horsepower range may have less than three phases. Motors with large ratings may contain more than three phases so as to distribute the power over more inverter legs, thus permitting the use of power semiconductor switches with smaller ratings.

3.2.2 Sensing unit

i. Speed Sensing

ii. Current Sensing

Speed sensing is required for implementation of closed loop speed control schemes. Speed is usually sensed by using tachometers. When very high speed accuracies required, as in computer peripherals and paper mills etc., digital tachometers are used.

Two commonly used methods of sensing the current (i) Use of current sensor employing Hall Effect. (ii) It involves the use of a non – inductive resistance shunt in conjunction with an isolation amplifier which has an arrangement for an amplification and isolation between power and control circuits.

3.2.3 Hall Sensor

For the estimation of the rotor position, the motor is equipped with three hall sensors. These hall sensors are placed every 120^0. With these sensors, 6 different commutations are possible. Phase commutation depends on hall sensor values. Power supply to the coils changes when hall sensor values change. With right synchronized commutations, the torque remains nearly constant and high. Fig 3.2 shows the hall sensor signals for the clockwise rotation.
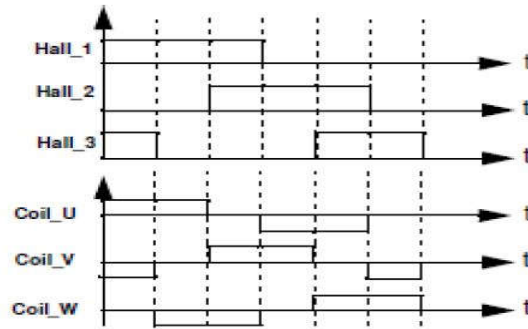
Fig 3.2 Hall Sensor signals for CW rotation

Fig 3.3 Hall Sensor

Fig 3.3 shows the Hall Sensor image. The Hall sensor is this little component under the right electromagnet. When it senses the South Pole, it keeps the coils turned off. When it senses no magnetic field (or could be also the South Pole), then it turns on the coils. The coils have both the same magnetic polarity which is north. So they pull the opposite pole and torque is then created. If you put a probe to the Hall sensor and watch the signal, then you will discover that during a full rotation of the rotor, the Hall sensor is two times HIGH and two times LOW. Fig 3.4 shows the back EMF, Current waveforms and Hall position sensors for a BLDC motor drive. Motor commutation is usually related to Hall Effect sensor outputs.

All of the electrical motors that do not require an electrical connection (made with brushes) between stationary and rotating parts can be considered as brushless permanent magnet (PM) machines, which can be categorized based on the PMs mounting and the back EMF shape. The PMs can be surface mounted on the rotor (SMPM) or installed inside of the rotor (IPM), and the back EMF shape, PMAC synchronous motors (PMAC   or

PMSM) have sinusoidal back EMF and Brushless DC motor (BLDC or BPM) have trapezoidal back EMF. A PMAC motor is typically excited by a three-phase sinusoidal current, and a BLDC motor is usually powered by a set of currents having a quasi-square waveform.
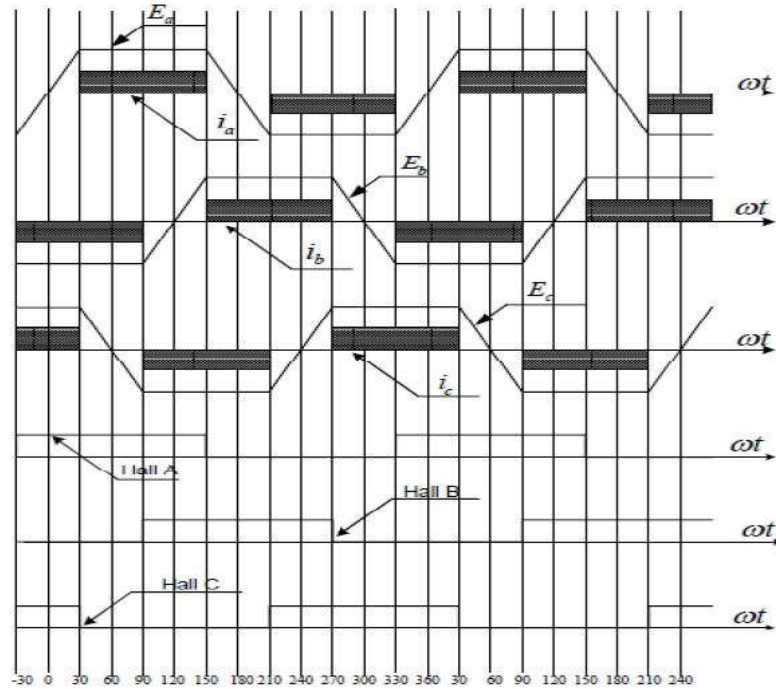
Fig 3.4 Back EMF, Current Waveforms and Hall Position Sensors for A BLDC Motor Drive

However, the BLDC motors are inherently electronically controlled and require rotor position information for proper commutation of currents in its stator windings. It is not desirable to use the position sensors for applications where reliability is of utmost importance because a sensor failure may cause instability in the control system. These limitations of using position sensors combined with the availability of powerful and economical microprocessors have spurred the development of sensor less control technology.

In recent years PWM techniques were effectively introduced to improve the performance of nonlinear systems. The application of PWM is very promising in system identification and control due to learning ability, massive parallelism, fast adaptation, inherent approximation capability, and high degree of tolerance. A single phase uniform PWM DC-DC converter with only one switching device able to produce a controllable DC voltage ranging

from zero to more than the maximum value of input dc voltage has been used for armature voltage control method of a BLDC motor.

3.2.4 Phase Commutation

To simplify the explanation of how to operate a three phase BLDC motor, a typical BLDC motor with only three coils is considered. As previously shown, phases commutation depends on the Hall sensor values. When motor coils are correctly supplied, a magnetic field is created and the rotor moves. The most elementary commutation driving method used for BLDC motors is an ON & OFF scheme: a coil is either conducting or not conducting. Only two windings are supplied at the same time and the third winding is floating. Connecting the coils to the power and neutral bus induces the current flow. This is referred to as trapezoidal commutation or block commutation. Fig 3.5 shows the power circuit diagram for BLDC motor.
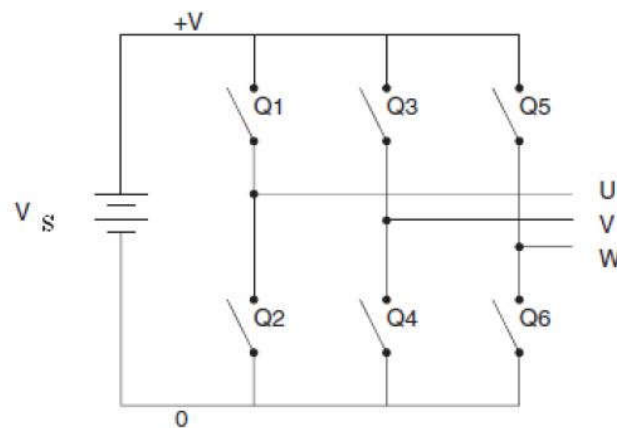
Fig 3.5 Power Circuit Diagram

For motors with multiple poles the electrical rotation does not correspond to a mechanical rotation. A four pole BLDC motor uses four electrical rotation cycles to one mechanical rotation. The strengthof the magnetic field determines the force and speed of the motor. By varying the current flow through the coils, the speed and torque of the motor can be adjusted. The most common way to control the current flow is to control the average current flow through the coils. PWM (Pulse Width Modulation) is used to adjust the average voltage and thereby the average current, inducing the speed. For example, the PWM frequency selected is the range from 10

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KHz to 200 KHz according to the application (commutation losses) of audible frequency.

3.3 CLASSIFICATION OF BLDC MOTORS

Permanent magnet brushless motors can be divided into two subcategories. The first category uses continues rotor-position feedback for supplying sinusoidal voltages and currents to the motor. The ideal motional EMF is sinusoidal, so that the interaction with sinusoidal currents produces constant torque with very low torque ripple. This called a Permanent Magnet Synchronous Motors (PMSM) drives, and is also called a PM AC drive, brushless AC drive, PM sinusoidal fed drive. The second category of Permanent Magnet motor drives is known as brushless DC (BLDC) motor drive and it is also called a trapezoidal brushless DC drive, or rectangular fed drive. It is supplied by three-phase rectangular current locks of 120^0 duration, in which the total ideal motional EMF is trapezoidal, with the constant part of the waveform timed to coincide with the intervals of constant phase current. These machines need rotor-position information only at the commutation points, e,g. every 60^0 electrical in three-phase motors.

The PMBLDC motor has its losses mainly in the stator due to its construction; hence the heat can easily be dissipated into the atmosphere. As the back EMF is directly proportional to the motor speed and the developed torque is almost directly proportional to the phase current, the torque can be maintained constant by a stable stator current in a PMBLDC motor. The average torque produced is high with fewer ripples in PMBLDC motors as compared to PMSM. Amongst two types of Permanent magnet Brushless motors, PMSM is, therefore, preferred for applications where accuracy is desired e.g. robotics, numerical controlled machines etc. However, the PMBLDC motor can be used in general and low cost automotive and industrial applications. These motors are preferred for numerous applications, due to their features of high efficiency, silent operation, compact in size and low maintenance.

3.4 BRUSHLESS VERSUS BRUSHED DC MOTORS

Brushed DC meters have been in commercial use since 1886. Brushless motors on the other hand did not become commercially viable until 1962. Brushless motors develop a maximum torque when stationary, linearly decreasing as velocity increases. Some limitations of brushed motors can be overcome by brushless motors; they include higher efficiency and a lower susceptibility of the commutator assembly to mechanical wear. These benefits come at the cost of potentially less rugged, more complex, and more expensive control electronics.

A typical brushless motor has permanent magnets which rotate and a fixed armature, eliminating problems associated with connecting current to the moving armature. An electronic controller replaces the brush/commutator assembly of the brushed DC motor, which continually switches the phase to the windings to keep the motor turning. The controller performs similar timed power distribution by using a solid-state circuit rather than the brush/commutator system.

The maximum power that can be applied to a brushless motor is limited almost exclusively by heat; too much of which weakens the magnets, and may damage the winding's insulation. A brushless motor's main disadvantage is higher cost, which arises from two issues. First, brushless motors require complex electronic speed controllers (ESCs) to run. Brushed DC motors can be regulated by a comparatively simple controller, such as a rheostat (variable rheostat). However, this reduces efficiency because power is wasted in the rheostat. Second, some practical uses have not been well developed in the commercial sector. For example, in the radio control (RC) hobby arena, brushless motors are often hand-wound while brushed motors are usually machine-wound.

Brushless motors are more efficient at converting electricity into mechanical power than brushed motors. This improvement is largely due to motor's velocity being determined by the frequency at which the electricity is switched, not the voltage. Additional gains are due to the absence of brushes, alleviating loss due to friction. The enhanced efficiency is greatest in the no-load and low-load region of the motor's performance curve. Under high mechanical loads, brushless motors and high-quality brushed motors

are comparable in efficiency.

Environments and requirements in which manufactures use brushless-type DC motors include maintenance-free operation, high speeds, and operation where sparking is hazardous (i.e. explosive environments), or could affect electronically sensitive equipment. Brushless motor commutation can be implemented in software using a microcontroller or computer, or may alternatively be implemented in analogue hardware or digital firmware using a PSIM.

3.5 SIMPLIFIED MODEL OF A BLDC MOTOR

A simplified model of a BLDC motor consists of three coils arranged in three directions A,B and C as shown in Fig 3.6. A permanent magnet forms the rotor. Here the rotor is outlined as a bar magnet with its rotary axis at the intersection of three axis A, B, C perpendicular to the plane of these axis. The orientation position of the permanent magnet can be controlled by driving a configuration of currents through the three coils. The bar magnet comes to the opposite orientation when a current is driven from B to C. For a BLDC motor that is equipped with Hall sensors these give the actual rotor position.
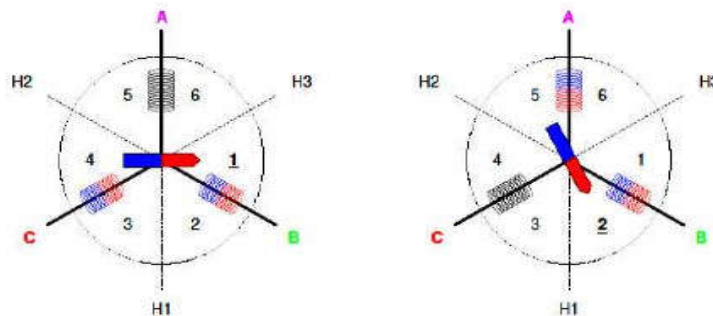
Fig 3.6 Simplified Model of a Two-Pole BLDC Motor

The motion of the rotor induces alternating voltages called Back Electromotive Force (BEMF) is proportional to the angular velocity of the rotor. Hall sensors are mounted in such a way that the zero crossing of the Hall sensor signal associated with the corresponding coil. H1 is associated with A, H2 is associated with B, H3 is associated with C. Alternatively, the connections A, B & C of BLDC motors are also labeled as U, V, W respectively. The BEMF can be modeled as a voltage source in series with

each coil that has voltage amplitude is proportional to the speed of the rotor. The BEMF voltage varies with the angle between the coil axis and the angle of the rotor, Following the shape of the BEMF is assumed to be sine wave, Alternatively, the shape can be triangular or trapezoidal or somewhat between these shapes.

3.6 ELECTRONIC COMMUTATION

The polarities of two coil currents with one coil left unconnected define six different positions of rotor. Switching the currents in a way that the currents pull the rotor to the position lets the rotor turn. Each position of the rotor is associated with a configuration of coil currents by a successive switching scheme configuration that pulls the rotor to its next position. The coil currents are driven by three voltage sources.
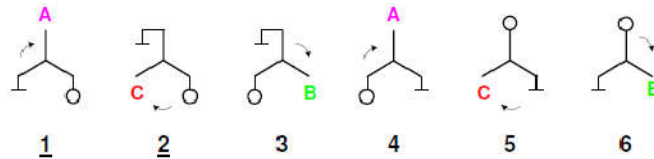
Fig 3.7 Outline of Electronic Commutation Scheme

The voltage sources are realized with fast switches (power MOSFETs) that are PWM controlled for adjustment of elective voltage. The block commutation scheme is outlined by Fig 3.7 for each commutation step there is one terminal connected to ground (ground symbol), one terminal is connected to the power supply (circle), and one terminal is left open (terminal name A, B, C). Permanent connection to ground and power supply drives the maximum speed that is possible for a given motor with a given supply voltage.

For the block commutation, each sector of the rotor is mapped to the successive sector concerning current switching. So, the commutation via interrupts become simple if each charge of a Hall sensor signal forces an interrupt. Then, the actual triple of Hall sensor signals defines the commutation sector. In other words, the block commutation can be described as a periodic sequence of 0Z11Z0 where 0 is connection to ground, Z represents an open terminal, and 1 is connection to the supply voltage source. This sequence is delayed by two steps for A is Z00Z11, B is 11Z00Z and for C is 0Z11Z0. For revolution into the opposite direction 654321, A is

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Z00Z11, B is Z00Z11, C is 0Z11Z0. The coils of the motor can be connected in star (Y connection) or triangle (Delta connection). Whatever is the type of connection, the idea is to get an access to the null point be able to measure the BEMF and some motors allow this access via an additional wire. Direct access to the null point N enables direct measurement of the BEMF. The voltage of the null point N is affected by the supply voltage together with a given PWM scheme.

Pulse width modulation (PWM) is a very popular method for controlling the speed of electric motors, In this control method, a fixed DC input voltage is given to the inverter and a controlled AC output voltage is obtained by adjusting the ON & OFF periods of the inverter components. The width of the inverter switching pulses modulated to obtain the required output voltage control and to reduce its harmonic content. For example, if the speed should be 50% of the maximum speed, the voltage is not turned down to 50%. Instead, the voltage is quickly turned on and off resulting in an average voltage of 50%. If 75% is required, called a duty cycle of 75%, then the voltage is kept turned off 25% of the time. If the switching frequency is high enough, the motor will run at steady speed due to the inertia and inductance of the motor. PWM inverters are quite popular in industrial applications. This method has some advantages:

- The output voltage control can be obtained without any additional components.
- With this control, lower order harmonics can be eliminated and higher order harmonics can also be filtered easily.
- It is easy to implement in a microcontroller. Only one output pin is needed to control the speed.
- No battery power is lost at low speeds.
- A motor controlled by PWM will generate more torque as the pulse use the full power supply in short intervals.

3.7 ADVANTAGES OF BLDC MOTOR OVER DC MOTOR

Performance: The dynamic accuracy of the brushless DC motor is very high. Dynamic accuracy means the machine performs consistently, with the same

efficiency.

Size: The brushless DC motor is the smallest of the motors available with a given power rating. Thus the machine occupies lesser floor space, weighs lighter and hence it makes handling of the machine easier.

Efficiency: The brushless DC motor is the most efficient motor available in the present industry.

Bearing stress: In large AC motors, heat current flows from the rotor through the bearings. The rotor heating in the brushless DC motor is the least because there is no winding in the rotor since it has a permanent magnet.

The rotor heat in brush motors is transferred to the stator through the bearings and the shaft before being removed by the ambient air. In brushless DC motor, the rotor heat produced is low thus it reduces the bearing stress. Brushless motors offer several advantages over brushed DC motors, including more torque per watt (increased efficiency), increased reliability, reduced noise, longer lifetime (no brush and commutator erosion), elimination of ionizing sparks from the commutator, and overall reduction of electromagnetic interference (EMI). With no windings on the rotor, they are not subjected to centrifugal forces, and because the windings are supported by the housing, they can be cooled by conduction, requiring no airflow inside the motor for cooling, This in turn means that the motor's internals can be entirely enclosed and protected from dirt or other foreign matter. Brushless DC motors are available in wide range of torque, speed and power.

3.8 APPLICATION POTENTIAL OF BLDC MOTORS

Classic electric motors are mostly preferred for motion control, in general and household appliances, in particular. The most common motors for household appliances are single phase AC induction motors, including split phase, capacitor start, capacitor run types and universal motors. These motors operate at constant speed directly from AC mains irrespective of efficiency; however, consumers now demand appliances with low energy

consumption, improved performance, reduced acoustic noise and many more convenient features. Therefore, household appliances are expected to be one of largest end product markets for BLDC motors over the next few years. The major household appliances include fans, blowers, washing machines, room air conditioners, refrigerators, vacuum cleaners, food processors, etc., The major possibilities of cost reduction have to be explored to commercialize BLDC motor drives, apart from technological advancements. The cost of a BLDC motor drive has two main components; one is motor and the other is the controller. Extensive research attempts have been made to reduce the cost and improve the performance of the motor. Comparative analysis has also been presented in the chapters for the choice of the BLDC motor to suit a particular application.

Recently, there has been growing research interest for the use of BLDC motors in Electric Vehicles (EVs) and Hybrid Electric Vehicles (HEVs) due to environmental concerns of vehicular emissions. An electric drive is one of the main parts of an EV/HEV and requires multidisciplinary power electronic technologies, including motors, converter topologies, switching devices, microprocessors/DSPs, and control strategies. The BLDC motor is more suitable for EVs/HEVs and low power applications, due to high power density, less volume, high torque, high efficiency, easy to control, simple hardware and software, and low maintenance. It is very difficult to identify a unique drive solution for all kinds of Electric vehicles (i.e. bikes, cars, vans, trucks, etc.,). For many applications, the motor should have shape flexibility, compactness, robustness, high efficiency and high torque.

BLDC motors have been used in various high-speed applications such as the hard disk drive (HDD) of computers which run at very high speed to reduce the access time of the data written on the surface of a rotating disk. In order to run the motor at high speed, back electromotive force (EMF) constant is designed to be small to reduce the voltage drop due to back EMF. But, it results in small starting torque, thereby a long transient period. It is one of the drawbacks.

CHAPTER-4
VOLTAGE SOURCE INVERTER

4.1 INTRODUCTION

Inverters are static power converters that produce an AC output waveform from a DC power supply. They are applied in adjustable AC speed drives, Uninterruptible Power Supplies (UPS), shunt active power filter, etc. For sinusoidal AC outputs, the magnitude, frequency, and phase should be controllable. If a DC input is a voltage source, then the inverter is called a Voltage Source Inverter (VSI). Similarly in case of a Current Source Inverter (CSI), the input to the circuit is a current source. The VSI circuit has a capability of controlling AC output voltage, whereas the CSI directly controls AC output current. Sketch of output voltage waveforms by an ideal VSI, should be independent of load connected at the output.

According to a number of phases, inverters are classified into two types

1. Single Phase Voltage Source Inverter
2. Three Phase Voltage Source Inverter

4.2 SINGLE PHASE VOLTAGE SOURCE INVERTER

Single phase inverters are basic inverters which produce a square shape AC output with a DC input. These inverters have simple on-off control logic and obviously they operate at much lower frequencies. Due to a capacity of low power, they are widely used in power supplies and single phase UPS. They can be divided into two categories.

1. Half bridge Single Phase Voltage Source Inverter
2. Full bridge Single Phase Voltage Source Inverter.

4.2.1 Half Bridge Voltage Source Inverter

Figure 4.1 shows a circuit topology of a Half-Bridge VSI, where two large capacitors are required to provide a neutral point O, such that each capacitor maintains a constant voltage ($V_1 = V_2 = V_{dc}/2$). Due to reason that the current harmonics produced by the operation of the inverter are low-order harmonics, a set of large capacitors (C_1 and C_2) are required. In this topology, it has a single leg with two power switches Q_1 and Q_2.

According to Figure 4.1, it is clear that both switches cannot be ON simultaneously, because both are directly connected across the DC link source. If two switches conduct at the same time, a short circuit across the DC link voltage source $dc\ V$ would be produced. There are two defined switching states (States 1 and 2). In order to avoid the short circuit across the DC bus and the undefined AC output voltage condition, the modulating technique should make sure that at any moment either the top or the bottom switch of the inverter leg is on

In a half bridge topology, the input DC voltage is split in two equal parts (V_1 and V_2) through an ideal and loss-less capacitive potential divider. The half bridge topology consists of one leg (one pole) of switches whereas the full bridge topology has two such legs. Each leg of the inverter consists of two series connected power electronic switches (Q_1 and Q_2) shown in the Figure 4.1.

Fig 4.1 Circuit topology of half bridge inverter

Each of these switches consists of an IGBT type controlled switch across which, an uncontrolled diode is put in anti-parallel approach. These switches are capable of conducting bi-directional current, but they have to obstruct only one polarity of voltage. In a half bridge topology, the single phase load is connected between the mid-point of the input DC supply and the junction point of the two switches. These points are marked as 'O' and 'A' respectively.

4.2.2 Full Bridge Voltage Source Inverter

Figure 4.2 shows the power topology of a full bridge VSI. This inverter is similar to the half bridge inverter, however a second leg provides the neutral point to the load. As in the half bridge inverter, both switches Q_1 and Q_2 or Q_3 and Q_4 in a single leg cannot be on simultaneously because a short circuit across the dc link voltage source V_{dc} would be occurred.

In a full bridge inverter, there are four defined (states 1, 2, 3, and 4) switching states. The undefined condition should be avoided so as to be always capable of defining the AC output voltage. It can be observed that the AC output voltage can acquire values up to the DC link value V_{dc} which is twice that obtained with half bridge voltage source inverter topologies. Output voltage is denoted as V_{AB} taken from the load.

Fig 4.2 Circuit diagram of full bridge voltage source inverter

The single-phase full bridge circuit shown in Figure 4.2 is similar to that of two half bridge circuits sharing the same DC bus. The full bridge circuit has two pole-voltages (V_{AO} and V_{BO}), which are similar to the pole voltage (V_{AO}) of the half bridge circuit. Both (V_{AO}) and (V_{BO}) of the full bridge circuit are square waves but they will have some phase difference.

4.3 THREE PHASE VOLTAGE SOURCE INVERTER

From the section 4.2.2, it can be understood that the single phase voltage source inverters can manage only low power applications. For high power applications, three phase voltage source inverters are preferred to provide three phase voltage source in addition to that the magnitude, phase and frequency of voltages should be controlled.

The typical three-phase VSI topology is shown in Figure 4.3 and middle points of the inverter legs are connected to three phase RL load. There are the eight valid switch states. The switches of any leg of the inverter (S_1 and S_4, S_3 and S_6 or S_5 and S_2) cannot be switched on simultaneously. Because it would result in short circuit across the DC link voltage supply. Similarly, the switches of any leg of the inverter cannot be switched off simultaneously to avoid undefined states in the VSI and thus undefined ac output line voltages.
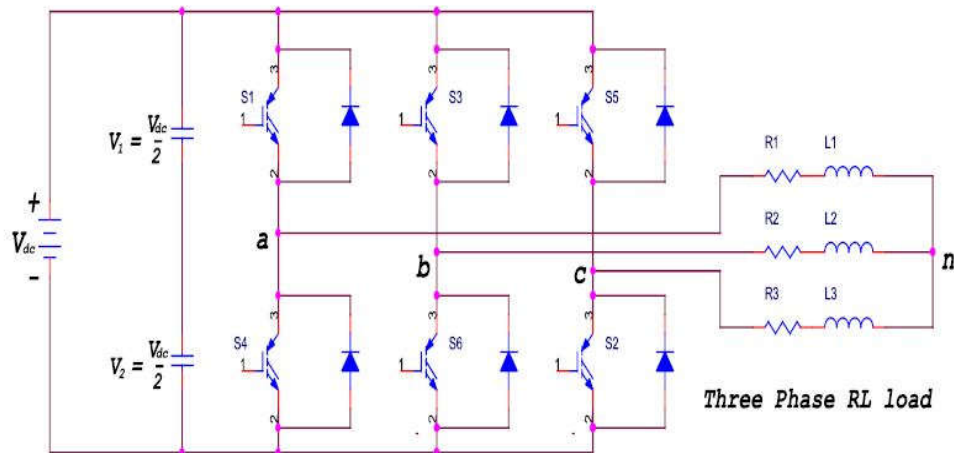
Fig 4.3 Circuit topology of three phase voltage source inverter

Two of eight valid states (7 and 8) are called as zero switch states to produce zero AC line voltages. In this case, the AC line currents freewheel through either the upper or lower components. The remaining states are called as non-zero switch states to produce non-zero AC output voltages. The resulting AC output line voltages consist of discrete values of voltages that are V_{dc}, 0, and $-V_{dc}$.

4.4 HYSTERESIS CURRENT CONTROLLER

Three major classes of regulators have been developed over last few decades: hysteresis regulators, linear PI regulators and predictive dead-beat regulators. A short review of the available current control techniques for the three phase systems is presented. Among the various PWM techniques, the hysteresis band current control is used very often because of its simplicity of implementation. Also, besides fast response current loop, the method does not need any knowledge of load parameters. However, the current control

with a fixed hysteresis band has the disadvantage that the PWM frequency varies within a band because peak-to peak current ripple is required to be controlled at all points of the fundamental frequency wave.

The method of adaptive hysteresis-band current control PWM technique where the band can be programmed as a function of load to optimize the PWM performance is described. The basic implementation of hysteresis current control is based on deriving the switching signals from the comparison of the current error with a fixed tolerance band. This control is based on the comparison of the actual phase current with the tolerance band around the reference current associated with that phase. On the other hand, this type of band control is negatively affected by the phase current interactions which is typical in three-phase systems. This is mainly due to the interference between the commutations of the three phases, since each phase current not only depends on the corresponding phase voltage but is also affected by the voltage of the other two phases. Depending on load conditions switching frequency may vary during the fundamental period, resulting in irregular inverter operation.

The current control strategy plays an important role in the development of shunt active filter. The hysteresis-band current control method (Anshuman shukla et al 2007) is popularly used because of its simplicity in implementation. Hysteresis current controller derives the switching signals of the inverter power switches in a manner that reduces the current error. The switches are controlled asynchronously to ramp the current through the inductor up and down so that it follows the reference.

The current ramping up and down between two limits is illustrated in Figure 4.4. When the current through the inductor exceeds the upper hysteresis limit, a negative voltage is applied by the inverter to the inductor. This causes the current through the inductor to decrease. Once the current reaches the lower hysteresis limit, a positive voltage is applied by the inverter through the inductor and this causes the current to increase and the cycle repeats. The current controllers of the three phases are designed to operate independently. They determine the switching signals to the respective phase of the inverter.
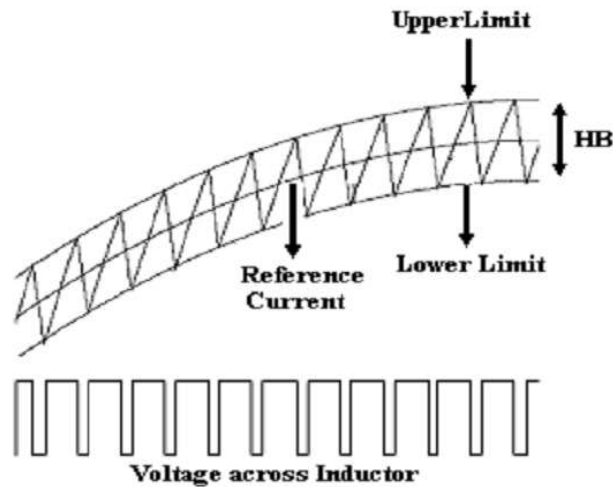
Figure.4.4Hysteresis Current Control Operation Waveform

This method has the drawbacks of variable switching frequency,heavy interference between the phases in case of three phase active filter with isolated neutral and irregularity of the modulation pulse position (Simone et al2000). These drawbacks result in high current ripples, acoustic noise and difficulty in designing input filter. In this chapter, a constant frequency hysteresis current controller is proposed for shunt active filter applications. One of the simplest current control PWM techniques is the hysteresis band (HB) control shown in this figure 4.4. Basically, it is an instantaneous feedback current control method in which the actual current continuously tracks the command current within a pre assigned hysteresis band.

As indicated in the figure 4.4, if the actual current exceeds the HB, the upper device of the half-bridge is turned off and the lower device is turned on. As the current decays and crosses the lower band, the lower device is turned off and the upper device is turned on. If the HB is reduced, the harmonic quality of the wave will improve, but the switching frequency will increase, which will in turn cause higher switching losses.

This same logic can applied to three phase waveform also. In three phase 3 reference signal 120 phase shifted is used and is compared with load current as a result we get desired output.

Low cost with easy implementation and its excellent dynamic response makes hysteresis control a prior option as control strategy. One of the simplest current control PWM techniques is the hysteresis band (HB) control shown in this figure 4.5. The obtained current reference signal, while

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converted from dq/abc transformation, is split into each phase reference currents and is measured with the actual phase currents of individual grid phases. The error signal thus generated fed to relay producing pulses. This method contains hysteresis band (HB) to obtain pulses to the switches of grid interfacing converter. Pulse generation is explained in figure 4.5.

Basically, it is an instantaneous feedback current control method in which the actual current continuously tracks the command current within a pre assigned hysteresis band. As indicated in the figure 4.5, if the actual current exceeds the HB, the upper device of the half-bridge is turned off and the lower device is turned on. As the current decays and crosses the lower band, the lower device is turned off and the upper device is turned on. If the HB is reduced, the harmonic quality of the wave will improve, but the switching frequency will increase, which will in turn cause higher switching losses.

The physical phenomenon of current management (HCC) is that the best management methodology to implement; it had been developed by Brod and Novotny in 1985. The shunt APF is enforced with three sections current controlled VSI and is connected to the ac mains for compensating the present harmonics. The VSI gate signals area unit brought out from physical phenomenon current controller.

A Hysteresis current controller is enforced with a closed-loop system and waveforms area unit shown in Fig. 4.6. An error signal is employed to manage the switches during voltage supply electrical converter. This error is that the distinction between the specified current and the current being injected by the electrical converter. If the error exceeds the higher limit of the physical phenomenon band, the higher switch of the inverter arm is turned off and also the lower switch is turned on. As a result, the present starts decaying.
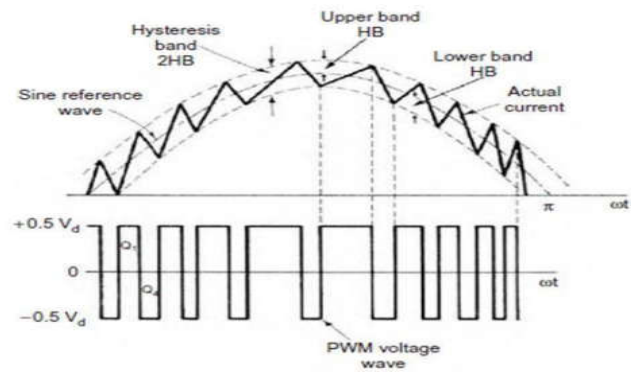
Fig.4.5: Hysteresis Band Current control
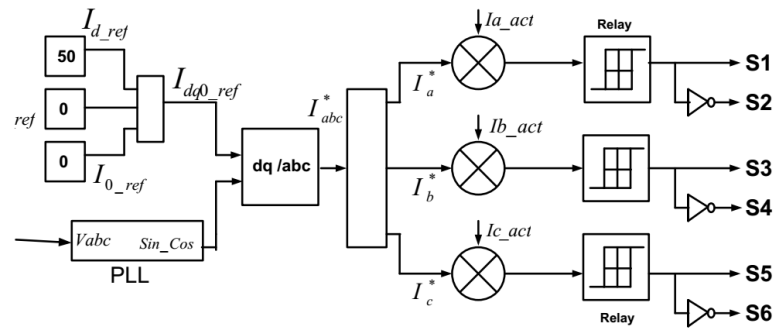
Fig.4.6: Hysteresis Current Controller

CHAPTER-5
PROPOSED CONCEPT

5.1 INTRODUCTION

The solar photovoltaic (SPV) power generation being noise-free, clean and abundant in nature, is indeed becoming prominent among various renewable energies. A continuous reduction in the cost of PV panels and the power electronics devices has encouraged researchers and industries to utilize the SPV array generated power for different applications. The water pumping has gained a broad attention as a crucial and cost-effective application of the SPV array generated power. A maximum efficiency of the SPV array is mostly achieved through a maximum power point tracking (MPPT) algorithm using the DC–DC converters.

Various DC–DC converters such as buck, boost, buck–boost, Cuk and single-ended primary inductor converter (SEPIC) have been used for MPPT in different SPV array-based applications. The afore said non-isolated DC–DC converters are compared to find a best solution suiting an application with MPPT. It has been concluded that the best selection of DC–DC converter in the PV system is the buck–boost DC–DC converter since it is capable of achieving optimal operation regardless of the atmospheric condition and load, hence adopted in this paper.

On the other hand, when a buck or a boost converter is used for MPPT, the MPP is tracked as if it is restricted to within the operating region. Besides that, due to the large number of energy storage components, the Cuk converter, SEPIC and other derived topologies of buck–boost converter contribute to their main drawback. The other recently proposed converters for MPPT are D converter, two-input buck (TI Buck) converter, boost–buck converter, combination of buck and buck–boost converter, push-pull converter, transformer coupled dual-input converter and two inductor boost converter.

These converters have excessive number of reactive components and sophisticated control. An induction motor is extensively used in fluid pumps because of its robustness, low cost, availability in local markets, low maintenance cost and potential to operate even in the hazardous and

contaminated areas. Some of the limitations of the induction motor are not favorable for SPV array-based water pumping such as prone to overheating if the voltage is too low and requirement of complicated control. It deviate the researchers toward an efficient and reliable motor with less complexity and capable to operate under low voltage. The brushless DC (BLDC) motors have the merits of high efficiency, high reliability, high ruggedness, low electromagnetic interference, simple control, no maintenance and capability to operate at low voltage, high torque/weight ratio, easy-to-drive features and excellent performance over a wide range of speed.

It can undoubtedly compete with the induction motor especially in SPV array-based pumping applications, where cost, efficiency, simplicity, compactness and easy-to-drive features are the primary and essential factors for consideration. Moreover, this motor and pump technology, and integrated design result in both increased component utilization and reliability.SPV array fed BLDC motors have already superseded partially AC motor drives in the various conventional energy-based applications including water pumping. The BLDC motor is receiving popularity for water pumping application day-by-day owing to its aforementioned advantages, constituting desirable features for this application. The existing literature exploring SPV array-based BLDC motor driven water pump is based on the configuration shown in Fig.5.1a.ADC–DC converter is used for MPPT of SPV array as usual.

At least two phase currents are sensed along with the Hall signals feedback for control of BLDC motor, resulting in the increased cost. The additional control scheme, increasing cost and complexity, is required to control the speed of BLDC motor. Moreover, the voltage-source inverter (VSI) is operated with high-frequency pulse-width modulation (PWM) pulses, resulting in the increased switching loss and hence the reduced efficiency.

However, a Z-source inverter (ZSI) replaces DC–DC converter, other schematic of Fig. 5.1aremaining unchanged, promising high efficiency and low cost. Contrary to it, ZSI also necessitates phase currents and DC-link voltage sensing resulting in the complex control and increased cost.

To overcome these problems and drawbacks, a simple, cost-effective and efficient water pumping system based on SPV array fed BLDC motor is

proposed, as shown in Fig. 5.1b by modifying the existing topology (Fig.5.1a).

A DC–DC buck–boost converter is utilized to extract the maximum power available from the SPV array. The additional functions of buck–boost converter are soft starting and speed control of the BLDC motor coupled to a water pump, by applying the MPPT algorithm appropriately. Owing to the single switch and least number of reactive components, this converter possesses very good conversion efficiency and offers boundless region for MPPT. This converter is operated in continuous conduction mode (CCM) resulting in a reduced stress on its power devices and components.

Furthermore, the switching loss of VSI is reduced by adopting fundamental frequency switching resulting in an additional power saving and hence the enhanced efficiency. The phase currents as well as the DC-link voltage sensors are completely eliminated, offering simple and economical system without sacrificing its performance.

The speed of BLDC motor is controlled, without any additional control, through the variable DC-link voltage of VSI. Moreover, the soft starting of BLDC motor is achieved by proper initialization of MPPT algorithm of SPV array. These features offer an increased simplicity of the proposed system. Such work is reported however, the operation of buck–boost converter is constrained to the buck mode only. Its utilization is therefore not properly justified. Moreover, the contribution of the work is distinctly neither highlighted nor represented. Besides this, an experimental validation is no where presented and the reported work is limited to the MATLAB/Simulink-based simulation.

The advantages and desirable features of both the buck–boost converter and BLDC motor drive contribute to develop a simple, efficient, cost-effective and reliable water pumping system based on the green energy. In this paper, the ratings of the SPV array and the BLDC motor are selected such that the proposed system operates successfully under all thevariations in the atmospheric conditions and the utilization ofbuck–boost converter is properly justified.

5.2 PROPOSED SYSTEM CONFIGURATION AND OPERATING PRINCIPLE

Fig.5.1bshows the configuration of the proposed SPV-based buck–boost converter fed BLDC motor drive for water pumping. From left to right, the proposed system consists of an SPV array, a buck–boost DC–DC converter, a VSI, a BLDC motor and a water pump. As shown in Fig.5.1b, the SPV array generates the electrical energy and feeds the DC–DC buck–boost converter.

The insulated gate bipolar transistor (IGBT) switch of the buck–boost converter is operated through an incremental conductance (INC) MPPT algorithm such that the operation of the SPV array is optimized and the BLDC motor has the soft starting. The buck–boost converter is operated in CCM to reduce the stress on the components and semiconductor devices. Furthermore, the buck–boost converter feeds power to the VSI, supplying the BLDC motor coupled to a water pump. Switching sequence for the VSI is provided by the electronic commutation of BLDC motor. An electronic commutation is a process of decoding the Hall Effect signals generated by the inbuilt encoder of the motor according to position of the rotor.
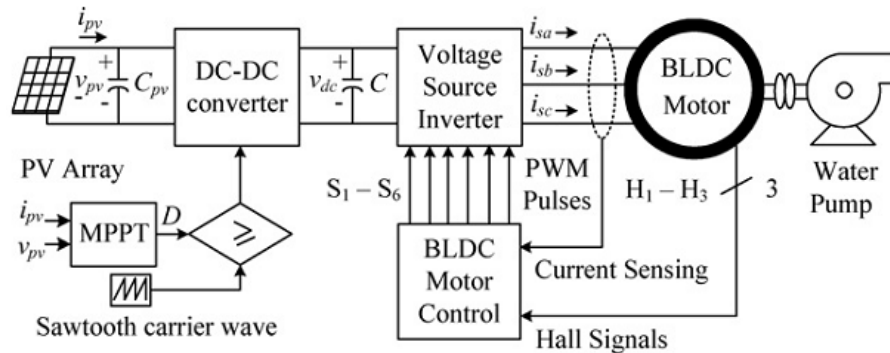
(a)
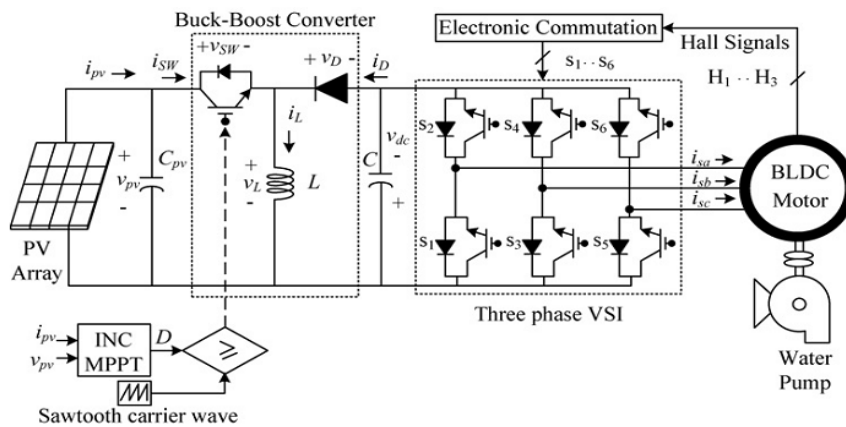
(b)

Fig. 5.1 Configuration of the SPV array fed BLDC motor driven water pumping system(a) Conventional (b) Proposed

5.3 DESIGN OF THE PROPOSED SYSTEM

The various operating stages of the configuration shown in Fig.5.1bsuch as the SPV array, the buck–boost converter and the water pump are designed such that a satisfactory operation is always accomplished under any kind of change in solar insulation level. A BLDC motor of 0.7 kW rated power is selected and each stage of the proposed system are designed accordingly, as follows

5.3.1 Design of SPV Array

A Solar PV array of 0.7 KW peak power capacity, is required by the BLDC motor. The BLDC motor is selected so that the performance of the system will not affected by the losses associated with the both converters and BLDC motor. The parameters of the Solar PV array are estimated at the standard solar isolation level of 1000 W/m2. A PV module AP-100, manufactured by Astropower Inc. with peak power of 100 W, maximum voltage of 16.1 V and maximum current of 2.4 A is considered to design an Solar PV array of required capacity. First of all, the voltage of the Solar PV array at MPP is selected in view of the DC voltage rating of the BLDC motor same as DC-link voltage of the VSI. Selecting this voltage as V_{mpp} = v_{pv}= 300 V, the other parameters are estimated as:

The current at MPP

$$I_{mpp} = i_{pv} = \frac{p_{pv}}{v_{pv}} = 700/300 = 2.4A \tag{5.1}$$

Where p_{pv} = P_{mpp} = 700 W is the peak power capacity.

Numbers of modules connected in series are as

$$= \cdot = 300/16.1 = 19 \tag{5.2}$$

Numbers of modules connected in parallel are as

$$= \cdot = 2.4/2.4 = 1 \tag{5.3}$$

where$V_m$and I_m are voltage and current of a module at MPP.

5.3.2 Design of Buck-Boost Converter

The Solar PV array voltage at MPP, $v_{pv} =$ = 300 V appears as the input voltage source, whereas DC-link voltage of VSI, v_{dc} appears as the output voltage of the buck–boost converter. The duty ratio, D of buck–boost converter is estimated, using the input–output relationship as

$$= \frac{}{+} = \frac{310}{310+300} = 0.51 \quad (5.4)$$

where V_{dc} = 310 V is rated DC-link voltage of VSI on the other hand, neglecting the buck–boost converter losses, an average current flowing through DC link, I_{dc} is as

$$I_{dc} = \frac{P_{mpp}}{V_{dc}} = 700/310 = 2.26\text{A} \quad (5.5)$$

An addition of the two currents, i_{pv} and I_{dc} flow through the inductor, L. The inductor, L is estimated as

$$L = \frac{D \times v_{pv}}{f_{sw}\Delta I_L} = \frac{0.51 \times 300}{10000 \times 11 \times 0.4} = 3.4\text{mH} \quad (5.6)$$

Where f_{sw} is the switching frequency of the buck–boost converter and ΔI_L is an amount of ripple permitted in the inductor current.

The highest and lowest frequencies of the VSI output voltage are considered to estimate the DC-link capacitor, C. The highest value of VSI output voltage frequency, ω_h(in rad/s) is calculated corresponding to the rated speed of the motor (N_{rated} = 3000 rpm) while the lowest value of VSI output voltage frequency, ω_l (in rad/ s) is calculated corresponding to the minimum speed of a motor required to pump the water (N = 1100 rpm) as

$$\omega_h = 2\pi f = 2\pi \frac{N_{rated}P}{120} = 2\pi \times \frac{3000 \times 4}{120} = 628.3 \ rad/s \quad (5.7)$$

$$\omega_l = 2\pi f = 2\pi \frac{NP}{120} = 2\pi \times \frac{1100 \times 4}{120} = 230.38 \ rad/s \quad (5.8)$$

Where f is the frequency of VSI output voltage in hertz, N_{rated} is rated speed of the BLDC motor and P is the numbers of poles.

Since sixth harmonic component of VSI output voltage appears on DC link of VSI, limiting the voltage ripple, ΔV_{dc} in vdc to 1%, the DC-link capacitor, C is estimated corresponding to ω_h and ω_l as

$$C_{\omega_h} = \frac{I_{dc}}{6 \times \omega_h \times \Delta V_{dc}} = \frac{4.8}{6 \times 628.3 \times 310 \times 0.01} = 410.7 \ \mu F \quad (5.9)$$

$$C_{\omega_l} = \frac{I_{dc}}{6 \times \omega_l \times \Delta V_{dc}} = \frac{4.8}{6 \times 230.38 \times 310 \times 0.01} = 1120 \ \mu F \quad (5.10)$$

As per the estimation in, to ensure the satisfactory performance of the

BLDC motor, somewhat a higher value of C = 1500 µF is selected.

5.4 CONTROL OF THE PROPOSED SYSTEM

The proposed solar PV array system is controlled by Maximum power point tracking (MPPT) and electronic commutation of BLDC motor. These are explained in the following sections.

5.4.1 Maximum Power Point Tracking

The MPPT technique is mostly used to optimize the utilization of Solar PV array. An INC type of MPPT technique is used here because of its high precision of tracking even under rapid changes in the atmospheric conditions. The perturbation size is wisely selected such that the oscillation around the peak power point is avoided and the soft starting of the BLDC motor is ensured under all the possible variations in the solar isolation level.

A low perturbation size is selected (0.001) to control the tracking speed. To achieve the soft starting of motor, the output voltage of buck–boost converter is controlled at starting by initializing the duty ratio as zero. Therefore, as the operating power point of Solar PV array moves toward MPP, the DC-link voltage of VSI increases with a controlled rate. This results in a reduced rate of rise of stator current, ensuring a soft starting.
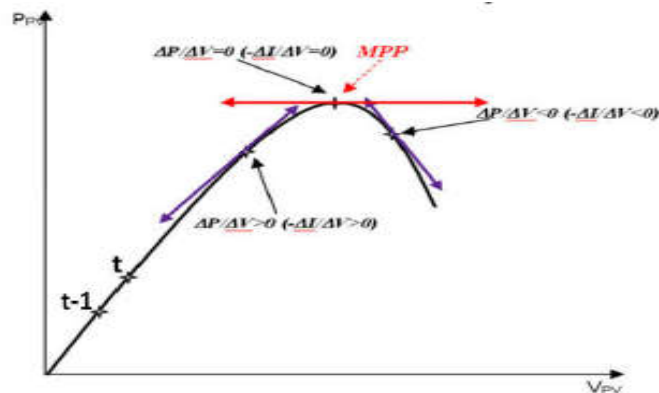
Fig 5.2 Illustration of modified INC-MPPT with solar PV array
P_{pv}–V_{pv} characteristics

5.4.2 Electronic Commutation

In VSI, the switching pulses to the semiconductor devices are generated by electronic commutation mechanism. Three Hall Effect signals

are provided by the encoder with respect to the angular position of rotor of the motor. The output of Hall sensors are logically converted as switching pulses and given to the semiconductor switching devices of VSI, as shown in table-5.1.

Θ,deg	Hall Signals			Switching States					
	H_3	H_2	H_1	S_1	S_2	S_3	S_4	S_5	S_6
NA	0	0	0	0	0	0	0	0	0
0-60	1	0	1	1	0	0	1	0	0
60-120	0	0	1	1	0	0	0	0	1
120-180	0	1	1	0	0	1	0	0	1
180-240	0	1	0	0	1	1	0	0	0
240-300	1	1	0	0	1	0	0	1	0
300-360	1	0	0	0	0	0	1	1	0
NA	1	1	1	0	0	0	0	0	0

TABLE 5.1 Switching states for electronic commutation of BLDC motor

5.4.3 Hysteresis Current Control of BLDC motor

In the sensored BLDC drive, hall sensors are used to obtain the rotor position information. The drive control system consists of an outer speed loop for speed control and an inner current loop for current control. Three separate current sensors are used to measure the phase currents.

Using current waveforms the torque ripple harmonics will be reduced in BLDC motor. Hysteresis current control strategy produces accurate torque in BLDC motor with reduced torque ripples. Torque ripple in BLDC motor by non-ideal current waveform is minimized by using phase current sensors with help of feedback controllers.

The torque ripple content with and without Hysteresis Current Control is shown in below table 5.2.

1	Without HCC	With HCC
Torque Ripple Percentage	36%	16%

Table 5.2 Torque ripple percentage with and without HCC

CHAPTER-6
EVALUATION OF MATLAB/SIMULINK MODELING & RESULTS

6.1 INTRODUCTION TO MATLAB

MATLAB was initially developed by a lecturer in 1970's to help students learn linear algebra. It was later marketed and further developed under Math Works Inc. (founded in 1984) www.mathworks.com. MATLAB is a software package which can be used to perform analysis and solve mathematical and engineering problems. It has excellent programming features and graphics capability – easy to learn and flexible. Available in many operating systems – Windows, Macintosh, UNIX, DOS It has several tool boxes to solve specific problems.

MATLAB (matrix laboratory) is a multi-paradigm numerical computing environment and fourth-generation programming language. A proprietary programming language developed by Math Works, MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, Java, Fortran and Python.

Although MATLAB is intended primarily for numerical computing, an optional toolbox uses the MuPAD symbolic engine, allowing access to symbolic computing abilities. An additional package, Simulink, adds graphical multi-domain simulation and model-based design for dynamic and embedded systems.

6.2 SIMULINK

Simulink, developed by Math Works, is a graphical programming environment for modeling, simulating and analyzing multi domain dynamic systems. Its primary interface is a graphical block diagramming tool and a customizable set of block libraries. It offers tight integration with the rest of the MATLAB environment and can either drive MATLAB or be scripted from it. Simulink is widely used in automatic control and digital signal processing for multi domain simulation and Model-Based Design.

Used to model, analyze and simulate dynamic systems using block diagrams. Fully integrated with MATLAB, easy and fast to learn and flexible.

It has comprehensive block library which can be used to simulate linear, non–linear or discrete systems – excellent research tools. C codes can be generated from Simulink models for embedded applications and rapid prototyping of control systems.

6.3 SIMULINK AND ITS RELATION TO MATLAB

The MATLAB and Simulink environments are integrated into one entity, and thus we can analyze, simulate, and revise our models in either environment at any point. We invoke Simulink from within MATLAB.

MATLAB is an interactive programming language that can be used in many ways, including data analysis and visualization, simulation and engineering problem solving. It may be used as an interactive tool or as a high level programming language. It provides an effective environment for both the beginner and for the professional engineer and scientist. SIMULINKTM is an extension to MATLAB that provides an iconographic programming environment for the solution of differential equations and other dynamic systems.

The package is widely used in academia and industry. It is particularly well known in the following industries: aerospace and defence; automotive; biotech, pharmaceutical; medical; and communications. Specialist toolboxes are available for a diverse range of other applications, including statistical analysis, financial modeling, image processing and so on. Furthermore, real time toolboxes allow for on-line interaction with engineering systems, ideal for data logging and control.

Building on MATLAB (the language of technical computing), Simulink provides a platform for engineers to plan, model, design, simulate, test and implement complex electromechanical, dynamic control, signal processing and communication systems. Simulink-Matlab combination is very useful for developing algorithms, GUI assisted creation of block diagrams and realization of interactive simulation based designs. The eleven chapters of the book demonstrate the power and capabilities of Simulink to solve engineering problems with varied degree of complexity in the virtual environment.

6.4 SIMULATION MODELS & RESULTS

Fig 6.1 Simulation model of BLDC motor drive fed by a solar PV system without HCC

Fig 6.2 Simulation model of Solar PV system
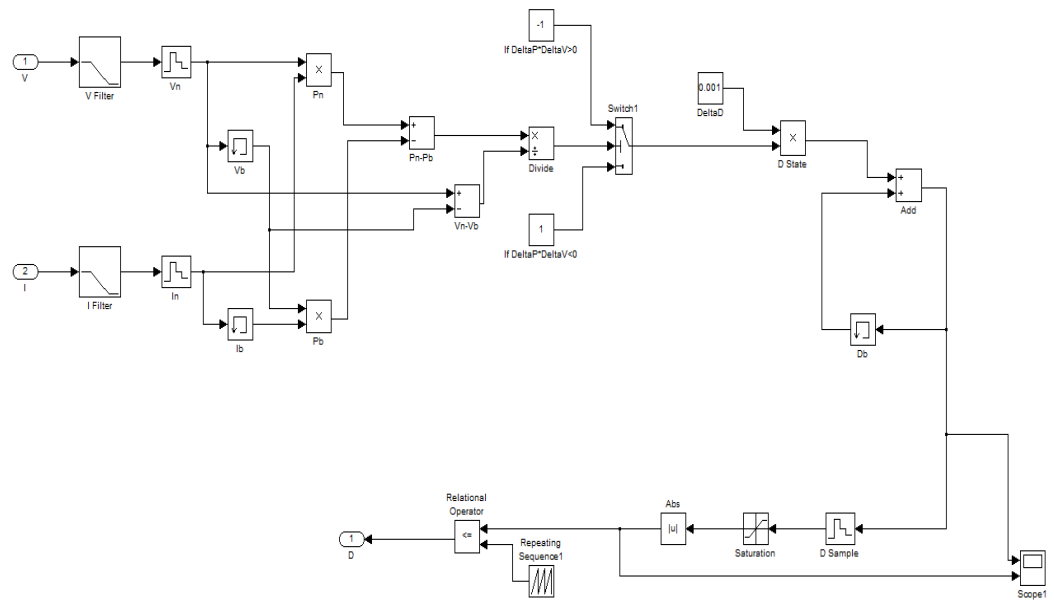
Fig 6.3 Simulation model of MPPT system of Solar PV system
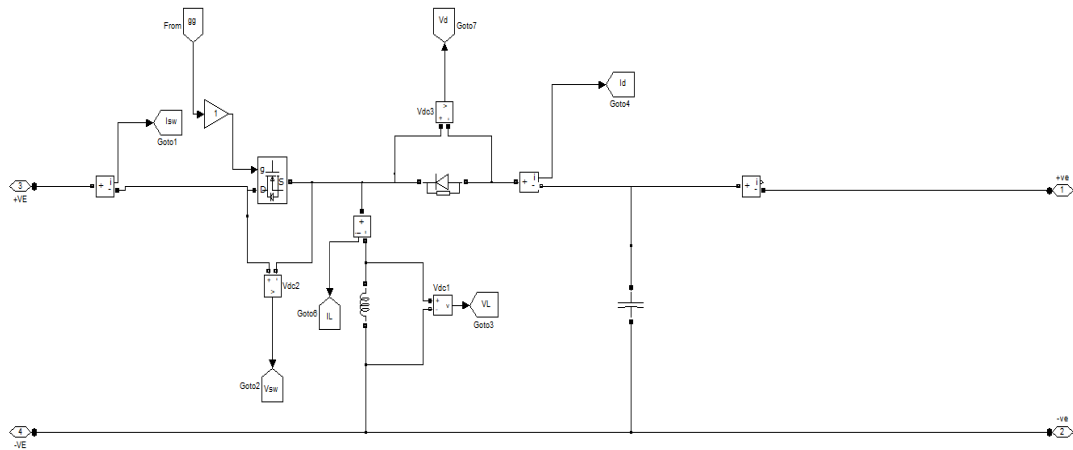
Fig 6.4 Simulation model of DC-DC Buck Boost Converter
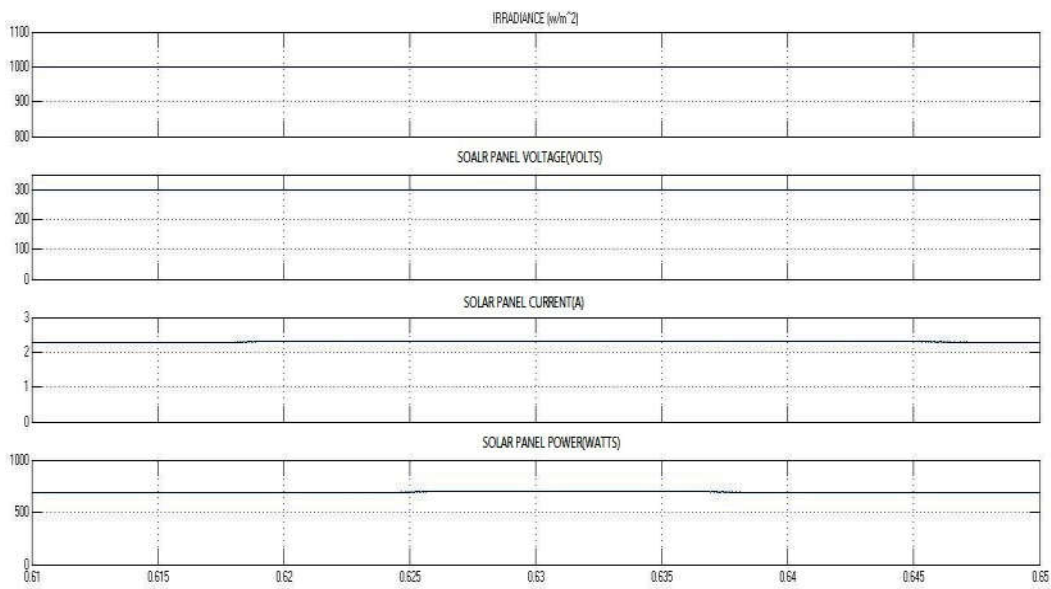
Fig 6.5 Simulated waveforms of solar photovoltaic system output
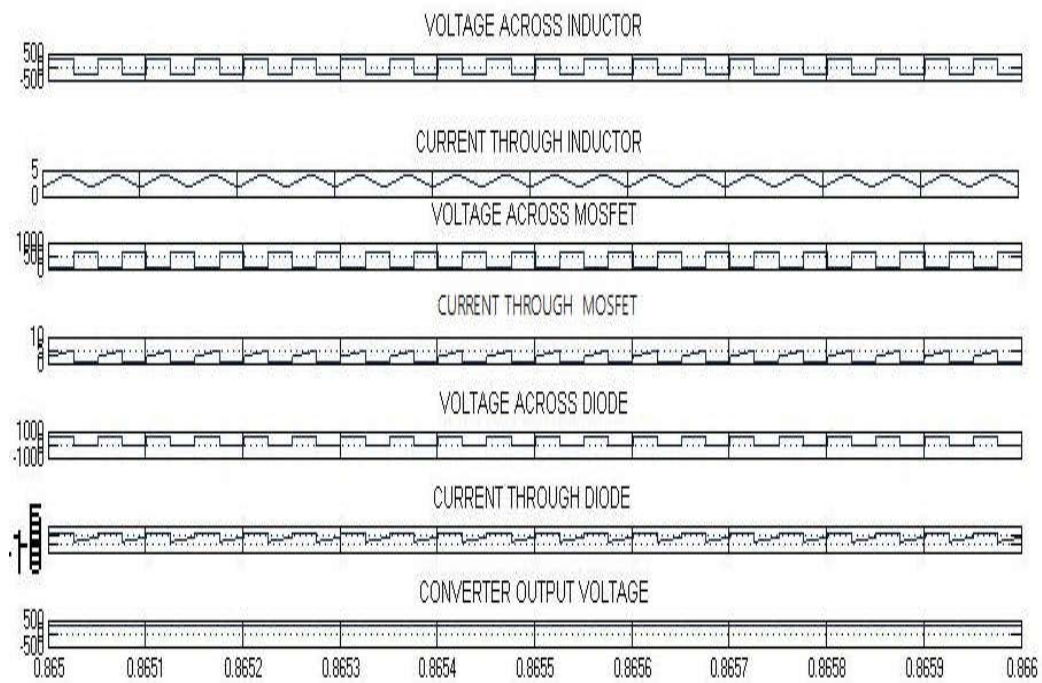
Fig 6.6 Simulated waveforms of DC-DC buck boost converter
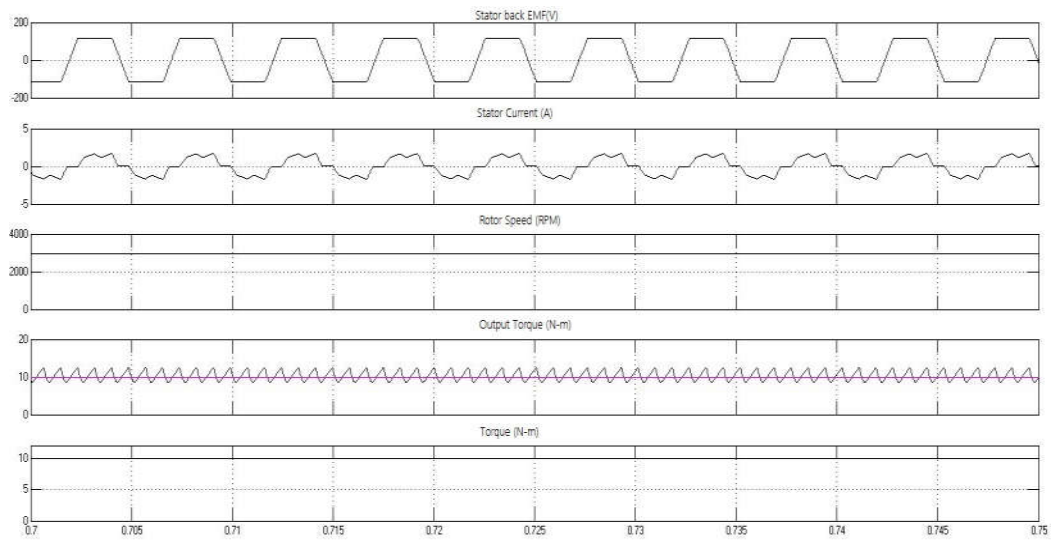
Fig 6.7 Simulated waveforms of BLDC motor without HCC
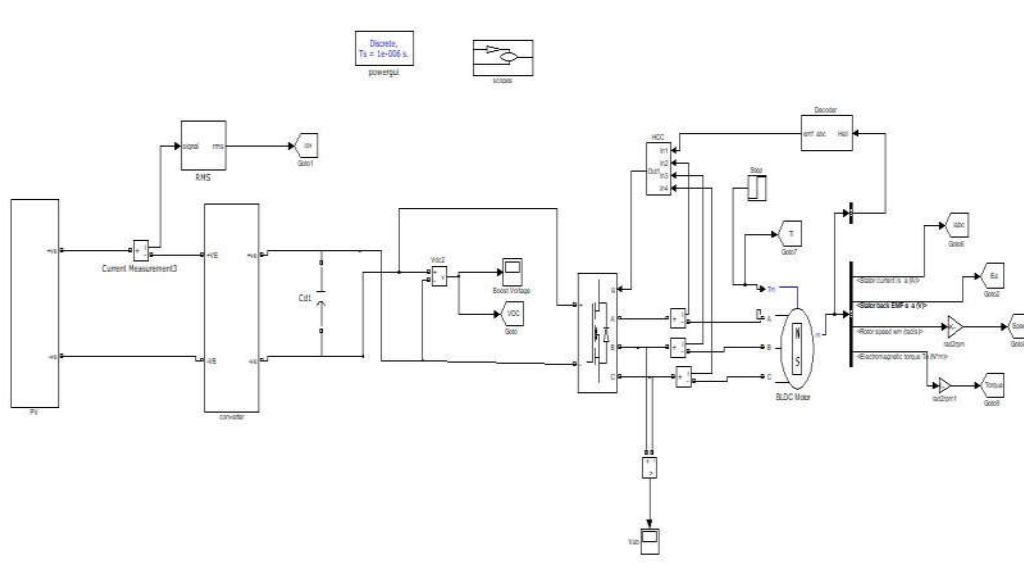
Fig 6.8 Simulation model of BLDC motor drive fed by a solar PV system with HCC

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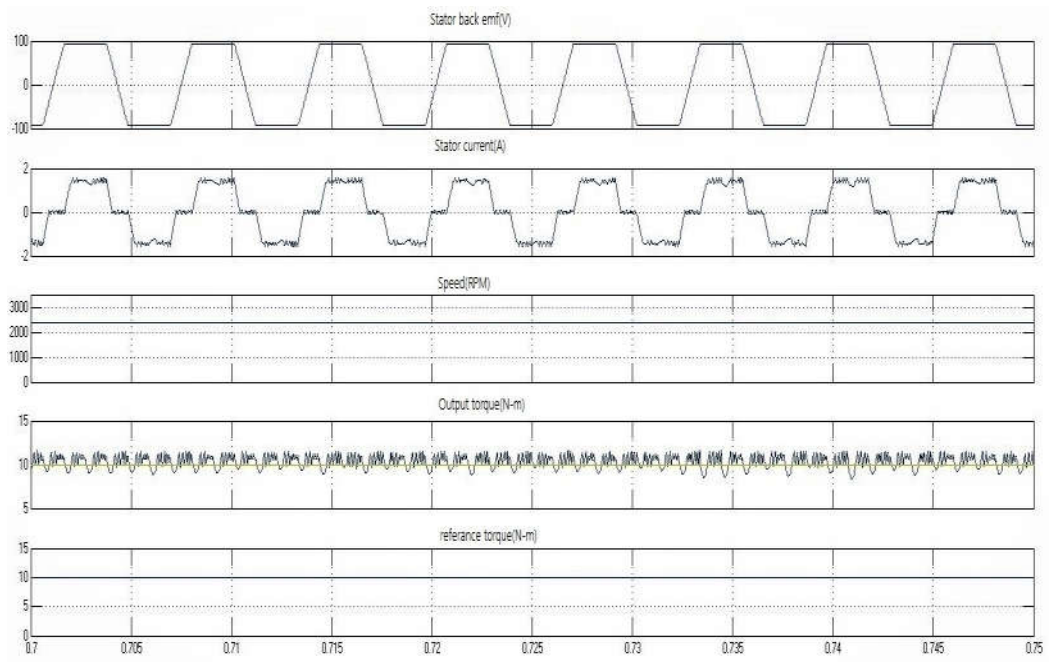
Fig 6.9 Simulated waveforms of motor with HCC

CHAPTER-7
CONCLUSION

The starting, dynamic and steady-state behaviors of the proposed SPV array-based buck–boost converter fed BLDC motor have been validated for water pumping. The proposed system has been designed, modeled and simulated in MATLAB/Simulink environment Simulation and test results have been found precisely similar. The buck–boost converter has offered an unbounded region for MPPT. The fundamental frequency switching of VSI, the absolute elimination of current and voltage sensing elements, and the speed control without any additional control scheme or circuit are the significant features which have contributed to develop a simple, cost-effective and optimized efficiency system for water pumping without scarifying its performances. The proposed system has been designed, such that the performance is not deteriorated by the weather condition and efficiency limitations of the converters and motors. On the basis of the simulation and experimental results, a BLDC motor with the buck–boost converter has been proved as a suitable and compatible combination for SPV-based water pumping regardless of the weather condition.

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Modelling and Simulation of Solar PV and DFIG Based Wind Hybrid System for Rural Electrification

Submitted in partial fulfillment of the requirements for award of the degree of

MASTER OF TECHNOLOGY

In

POWER INDUSTRIAL DRIVES

Submitted by

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Under the Esteemed Guidance of
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2020

CERTIFICATE

This is to certify that the project work entitled "Modelling and Simulation of Solar PV and DFIG Based Wind Hybrid System for Rural Electrification" has been carried out by L.YASWANTH (19U41D4205) submitted in the partial fulfillment of the requirement for the award of the degree of MASTER OF TECHOLOGY for POWER AND INDUSTRAL DRIVES during the academic year 2019-2021.

(Project Guide)   (Head of the Department)

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AssistantProfessorofEEE.   AssociateProfessorofEEE.

EXTERNAL EXAMINER

DECLARATION

I hereby declare that the dissertation entitled "Modelling and Simulation of Solar PV and DFIG Based Wind Hybrid System for Rural Electrification" was carried out and written by me under the guidance of Mr.CH.RAVI KUMAR, Assistant Professor, Department of Electrical and Electronics Engineering, Dadi Institute of Engineering & Technology. This work has not been previously formed the basis for the award of any degree of diploma or certificate nor has been submitted elsewhere for the award of any degree or diploma.

BY

L.YASWANTH   (19U41D4205)

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ABSTRACT

The increasing energy demand and depletion of fossil fuels has risen in awareness of searching for alternative energy source thus the inexhaustible solar and wind energy is becoming an interesting topic which has grabbed the attention of researchers to make it sustainable power. The objective of this project is to provide sustainable power for rural areas and remote places. The proposed system consists of solar PV and Doubly Fed Induction Generator (DFIG) based wind turbine. In Solar PV MPPT technique is used to maximize the power and boost converter is used to rise the DC voltage of solar PV and fed to the three phase inverter. The DFIG has two controllers Rotor side control and Grid side control. Rotor side converter and Grid side Converter have the capability of generating or observing reactive power and to maintain constant rotor speed, and controls the DC-link voltage. Simulation study of the proposed system is carried out with MATLAB Simulink and simulation results are provided.

Keywords—Hybrid system, DFIG, PV cell, MPPT, Converter.

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CHAPTER-1

INTRODUCTION

1.1 THE NEED FOR RENEWABLE ENERGY

Renewable energy is the energy which comes from natural resources such as sunlight, wind, rain, tides and geothermal heat. These resources are renewable and can be naturally replenished. Therefore, for all practical purposes, these resources can be considered to be inexhaustible, unlike dwindling conventional fossil fuels. The global energy crunch has provided a renewed impetus to the growth and development of Clean and Renewable Energy sources. Clean Development Mechanisms (CDMs) are being adopted by organizations all across the globe.

Apart from the rapidly decreasing reserves of fossil fuels in the world, another major factor working against fossil fuels is the pollution associated with their combustion. Contrastingly, renewable energy sources are known to be much cleaner and produce energy without the harmful effects of pollution unlike their conventional counterparts.

1.2 DIFFERENT SOURCES OF RENEWABLE ENERGY

1.2.1 Wind power

Wind turbines can be used to harness the energy available in airflows. Current day turbines range from around 600 kW to 5 MW of rated power. Since the power output is a function of the cube of the wind speed, it increases rapidly with an increase in available wind velocity. Recent advancements have led to aerofoil wind turbines, which are more efficient due to a better aerodynamic structure.

Wind power is the use of airflow through wind turbines to provide the mechanical power to turn electric generators. Wind power, as an alternative to burning fossil fuels, is plentiful, renewable, widely distributed, clean, produces no greenhouse gas emissions during operation, consumes no water, and uses little land. The net effects on the environment are far less problematic than those of fossil fuel sources.

In 2018, global wind power capacity expanded 10% to 539 GW. Yearly wind energy production grew 17% reaching 4.4% of worldwide electric power usage, and providing 11.6% of the electricity in the European Union. Denmark is the country with the highest penetration of wind power, with 43.4% of its consumed electricity from wind in 2018. At least 83 other countries around the world are using wind power to supply their electric power grids.

Figure 1.1 Wind Power

1.2.2   Solar power

The tapping of solar energy owes its origins to the British astronomer John Herschel who famously used a solar thermal collector box to cook food during an expedition to Africa.

Solar energy can be utilized in two major ways. Firstly, the captured heat can be used as solar thermal energy, with applications in space heating. Another alternative is the conversion of incident solar radiation to electrical energy, which is the most usable form of energy. This can be achieved with the help of solar photovoltaic cells or with concentrating solar power plants.

Solar power is the conversion of energy from sunlight into electricity, either directly using photovoltaic (PV), indirectly using concentrated solar power, or a combination. Concentrated solar power systems use lenses or mirrors and tracking systems to focus a large area of sunlight

into a small beam. Photovoltaic cells convert light into an <u>electric current</u> using the <u>photovoltaic effect</u>.
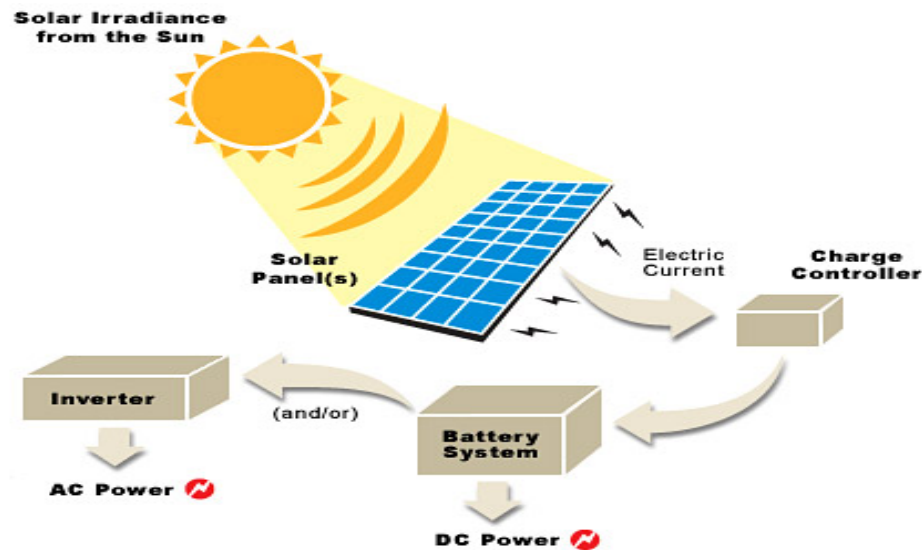
Figure1.2 Solar Power

1.2.3　　Small Hydropower

Hydropower installations up to 10MW are considered as small hydropower and counted as renewable energy sources .These involve converting the potential energy of water stored in dams into usable electrical energy through the use of water turbines. Run-of-the-river hydroelectricity aims to utilize the kinetic energy of water without the need of building reservoirs or dams.

1.2.4　　Biomass

Plants capture the energy of the sun through the process of photosynthesis on combustion these plants release the trapped energy. This way, biomass works as a natural battery to store the sun's energy and yield it on requirement.

1.2.5　　Geothermal

Geothermal energy is the thermal energy which is generated and

stored within the layers of the Earth. The gradient thus developed gives rise to a continuous conduction of heat from the core to the surface of the earth. This gradient can be utilized to heat water to produce superheated steam and use it to run steam turbines to generate electricity. The main disadvantage of geothermal energy is that it is usually limited to regions near tectonic plate boundaries, though recent advancements have led to the propagation of this technology.
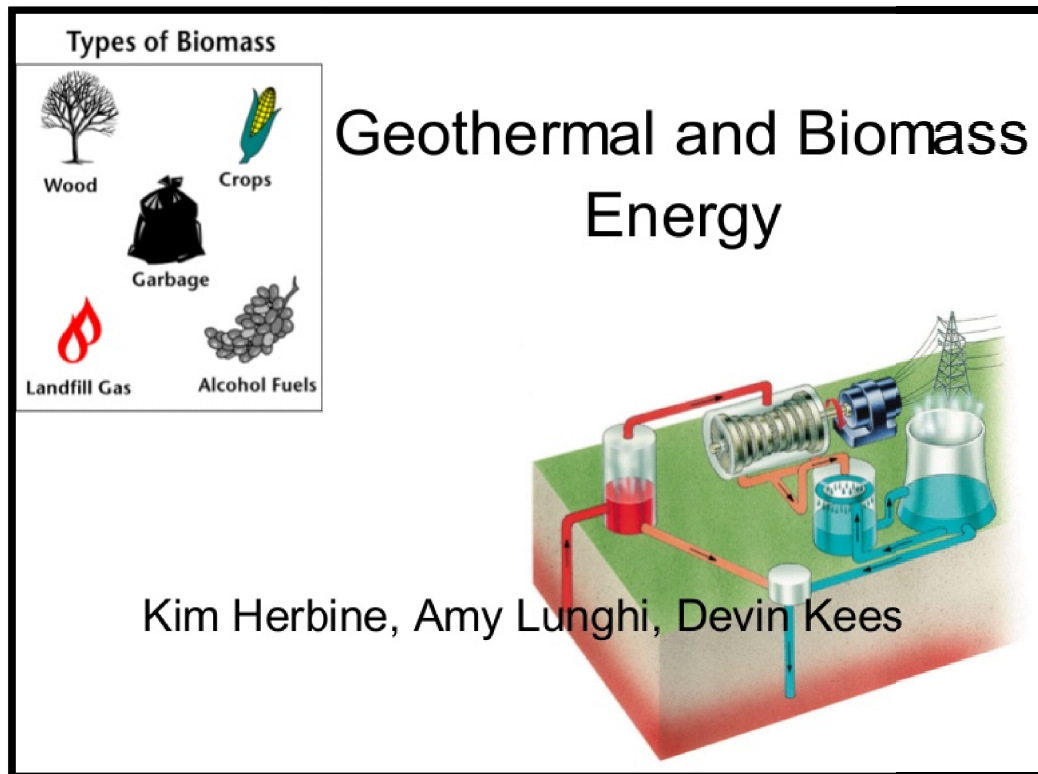
Figure1.3 Geothermal and Biomass energy

1.3RENEWABLE ENERGY TRENDS ACROSS THE GLOBE

The current trend across developed economies tips the scale in favour of Renewable Energy. For the last three years, the continents of North America and Europe have embraced more renewable power capacity as compared to conventional power capacity. Renewable accounted for 60% of the newly installed power capacity in Europe in 2009 and nearly 20% of the annual power production.
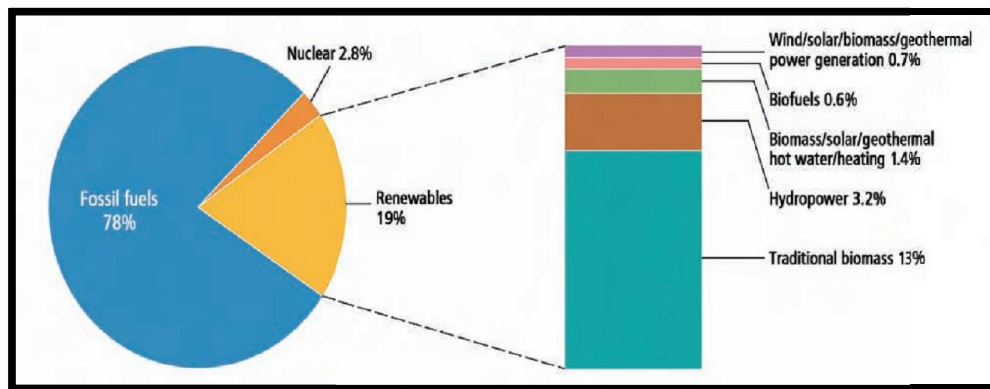
Figure 1.4 Global energy consumption in the year 2018

As can be seen from the figure 1.4.wind and biomass occupy a major share of the current renewable energy consumption. Recent advancements in solar photovoltaic technology and constant incubation of projects in countries like Germany and Spain have brought around tremendous growth in the solar PV market as well, which is projected to surpass other renewable energy sources in the coming years.

By 2009, more than 85 countries had some policy target to achieve a predetermined share of their power capacity through renewable. This was an increase from around 45 countries in 2005. Most of the targets are also very ambitious, landing in the range of 30-90% share of national production through renewable. Noteworthy policies are the European Union's target of achieving 20% of total energy through renewable by 2020 and India's Jawaharlal Nehru Solar Mission, through which India plans to produce 20GW solar energy by the year 2022.

1.4 DRIVERS OF RENEWABLE ENERGY GENERATION

The main drivers of the increased popularity in RE electricity generation by wind, solar, biomass, small hydro and hybrid are due to emergence of cleaner and sustainable energy technologies brought along with financial incentives, promotion mechanisms, economic and regulatory changes introduced in various countries. According to a study of (lEA, 2002), renewed interest in small scale electricity generation is

   i) Development in distributed electricity generation technologies,

   ii) Difficulties in laying new transmission lines,

   iii) Demand of reliable electricity supply,

iv) Climate change and liberalization of electric power market.

In Europe and USA, distributed RES growth has been reported which are due to (i)Flexibility in deployment due to their small size, (ii) shorter lead time for installation and commissioning, operation and capacity expansion, (iii) cost effective source of electricity for peak load, (iv) minimal cost of transmission and distribution which could be as high as 40%, (iii) insurance against volatile prices of electricity, (iv) minimal transmission and distribution losses, and (v) effective use of locally available cheap primary RE.

CHAPTER-2

PHOTOVOLTAIC SYSTEM

2.1 HISTORY

In 1839, a French physicist Edmund Becquerel proposed that few materials have theability toproduce electricity when exposed to sunlight. But Albert Einstein explained the photoelectric effect and the nature of light in 1905. Photoelectric effect, state that when photons or sunlight strikes to a metal surface flow of electrons will take place. Later photoelectric effect became the basic principle for the technology of photovoltaic power generation. The first PV module was manufactured by Bell laboratories in1954.

2.2 PHOTOVOLTAIC ARRANGEMENT

A photovoltaic energy systemis mainly powered by solar energy. The configuration of PV system is manifested in figure2.1.
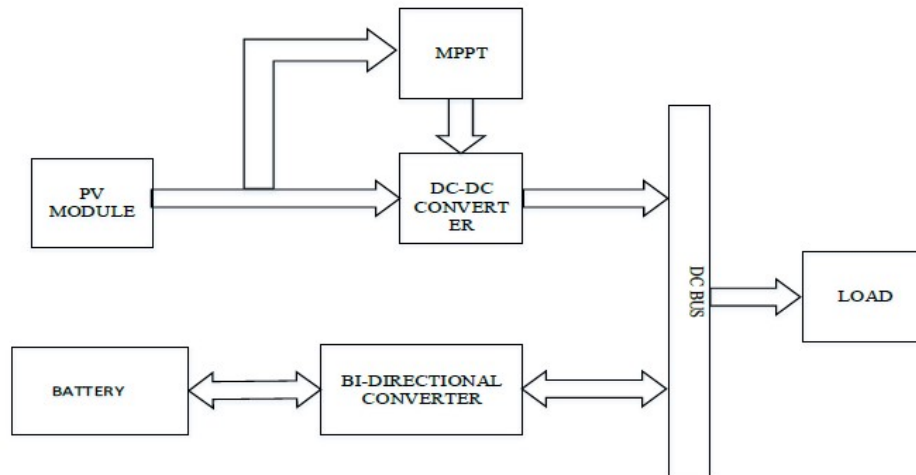
Figure 2.1 Overall block diagram of PV energy system

It contains PV modules or arrays, which convert solar energy in the form of solarirradiation into electric energy. The dc-dc converter changes the level of the voltage to match it with the electrical appliances that are supplied by thissystem. This DC-DC converter may be either buck or boost or buck-boost contingent onthe required and available voltage levels. The maximum power point tracing system coerces the maximumpower from the PV modules. A bi-

directional converter which is able to supply the current in both the directions is used to charge the battery when there is a power surplus and the energy stored by the battery is discharged intotheloadwhenthereis a power deficit.

2.3 SOLAR CELL STRUCTURE

In most of today solar cells the absorption of photons, which results in the generation of the charge carriers, and the subsequent separation of the photo-generated charge carriers take place in semiconductor materials. Therefore, the semiconductor layers are the most important parts of a solar cell; they form the heart of the solar cell

There are a number of different semiconductor materials that are suitable for the conversion of energy of photons into electrical energy, each having advantages and drawbacks. In this chapter the most important semiconductor properties that determine the solar cell performance will be discussed.

The crystalline silicon (c- Si) solar cell, which dominates the PV market at present, has a simple structure, and provides a good example of a typical solar cell structure. An absorber material is typically a moderately-doped p-type square wafer having thickness around 300 μm and an area of 10×10 cm^2 or 12.5×12.5 cm^2.

On both sides of the c-Si wafer a highly doped layer is formed, n^+-type on the top side and p^+-type on the back side, respectively. These highly doped layers help to separate the photo-generated charge carriers from the bulk of the c-Si wafer.

In addition to semiconductor layers, solar cells consist of a top and bottom metallic grid or another electrical contact that collects the separated charge carriers and connects the cell to a load. Usually, a thin layer that serves as an antireflective coating covers the topside of the cell in order to decrease the reflection of light from the cell. In order to protect the cell against the effects of outer environment during its operation, a glass sheet or other type of transparent encapsulate is attached to both sides of the cell. In case of thin- film solar cells, layers that constitute the cell are deposited on a substrate carrier. When the processing

temperature during the deposition of the layers is low, a wide range of low-cost substrates such as glass sheet, metal or polymer foil can be used.
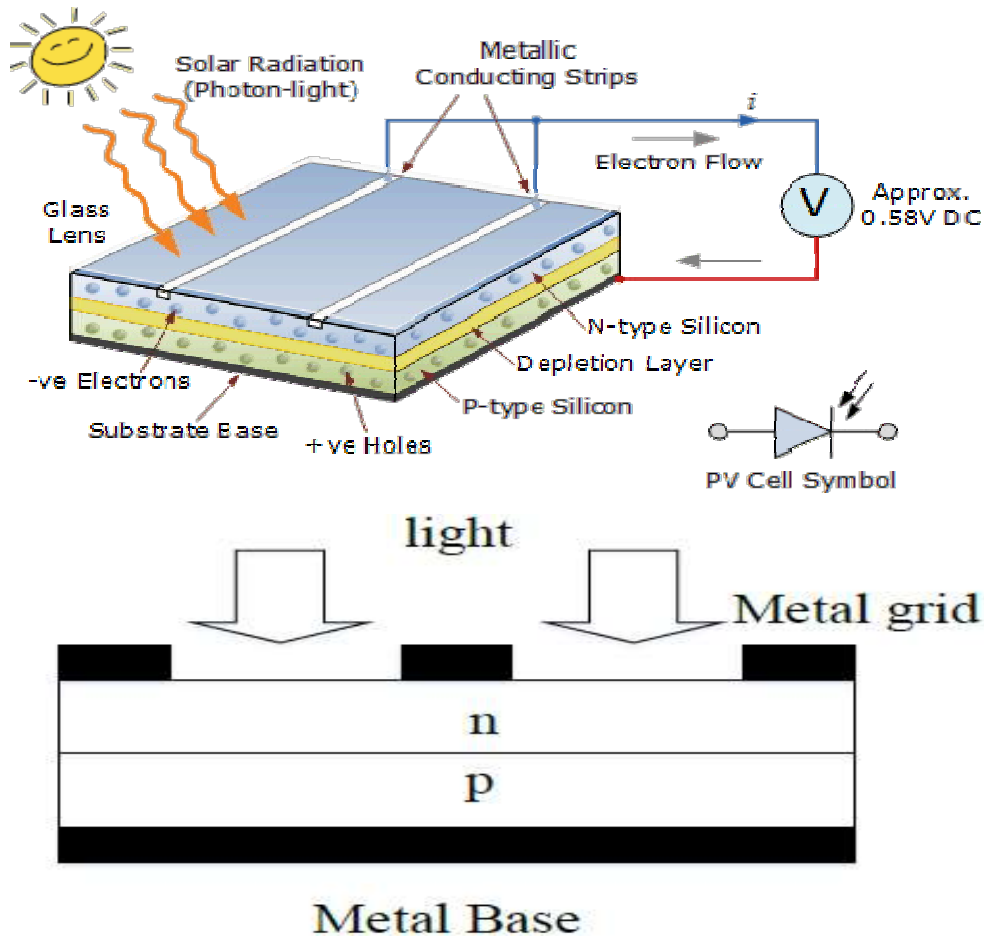
Figure 2.2 Basic structure of PV cell

The first successful solar cell was made from c -Si and c-Si is still the most widely used PV material. Therefore we shall use c-Si as an example to explain semiconductor properties that are relevant to solar cell operation. This gives us a basic understanding of how solar cells based on other semiconductor materials work.

2.4 PV CELL

Photovoltaic cell is the building block of the PV system and semiconductor material such as silicon and germanium are the building block of PV cell. Silicon is used for photovoltaic cell due to its advantages over germanium. When photons hit the surface of solar cell, the

electrons and holes are generated by breaking the covalent bond inside the atom of semiconductor material and in response electric field is generated by creating positive and negative terminals. When these terminals are connected by a conductor an electric current will start flowing. This electricity is used to power a load.

2.5 PV MODULE

A single cell generatevery low voltage (around 0.4), so more than one PV cells can be connected either in serial or in parallel or as a grid (both serial and parallel) to form a PV module as shown in fig.2.2. When we need higher voltage, we connect PV cell in series and if load demand is high current then we connect PV cell in parallel. Usually thereare 36 or 76 cells in general PV modules. Module we are using having 54 cells. The frontside ofthe module is transparent usually buildup of low-iron and transparent glass material, and the PV cell is encapsulated.

2.6 PV ARRAY

A photovoltaic array is simply an interconnection of several PV modules in serialand/or parallel. The power generated by individualmodules may not be sufficient to meet the requirement of trading applications, so the modules are secured in a grid form or as an array to gratify the load demand. In anarray, the modules are connected like as that of cells connected in a module. While making a PV array, generally the modules are initially connected in serial manner to obtain the desired voltage, and then strings so obtained are connected in parallel in order to produce more current based on therequirement.
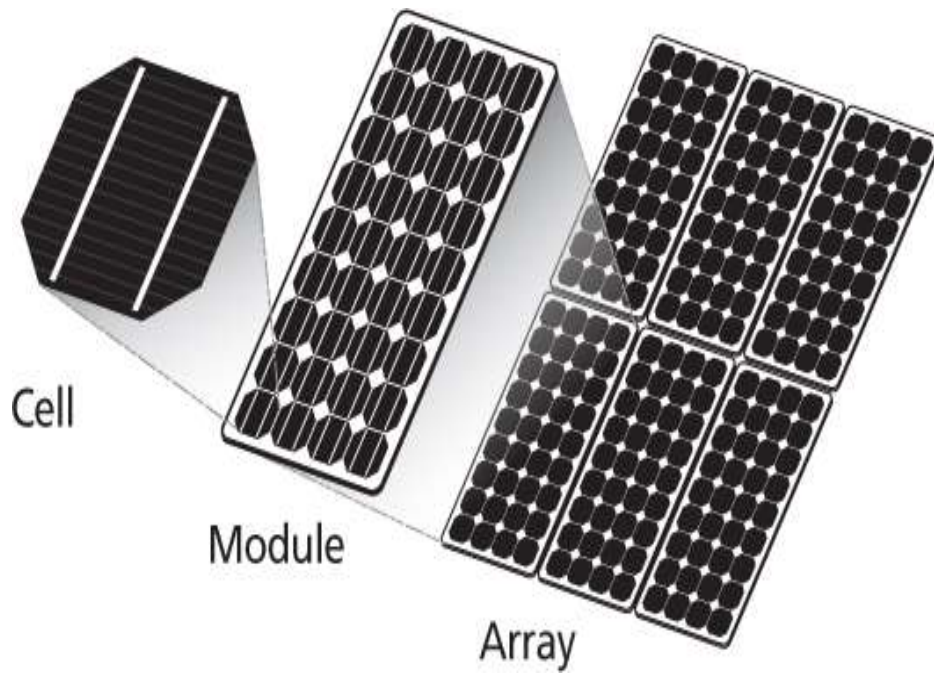
Figure 2.3 PV Cell, PV Module, PV Array

2.7 WORKING OF PV CELL

The basic theory involved in working of an individual PV cell is the Photoelectric effect according to which, when a photon particle hits a PV cell,
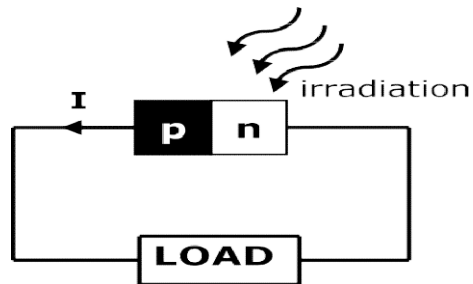
after receivingenergy

Figure 2.4 Working of PV cell

fromsunbeam the electrons of the semiconductor get excitedand hop to the conduction band from the valence band and become free to move. Movement ofelectrons create positive and negative terminal and also create potential difference across these two terminals. When an external circuit is connected between these terminals anelectric current start flowing through thecircuit.

2.8 MODELING OF PV CELL

The photovoltaic system converts sunlight directly to electricity without having any disastrous effect on our environment. The basic segment of PV array is PV cell, which is just a simplep-njunctiondevice.Thefig.2.5manifeststheequivalentcircuitofPVcell .Equivalent circuit has acurrent source (photocurrent), a diode parallel to it, a resistor in series describing an internal resistanceto the flow of current and a shunt resistance which expresses a leakage current. The current supplied to the load can be givenas.

$$I = I_{PV} - I_0\left[\exp\left(\frac{V + IR_S}{aV_T}\right) - 1\right] - \left[\frac{V + IR_S}{R_P}\right]$$

(2.1)

Where

I_{PV}–Photocurrent current,

I_O–diode's Reverse saturation current,

V–Voltage across the diode,

a– Ideality factorV_T–Thermal voltage R_s– Series resistance R_p–Shuntresistance
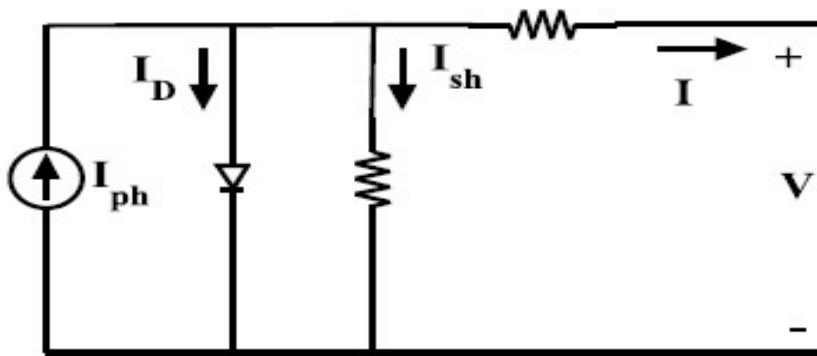
Figure 2.5 Equivalent circuit of Single diode model of a solar cell

PV cell photocurrent, which depends on the radiation and temperature, can be expressed as.

$$I_{PV} = \left(I_{PV\_STC} + K_I\Delta T\right)\frac{G}{G_{STC}}$$

(2.2)

Where

K_I– cell's short circuit current temperature coefficient,

G–solar irradiation in W/m²

G_{STC}–nominal solar irradiation in W/m²

I_{PV_STC}– Light generated current under standard test condition

The reverse saturation current varies as acubic function of temperature, which is representedas

$$I_0 = I_{0\_STC}\left(\frac{T_{STC}}{T}\right)^3 \exp\left[\frac{qE_s}{aK}\left(\frac{1}{T_{STC}} - \frac{1}{T}\right)\right]$$

$$(2.3)$$

Where

I_{0_STC}– Nominal saturation current

E_g– Energy band gap of semiconductor T_{STC}–temperature at standard test condition q – Charge ofelectrons

The reverse saturation current can be further improved as afunction of temperature as follows

$$I_0 = \frac{\left(I_{SC\_STC} + K_1\Delta T\right)}{\exp\left[\frac{\left(V_{OC\_STC} + K_V\Delta T\right)}{aV_T}\right] - 1}$$

$$(2.4)$$

I_{SC_STC}– short circuit current at standard test condition V_{OC_STC}– short circuit voltage at standard test condition K_V– temperature coefficient of open circuit voltage

Many authors proposed more developed models forbetter accuracy and for different purposes. In some of the models, the effect of the recombination of carriers is represented by an extra diode. Some authors also used three diode models which included influences of some other effects that are not considered in previous models. But dueto simplicity we use single diode model for ourwork .

Efficiency of a PV cell does notdepend on the variation in theshuntresistance$R_p$of the cell but efficiency of a PV cell greatly depends on thevariationinseriesresistanceR_s. As $R_p$of the cell is inversely proportionalto the shunt leakage current to ground so it can be assumed to be very large value

for a very small leakage current toground.As the total power generated by a single PV cellis very low, we used a combination of PV cells to fulfill our desired requirement. The equations of the PV array can be representedas

$$I = I_{PV}N_P - I_0 N_P \left[\exp\left(\frac{V + IR_S\left(\dfrac{N_S}{N_P}\right)}{aV_T N_S} \right) - 1 \right] - \left[\frac{V + IR_S\left(\dfrac{N_S}{N_P}\right)}{R_P\left(\dfrac{N_S}{N_P}\right)} \right]$$

(2.5)

N_S– Number of seriescells,

N_P– Number of parallel cells
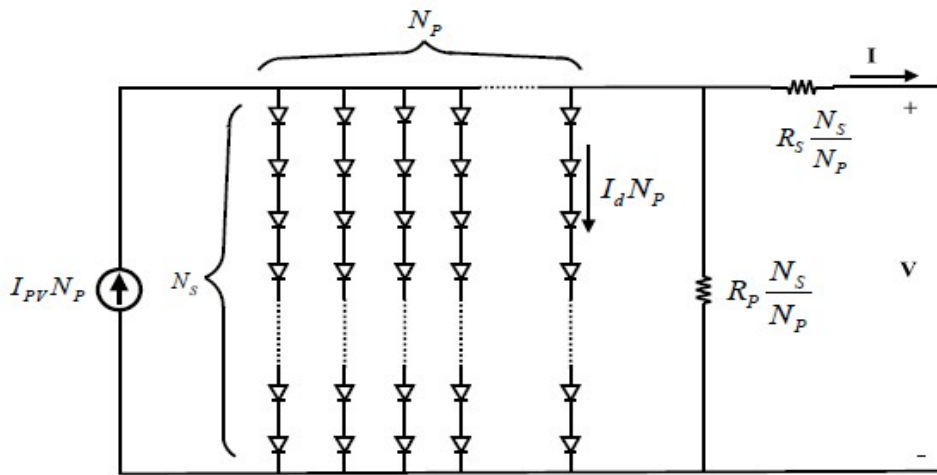
Figure 2.6 Representation of PV module

A small change in series resistance canaffect more on the efficiency of a PV cells but variation in shunt resistance does not affect more. For very small leakage current to ground, shunt resistance assumed to be infinity and can be treated as open. After considering shunt resistance infinity, the mathematical equationof the model can be expressedas.

$$I = I_{PV}N_P - I_0 N_P \left[\exp\left(\frac{V + IR_S\left(\dfrac{N_S}{N_P}\right)}{aV_T N_S} \right) - 1 \right]$$

CHAPTER-3

OVERVIEW OF MAXIMUM POWER POINT TRACKING

3.1 INTRODUCTION

Studies show that a solar panel converts 30-40% of energy incident on it to electrical energy. A Maximum Power Point Tracking algorithm is necessary to increase the efficiency of the solar panel.

There are different techniques for MPPT such as Perturb and Observe (hill climbing method), Incremental conductance, Fractional Short Circuit Current, Fractional Open Circuit Voltage, Fuzzy Control, Neural Network Control etc. Among all the methods Perturb and observe (P&O) and Incremental conductance are most commonly used because of their simple implementation, lesser time to track the MPP and several other economic reasons.

Under abruptly changing weather conditions (irradiance level) as MPP changes continuously, P&O takes it as a change in MPP due to perturbation rather than that of irradiance and sometimes ends up in calculating wrong MPP. However this problem gets avoided in Incremental Conductance method as the algorithm takes two samples of voltage and current to calculate MPP. However, instead of higher efficiency the complexity of the algorithm is very high compared to the previous one and hence the cost of implementation increases. So we have to mitigate with a trade off between complexity and efficiency.

It is seen that the efficiency of the system also depends upon the converter. Typically it is maximum for a buck topology, then for buck-boost topology and minimum for a boost topology.

When multiple solar modules are connected in parallel, another analog technique TEODI is also very effective which operates on the principle of equalization of output operating points in correspondence to force displacement of input operating points of the identical operating system.

It is very simple to implement and has high efficiency both under

stationary and time varying Atmospheric condition.

A typical solar panel converts only 30 to 40 percent of the incident solar irradiation into electrical energy. Maximum power point tracking technique is used to improve the efficiency of the solar panel.

According to Maximum Power Transfer theorem, the power output of a circuit is maximum when thethevenin's impedance of the circuit (source impedance) matches with the load impedance.

Hence our problem of tracking the maximum power point reduces to an impedance matching problem. In the source side we are using a boost convertor connected to a solar panel in order to enhance the output voltage so that it can be used for different applications like motor load. By changing the duty cycle of the boost converter appropriately we can match the source impedance with that of the load impedance.

3.2DIFFERENT MPPT TECHNIQUES

There are different techniques used to track the maximum power point. Few of the most popular techniques are

i)   Perturb and Observe (hill climbing method)
ii) Incremental Conductance method
iii) Fractional short circuit current
iv) Fractional open circuit voltage
v)   Neural networks
vi) Fizzy logic

The choice of the algorithm depends on the time complexity the algorithm takes to track the MPPT, implementation cost and the ease of implementation

3.2.1Perturb & Observe method

Perturb & Observe (P&O) is the simplest method. In this we use only one sensor, that is the voltage sensor, to sense the PV array voltage and so the cost of implementation is less and hence easy to implement. The time complexity of this algorithm is very less but on reaching very close to the MPP it doesn't stop at the MPP and keeps on perturbing on both the directions. When this happens the algorithm has reached very close to the MPP and we can set an appropriate error limit or can use a wait function which ends up increasing the time complexity of the algorithm. However the method does not take account of the rapid change of irradiation level (due to which MPPT changes) and considers it as a change in MPP due to perturbation and ends up calculating the wrong MPP. To avoid this problem we can use incremental conductance method.

3.2.2   Incremental Conductance

Incremental conductance method uses two voltage and current sensors to sense the output voltage and current of the PV array.
At MPP the slope of the PV curve is 0

$$\left(\frac{dP}{dV}\right)_{MPP} = \frac{d(VI)}{dV}$$

(3.1)

$$0 = I + V\left(\frac{dI}{dV}\right)_{MPP}$$

(3.2)

$$\left(\frac{dI}{dV}\right)_{MPP} = \frac{-I}{V}$$

(3.3)

The left hand side is the instantaneous conductance of the solar panel. When this instantaneous conductance equals the conductance of the solar then MPP is reached. Here we are sensing both the voltage and current simultaneously. Hence the error due to change in irradiance is eliminated. However the complexity and the cost of implementation increase. As we go down the list of algorithms the complexity and the cost of implementation goes on increasing which may be suitable for a highly complicated system.

This is the reason that Perturb and Observe and Incremental Conductance method are the most widely used algorithms. Owing to its

simplicity of implementation we have chosen the Perturb & Observe algorithm for our study among the two.

3.2.3   Fractional open circuit voltage

The near linear relationship between V_{MPP} and V_{OC} of the PV array, under varying irradiance and temperature levels, has given rise to the fractional V_{OC} method

$$V_{MPP} = K_1 V_{OC}$$

(3.4)

Where k_1 is a constant of proportionality. Since k_1 is dependent on the characteristics of the PV array being used, it usually has to be computed beforehand by empirically determining V_{MPP} and V_{OC} for the specific PV array at different irradiance and temperature levels. The factor k_1 has been reported to be between 0.71 and 0.78. Once k_1 is known, V_{MPP} can be computed with V_{OC} measured periodically by momentarily shutting down the power converter. However, this incurs some disadvantages, including temporary loss of power.

3.2.4   Fractional short circuit current

Fractional I_{SC} results   from the fact that, under varying atmospheric conditions, I_{MPP} is approximately linearly related to the I_{SC} of the PV array.

$$I_{MPP} = K_2 I_{SC}$$

(3.5)

Where k_2 is a proportionality constant. Just like in the fractional V_{OC} technique, k_2 has to be determined according to the PV array in use. The constant k_2 is generally found to be between 0.78 and 0.92. Measuring I_{SC} during operation is problematic. An additional switch usually has to be added to the power converter to periodically short the PV array so that ISC can be measured using a current sensor.

3.2.5   Fuzzy Logic Control

Microcontrollers have made using fuzzy logic control popular for MPPT over last decade. Fuzzy logic controllers have the advantages of working with imprecise inputs, not needing an accurate mathematical model, and handling nonlinearity

3.2.6   Neural Network

Another technique of implementing MPPT which are also well adapted for microcontrollers   is neural networks. Neural networks commonly have three layers input, hidden, and output layers. The number nodes in each layer vary and are user-dependent. The input variables can be PV array parameters like V_{OC} and I_{SC}, atmospheric data like irradiance and temperature, or any combination of these. The output is usually one or several reference signals like a duty cycle signal used to drive the power converter to operate at or close to the MPP.

TABLE 3.1 CHARACTERISTICS OF DIFFERENT MPPT TECHNIQUES

MPPT technique	ConvergenceSpeed	Implementation complexity	Periodic tuning	Sensed parameters
Perturb & observe	Varies	Low	No	Voltage
Incremental conductance	Varies	Medium	No	Voltage, Current
Fractional V_{oc}	Medium	Low	Yes	Voltage
Fractional I_{sc}	Medium	Medium	Yes	Current
Fuzzy logic control	Fast	High	Yes	Varies
Neural network	Fast	High	Yes	Varies

CHAPTER-4

DC –DC CONVERTER

4.1 INTRODUCTION

Before the development of power semiconductors and allied technologies, one way to convert the voltage of a DC supply to a higher voltage, for low-power applications, was to convert it to AC by using a <u>vibrator</u>, followed by a step-up <u>transformer</u> and <u>rectifier</u>. For higher power an electric motor was used to drive a generator of the desired voltage (sometimes combined into a single "dynamotor" unit, a motor and generator combined into one unit, with one winding driving the motor and the other generating the output voltage). These were relatively inefficient and expensive procedures used only when there was no alternative, as to power a car radio (which then used thermionic valves/tubes requiring much higher voltages than available from a 6 or 12 V car battery). The introduction of power semiconductors and integrated circuits made it economically viable to use techniques as described below, for example to convert the DC power supply to high-frequency AC, use a transformer—small, light, and cheap due to the high frequency—to change the voltage, and rectify back to DC.

DC to DC converters are used in portable electronic devices such as <u>cellular phones</u> and <u>laptop computers</u>, which are supplied with power from <u>batteries</u> primarily. Such electronic devices often contain several sub-<u>circuits</u>, each with its own voltage level requirement different from that supplied by the battery or an external supply (sometimes higher or lower than the supply voltage). Additionally, the battery voltage declines as its stored energy is drained. Switched DC to DC converters offer a method to increase voltage from a partially lowered battery voltage thereby saving space instead of using multiple batteries to accomplish the same thing. One of the DC-DC converter used to convert is Fly back converter and Boost converter.

4.2 APPLICATIONS OF DC-DC CONVERTERS

1. Dc converters can be used in regenerative braking of dc motors to return energy   back into the supply and this feature results in energy savings for transportation system with frequent stops. As for example

a) Traction motor control in electric automobiles.

b) Trolley cars

c) Marine Hoists

d) Forklift trucks

e) Mine Haulers

2. Also used in DC voltage regulators and also are used in conjunction with an inductor to generate a dc current source especially for the current source inverter.

4. 3 SWITCHING CONSIDERATION OF DC-DC CONVERTERS

The converter switch can be implemented by using

a) Power bipolar junction transistor (BJT)

b) Power Metal Oxide Semiconductor Field Effect Transistor (MOSFET)

c) Gate Turn Off Thyristor (GTO)

d) Insulated gate bipolar transistor (IGBT)

Practical devices have a finite voltage drop ranging from 0.5V to 2V but during the calculations for the sake of simplicity of the understanding, these switches are considered lossless.

4.4 TYPES OF DC-DC CONVERTERS

DC-DC converter is an electrical circuitwhose main application is to transform   a   dc voltage from one level to another level. It is   similarto   a transformer in AC source, it can able to step the voltage level up or down. The variabledc voltage level can be regulated by controlling the duty ratio (on-off time of a switch) of the converter.

There are various types of dc-dc converters thatcan be used to transform the level of the voltage as per the supply availability and load requirement. Some ofthem are discussedbelow

- Buck converter
- Boost converter
- Buck-Boost converter
- The CUK converter
- The Fly-back converter
- The Forward Converter
- The Push-pull Converter
- The Full Bridge converter
- The Half Bridge Converter
- Current Fed converter
- Multiple output converters

4.4.1 Buckconverter

The functionality of a buck converter is to reduce the voltagelevel. The circuitdiagram of the buck converter is manifested in figure4.1.
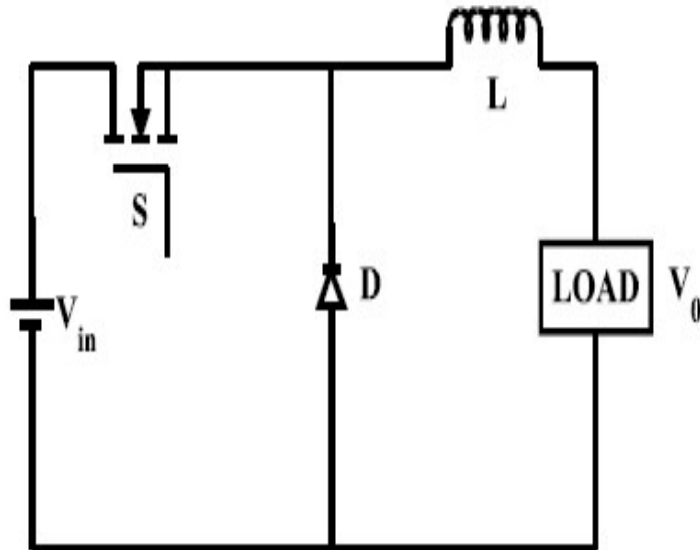
Figure 4.1 circuit diagram of buck converter

When the switching element is instate of conduction the voltage appearing across the load is $V_{in}$and the current is supplied from source to load. When the switch is offthe load voltage is zero and the direction of current remains the same. As thepower flows from source side to load side, the load sidevoltage remains less than the source side voltage. The output voltage is determined as a functionof source voltage using the duty ratio of the gate pulse given to the switch. It is the product of the duty ratio andthe input voltage.

The buck converter is a ubiquitous DC-DC converter that efficiently converts a high voltage to a low voltage efficiently. Efficient power conversion extends battery life, reduces heat, and allows for smaller gadgets to be built. The buck converter can be used in lots of cool applications.

(a) Continuous Conduction Mode
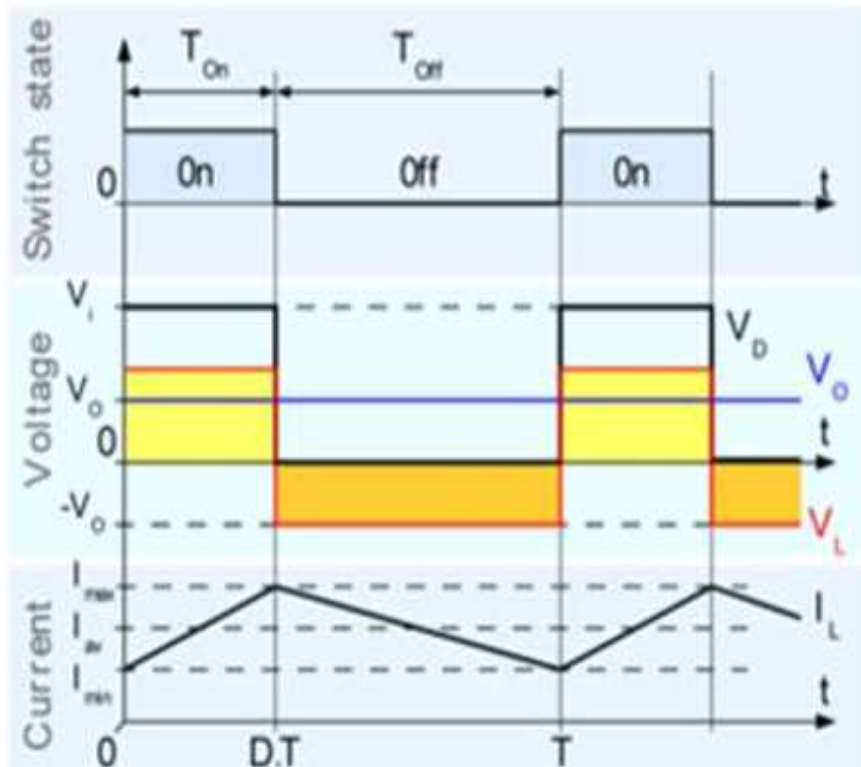
Figure 4.2 Evolution of the voltages and currents with time in an ideal buck converter operating in continuous mode

(b) Discontinuous Conduction Mode
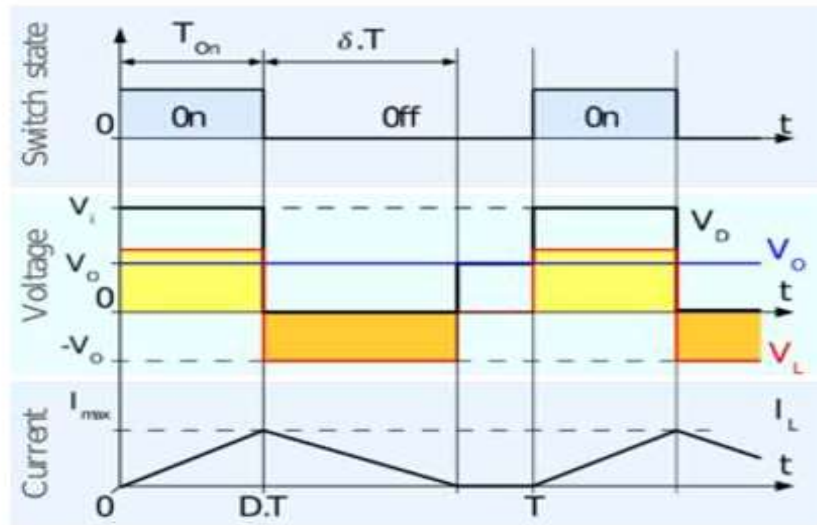
Figure 4.3 Evolution of the voltages and currents with time in an ideal buck converter operating in discontinuous mode.

4.4.2 Boostconverter

The functionality of boost converter is toincreasethevoltagelevel.
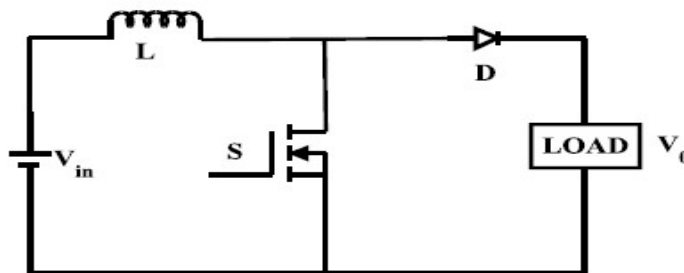
Figure 4.4 circuit diagram of boost converter

Thecircuit configuration of the boost converter is manifested in figure4.4.Thecurrent carried by the inductor starts rising and it stores energy during ON time of the switching element. The circuit is said to be incharging state. During OFFcondition, the reserve energy of the inductor starts dissipating into the load along with the supply. The output voltage level exceeds that of the input voltage and is dependent on the inductor time constant.

The load sidevoltage is the ratio of source side voltage and the duty ratio of the switchingdevice.

(a) Continuous Conduction Mode
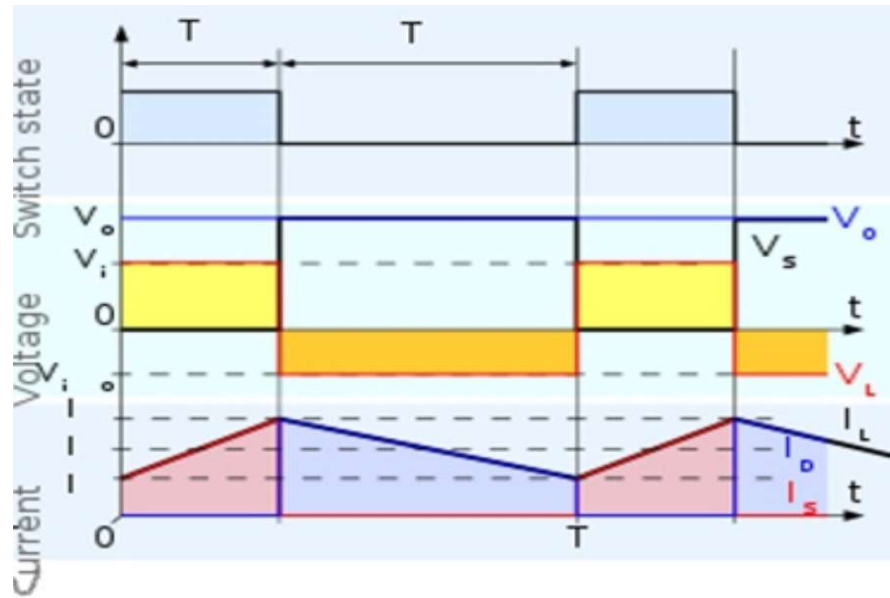
Figure 4.5 Waveforms of current and voltage in a boost converter operating in continuous mode

(b) Discontinuous Conduction Mode
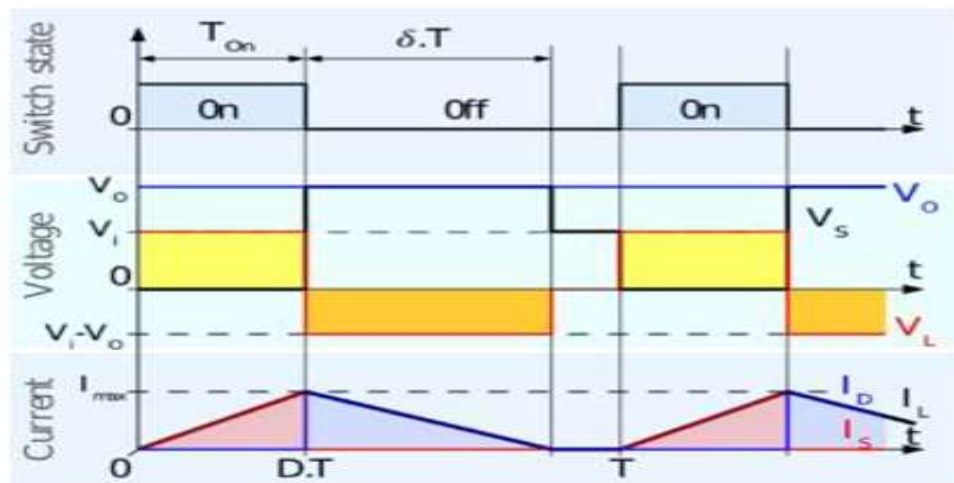
Figure 4.6 Waveforms of current and voltage in a boost converter operating in discontinuous mode

4.4.3 Buck-Boostconverter

The functionality of abuck-boostconverteris toset the level of load side voltage to either greater than or less than that of the source side voltage. The circuitconfiguration of the buck-boost converter is manifested in figure4.7.
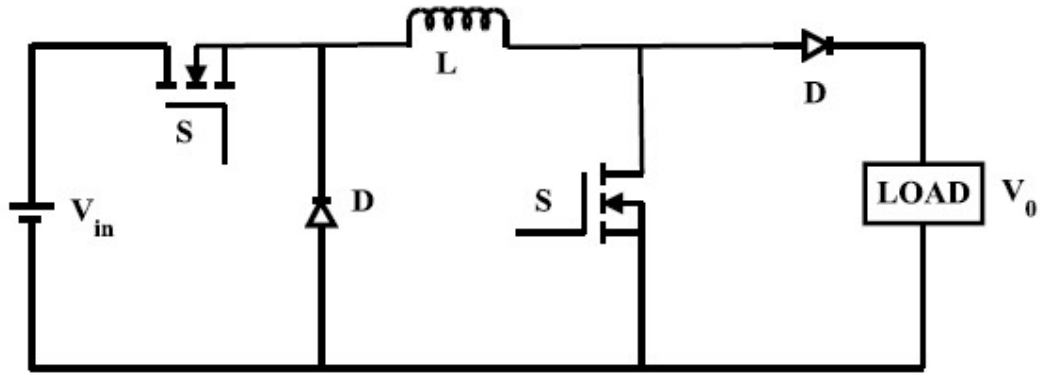
Figure 4.7 circuit diagram of buck-boost converter

When the switches are in the state of conduction, thecurrent carried by the inductor starts rising and it stores energy. The circuit issaid to be in charging state. While the switches are in the OFF state, thisstoredenergyof the inductor isdissipated to the load through the diodes.

The output voltage can be varied based on the On-time of the switches. The buck-boost converter acts as both buck andboost converters depending on the duty cycle of the switches. For the duty ratio less than 50% it acts as a buck converter and for the duty ratio exceeds than 50% it acts as boostconverter.As the voltage can be stepped both up and down, we usebuck-boost converter for our convenience in ourwork.

It is used in the self regulating power supplies, It is used in consumer electronics, It is used in the Battery power systems, Adaptive control applications, Power amplifier applications.

(a) Continuous Conduction Mode
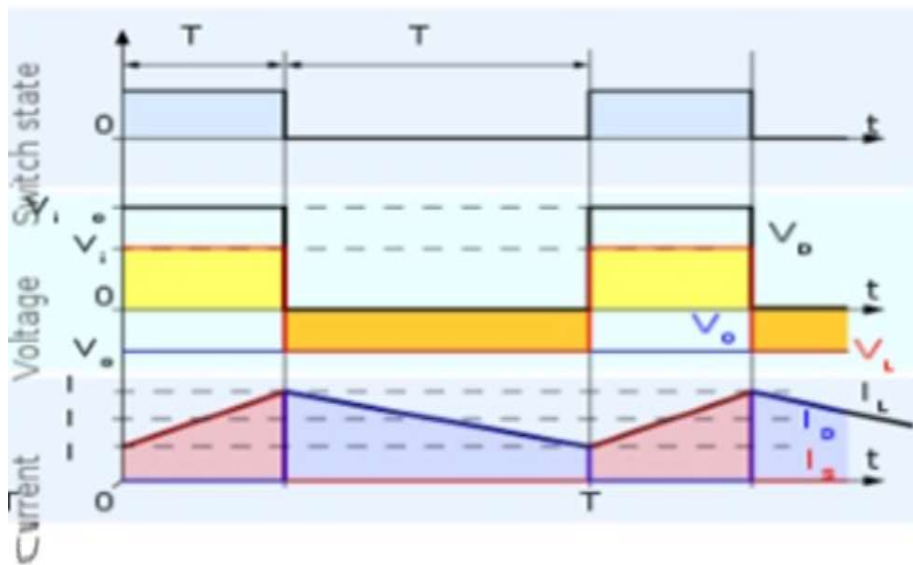
Figure 4.8 Waveforms of current and voltage in a buck–boost converter operating in continuous mode

(b) Discontinuous Conduction Mode
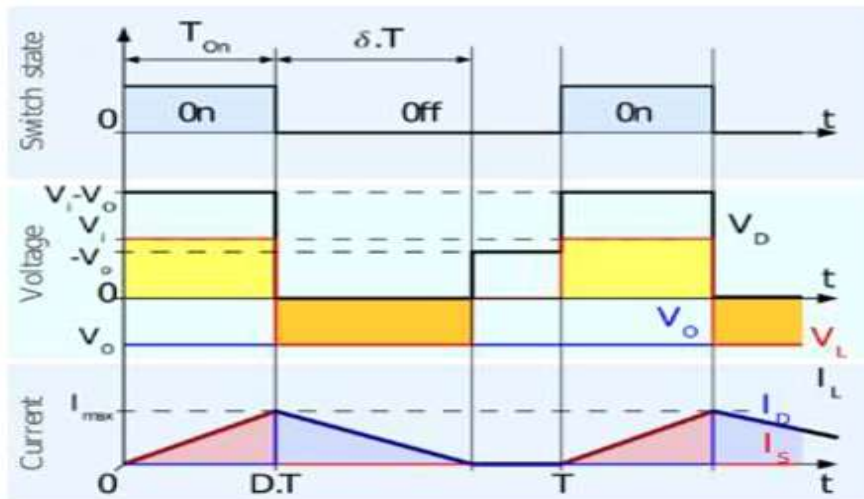
Figure 4.9 Waveforms of current and voltage in a buck–boost converter operating in discontinuous mode

CHAPTER-5

INVERTERS

5.1 INTRODUCTION

An inverter is a power electronic device that converts <u>direct current</u> (DC) to <u>alternating current</u> (AC) at the required frequency and voltage output. It is not the same thing as an <u>alternator</u>, which converts <u>mechanical energy</u> (e.g. <u>movement</u>) into alternating current.

Direct current is created by devices such as <u>batteries</u> and <u>solar panels</u>. When connected, an inverter allows these devices to provide <u>electric power</u> for small household devices. The inverter does this through a complex process of electrical adjustment. From this process, AC electric power is produced. This form of electricity can be used to power an <u>electric light</u>, a <u>microwave oven</u>, or some other electric machine.

An inverter usually also increases the <u>voltage</u>. In order to increase the voltage, the current must be decreased, so an inverter will use a lot of current on the DC side when only a small amount is being used on the AC side.

Inverters are made in many different sizes. They can be as small as 150 <u>watts</u>, or as large as 1 megawatt (1 million watts). Smaller inverters often plug into a car's cigarette lighter socket and provide 120 or 240 volt AC power from the car's 12 volt supply.

The earliest inverters consisted of a DC motor connected mechanically to an AC generator. A later design often used with vacuum tube car radios consisted of a rapidly switching <u>relay</u>. Modern inverters are based on <u>MOSFET</u> or IGBT <u>transistors</u>.

5.2 CLASSIFICATION OF INVERTER

Inverter can be classified into many types based on output, source, type of load etc. Below is the complete classification of the inverter circuits

(I) According to the Output Characteristic

1. Square Wave Inverter
2. Sine Wave Inverter
3. Modified Sine Wave Inverter

(II) According to the Source of Inverter

1. Current Source Inverter
2. Voltage Source Inverter

(III) According to the Type of Load

1. Single Phase Inverter

    1. Half Bridge Inverter
    2. Full Bridge Inverter

2. Three Phase Inverter

    1. 180-degree mode
    2. 120-degree mode

(IV) According to different PWM Technique

1. Simple Pulse Width Modulation (SPWM)
2. Multiple Pulse Width Modulation (MPWM)
3. Sinusoidal Pulse Width Modulation (SPWM)
4. Modified sinusoidal Pulse Width Modulation (MSPWM)

(V) According to Number of Output Level

1. Regular Two-Level Inverter
2. Multi-Level Inverter

5.3 MULTI LEVEL INVERTER

Multilevel Converters has been attracted a large interest in the power industry in the recent years. Industry has started to involve in higher power equipment, which already reaches megawatt level. Conventional power electronic converters are only able to switch each individual input or output link between two possible voltage levels, especially those of the internal DC voltage link. The general structure of the multilevel converter is to generate a sinusoidal voltage from several levels of voltages which are usually obtained from capacitor voltage sources. Three different topologies have been projected for multilevel converters Diode clamped converter; Flying capacitor converter (Capacitor Clamped); and lastly cascaded converter. Several

modulation and control strategies have been developed or being used for multilevel converters including the following Multilevel sinusoidal pulse width modulation (PWM), multilevel selective harmonic elimination, and space-vector modulation (SVM).

5.3.1 Advantages of multilevel Inverter

1. They are able to generate output voltages with very low distortion and lower dv/dt.

2. They are able to bring in input current with very low input distortion.

3. They are able to produce smaller common mode (CM) voltage, therefore, reducing the stress in the motoring bearings.

4. They can be functioned with a much lower switching frequency.

5.3.2 DC-AC three-level NPC Inverter
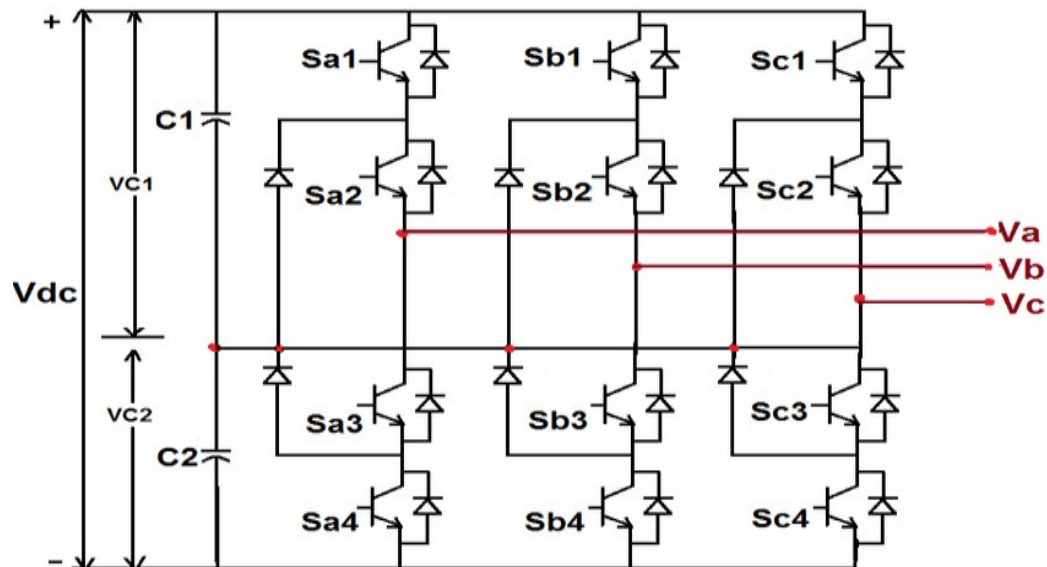
Figure 5.1 Three-level Neutral point-Clamped inverter

The three level neutral point clamped inverter is shown in the Figure 5.1. This inverter is the modified form of two-level inverter topology with the addition of two new semiconductor switches per phase. The two capacitor C1 and C2 split the dc bus voltage which make the neutral point 'P' that generate an additional voltage level hence making it three-level inverter. The

clamping diode limits the voltage stress across the switches to the value of the voltage across the capacitor that is Vdc/2. Table 5.1 shows the switching states for three-level inverter. The inverter output is Vdc/2 when switch S1 and S2 are on while output –Vdc/2 when switch S3 and S4 are switched on. The inverter generates switching state 0 when S2 and S3 are on. NPC offers many advantages like the capacitance requirement in this topology is reduced as all phases share common dc bus; hence back to back topology is suitable for practical uses just like for multi drive and high voltage back to back interconnections. Further, capacitors can be charged prior treating them as group. However, NPC has some disadvantages too, the number of clamping diode increase with the increase in number of levels which can be unmanageable. The reverse recovery of these clamping diode presents a major design challenge when the inverter is operating under PWM in high voltage high power application.

TABLE 5.1 THREE-LEVEL INVERTER SWITCHING STATES

Switching State	Device Switching Status (Phase A)				Inverter Terminal Voltage
	S1	S2	S3	S4	
1	ON	ON	OFF	OFF	+0.5Vdc
0	OFF	ON	ON	OFF	0Vdc
-1	OFF	OFF	ON	ON	-0.5Vdc

CHAPTER-6

WIND ENERGY SYSTEM

6.1 INTRODUCTION

Wind turbines are commonly described in terms of rated power, also known as rated output or rated capacity. Rated power is the instantaneous output of the turbine (measured in watts) at a certain wind speed (called the rated speed) at a standard temperature and altitude. The rated power of small wind turbines falls in the range of 1,000 to 100,000 watts. One thousand watts is one kilowatt (kW). Large wind turbines include all of those turbines over 100 kilowatts. Most larger turbines, however, are rated at one megawatt or higher. A megawatt is a million watts or 1,000 kilowatts. It is important to note that wind turbines do not produce their rated power all of the time, only when they're running at their rated wind speed.

6.2 ADVANTAGES OF WIND ENERGY

Although residential wind turbines and their energy source, the wind, have a few downsides, wind energy is an abundant and renewable resource. We won't run out of wind for the foreseeable future, unlike oil and natural gas. Small-scale wind energy could also help decrease our reliance on declining and costly supplies of oil, if electricity generated by wind is used to power electric or plug-in electric hybrid cars and trucks, displacing gasoline, which is refined from oil. Wind could even eventually reduce our dependence on nuclear power as well.

In the developed countries, nuclear power plants generate about 20 percent of the nation's electricity. Although wind energy does have its impacts, it is a relatively benign technology compared to conventional sources of electricity. It could help all countries create cleaner and safer energy at a fraction of the environmental cost of conventional electrical energy production. Wind energy can help nations reduce global warming and devastating changes in our climate. Wind can also help homeowners and businesses do their part in solving other costly environmental problems such as acid rain. An increasing reliance on wind energy could therefore ease

international political tension. Wind is also a free resource. The cost of wind is not subject to price increases.

A wind- and solar-powered future might be one subject to less inflation. This is not to say that wind energy will be free of price increases. While the fuel itself (the wind) is free, the price of wind generators is likely to increase. That's because it takes energy to extract and process minerals to make the steel and copper needed for wind turbines and towers. It also takes energy to make turbines and towers and ship and install them.

As the price of conventional fuels and raw materials increases, the cost of wind energy also will go up. Yet another advantage of wind-generated electricity is that it uses existing infrastructure, the electrical grid, and existing technologies. A transition to wind energy could occur fairly seamlessly. In remote locations, wind or wind and solar electric hybrid systems can be cheaper than conventional power.

6.3 WIND GENERATORS

Horizontal axis wind turbines consist of three main parts (1) a rotor, (2) an alternator, and (3) a tail. The rotor consists of blades attached to a central hub covered by a nose cone to improve aerodynamics. Most upwind turbines have three blades. This entire assembly rotates when wind blows past the blades, hence the name "rotor." In many small wind turbines the rotor is attached to a shaft that's attached to an alternator, a device that produces AC electricity. The anatomy of a Wind Generator is shown in fig. 6.1
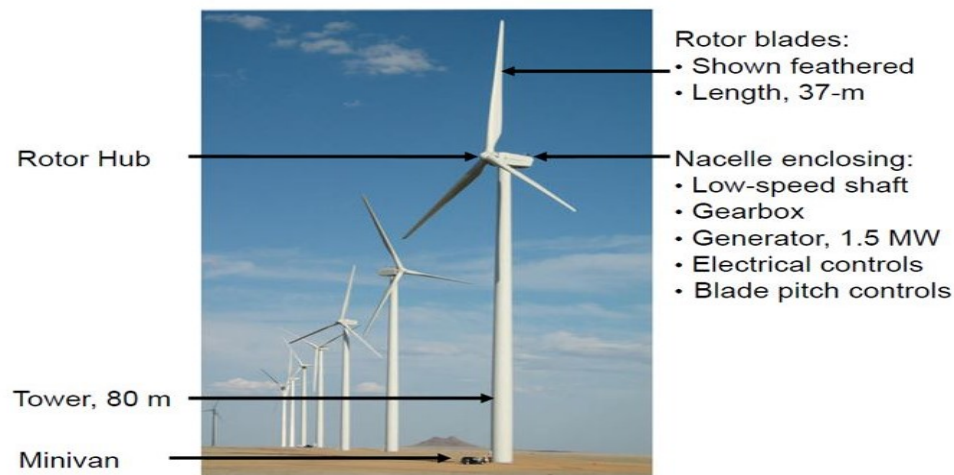
Figure 6.1 Anatomy of a Wind Generator

Alternators produce electricity. They consist of two main parts a set of stationary windings, known as the stator; and a set of rotating magnets, known as the rotor. Most small wind turbines use metal magnets, rather than electromagnets. The movement of the magnets around the windings (as the blades spin) induces an electrical current in the windings. Wind turbines, therefore, first convert the kinetic energy of the wind into mechanical energy (rotation). The mechanical energy is then converted into electrical energy in the alternator. Wind generators such as the ones shown in figure are known as direct drive turbines because the rotor of the turbine is attached directly to the rotor of the alternator.

As a result, the rotor and the alternator turn at the same speed. Although virtually all modern residential wind machines are direct drive, a few of the small wind turbines contain gearboxes. They're located between the rotor of the turbine and the rotor of the alternator. Gearboxes increase the speed at which the alternator spins, increasing the output of the alternator. This allows the alternator to be much smaller and also maintains a rotor speed (blade speed) that is safe and quiet. These turbines are known as generator.

6.4 POWER CONTAINED IN WIND

The power contained in wind is given by kinetic energy of the flowing air mass per unit time which is given by

$$P_{wind} = \frac{\pi}{8} dD^2 V_{wind}^3$$

(6.1)

Where P_{wind} is the power contained in wind, d is the air density

A is the rotor area

V_{wind} is the wind velocity.

There are several factors that contribute to the efficiency of the wind turbine in extracting the power from the wind. Firstly, the wind speed is one of the important factors in determining how much power can be extracted from the wind. This is because the power produced from the wind turbine is a function of the cubed of the wind speed.

Thus, the wind speed if doubled, the power produced will be increased by eight times the original power as shown in the curve of fig. 6.2. Then, location of the wind farm plays an important role in order for the wind turbine to extract the most available power from the wind.
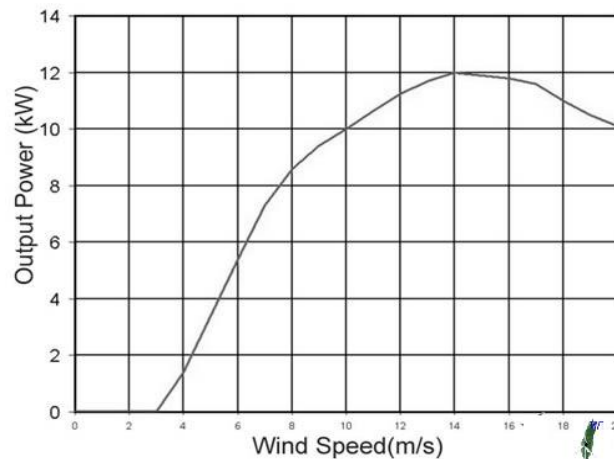
Figure 6.2 Power-Wind speed Curve

The second important factor of the wind turbine is the rotor blade. The rotor blades and length of the wind turbine is one of the important aspects of the wind turbine since the power produced from the wind is also proportional to the swept area of the rotor blades i.e. the square of the diameter of the swept area. Hence, by doubling the diameter of the swept area, the power produced will be four fold increased. It is required for the rotor blades to be strong and light and durable.

6.5 TYPES OF WIND TURBINES

Depending on their axis alignment Wind turbines can be categorized as

1) Horizontal-axis wind turbines
    a) Dutch-type grain-grinding windmills
    b) Multi-blade water-pumping windmills
    c) High-speed propeller type windmills
2) Vertical-axis wind turbines
    a) The Savonius rotor
    b) The Darrieus rotor

6.5.1 Horizontal-axis wind turbines

Horizontal axis wind turbines are the most common type used. All of the components (blades, shaft, and generator) are on top of a tall tower, and the blades face into the wind. The shaft is horizontal to the ground. The wind hits the blades of the turbine that are connected to a shaft causing rotation. The shaft has a gear on the end which turns a generator. The generator produces electricity and sends the electricity into the power grid. The wind turbine also has some key elements that add to efficiency. Inside the Nacelle (or head) is an anemometer, wind vane, and controller that read the speed and direction of the wind. As the wind changes direction, a motor (yaw motor) turns the nacelle so the blades are always facing the wind. The power source also comes with a safety feature. In case of extreme winds the turbine has a break that can slow the shaft speed. This is to inhibit any damage to the turbine in extreme conditions.

Figure 6.3 Horizontal-axis wind turbines

6.5.2 Vertical-axis wind turbine

In vertical axis turbines the shaft the blades are connected to is vertical to the ground. All of the main components are close to the ground. Also, the wind turbine itself is near the ground, unlike horizontal where everything is on a tower. There are two types of vertical axis wind turbines; lift based and drag based. Lift based designs are generally much more efficient than drag, or 'paddle' designs.

Figure 6.4 Vertical – axis wind turbines

6.6 COMPONENTS OF WIND TURBINE

The main important components of a wind turbine are shown in fig 6.5
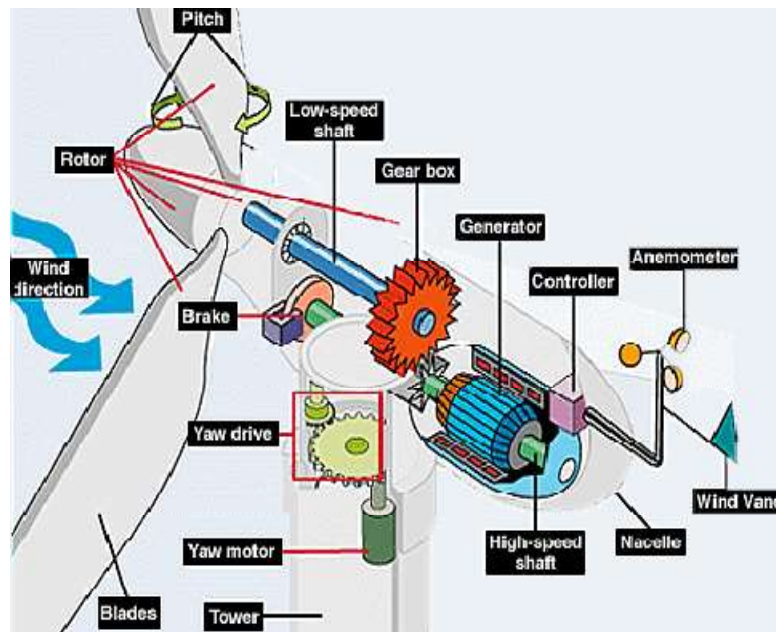
Figure 6.5 Components of wind turbine

6.6.1 Blades

Most wind turbines have three blades, though there are some with two blades. Blades are generally 30 to 50 meters (100 to165 feet) long, with the most common sizes around 40 meters (130 feet).

6.6.2 Controller

There is a controller in the nacelle and one at the base of the turbine. The controller monitors the condition of the turbine and controls the turbine movement.

6.6.3 Gearbox

Many wind turbines have a gearbox that increases the rotational speed of the shaft. A low-speed shaft feeds into the gearbox and a high-speed shaft feeds from the gearbox into the generator. Some turbines use direct drive generators that are capable of producing electricity at a lower rotational speed. These turbines do not require a gearbox.

6.6.4 Generators

Wind turbines typically have a single AC generator that converts the mechanical energy from the wind turbine's rotation into electrical energy. Clipper Wind power uses a different design that features four DC generators.

6.6.5 Nacelles

The nacelle houses the main components of the wind turbine, such as the controller, gearbox, generator and shafts.

6.6.6 Rotor

The rotor includes both the blades and the hub, the component to which the blades are attached.

6.6.7 Towers

Towers are usually tubular steel towers 60 to 80 meters (about 195 to 260 feet) high that consist of three sections of varying heights. (There are some towers with heights around 100 meters (330 feet)).

6.7 CLASSIFICATION OF WIND TURBINES

Based on speeds the wind turbines can be classified as

  i.   Fixed-Speed Wind Turbine

  ii.   Variable-Speed Wind Turbine

  iii. Variable-Speed Wind Turbine with Doubly-Fed Induction Generator

i. Fixed-Speed Wind Turbine

For the fixed-speed wind turbine the induction generator is directly connected to the electrical grid as shown in Fig. 6.6
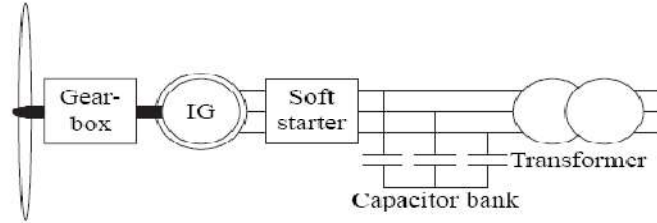
Figure 6.6 Fixed speed wind turbine with a an Induction Generator

The rotor speed of the fixed-speed wind turbine is in principle determined by a gearbox and the pole-pair number of the generator. The fixed-speed wind turbine system has often two fixed speeds. This is accomplished by using two generators with different ratings and pole pairs, or it can be a generator with two windings having different ratings and pole pairs. This leads to increased aerodynamic capture as well as reduced magnetizing losses at low wind speeds. This system (one or two-speed) was the "conventional" concept used by many Danish manufacturers in the 1980s and 1990s.

ii. Variable-Speed Wind Turbine
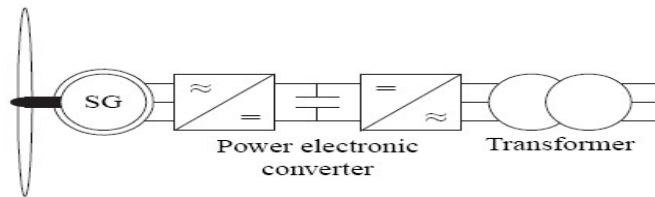
Figure 6.7 Variable speed driven wind turbine with a Synchronous Generator

The generator could either be a cage-bar induction generator or a synchronous generator. The gearbox is designed so that maximum rotor speed corresponds to rated speed of the generator. Synchronous generators or permanent-magnet synchronous generators can be designed with multiple poles which imply that there is no need for a gearbox, see Fig. 6.7. Since this "full-power" converter/generator system is commonly used for other

applications, one advantage with this system is its well-developed and robust control.

iii. Variable-Speed Wind Turbine with Doubly-Fed Induction Generator

This system, see Fig. 6.8, consists of a wind turbine with DFIG. This means that the stator is directly connected to the grid while the rotor winding is connected via slip rings to a converter. This system has recently become very popular as generators for variable-speed wind turbines.

This is mainly due to the fact that the power electronic converter only has to handle a fraction (20–30%) of the total power. Therefore, the losses in the power electronic converter can be reduced, compared to a system where the converter has to handle the total power. In addition, the cost of the converter becomes lower. There exists a variant of the DFIG method that uses controllable external rotor resistances (compare to slip power recovery). Some of the drawbacks of this method are that energy is unnecessary dissipated in the external rotor resistances and that it is not possible to control the reactive power.

6.8. DOUBLY FED INDUCTION GENERATOR

Doubly fed electrical generators are similar to AC electrical generators, but have additional features which allow them to run at speeds slightly above or below their natural synchronous speed. This is useful for large variable speed wind turbines, because wind speed can change suddenly. When a gust of wind hits a wind turbine, the blades try to speed up, but a synchronous generator is locked to the speed of the power grid and cannot speed up. So large forces are developed in the hub, gearbox, and generator as the power grid pushes back. This causes wear and damage to the mechanism. If the turbine is allowed to speed up immediately when hit by a wind gust, the stresses are lower and the power from the wind gust is converted to useful electricity.

One approach to allowing wind turbine speed to vary is to accept whatever frequency the generator produces, convert it to DC, and then convert it to AC at the desired output frequency using an inverter. This is

common for small house and farm wind turbines. But the inverters required for megawatt-scale wind turbines are large and expensive.

Doubly fed generators are one solution to this problem. Instead of the usual field winding fed with DC, and an armature winding where the generated electricity comes out, there are two three-phase windings, one stationary and one rotating, both separately connected to equipment outside the generator. Thus the term doubly fed.

One winding is directly connected to the output, and produces 3-phase AC power at the desired grid frequency. The other winding (traditionally called the field, but here both windings can be outputs) is connected to 3-phase AC power at variable frequency. This input power is adjusted in frequency and phase to compensate for changes in speed of the turbine.

Adjusting the frequency and phase requires an AC to DC to AC converter. This is usually constructed from very large IGBT semiconductors. The converter is bidirectional, and can pass power in either direction. Power can flow from this winding as well as from the output winding.

6.8.1 Basic Components Of DFIG –Based WECS

Wind turbines use a DFIG consisting of a wound rotor induction generator and an AC/DC/AC IGBT-based pulse width modulation (PWM)power converter. The schematic diagram of a WECS using DFIG is shown in fig.6.8
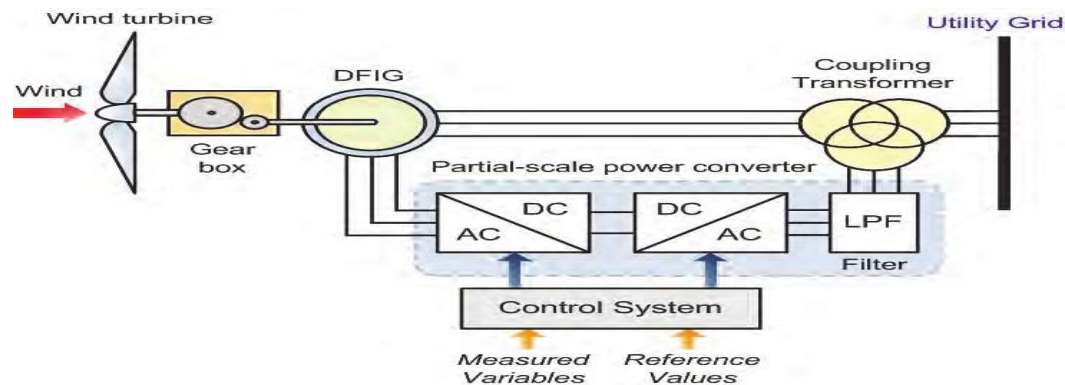
Figure 6.8 Basic configuration of DFIG in WECS

6.8.2 Operating Principle of DFIG

The principle of the DFIG is that rotor windings are connected to the grid via slip rings and back-to-back <u>voltage</u> source converter that controls both the rotor and the grid currents. Thus <u>rotor</u> <u>frequency</u> can freely differ from the grid frequency (50 or 60 Hz). By using the converter to control the rotor currents, it is possible to adjust the active and reactive power fed to the grid from the stator independently of the generator's turning speed. The control principle used is either the two-axis current <u>vector control</u> or <u>direct torque control</u> (DTC).DTC has turned out to have better stability than current vector control especially when high reactive currents are required from the generator.

The doubly-fed generator rotors are typically wound with 2 to 3 times the number of turns of the stator. This means that the rotor voltages will be higher and currents respectively lower. Thus in the typical ±30% operational speed range around the synchronous speed, the rated current of the converter is accordingly lower which leads to a lower cost of the converter. The drawback is that controlled operation outside the operational speed range is impossible because of the higher than rated rotor voltage. Further, the voltage transients due to the grid disturbances (three- and two-phase voltage dips, especially) will also be magnified. In order to prevent high rotor voltages (and high currents resulting from these voltages) from destroying the <u>insulated-gate   bipolar   transistors</u> and <u>diodes</u> of   the   converter,   a protection circuit (called <u>crowbar</u>) is used.

The crowbar will short-circuit the rotor windings through a small resistance when excessive currents or voltages are detected. In order to be able to continue the operation as quickly as possible an <u>active crowbar</u> has to be used. The active crowbar can remove the rotor short in a controlled way and thus the rotor side converter can be started only after 20–60 ms from the start of the grid disturbance when the remaining voltage stays above 15% of the nominal voltage. Thus, it is possible to generate reactive

current to the grid during the rest of the voltage dip and in this way help the grid to recover from the fault. For zero voltage ride through, it is common to wait until the dip ends because it is otherwise not possible to know the phase angle where the reactive current should be injected.

As a summary, a doubly-fed induction machine is a wound-rotor doubly-fed electric machine and has several advantages over a conventional induction machine in wind power applications. First, as the rotor circuit is controlled by a power electronics converter, the induction generator is able to both import and export reactive power. This has important consequences for power system stability and allows the machine to support the grid during severe voltage disturbances (low-voltage ride-through; LVRT). Second, the control of the rotor voltages and currents enables the induction machine to remain synchronized with the grid while the wind turbine speed varies. A variable speed wind turbine utilizes the available wind resource more efficiently than a fixed speed wind turbine, especially during light wind conditions. Third, the cost of the converter is low when compared with other variable speed solutions because only a fraction of the mechanical power, typically 25–30%, is fed to the grid through the converter, the rest being fed to grid directly from the stator. The efficiency of the DFIG is very good for the same reason.

CHAPTER-7

EVALUATION OF MATLAB/SIMULINK MODELLING & RESULTS

7.1 INTRODUCTION TO MATLAB

MATLAB is a high-level technical computing language and interactive environment for algorithm development, data visualization, data analysis, and numeric computation. Using the MATLAB product, you can solve technical computing problems faster than with traditional programming languages, such as C, C++, and FORTRAN.

MATLAB is used in wide range of applications, including signal and image processing, communications, control design, test and measurement, financial modeling and analysis, and computational biology. Add-on toolboxes (collections of special-purpose MATLAB functions, available separately) extend the MATLAB environment to solve particular classes of problems in these application areas.

MATLAB provides a number of features for documenting and sharing your work. You can integrate your MATLAB code with other languages and applications, and distribute your MATLAB algorithms and applications.

7.2 KEY FEATURES

- ➤ High-level language for technical computing.
- ➤ Development environment for managing code, files, and data
- ➤ Interactive tools for iterative exploration, design, and problem solving
- ➤ Mathematical functions for linear algebra, statistics, Fourier analysis, filtering, optimization, and numerical integration

- ➢ 2-D and 3-D graphics functions for visualizing data
- ➢ Tools for building custom graphical user interfaces
- ➢ Functions for integrating MATLAB based algorithms with external applications and languages, such as C, C++, Fortran, Java, COM, and Microsoft Excel

7.3 INTRODUCTION TO SIMULINK

Simulink is an environment for multi-domain simulation and Model-Based Design for dynamic and embedded systems. It provides an interactive graphical environment and a customizable set of block libraries that let you design, simulate, implement, and test a variety of time-varying systems, including communications, controls, signal processing, video processing, and image processing.

Add-on products extend Simulink software to multiple modeling domains, as well as provide tools for design, implementation, and verification and validation tasks. Simulink is integrated with MATLAB, providing immediate access to an extensive range of tools that let you develop algorithms, analyze and visualize simulations, create batch processing scripts, customize the modeling environment, and define signal, parameter, and test data.

A Simulink block diagram is a pictorial model of a dynamic system. It consists of a set of symbols, called blocks, interconnected by lines. Each block represents an elementary dynamic system that produces an output either continuously (a continuous block) or at specific points in time (a discrete block). The lines represent connections of block inputs to block outputs. Every block in a block diagram is an instance of a specific type of block. The type of the block determines the relationship between a block's outputs and its inputs, states, and time. A block diagram can contain any number of instances of any type of block needed to model a system. Blocks represent elementary dynamic systems that Simulink knows how to simulate. A block comprises one or more of the following

1) A set of inputs,

2) A set of states, and

3) A set of outputs

A block's output is a function of time and the block's inputs and states (if any). The specific function that relates a block's output to its inputs, states, and time depends on the type of block of which the block is an instance. Continuous Versus discrete Blocks Simulink standard block set includes continuous blocks and discrete blocks. Continuous blocks respond continuously to continuously changing input. Discrete blocks, by contrast, respond to changes in input only at integral multiples of a fixed interval called the block's sample time. Discrete blocks hold their output constant between successive sample time hits. Each discrete block includes a sample time parameter that allows you to specify its sample rate. The Simulink blocks can be either continuous or discrete, depending on whether they are driven by continuous or discrete blocks. A block that can be either discrete or continuous is said to have an implicit sample rate. The implicit sample time is continuous if any of the block's inputs are continuous. The implicit sample time is equal to the shortest input sample time if all the input sample times are integral multiples of the shortest time. Otherwise, the input sample time is equal to the fundamental sample time of the inputs, where the fundamental sample time of a set of sample times is defined as the greatest integer divisor of the set of sample times.

Simulink can optionally color code a block diagram to indicate the sample times of the blocks it contains, e.g., black (continuous), magenta (constant), yellow (hybrid), red (fastest discrete), and so on. The block contains block name, icon, and block library that contain the block, the purpose of the block.

7.4 THE POWER SYSTEM BLOCK SET

Electrical power systems are combinations of electrical circuits and Electro-mechanical devices, like motors and generators. Engineers working in this discipline are frequently tasked to improve the performance of the systems. Requirements for drastically increased efficiency have forced power system designers to use power electronic devices and sophisticated control

system concepts that tax traditional analysis tools and techniques. Further complicating the analyst's role is the fact that the system is often so nonlinear that the only way to understand it is through simulation. Land-based power generation from hydroelectric, steam, or other devices is not the only use of power systems. A common attribute of these systems is their use of power electronics and control systems to achieve their performance objectives. The Power System Block set was designed to provide a modern design tool that will allow scientists and engineers to rapidly and easily build models that simulate power systems. The block set uses the Simulink® environment allowing a model to be built using simple click and drag procedures. Not only can the circuit topology be drawn rapidly, but the analysis of the circuit can include its interactions with mechanical, thermal, control, and other disciplines. This is possible because all the electrical parts of the simulation interact with Simulink extensive modeling library. Because Simulink uses MATLAB® as the computational engine, you can use MATLAB's toolboxes as you design your simulation.

The block set can be put to work rapidly. The libraries contain models of typical power equipment, such as transformers, lines, machines, and power electronics. These models are proven ones coming from textbooks, and their validity is based on the experience of the Power Systems Testing and Simulation Laboratory of Hydro-Québec, a large North American utility located in Canada. The capabilities of the block set for modeling a typical electrical grid are illustrated in demonstration files. The block set fits well with other specialized analytical tools you use in the power system community.

7.5 SIMULINK BLOCKS USED IN THE SIMULATION

i. Three-Phase Source The Three-Phase Source block implements a balanced three-phase voltage source with internal R-L impedance. The three voltage sources are connected in Y with a neutral connection that can be internally grounded or made accessible. You can specify the source internal resistance and inductance either directly by entering R and L values or indirectly by specifying the source inductive short-circuit level and X/R ratio.
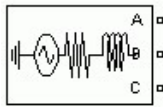
ii. In port In ports are the links from the outside world into a system. Inside a subsystem block, there is an in port corresponding to each input port on the block. A signal that arrives at an input port on a subsystem block flows out of the corresponding in port within that block.
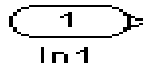
iii. Out port The Out port block provides a mechanism for labeling a system's outputs. In a subsystem, output ports correspond to outputs on the subsystem block.
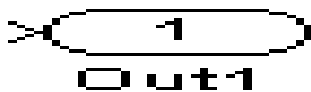
iv. Sub system Subsystem blocks represent one system within another system. Any set of blocks and lines can be converted to a Subsystem block with the Group command on the options menu. The Group command removes all selected objects from the active window and replaces them within a Subsystem block. This new block, when opened, redisplays all of the grouped objectives.

v. Gain The Gain block implements Y=KU, where Y is the output, U is the input, and K is the specified gain. The Gain block displays scalar gain data entered as variable or a constant. The block displays the text as it appears in the dialog box.

vi. Scope While the simulation is running, the Scope block displays the output of the block driving it. Opening a scope block produces a scope window. The title of this window matches the name of the block.

Scope
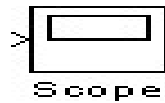
vii. Simplified Synchronous Machine The Simplified Synchronous Machine block models both the electrical and mechanical characteristics of a simple synchronous machine. The electrical system for each phase consists of a voltage source in series with RL impedance, which implements the internal impedance of the machine. The value of R can be zero but the value of L must be positive.

Simplified Synchronous
Machine pu Units
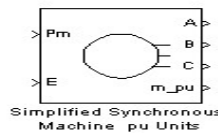
viii. Voltage Measurement The Voltage Measurement block is used to measure the instantaneous voltage between two electric nodes. The output is a Simulink signal that can be used by other Simulink blocks

Voltage Measurement
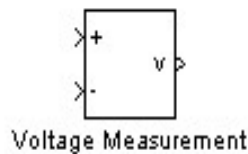
ix. Breaker The Breaker block implements a circuit breaker that is controlled by a Simulink signal applied on its second input. The control signal must be 0 or 1, 0 for open and 1 for closed. The arc extinction process is simulated by opening the breaker when the current passes through zero (first current zero-crossing following the transition of the Simulink control input from 1 to 0). When the breaker is closed, it behaves as a series RL circuit. The R and L values can be set as small as necessary in order to be negligible compared with external components. When the breaker is open, it has infinite impedance. If the breaker's initial state is set to 1 (closed), initializes all the states of the linear circuit and breaker initial current so that the simulation starts in steady-state.

60

3-Phase Breaker
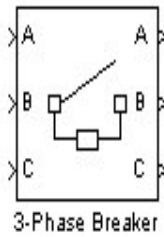
x. Bus bar The Bus Bar block is used to interconnect components. It allows multiple electrical block outputs and inputs to be connected together.

xi. Current Measurement The Current Measurement block is used to measure the instantaneous current flowing in any electrical block or connection line. The first output provides a Simulink signal that can be used by other Simulink blocks.

Current Measurement
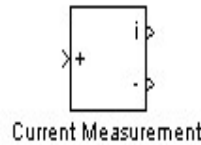
xii. Distributed Parameter Line The Distributed Parameter Line block implements an N-phase distributed parameter line model with lumped losses.

Distributed Parameters Line
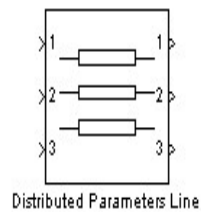
xiii. Linear Transformer The Linear Transformer block model shown below consists of three coupled windings wound on the same core.

Three-Phase
Transformer
(Three Windings)

61
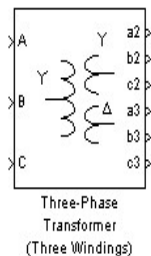
xiv. Saturable Transformer TheSaturable Transformer block model shown below consists of three coupled windings wound on the same core.

Three-phase
Transformer
(Two Windings)
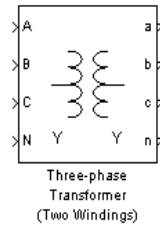
7.6 SIMULATION DIAGRAMS DESIGN USING MATLAB
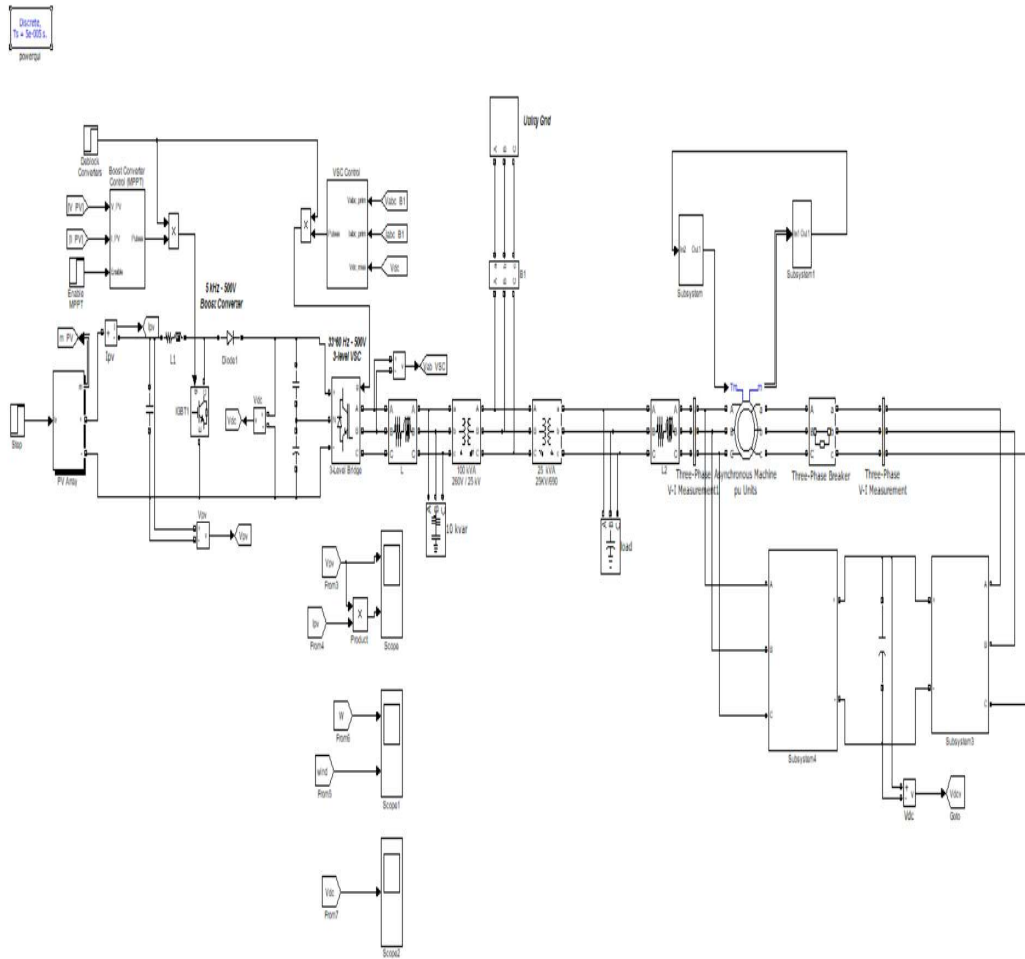
Figure 7.1 Simulation model of Hybrid System
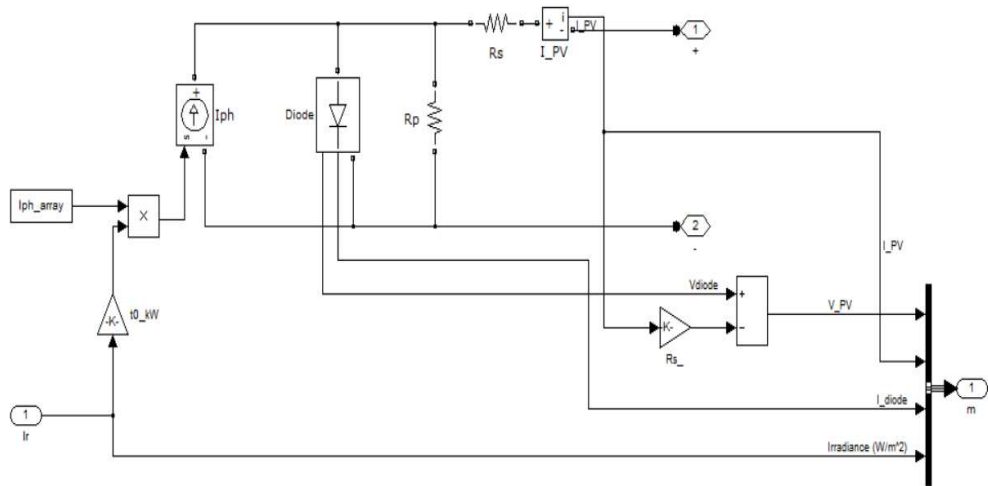
Figure 7.2 Simulink model of Solar cell using single diode
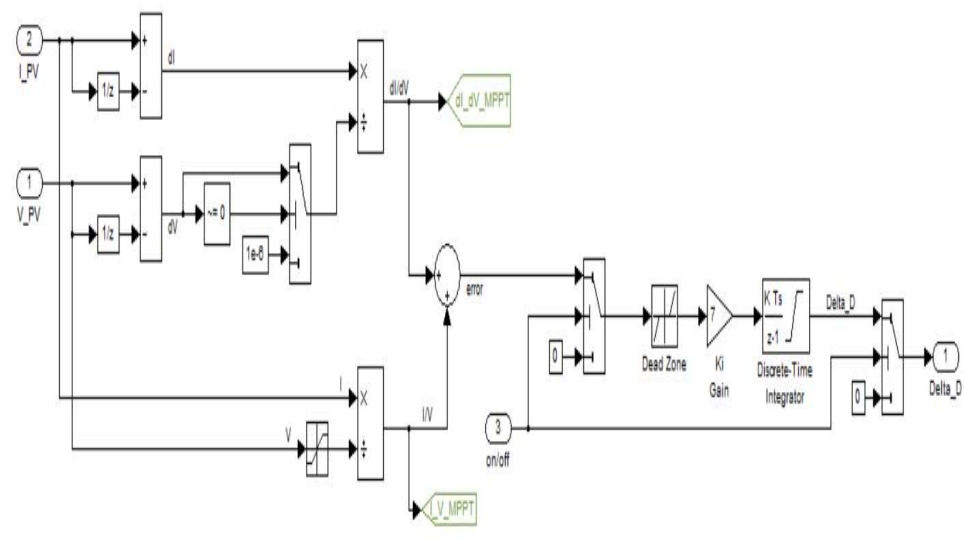
Figure 7.3 MPPT Control Model in Simulink
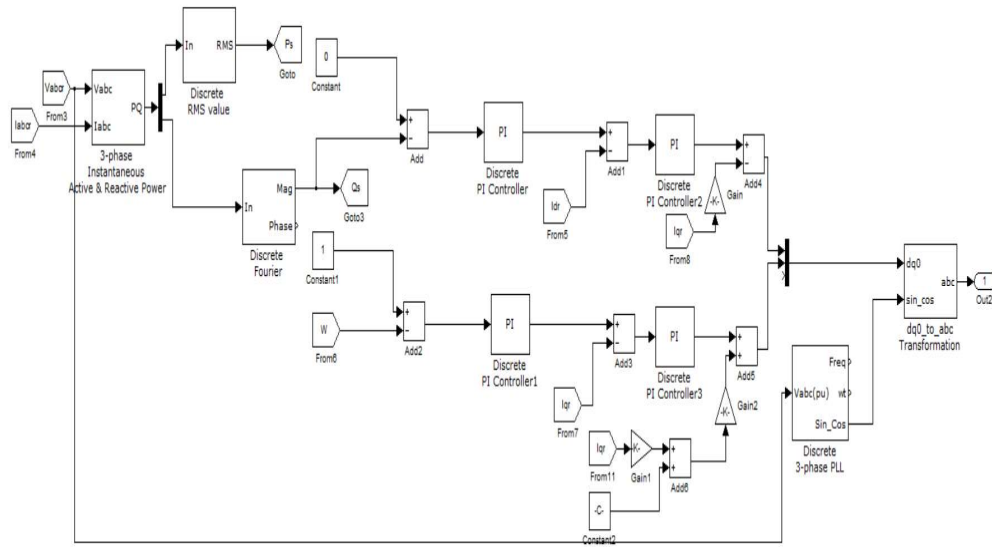
Figure 7.4 Rotor side controller in Simulink
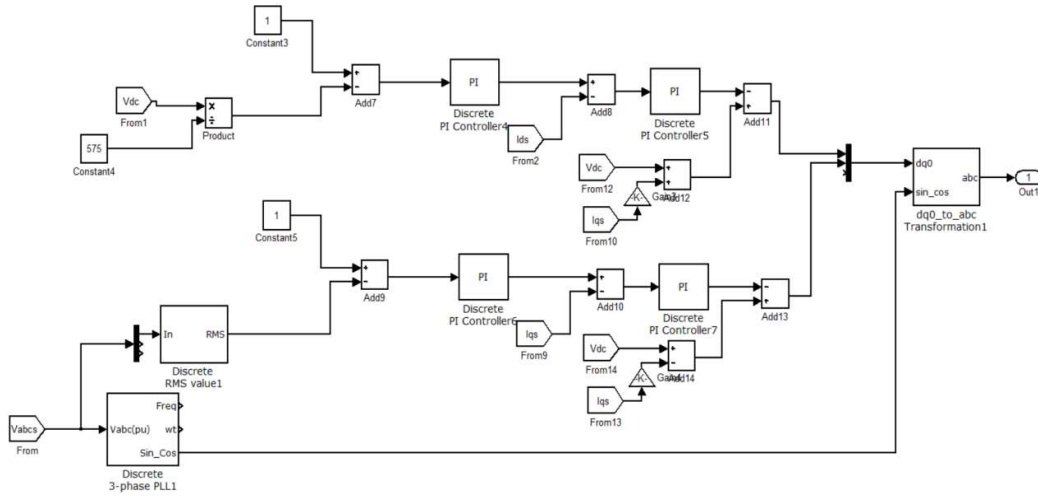
Figure 7.5 Grid side controller in Simulink.

7.7 RESULTS
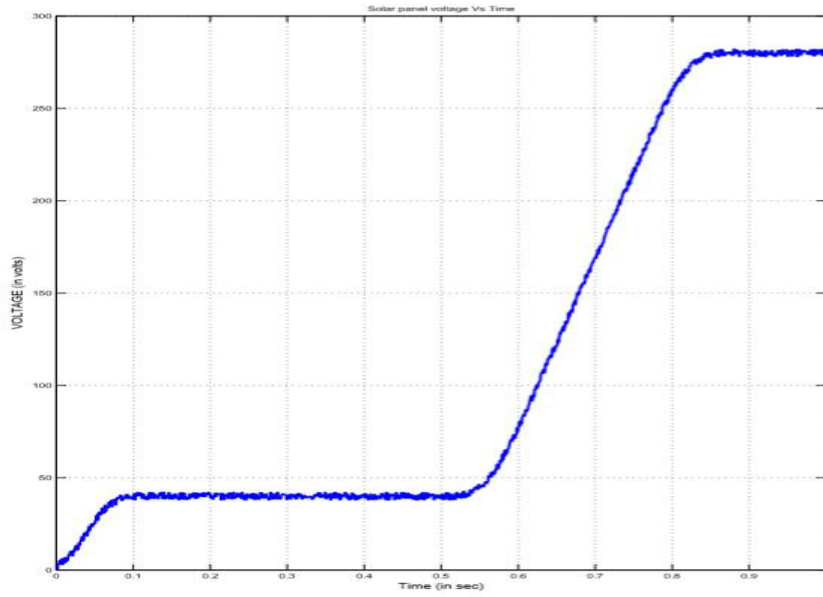
Figure 7.6 solar panel output voltage.
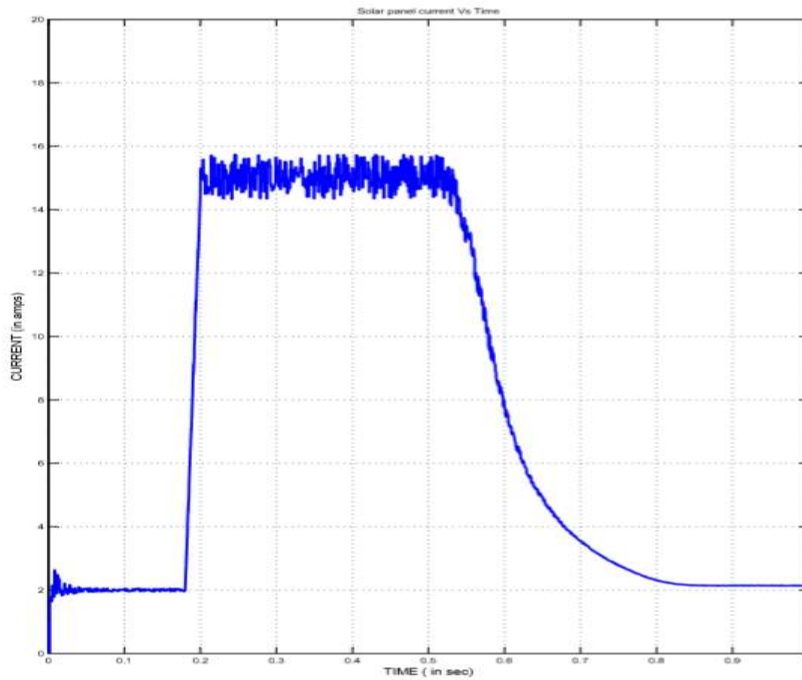
Figure 7.7 Solar panel output Current.
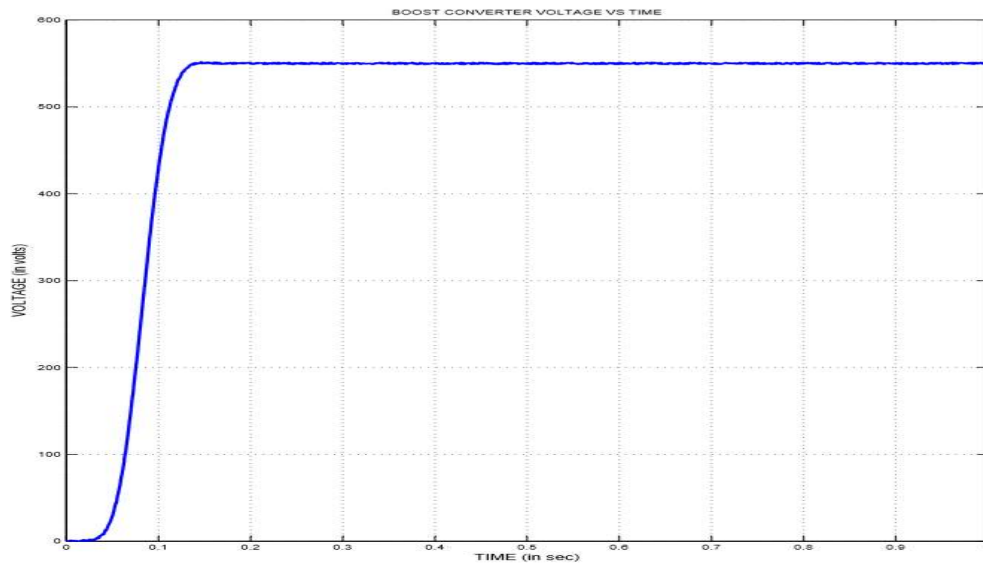
Figure 7.8 Boost converter output voltage.
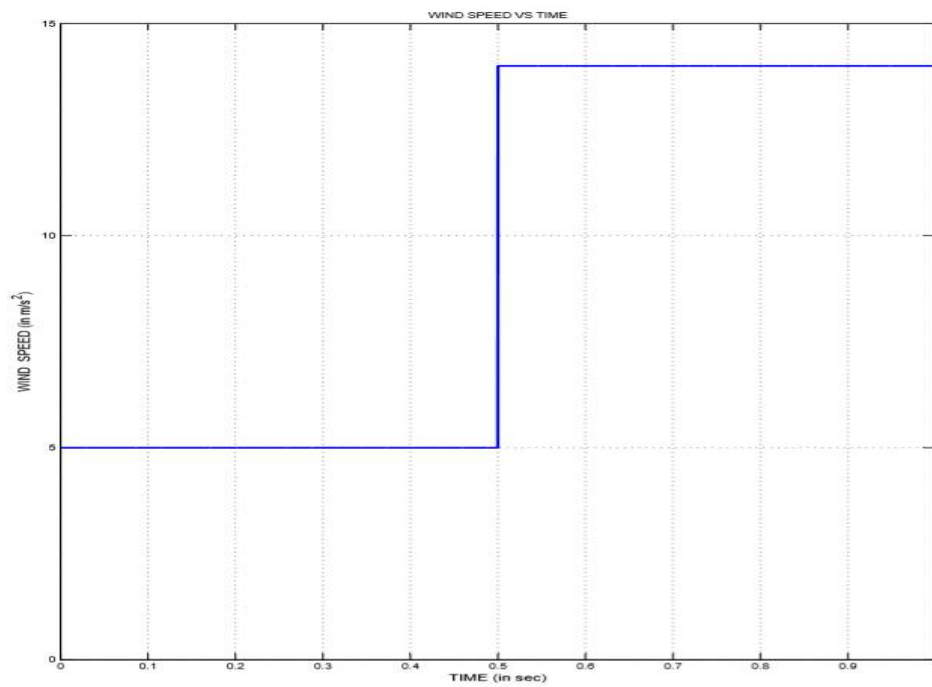
Figure 7.9 wind speed
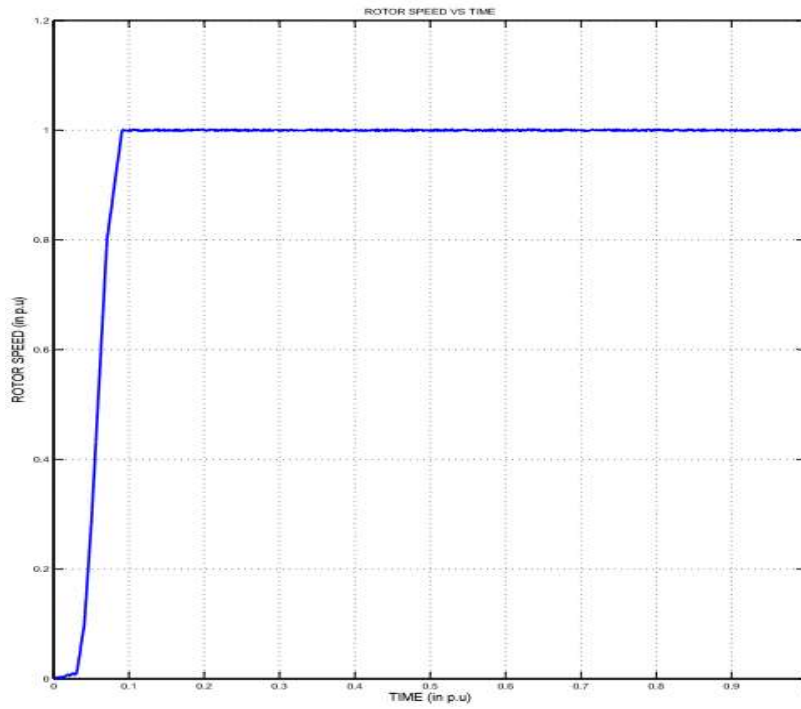
Figure 7.10 Rotor speed in p.u
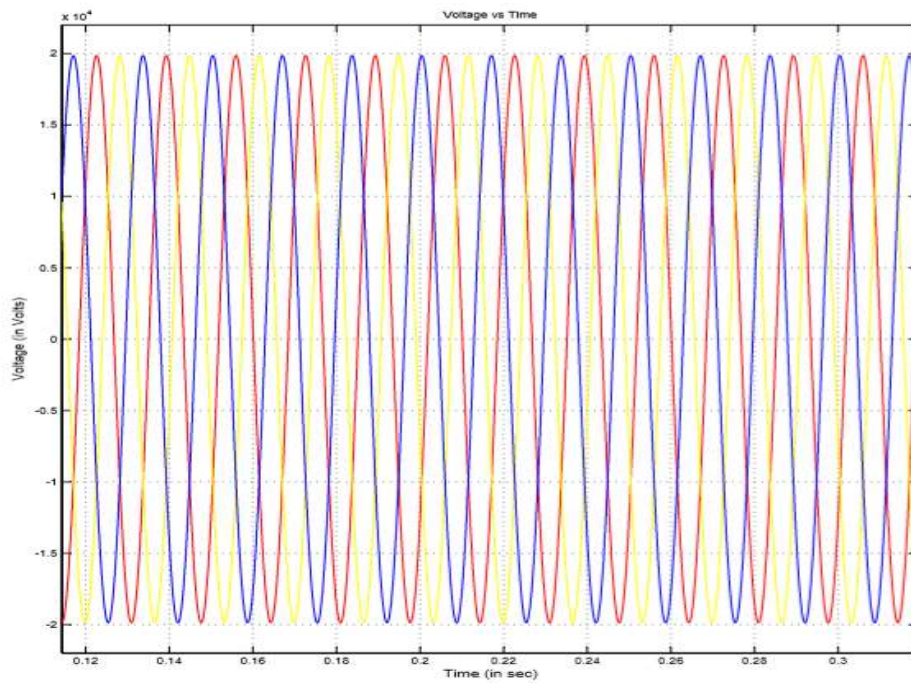
Figure 7.11 Grid Voltage

CONCLUSION

Using MPPT with solar panel installations has all the way advantages. The initial investment is smaller because smaller panel wattage is required. In this project, incremental conductance MPPT technique is developed the output of the MPPT is given to the comparator to generate PWM pulses which is required for Boost converter. To raise the solar panel voltage a boost converter circuit is designed, to convert DC-AC 3-level NPC inverter is used and vector control principle is used. One more energy source DFIG based wind turbine is used, now a days DFIG are extremely used in wind farms because it supplies power at constant voltage and frequency. To maintain constant voltage and frequency need a back to back converter and controller for back to back converter is implemented. Characteristics of DFIG are studied and also control technique of DFIG have been analysed in MATLAB-SIMULINK environment. The project provides architecture with modelling and simulation of a hybrid energy sources. Solar and wind power are the two sources being used. Established system of solar PV and DFIG based wind is simulated in MATLAB Simulink for step change condition.

By doing this project the following program outcomes, program specific outcomes are attained.

POs   : PO1, PO2, PO3, PO4, PO5, PO8, PO9, PO10, PO11

PSOs : PSO1

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A Double-input DC-DC Converter for Wide-input-voltage-range Application

A project report submitted in partial fulfillment of the requirement for the award of

MASTER OF TECHNOLOGY

in

POWER INDUSTRIAL DRIVES

Submitted by

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NAAC AccreditedInstitute

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National Highway-16,Anakapalle-531002,Visakhapatnam Dist.,A.P.

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CERTIFICATE

This is to certify that the project work entitled "**A Double-input DC-DCConverter for Wide-input-voltage-range Application**" has been carried out by **P.CHAITANYA (19U41D4206)** Submitted in partial fulfilment of their requirement for the M.Tech miniproject in POWERINDUSTRIAL DRIVES during the academic year2019-2021.

(Project guide)   (Head of the department)

Mr.K.Vijay Kumar B.E.,M.E.,(Ph.d)   Mr.A.Krishna Nag M.tech.,(Ph.d)

Associate professor   Associate professor

(External Examiner)

DECLARATION

I here by declare that the dissertation entitled "A Double-input DC-DC Converter for Wide-input-voltage-range Application" was carried out and written by me under the guidance of Mr.K.VIJAY KUMAR, Associate Professor, Department of Electrical and Electronics Engineering, Dadi Institute of Engineering & Technology. This work has not been previously formed the basis for the award of any degree of diploma or certificate nor has been submitted elsewhere for the award of any degree or diploma.

BY
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ACKNOWLEDGEMENT

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Abstract

The output power of most facilities for new energy power generation is unstable because of the external environment. In the distributed power system with two or more sources, a stable output can be achieved by the complementary power supply among different input sources. A double-input DC-DC converter for wide input voltage range applications is proposed in this paper, which has the following advantages: the circuit is simple, the input voltage range is wide and the sources can deliver power to the load individually or simultaneously. The operation modes and the steady-state analysis are proposed. Finally, the simulation result is proposed to verify the correctness of the analysis and feasibility of the proposed converter.

Keywords-New energy power generation, distributed power system, double-input, wide-input-voltage-range

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CHAPTER-1
INTRODUCTION

1.1 INTRODUCTION:

Fossil fuels are finite resources; because of that renewable energy sources are becoming more important. As population increases, our rate of consumptions of these fuels also increases. Due to their intermittent nature, a power imbalance exists between renewable sources and the load. In addition to this output voltages change significantly for renewable energy sources. Thus, wide input range characteristics is necessary for these applications. In previous times several separate converters connected to a common bus are employed to compose a distributed power system, it is complex. Thus, a dual input converter (or) multiple input converter is used to connect several complementary renewable energy sources. It leads to simple circuit and lower cost.

Compared with traditional fossil fuels, the renewable energy is more e0n0v0i2ronment friendly and sustainable. However, renewable energy sources such as photovoltaic (PV) solar energy and wind energy rely heavily on the climate and weather conditions. As a consequence, the available power is intermittent and stochastic. So, multiple renewable energy sources that are mutually complementary could be combined to maintain continuous power delivery to the load.

Such a system is referred to as a hybrid power system. A number of independent single-input converters can be used to interface these renewable energy sources. Recently, multiple-input converters (MICs) have received increased attention, and they are capable of replacing several single-input converters in order to reduce complexity and the cost of hybrid power systems. An multiple -input converter is capable of converting power from multiple input sources to a common load. Power management is required for an multiple -input converter to appropriately distribute the output power to the input sources according to the characteristics of the renewable energy sources, and at the same time regulate the output voltage. There- fore, Multiple -Input Converters control system is composed of one output voltage loop and several input current or input voltage loops. The input current or input voltage loops regulate the currents or voltages of the input sources, and, consequently, regulate the input power of these sources.

Multiple-input converter (MIC) can be classified into two categories: isolated multiple-input converter (MIC) and non-isolated multiple-input converter (MIC). An isolated can be constructed by multi-winding transformer and full bridge structure. It can accommodate multiple ports with different voltage levels and it can achieve electrical isolation for all of the ports. By using phase shift control, all of the switches of the converter can achieve zero voltage switching (ZVS) To accomplish a wider range of ZVS, a series resonant circuit is introduced into the full bridge structure. These MICs are good candidates for applications where galvanic isolation is necessary. However, these converters need a lot of power devices due to the utilization of full bridge structures. This leads to low efficiency, low power density and a complex modulation strategy. Therefore, non-isolated MICs are appropriate for some applications where isolation is not necessary. This is due in large part to their higher efficiency, higher power density and lower cost. Most non-isolated MICs are constituted with basic structures including buck and boost converters.

A multiple-input converter (MIC) has the following advantages over conventional solutions that employ multiple single converters: Multiple -Input Converter has a simpler structure, higher power density, and a lower cost characteristic because of multiplexing or sharing active switches and reactive component can improve the dynamic performance and avoid the complex communication among multiple different sources due to the unified power management with centralized control. Therefore, MIC is an excellent candidate for small scale renewable power systems which is economic and therefore has good development prospects. These MICs are good candidates for the applications where galvanic isolation is required. However, the major problem is that too many active switches are used. In contrast to isolated MIC design, non-isolated MIC features compact packaging, high-power density and high system efficiency. Due to their remarkable merits, many non-isolated Multiple -Input Converters have been proposed for various applications.

The double input DC–DC converter has a simple circuit structure, exhibits high renewable energy utilization, and is also capable of delivering power from two power sources to a DC load simultaneously and also the fault tolerance of the circuit is high, because if any one input source is failed in operation then we can get a constant output.

1.2 LITERATURE SURVEY:

1. D. Yang, M. Yang, and X. Ruan, "One-cycle control for a double-input DC/DC converter," IEEE Trans. Power Electron., Vol. 27, No. 11, pp. 4646-4655, Nov. 2012.

   A control method is proposed to eliminate the interaction between the control loops and to simplify the design of the controller. However, the fault tolerance of these converters is limited, and the output voltage cannot be maintained at the rating value when one input source stops powering the load.

2. X. Sun, Y. Zhou, W. Wang, B. Wang, and Z. Zhang, "Alternative source-port-tolerant series-connected double- input DC–DC converter," IEEE Trans. Power Electron., Vol. 30, No. 5, pp. 2733-2742, May 2015.

   A source-port-tolerant series-connected dc-dc converter with a bootstrap circuit is proposed. The converter can solve the fault tolerance problem in some designated occasions.

3. H. Krishnaswami and N. Mohan, "Three-port series- resonant dc–dc converter to interface renewable energy sources with bidirectional load and energy storage ports," IEEE Trans. Power Electron., Vol. 24, No. 10, pp. 2289- 2297, Aug. 2009.

   To accomplish a wider range of ZVS, a series resonant circuit is introduced into the full bridge structure.

4. Y. C. Liu and Y. M. Chen, "A systematic approach to synthesizing multi-input DC–DC converters," IEEE Trans. Power Electron., Vol. 24, No. 1, pp. 116-127, Feb. 2009.

   Most non-isolated MICs are constituted with basic structures including buck and boost converters. By changing the combination of the basic structure, a non-isolated MIC can be generated to accommodate specific applications.

5. F. Nejabatkhah, S.Danyali, S.H. Hosseini, and M. Sabahi, "Modelling and control of a new three-input DC–DC boost converter for hybrid PV/FC/Battery power system," IEEE Trans. Power Electron., Vol. 27, No. 5, pp. 2309-2324, Oct. 2011.

The converter is integrated with three boost units and it can connect three voltage sources simultaneously. However, the input voltages of the converter must be less than the output voltage, which limits the application of the converter.

CHAPTER-2
DC-DC CONVERTERS

2.1 INTRODUCTION:

Any type of power Converter whether it is AC to DC or DC to AC converter takes electrical power in one form and converts it in to another form. A DC to DC converter is an electronic circuit which by electronic switching transforms a DC source voltage from one level to another.

Significance of DC-DC Conversion:

But why DC to DC converters are needed? What is the need to convert DC voltage to DC voltage? It can be explained as follows for example consider electronic switch mode converters used in cell phones and laptop computers. These devices are powered using rechargeable batteries. This battery has to power all the components in the cellular phone or laptop such as display, USB devices etc. Each of these components may be operating at different voltages and current levels. DC to DC converters step up or step down DC voltage level so that it will be suited to the requirement of interest.

Also as the stored power drains with time, the battery voltage declines. By providing feedback from the output stage, DC to DC converters can be made to compensate this lowered battery voltage.

Often the input to these DC to DC converters is an uncontrolled DC voltage forms a diode rectifier which is unregulated. The input to DC to DC converters is unregulated not due to poor rectification of diode rectifier but due to fluctuations in line voltage. These line fluctuations gets reflected in the output which makes it unregulated. The DC to DC converters converts these unregulated DC input voltage into controlled DC output at desired voltage level. They can be thought to be analogous to transformers which step up or step down AC currents or voltages.

DC-DC converters are high-frequency power conversion circuits that use high-frequency switching and inductors, transformers, and capacitors to smooth out switching noise into regulated DC voltages. Closed feedback loops maintain constant voltage output even when changing input voltages and output currents. At 90% efficiency, they

are generally much more efficient and smaller than linear regulators. Their disadvantages are noise and complexity.

2.2 TYPES OF DC-DC CONVERTER:

There different kinds of DC-DC converters. A variety of the converter names are included here:

1. The BUCK converter

2. The BOOST converter

3. The BUCK-BOOST converter

.0.2.2.1 Study of DC-DC Converters:

There are a variety of DC-Dc converters are possible. But from the list of the converters only the first four of the converters are to be described which are basically of non-isolated input output terminals.

2.2.2 BUCK Converter:

The buck converter is a commonly used in circuits that steps down the voltage level from the input voltage according to the requirement. It has the advantages of simplicity and low cost. Figure 2.1 shows a buck converter. The operation of the Buck converters start with a switch that is open (so no current flow through any part of circuit) When the switch is closed, the current flows through the inductor, slowly at first, but building up over time. When the switch is closed the inductor pulls current through the diode, and this means the voltage at the inductors "output" is lower than it first was. This is the very basic principle of operation of buck circuit.

Figure 2.1: Buck Converter

2.2.2.1 Circuit analysis:

Analysis of the buck converter begins by making these assumptions:

➢ The circuit is operating in the steady state.

➢ The inductor current is continuous(always positive)

➢ The capacitor is very large, and the output voltage is held constant at voltage Vo. This restriction will be relaxed later to show the effects of finite capacitance.

➢ The switching period is T, the switch is closed for time DT and open for time (1-D)T .

The key to the analysis for determining the voltage Vo is to examine the inductor current and inductor voltage first for the switch closed and then for the switch open. The net change in inductor current over one period must be zero for steady state operation. The average inductor voltage is zero. There are two types of operational mode for this circuit a) Continuous Conduction Mode and b) Discontinuous Conduction Mode. They are described below.

2.2.2.2 Continuous Conduction Mode:

A buck converter operates in continuous mode if the current through the inductor (I_L) never falls to zero during the commutation cycle. In this mode, the operating principle is described by the chronogram in Figure 2.1.

(a) ON State   (b) OFF State
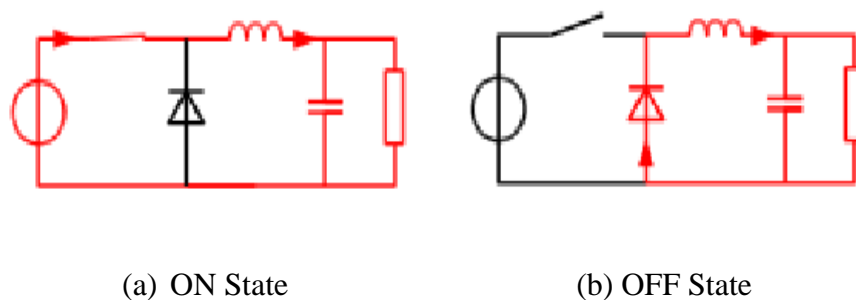
Figure 2.2: On and off state of Buck converter

Figure 2.2 shows the two circuit configurations of a buck converter: (a) On-state, when the switch is closed, and (b) Off-state, when the switch is open

➢ When the switch pictured above is closed (On-state, top of Figure 2.2), the voltage across the inductor is $V_L = V_i - V_o$. The current through the inductor rises linearly. As the diode is reverse-biased by the voltage source V, no current flows through it.

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➢ When the switch is opened (off state, bottom of figure 2.2), the diode is forward biased. The voltage across the inductor is $V_L = -V_o$ (neglecting diode drop). Current (I_L) decreases.

The energy stored in inductor L is $\qquad E = \frac{1}{2}L \times I_L^2$ (1)

Therefore, it can be seen that the energy stored in L increases during On-time (as (I_L) increases) and then decreases during the Off-state. L is used to transfer energy from the input to the output of the converter. The rate of change of I_L can be calculated from:

$$V_L = L\frac{dI_L}{dt} \qquad\qquad (2)$$

With V_L equal to $V_i - V_o$ during the On-state and to $-V_o$ during the Off-state. Therefore, the increase in current during the On-state is given by:

$$\Delta I_{Lon} = \int_0^{ton}\frac{V_L}{L}dt = \frac{(V_i - V_o)}{L}t_{on}, \qquad\qquad \{t_{on} = DT\} \ (3)$$

Identically, the decrease in current during the Off-state is given by:

$$\Delta I_{Loff} = \int_{ton}^{toff}\frac{V_L}{L}dt = -\frac{V_o}{L}t_{off}, \qquad\qquad \{t_{off} = T\}(4)$$

If we assume that the converter operates in steady state, the energy stored in each component at the end of a commutation cycle T is equal to that at the beginning of the cycle. That means that the current I_L is the same at t=0 and at t=T (see Figure 2.3).So we can write from the above equations:

$$\frac{(V_i - V_o)}{L}t_{on} - \frac{V_o}{L}t_{off} = 0 \qquad\qquad (5)$$

It is worth noting that the above integrations can be done graphically: In Figure 2.3,$\Delta I_{Lon}$is proportional to the area of the yellow surface, and ΔI_{Loff} to the area of the orange surface, as these surfaces are defined by the inductor voltage (red) curve. As these surfaces are simple rectangles, their areas can be found easily: $(V_i - V_o)t_{on}$ for the yellow rectangle and $-V_o t_{off}$ for the orange one. For steady state operation, these areas must be equal. As can be seen on figure 2.4, $t_{on} = DT$ and $t_{off} = (1 - D)T$. D is a scalar called the duty cycle with a value between 0 and 1. This yield:

$$(V_i - V_o)DT - V_o(1 - D) = 0$$

$$\Rightarrow V_o - DV_i = 0$$

$$\Rightarrow D = \frac{V_o}{V_i} \qquad (9)$$

From this equation, it can be seen that the output voltage of the converter varies linearly with the duty cycle for a given input voltage. As the duty cycle D is equal to the ratio between t_{on} and the period T, it cannot be more than 1. Therefore, $V_o \leq V_i$. This is why this converter is referred to as step-down converter. So, for example, stepping 12 V down to 3 V (output voltage equal to a fourth of the input voltage) would require a duty cycle of 25%, in our theoretically ideal circuit.
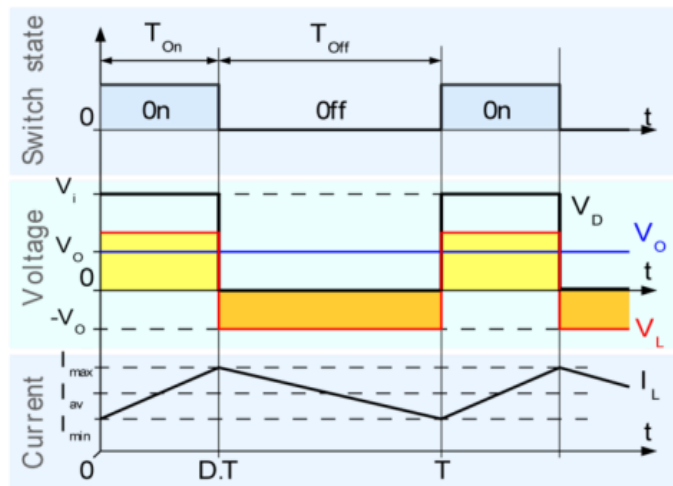
Figure 2.3: Evolution of the voltages and currents with time in an ideal buck converter operating in continuous mode

2.2.2.3 Discontinuous Conduction Mode
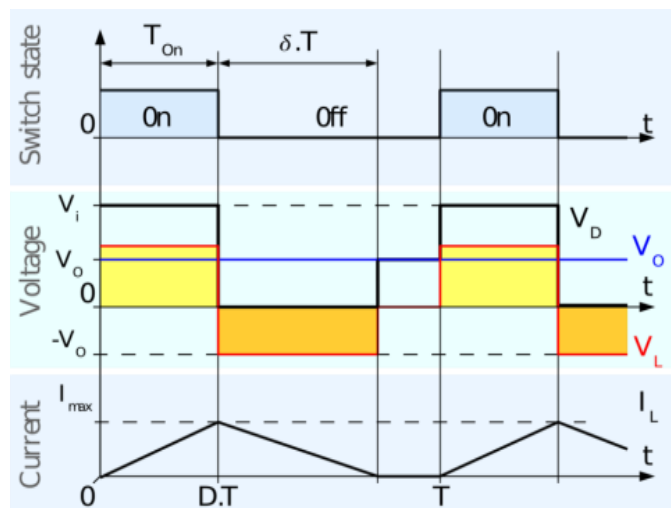
Figure. 2.4: Evolution of the voltages and currents with time in an ideal buck converter operating in discontinuous mode.

In some cases, the amount of energy required by the load is small enough to be transferred in a time lower than the whole commutation period. In this case, the current through the inductor falls to zero during part of the period. The only difference in the principle described above is that the inductor is completely discharged at the end of the commutation cycle (Figure 2.4). This has, however, some effect on the previous equations.

We still consider that the converter operates in steady state. Therefore, the energy in the inductor is the same at the beginning and at the end of the cycle (in the case of discontinuous mode, it is zero). This means that the average value of the inductor voltage (V_L) is zero; i.e., that the area of the yellow and orange rectangles in figure 2.4 are the same. This yields:

$$(V_i - V_o)DT - V_o\delta T = 0 \qquad (1)$$

So the value of δ is:

$$\delta = \frac{(V_i - V_o)}{V_o} D \qquad (2)$$

The output current delivered to the load (I_o) is constant; as we consider that the output capacitor is large enough to maintain a constant voltage across its terminals during a commutation cycle. This implies that the current flowing through the capacitor has a zero average value. Therefore, we have :

$$\overline{I_L} = I_o$$

Where $\overline{I_L}$ is the average value of the inductor current. As can be seen in figure 2.4, the inductor current waveform has a triangular shape. Therefore, the average value of I_L can be sorted out geometrically as follow:

$$\overline{I_L} = \left(\frac{1}{2}I_{Lmax}DT + \frac{1}{2}I_{Lmax}\delta T\right)\frac{1}{T}$$

$$= \frac{I_{Lmax}(D + \delta)}{2}$$

$$= I_o \qquad (3)$$

The inductor current is zero at the beginning and rises during t_{on} up to I_{Lmax}. That means that I_{Lmax} is equal to:

$$I_{Lmax} = \frac{(V_i - V_o)}{L} DT \qquad\qquad (4)$$

Substituting the value of I_{Lmax} in the previous equation leads to:

$$I_o = \frac{(V_i - V_o)DT(D+\delta)}{2L}(5)$$

And substituting δ by the expression given above yields:

$$I_o = \frac{(V_i - V_o)DT(D+\frac{V_i - V_o}{V_o}D)}{2L} \qquad\qquad (6)$$

This expression can be rewritten as:

$$V_o = V_i \frac{1}{\frac{2LI_o}{D^2 V_i T}+1} \qquad\qquad (7)$$

It can be seen that the output voltage of a buck converter operating in discontinuous mode is much more complicated than its counterpart of the continuous mode. Furthermore, the output voltage is now a function not only of the input voltage (V_i) and the duty cycle D, but also of the inductor value (L), the commutation period (T) and the output current (I_o).

2.2.3 BOOST Converter:

A boost converter (step-up converter) is a power converter with an output DC voltage greater than its input DC voltage. It is a class of switching mode power supply (SMPS) containing at least two semi-conductors switches (a diode and a transistor) and at least one energy storage element. Filters made of capacitors (sometimes in combination with inductors) are normally added to the output of the converter to reduce output voltage ripple. A boost converter is sometimes called a step-up converter since it "steps up" the source voltage. Since power (P=VI) must be conserved, the output current is lower than the source current.

The boost converter has the same components as the buck converter, but this converter produces an output voltage greater than the source. "Boost" converters start their voltage conversion with a current flowing through the inductor (switch is closed). Then they close the switch leaving the current no other path to go than through a diode (functions as one way valve) The current then wants to slow really fast and the only way it can do this is by increasing its voltage (akin to pressure) at the end that connects to the

diode, and switch. If the voltage is high enough it opens the diode, and one through the diode, the current can't flow back. This is the very basic concept of boost converter.

2.2.3.1 Circuit analysis:

Analysis of the boost converter begins by making these assumptions:

- ➤ The circuit is operating in the steady state.
- ➤ The inductor current is continuous (always positive).
- ➤ The capacitor is very large, and the output voltage is held constant at voltage Vo. This restriction will be relaxed later to show the effects of finite capacitance.
- ➤ The switching period is T, the switch is closed for time DT and open for time (1-D)T.
- ➤ The components are ideal.

Like Buck converter boost also has two mode of operation. Details are described below

2.2.3.2 Operating Principle:

The key principle that drives the boost converter is the tendency of an inductor to resist changes in current. When being charged it acts as a load and absorbs energy (somewhat like a resistor); when being discharged it acts as an energy source (somewhat like a battery). The voltage it produces during the discharge phase is related to the rate of change of current, and not to the original charging voltage, thus allowing different input and output voltages.
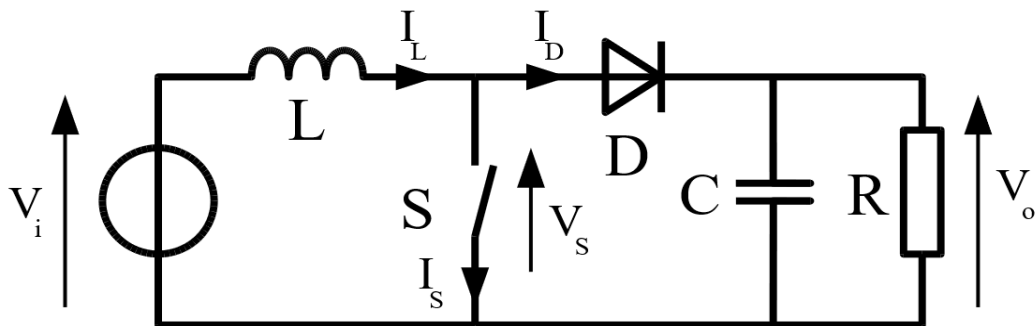
Figure 2.5: Boost converter

The basic principle of a Boost converter consists of 2 distinct states (Figure 6):

- ➤ in the On-state, the switch S (see figure 2.6) is closed, resulting in an increase in the inductor current;

➢ in the Off-state, the switch is open and the only path offered to inductor current is through the fly back diode D, the capacitor C and the load R.

➢ The input current is the same as the inductor current as can be seen in figure 2.6. So it is not discontinuous as in the buck circuit and the requirements on the input filter are relaxed compared to a buck converter.
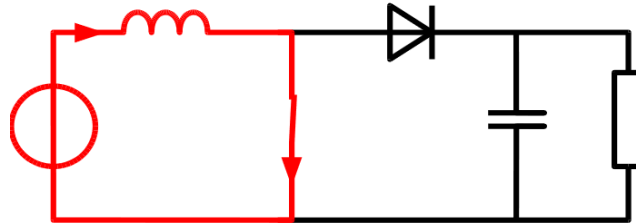
(a) ON state
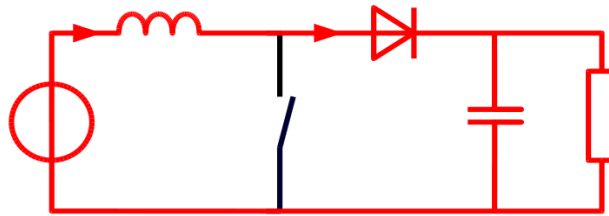
(b) OFF state

Figure 2.6: The two configurations of a boost converter, depending on the state of the switch S.

2.2.3.3 Continuous Conduction Mode:

When a boost converter operates in continuous mode, the current through the inductor (I_L) never falls to zero. Figure 2.7 shows the typical waveforms of currents
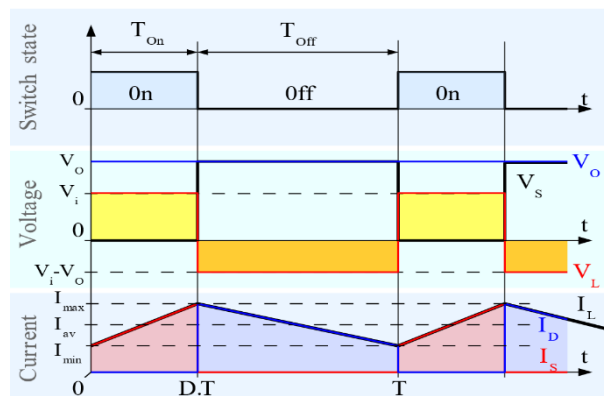
Figure 2.7: Waveforms of current and voltage in a boost converter operating in continuous mode.

and voltages in a converter operating in this mode. The output voltage can be calculated as follows, in the case of an ideal converter (i.e. using components with an ideal behaviour) operating in steady conditions:

During the On-state, the switch S is closed, which makes the input voltage (V_i) appear across the inductor, which causes a change in current (I_L) flowing through the inductor during a time period (t) by the formula:

$$\frac{\Delta I_L}{\Delta t} = \frac{V_i}{L} \tag{1}$$

At the end of the On-state, the increase of I_L is therefore:

$$\Delta I_{Lon} = \frac{1}{L} \int_0^{DT} V_i dt = \frac{DT}{L} V_i \tag{2}$$

D is the duty cycle. It represents the fraction of the commutation period T during which the switch is On. Therefore D ranges between 0 (S is never on) and 1 (S is always on).

During the Off-state, the switch S is open, so the inductor current flows through the load. If we consider zero voltage drop in the diode, and a capacitor large enough for its voltage to remain constant, the evolution of I_L is:

$$V_i - V_o = L \frac{dI_L}{dt} \tag{3}$$

Therefore, the variation of I_L during the Off-period is:

$$\Delta I_{Loff} = \int_{DT}^{T} \frac{(V_i - V_o)dt}{L} = \frac{(V_i - V_o)(1-D)T}{L} \tag{4}$$

As we consider that the converter operates in steady-state conditions, the amount of energy stored in each of its components has to be the same at the beginning and at the end of a commutation cycle. In particular, the energy stored in the inductor is given by:

$$E = \frac{1}{2} L I_L^2 \tag{5}$$

So, the inductor current has to be the same at the start and end of the commutation cycle. This means the overall change in the current (the sum of the changes) is zero:

$$\Delta I_{Lon} + \Delta I_{Loff} = 0 \tag{6}$$

Substituting ΔI_{Lon} and ΔI_{Loff} by their expressions yields:

$$\Delta I_{Lon} + \Delta I_{Loff} = \frac{DT}{L}V_i + \frac{(V_i - V_o)(1-D)T}{L} \qquad (7)$$

This can be written as:

$$\frac{V_o}{V_i} = \frac{1}{1-D} \qquad (8)$$

Which in turns reveals the duty cycle to be:

$$D = 1 - \frac{V_i}{V_o} \qquad (9)$$

From the above expression it can be seen that the output voltage is always higher than the input voltage (as the duty cycle goes from 0 to 1), and that it increases with D, theoretically to infinity as D approaches 1. This is why this converter is sometimes referred to as a step-up converter.

2.2.3.4 Discontinuous Conduction Mode:
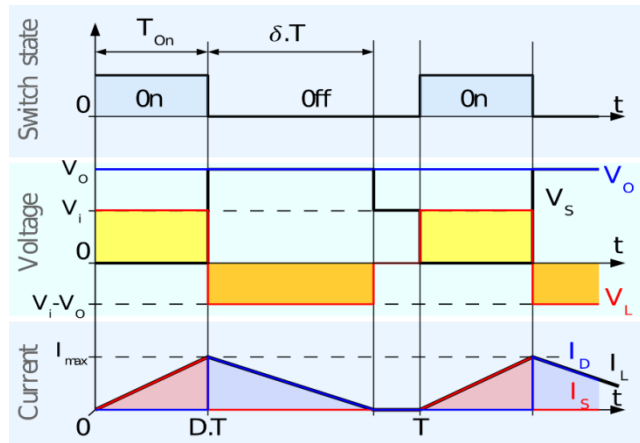
Figure 2.8: Waveforms of current and voltage in a boost converter operating in discontinuous mode.

In some cases, the amount of energy required by the load is small enough to be transferred in a time smaller than the whole commutation period. In this case, the current through the inductor falls to zero during part of the period. The only difference in the principle described above is that the inductor is completely discharged at the end of the commutation cycle (see waveforms in figure 2.8). Although slight, the difference has a strong effect on the output voltage equation. It can be calculated as follows:

As the inductor current at the beginning of the cycle is zero, its maximum value I_{Lmax} (at t= DT) is

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$$I_{Lmax} = \frac{V_i DT}{L} \qquad\qquad (1)$$

During the off-period, I_L falls to zero after δT:

$$I_{Lmax} + \frac{(V_i - V_o)\delta T}{L} = 0 \qquad\qquad (2)$$

Using the two previous equations δ is:

$$\delta = \frac{V_i D}{V_o - V_i} \qquad\qquad (3)$$

The load current I_o is equal to the average diode current (I_D). As can be seen on figure 4, the diode current is equal to the inductor current during the off-state. Therefore the output current can be written as:

$$I_o = \overline{I_D} = \frac{I_{Lmax}}{2}\,\delta \qquad\qquad (4)$$

Replacing I_{Lmax} and δ by their respective expressions yields:

$$I_o = \frac{V_i DT}{2L} \cdot \frac{V_i D}{V_o - V_i} = \frac{V_i^2 D^2 T}{2L(V_o - V_i)} \qquad\qquad (5)$$

Therefore, the output voltage gain can be written as follows:

$$\frac{V_o}{V_i} = 1 + \frac{V_i D^2 T}{2L I_o} \qquad\qquad (6)$$

Compared to the expression of the output voltage for the continuous mode, this expression is much more complicated. Furthermore, in discontinuous operation, the output voltage gain not only depends on the duty cycle, but also on the inductor value, the input voltage, the switching frequency, and the output current.

2.2.4 BUCK-BOOST Converter:

Another basic switched mode converter is the buck-boost converter. The output of the buck-boost converter can be either higher or lower than the input voltage.

2.2.4.1 Principle Of Operation:
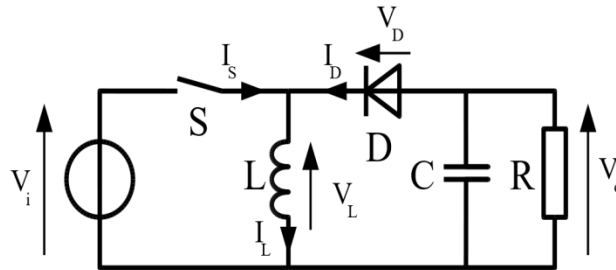
Figure 2.9: Schematic of a buck–boost converter.

Figure 2.10 shows the two operating states of a buck–boost converter: When the switch is turned-on, the input voltage source supplies current to the inductor, and the capacitor supplies current to the resistor (output load).When the switch is opened, the inductor supplies current to the load via the diode D
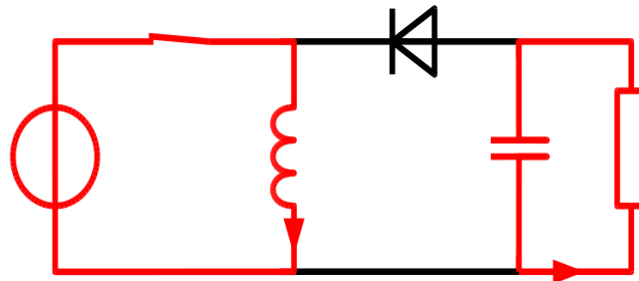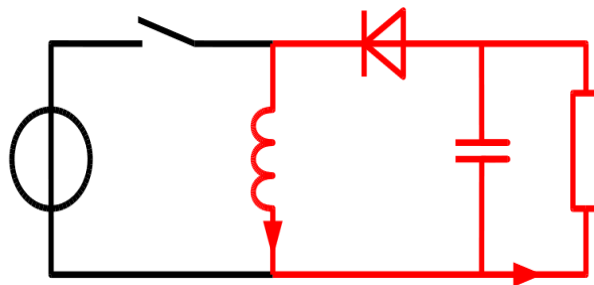
(a) ON state

(b)OFF state

Figure 2.10: The two configurations of a buck-boost converter, depending on the state of the switch S.

The basic principle of the buck–boost converter is fairly simple (Figure 2.10):

➢ While in the On-state, the input voltage source is directly connected to the inductor (L). This results in accumulating energy in L. In this stage, the capacitor supplies energy to the output load.

➢ While in the Off-state, the inductor is connected to the output load and capacitor, so energy is transferred from L to C and R. Compared to the buck and boost converters, the characteristics of the buck–boost converter are mainly:

➢ Polarity of the output voltage is opposite to that of the input;

➢ The output voltage can vary continuously from 0 to -∞(for an ideal converter). The output voltage ranges for a buck and a boost converter are respectively 0 to V_i and V_i to ∞ .The circuit has two main mode of operations. They are described below.

2.2.4.2 Continuous Conduction Mode:

If the current through the inductor L never falls to zero during a commutation cycle, the converter is said to operate in continuous mode. The current and voltage waveforms in an ideal converter can be seen in Figure 2.11.
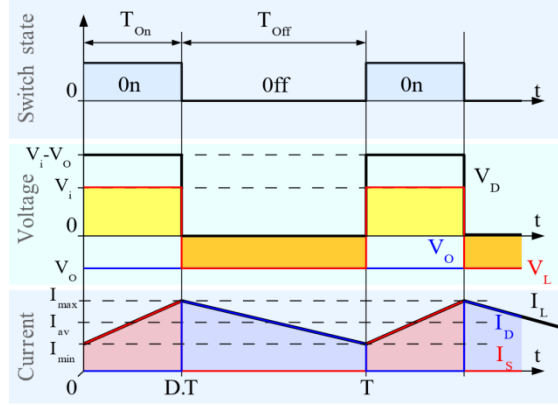
Figure 2.11: Waveforms of current and voltage in a buck–boost converter operating in continuous mode.

From $t = 0$ to $t = DT$, the converter is in On-State, so the switch S is closed. The rate of change in the inductor current (I_L) is therefore given by

$$\frac{dI_L}{dt} = \frac{V_i}{L} \tag{1}$$

At the end of the On-state, the increase of I_L is therefore:

$$\Delta I_{Lon} = \int_0^{DT} dI_L = \int_0^{DT} \frac{V_i}{L} dt = \frac{V_i DT}{L} \tag{2}$$

D is the duty cycle. It represents the fraction of the commutation period T during which the switch is On. Therefore D ranges between 0 (S is never on) and 1 (S is always on).

During the Off-state, the s0000.

…..3witch S is open, so the inductor current flows through the load. If we assume zero voltage drop in the diode, and a capacitor large enough for its voltage to remain constant, the evolution of I_L is:

$$\frac{dI_L}{dt} = \frac{V_o}{L} \tag{3}$$

Therefore, the variation of I_L during the Off-period is:

$$\Delta I_{Loff} = \int_0^{(1-D)T} dI_L = \int_0^{(1-D)T} \frac{V_o dt}{L} = \frac{V_o(1-D)T}{L} \tag{4}$$

As we consider that the converter operates in steady-state conditions, the amount of energy stored in each of its components has to be the same at the beginning and at the end of a commutation cycle. As the energy in an inductor is given by:

$$E = \frac{1}{2}LI_L^2 \quad (5)$$

It is obvious that the value of I_L at the end of the Off state must be the same as the value of I_L at the beginning of the On-state, i.e. the sum of the variations of I_L during the on and the off states must be zero:

$$\Delta I_{Lon} + \Delta I_{Loff} = 0 \qquad (6)$$

Substituting ΔI_{Lon} and ΔI_{Loff} by their expressions yields:

$$\Delta I_{Lon} + \Delta I_{Loff} = \frac{V_i DT}{L} + \frac{V_o(1-D)T}{L} = 0 \qquad (7)$$

This can be written as:

$$\frac{V_o}{V_i} = \left(\frac{-D}{1-D}\right) \qquad (8)$$

This in return yields that:

$$D = \frac{V_o}{V_o - V_i} \qquad (9)$$

From the above expression it can be seen that the polarity of the output voltage is always negative (as the duty cycle goes from 0 to 1), and that its absolute value increases with D, theoretically up to minus infinity as D approaches 1. Apart from the polarity, this converter is either step-up (as a boost converter) or step-down (as a buck converter). This is why it is referred to as a buck–boost converter.

2.2.4.3 Discontinuous Conduction Mode:

In some cases, the amount of energy required by the load is small enough to be transferred in a time smaller than the whole commutation period. In this case, the current through the inductor falls to zero during part of the period. The only difference in the principle described above is that the inductor is completely discharged at the end of the commutation cycle (see waveforms in figure 2.12). Although slight, the difference has a strong effect on the output voltage equation. It can be calculated as follows:
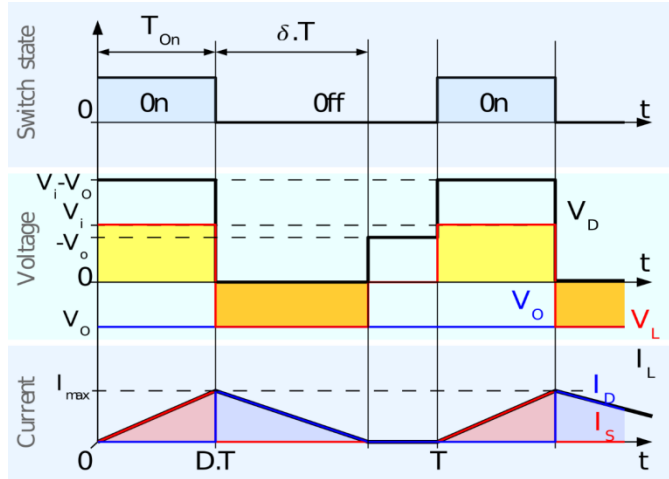
Figure 2.12: Waveforms of current and voltage in a buck–boost converter operating in discontinuous mode.

As the inductor current at the beginning of the cycle is zero, its maximum value I_{Lmax} (at $= DT$) is

$$I_{Lmax} = \frac{V_i DT}{L} \qquad (1)$$

During the off-period, I_L falls to zero after δT:

$$I_{Lmax} + \frac{V_o \delta T}{L} = 0 \qquad (2)$$

Using the two previous equations, δ is:

$$\delta = \frac{V_i D}{V_o} \qquad (3)$$

The load current I_o is equal to the average diode current (I_D). As can be seen on figure 2.14, the diode current is equal to the inductor current during the off-state. Therefore, the output current can be written as:

$$I_o = \overline{I_D} = \frac{I_{Lmax}}{2} \delta \qquad (4)$$

Replacing I_{Lmax} and δ by their respective expressions yields:

$$I_o = - \frac{V_i DT}{2L} \cdot \frac{V_i D}{V_o} = - \frac{V_i^2 D^2 T}{2LV_o} \qquad (5)$$

Therefore, the output voltage gain can be written as:

$$\frac{V_o}{V_i} = - \frac{V_i D^2 T}{2LI_o} \qquad (6)$$

Compared to the expression of the output voltage gain for the continuous mode, this expression is much more complicated. Furthermore, in discontinuous operation, the output voltage not only depends on the duty cycle, but also on the inductor value, the input voltage and the output current.

2.3 APPLICATIONS:

DC/DC converters are for converting from one DC power level to another DC power level. The most typical example of application of DC/DC converters is DC power supplies. However, in most cases of both in commercial fields and industries, power source is AC. In this case, DC/DC converters cannot operate standalone. Operating together with other circuits, such as rectifiers as shown in Fig. 2.13, DC/DC converters are very useful in many applications.
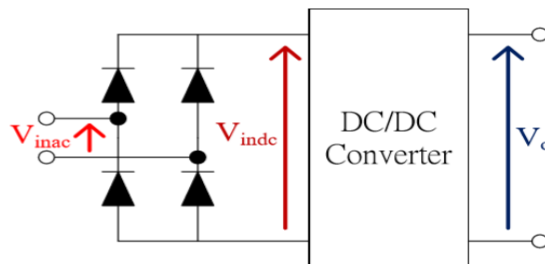
Figure. 2.13: Block diagram of DC/DC converter with a rectifier

Examples of applications of DC/DC Converters are listed in the followings:

➢ DC power supplies (for DC or AC input, usually called switched-mode power supplies (SMPS))
➢ Battery chargers
➢ Power factor correction converters (PFCC)
➢ Motor drives (DC drives, brushless DC drives, switched reluctance motor (SRM) drives, etc)
➢ Electric brakes
➢ Electric Vehicles

CHAPTER-3
PROPOSED CONCEPT

3.1 THE OPERATION PRINCIPLE:

The converter shown in Fig. 3.1, V_{in1} and V_{in2} are the voltages of the input sources, S_1, S_2 and S_3 are switches, D_1 and D_2 are freewheeling diodes, L is the filter inductor, C_o is the output capacitor, R is the load, and V_o is the output voltage. According to the input voltages of the input sources, the converter can work in three modes. When the voltages are large enough, the converter works in mode I, where the output voltage is smaller than the sum of the input voltages. When the input voltages decrease gradually, the converter transfers to mode II, where output voltage may be larger or smaller than the sum of the input voltages. If one of the input sources quits, the converter works in the fault-tolerant mode.
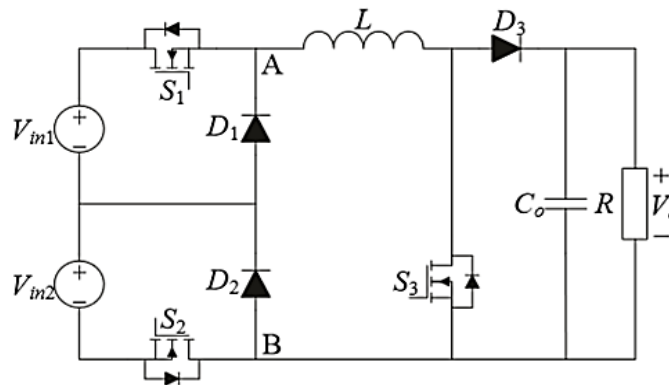
Figure 3.1: Circuit of Proposed Converter

3.1.1 The Operation Principles of Mode1:

In this mode, S_3 is kept OFF, and there are three switching states in one operating period. The key waveforms of this mode are shown in Fig. 3.5, where G_{s1} and G_{s2} are the driving signals for S_1 and S_2 with duty cycles of D_{S1} and D_{S2}, respectively. T_S is the switch period, V_{AB} is the voltage between points A and B, and I_L is the current flowing through the inductor L.

State I:

In Fig. 3.2 : S_1 is ON and S_2 is OFF. V_{AB} is V_{in1}, the load absorbs energy from V_{s1}, and I_L increases linearly when $V_{in1} > V_O$ and decreases linearly when $V_{in1} < V_O$.

$$L\frac{di_L}{dt} = V_{in1} - V_O \tag{1}$$
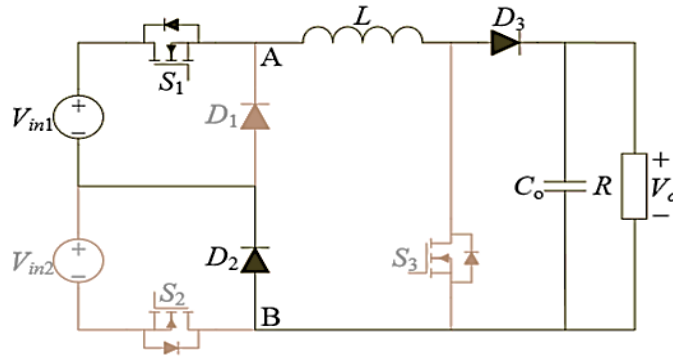
Figure 3.2: Circuit of proposed converter in state-1

State II:

In Fig. 3.3 : S1 and S2 are both OFF. V_{AB} is zero, L supplies energy to the load, and i_L decreases linear

$$L\frac{di_L}{dt} = -V_O \tag{2}$$
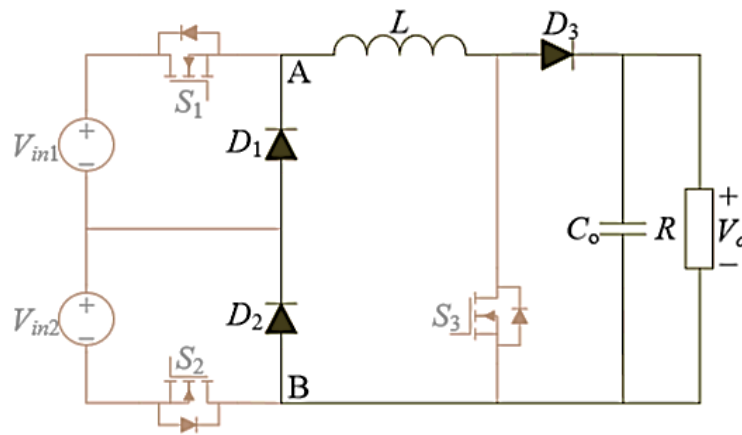
Figure 3.3: Circuit of Proposed Converter in state-2

State III:

In Fig.3.4: S_1 is OFF and S_2 is ON. V_{AB} is V_{in2}, the load absorbs energy from V_{in2}, and I_L increases linearly when $V_{in2} > V_O$ and decrease linearly when $V_{in2} < V_O$

$$L\frac{di_L}{dt} = V_{in2} - V_O \tag{3}$$

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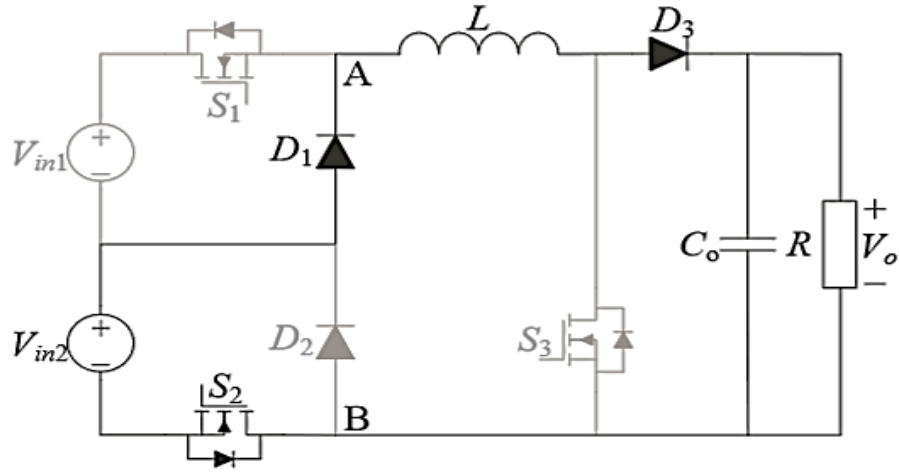
Figure 3.4: Circuit of Proposed Converter in state-3
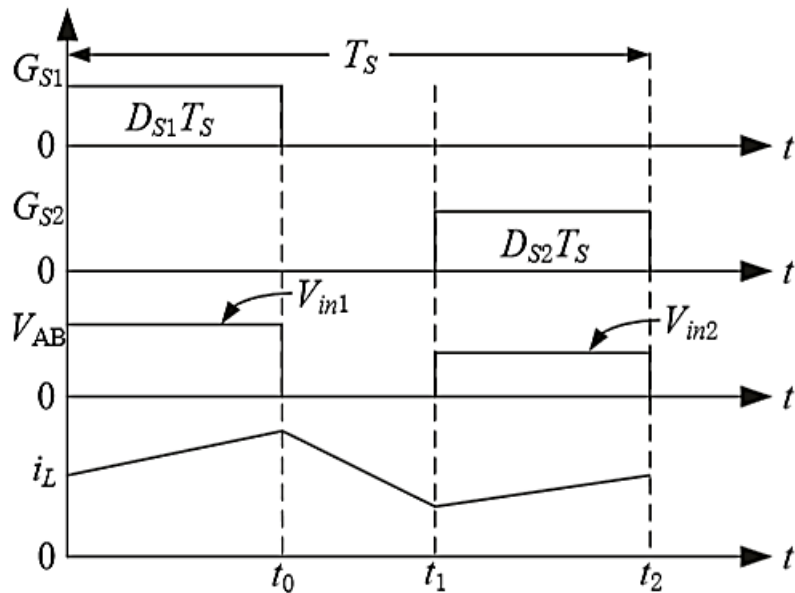
Figure 3.5: Key waveforms of the Converter in mode-1 operation

3.1.2 The Operation Principles of Mode II:

In this mode, S_3 takes part in the power transmission, and there are three switching states in one operating period. In this section, state II will be introduced alone. This is due to the fact that the switching states in this mode are same as those in mode I with the exception of state II. Key waveforms are shown in Fig. 4, where G_{S3} is the driving signal for S_3 with a duty cycle of D_{S3}.

State I:

In Fig. 3.6: S_1 is ON and S_2 is OFF. V_{AB} is V_{in1}, the load absorbs energy from V_{s1}, and I_L increases linearly when $V_{in1} > V_O$ and decreases linearly when $V_{in1} < V_O$
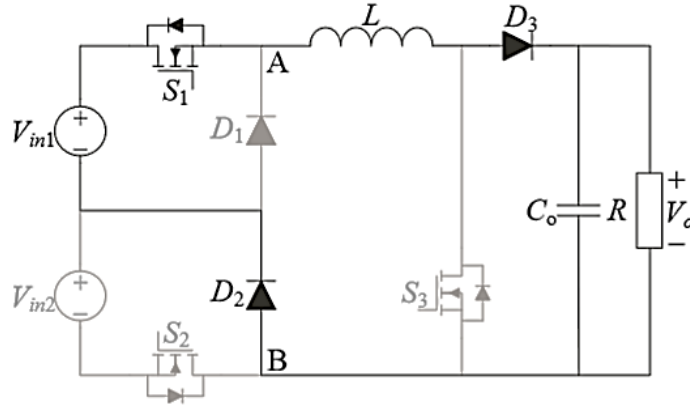
$$L\frac{di_L}{dt} = V_{in1} - V_O$$

Figure 3.6: Circuit of Proposed Converter in state-1

State II:

In Fig. 3.7 : S_1, S_2 and S_3 are ON. V_{AB} is the sum of V_{in1} and V_{in2}, L absorbs energy from two input sources, and i increases linearly

$$L\frac{di_L}{dt} = V_{in2} + V_{in2}$$
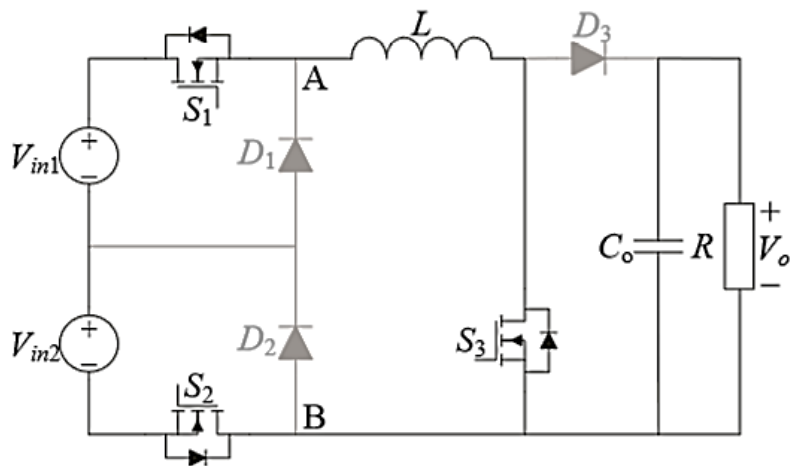
Figure 3.7: Circuit of Proposed Converter in state-2

State III:

In Fig. 3.8:S_1 is OFF and S_2 is ON.$V_{AB}$is V_{in2}, the load absorbs energy from V_{in2}, and I_L increases linearly when $V_{in2}>V_O$ and decrease linearly when $V_{in2}<V_O$

$$L\frac{di_L}{dt} = V_{in2} - V_O \tag{4}$$
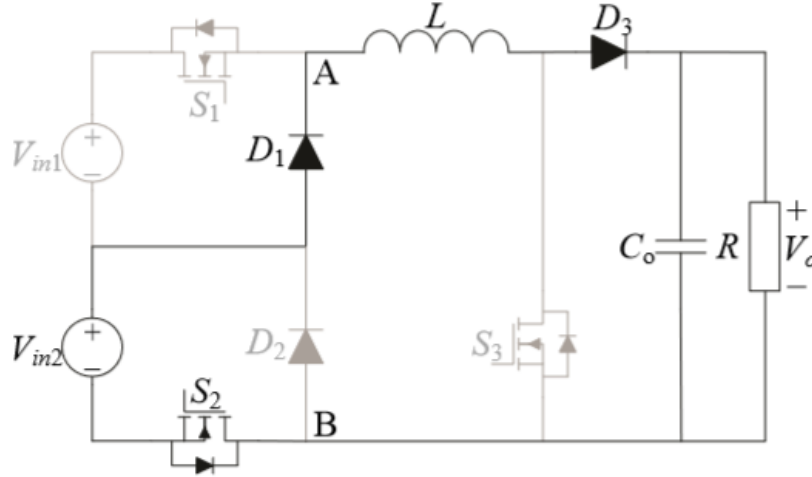
Figure 3.8: Circuit of Proposed Converter in state-3
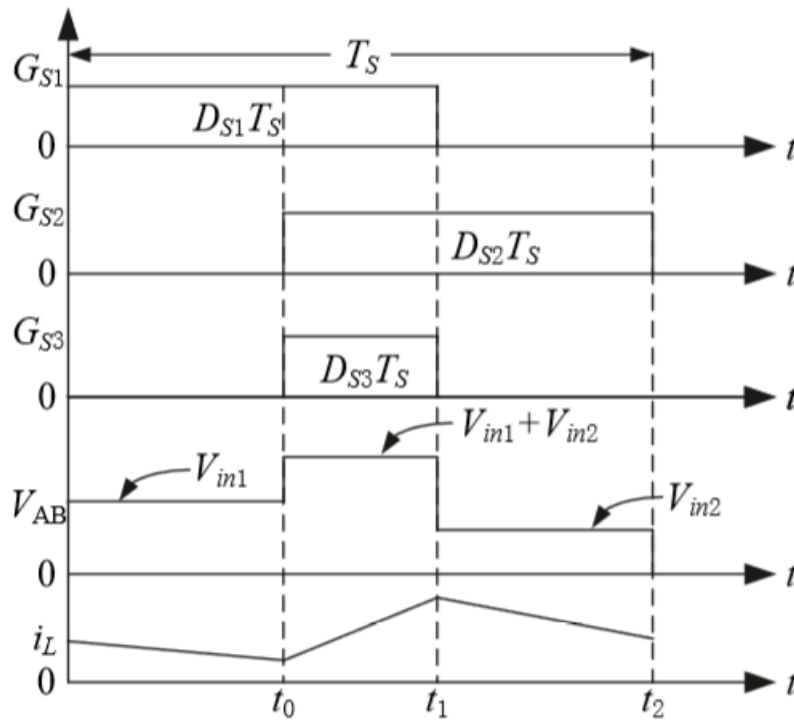
Figure 3.9: Key waveforms of the Converter in mode-1 operation

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3.1.3 The Operation Principles of the Fault-Tolerant Mode:

In this mode, only one input source supplies energy to the load. Due to the symmetry of the proposed converter, it is enough to introduce the situation where V_{in1} supplies energy to the load alone. The proposed converter can work as a conventional buck or boost converter. The buck converter has two switching states in one operating period, and equivalent circuits are shown in Fig.3.2 and 3.3. Similarly, the boost converter also has two switching states in one operating period, and equivalent circuits are shown in Fig. 3.2 and 3.10
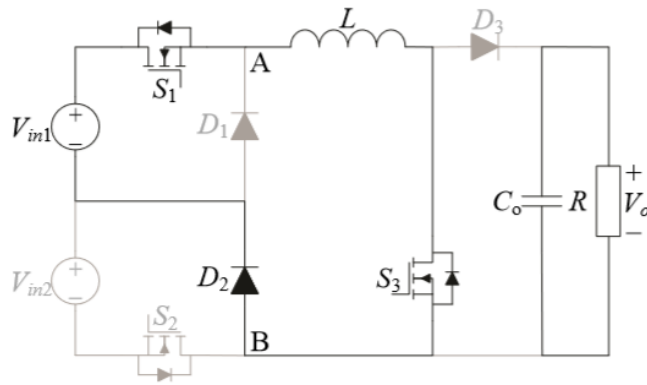
Figure 3.10: Proposed Converter in fault tolerance mode under boost operation

3.2 THE STEADY-STATE ANALYSIS:

3.2.1 The Analysis of Voltage Gain:

Before the analysis, it is assumed that all of the devices of the converter is ideal and that the inductor current is continuous. In mode I, applying the voltage-second balance to L, the following equation can be obtained:

$$V_O(1- D_{S1} - D_{S2}) = (V_{in1} - V_O)\, D_{S1} + (V_{in2} - V_O)\, D_{S1} \qquad (5)$$

Thus, V_O can be derived as:

$$V_O = V_{in1}D_{S1} + V_{in2}D_{S2} \qquad (6)$$

In mode II, applying the voltage-second balance to L, the following equation   can be obtained:

$$(V_{in1} + V_{in2})\ D_{S3} = (V_O - V_{in1})D_{S1} + (V_O - V_{in2})D_{S2} \qquad (7)$$

V_O can be derived as:

$$V_O = \frac{V_{in1}D_{S1} + V_{in2}\ D_{S2}}{1 - D_{S3}} \quad (8)$$

From Fig. 3.9, it can be found that:

$$D_{S3} = D_{S1} + D_{S2} - 1 \qquad\qquad\qquad (9)$$

By substituting (9) into (8), equation (8) can be rewritten as:

$$V_O = \frac{V_{in1}D_{S1} + V_{in2}D_{S2}}{2 - D_{S1} - D_{S2}} \quad (10)$$

For the fault-tolerant mode, the proposed converter is a buck converter when $V_{in1} > V_o$. The relationship between V_{in1} and V_o can be derived as:

$$V_o = V_{in}D_{s1} \quad (11)$$

The proposed converter is a boost converter when $V_{in1} < V_o$. The relationship between V_{in1} and V_o can be derived as:

$$V_O = \frac{V_{in}}{1 - D_{S1}} \qquad\qquad\qquad (12)$$

3.2.2 The Wide-Input-Voltage-Range Characteristic:

The equations of (6) and (10) have given the input-output relationship of the proposed converter. It can be found that the output voltage is determined by V_{in1}, V_{in2}, D_{s1} and D_{s2} in both modes I and II. To observe the input voltage range intuitionally, the relationship curves of V_{in2} and D_{s2} are demonstrated in Fig. 6 with fixed values of V_{in1}, D_{s1} and V_o.

In Fig. 3.11(a), V_{in1} is 30 V and V_o is 50 V. The three curves can be plotted when D_{s1} is 0.4, 0.5 and 0.6. When S_3 is kept OFF, the relationship curves between V_{in2} and D_2 are A_0A_2, B_0B_2 and C_0C_2, respectively. When the converter adopts the proposed modulation scheme, the relationship curves are A_0A_3, B_0B_3 and C_0C_3. A_1, B_1 and C_1 are critical points between modes I and II.

In Fig. 3.11(b), D_{s1} is 0.5, and V_o is 50 V. Three curves can be plotted when V_{in1} is 20 V, 30 V and 40 V. When S_3 is kept OFF, the relationship curves between V_{in2} and D_2 are A_0A_2, B_0B_2 and C_0C_2, respectively. When the converter adopts the proposed modulation scheme, the relationship curves are A_0A_3, B_0B_3 and C_0C_3. A_1, B_1 and C_1 are critical points between modes I and II.
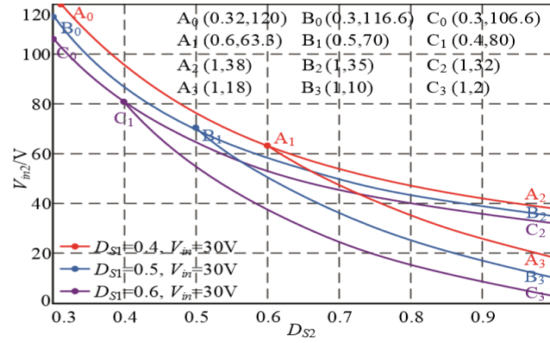
(a)
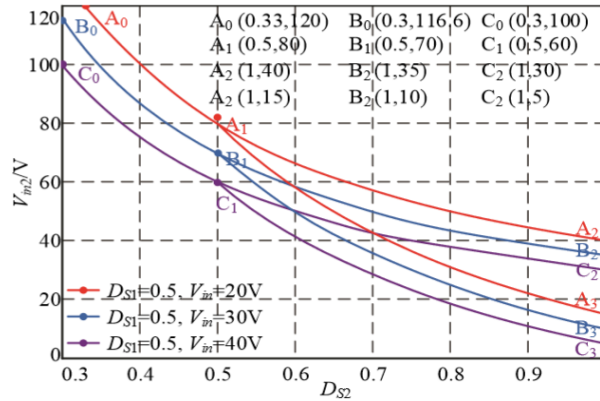
(b)

Figure 3.11: The relationship curves of V_{in2} and D_{s2}: (a) V_{in1}=30V, D=0.4,0.5 or 0.6; (b) D1=0.5, V_{in1}=30V,40V or 50V

According to Fig. 3.11, it is obvious that the input voltage range becomes wider under the proposed modulation scheme. Hence, the wide-input-voltage-range characteristic is achieved.

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3.2.3 The Fault-Tolerant Capability:

A double-input converter is proposed for renewable energy generation systems, and the input sources may stop powering the load due to their intermittent nature. Thus, it is necessary to discuss the fault-tolerant capability of the converter. A schematic diagram of the fault-tolerant capability is shown in Fig 3.12.
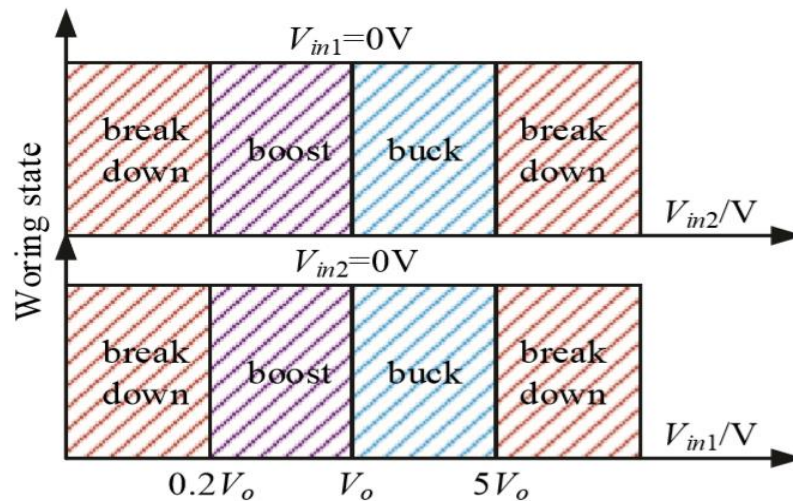
Figure 3.12 :Schematic diagram of the fault-tolerant capability

When V_{in2} is 0, the converter has three working states with different values of V_{in1}. When $0.2\ V_o < V_{in1} < V_o$, the proposed converter operates as a boost converter. When $V_o < V_{in1} < 5\ V_o$, the proposed converter operates as a buck converter. When $V_{in1} < 0.2\ V_o$ and $V_{in1} > 5\ V_o$, the converter breaks down due to limitations of the voltage gain. Similarly, when V_{in1} is 0, the converter has three working states with different values of V_{in2}. The working states are the same as the situation described above. Consequently, the proposed converter has excellent fault-tolerant capability when two input sources vary from $0.2\ V_o$ to 5V.

3.2.4 Efficiency Analysis:

Efficiency curves of the converter are shown in Fig 3.13 The efficiency of the converter is about 92%-95% when the output power P_o is in the range of 20 W-160 W. It can be found that the efficiency of mode I is higher than that of mode II. Mode III has the highest efficiency among the three modes.
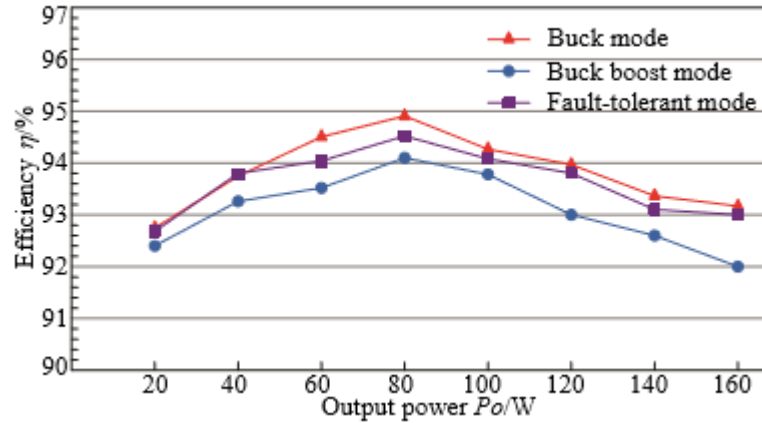
Figure 3.13: Efficiency in different operation modes.

3.3 PARAMETERS OF THE PROPOSED CONVERTER:

Parameter	Value
Output voltage (Vo)	50V
Rating power (Po)	100W
Output capacitor (Co)	220 µF
Inductor (L)	300 µH
Switching frequency (fs)	30 kHz

Table 3.1: Parameters ofthe Proposed Converter

3.4 COMPARISON AMONG THE EXISTING CONVERTERS:

Comparisons are conducted among the proposed converter and the converters in [1] and [2]. These comparisons include components number, minimum input voltage, fault- tolerant capability and theoretical efficiency. As shown in Table 3.2, the proposed converter needs more components when compared with the converter in [1]. Meanwhile, the performance of the proposed converter has been significantly improved. When Vin1 is 30 V and D_{s1} is 0.5, the minimum voltage of V_{in2} is 10 V, which is a lot less than the 35 V minimum voltage of the converters in [1] and [2]. On the other hand, the maximum voltages of the three converters are the same. Thus, the proposed converter has a wider input voltage range. In terms of system reliability, the proposed converter can achieve fault-tolerance with a full input voltage range when V_{in1} and V_{in2} vary from $0.2V_o$ to $5V_o$. The tolerant input voltage ranges of the three converters are listed, and the proposed

converter obviously has an advantage when compared with the other two converters. Finally, the theoretical efficiencies are compared when the three converters operate at 100 W with the same parameters. It can be seen that the proposed converter sacrifices some of its efficiency to improve the system performance.

Comparison Items	Proposed converter	[1]	[2]
Switch number	3	2	3
Diode number	3	2	4
Minimum input voltage	10V	35V	35V
Fault-tolerant ability	$(0.2V_o, 5V_o)$ $(0.2V_o, 5V_o)$	$(V_o, 5V_o)$ $(0.5V_o, 5V_o)$	$(V_o, 5V_o)$ $(V_o, 5V_o)$
Efficiency	94.16%	95.51%	95.35%

Table 3.2: Comparison among the existing converters

CHAPTER-4
MATLAB/SIMULINK

4.1 Introduction to MATLAB:

MATLAB is an abnormal state specialized registering dialect and intuitive environment for calculation improvement, information perception, information investigation, and numeric calculation. Utilizing the MATLAB item, you can tackle specialized processing issues speedier than with customary programming dialects, for example, C, C++, and FORTRAN.

MATLAB is utilized as a part of extensive variety of utilizations, including flag and picture preparing, correspondences, control outline, test and estimation, money related demonstrating and investigation, and computational science. Add-on tool stash (accumulations of uncommon reason MATLAB capacities, accessible independently) extend the MATLAB environment to take care of specific classes of issues in these application zones.

MATLAB gives various elements to recording and sharing your work. You can coordinate your MATLAB code with different dialects and applications, and disseminate your MATLAB calculations and application.

Key Features:

- ➢ High-level language for technical computing.
- ➢ Development environment for managing code, files, and data.
- ➢ Interactive tools for iterative exploration, design, and problem solving.
- ➢ Mathematical functions for linear algebra, statistics, Fourier analysis, filtering, optimization, and numerical integration.
- ➢ 2-D and 3-D graphics functions for visualizing data.
- ➢ Tools for building custom graphical user interfaces.
- ➢ Functions for integrating MATLAB based algorithms with external applications and languages, such as C, C++, Fortran, Java, COM, and Microsoft Excel.

4.2 Introduction to SIMULINK:

Simulink is a situation for multi-space re-enactment and Model-Based Design for dynamic and inserted frameworks. It gives an intuitive graphical environment and an adjustable arrangement of piece libraries that let you outline, mimic, actualize, and test an assortment of time-fluctuating frameworks, including interchanges, controls, sign handling, video preparing, and picture handling.

Add-on items stretch out Simulink programming to different displaying spaces, and in addition give devices to plan, execution, and confirmation and approval errands.

Simulink is incorporated with MATLAB, giving quick access to a broad scope of instruments that let you create calculations, dissect and picture recreations, make group handling scripts, redo the displaying environment, and characterize sign, parameter, and test information.

Key Features:

- ➢ Extensive and expandable libraries of predefined blocks.
- ➢ Interactive graphical editor for assembling and managing intuitive block diagrams.
- ➢ Ability to manage complex designs by segmenting models into hierarchies of 51design components.
- ➢ Model Explorer to navigate, create, configure, and search all signals, parameters, properties, and generated code associated with your model.
- ➢ Application programming interfaces (APIs) that let you connect with other simulation programs and incorporate hand-written code.
- ➢ Embedded MATLAB Function blocks for bringing MATLAB algorithms into Simulink and embedded system implementations.
- ➢ Simulation modes (Normal, Accelerator, and Rapid Accelerator) for running simulations interpretively or at compiled C-code speeds using fixed- or variable-step solvers.
- ➢ Graphical debugger and profiler to examine simulation results and then diagnose performance and unexpected behavior in your design.

- Full access to MATLAB for analysing and visualizing results, customizing the modelling environment, and defining signal, parameter, and test data.
- Model analysis and diagnostics tools to ensure model consistency and identify modelling errors.

4.3 Block Diagram:

A Simulink block diagram is a pictorial model of a dynamic system. It comprises of an arrangement of images, called blocks, interconnected by lines. Every block speaks to a rudimentary dynamic system that delivers a yield either consistently (a constant block) or at particular focuses in time (a discrete block). The lines represents to associations of block inputs to block outputs. Each block in a block diagram is a case of a particular kind of block. The sort of the square decides the relationship between a block outputs and its inputs, states, and time. A block diagram can contain any number of cases of a block expected to show a system. Block speak to rudimentary element frameworks that Simulink knows how to simulate. A block contains one or a greater amount of the following:

1)   A set of inputs,

2)   A set of states, and

3)   A set of outputs

A blocks output is a component of time and the block's inputs and states (if any). The particular capacity that relates a blocks output to its inputs, states, and time relies on upon the sort of square of which the piece is an example. continuous Versus discrete Blocks Simulink's standard block set incorporates ceaseless squares and discrete block. Ceaseless pieces react persistently to consistently evolving information. Discrete blocks, by differentiation, react to changes in data just at necessary products of an altered interim called the blocks sample time. Discrete pieces hold their output steady between progressive sample time hits. Each discrete block incorporates a specimen time parameter that permits you to determine its sample rate. The Simulink block can be continuous or discrete, contingent upon whether they are driven by continuous or discrete block. A square that can be either discrete or continuous is said to have a certain sample rate. The certain specimen time is ceaseless if any of the square's inputs are nonstop. The verifiable example time is equivalent to the most limited info test time if all the information test times are essential products of the briefest time. Something else, the

information test time is equivalent to the central example time of the inputs, where the major specimen time of an arrangement of sample times is characterized as the best whole number divisor of the arrangement of sample times.

Simulink can alternatively shading code a block diagram to show the sample times of the pieces it contains, e.g., black (continuous), maroon (constant), yellow (hybrid), red (speediest discrete), etc. The block contains block name, symbol, and piece library that contain the block, the reason for the block.

4.3.1 SIMULINK Block Libraries:

Simulink organizes its blocks into block libraries according to their behavior:

1) The Sources library contains blocks that generate signals.
2) The Sinks library contains blocks that display or write block output.
3) The Discrete library contains blocks that describe discrete-time components.
4) The Continuous library contains blocks that describe linear functions.
5) The Math library contains blocks that describe general mathematics functions.
6) The Functions & Tables library contains blocks that describe general functions and table look-up operations.
7) The Nonlinear library contains blocks that describe nonlinear functions.
8) The Signal & Systems library contains blocks that allow multiplexing and demultiplexing, implement external input/output, pass data to other parts of the model, and perform other functions.
9) The Subsystems library contains blocks for creating various types of subsystems.
10) The Block sets and Toolboxes library contains the Extras block library of specialized blocks.

4.4 The Power System Block Set:

Electrical power systems are mixes of electrical circuits and Electro-mechanical gadgets, similar to engines and generators. Designers working in this order are every now and again tasked to enhance the execution of the system. Necessities for definitely expanded proficiency have constrained force framework creators to utilize power electronic gadgets and complex control framework ideas that duty conventional investigation apparatuses and strategies. Further convoluting the expert's part is the way that the framework is regularly so nonlinear that the best way to comprehend it is through re-enactment. Area based force era from hydroelectric, steam, or different gadgets is by

all account not the only utilization of force system. A typical characteristic of these frameworks is their utilization of force hardware and control frameworks to accomplish their execution targets. The Power System Block set was intended to give a present day configuration apparatus that will permit researchers and designers to quickly and effectively assemble models that reproduce power frameworks. The blocks set uses the Simulink environment permitting a model to be assembled utilizing basic snap and drag methods. Not just can the circuit topology be drawn quickly, yet the examination of the circuit can incorporate its connections with mechanical, warm, control, and different orders. This is conceivable in light of the fact that all the electrical parts of the re-enactment interface with Simulink's broad displaying library. Since Simulink utilizes MATLAB as the computational motor, you can utilize MATLAB's tool kits as you plan your re-enactment.

The block set can be given something to do quickly. The libraries contain models of run of the mill power gear, for example, transformers, lines, machines, and power gadgets. These models are demonstrated ones originating from course readings, and their legitimacy depends on the experience of the Power Systems Testing and Simulation Laboratory of Hydro-Québec, a substantial North American utility situated in Canada. The abilities of the piece set for displaying a commonplace electrical framework are delineated in showing records. The block set fits well with other specific logical devices you use in the power system.

4.5 SIMULINK Blocks Used In the Simulation:

1. DC Voltage Source:
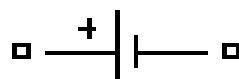
Purpose: Implement DC Voltage source

Description: The DC Source block implements DC voltage source.

2.In Port:

Purpose: Provide a link to an external input and for linearization.

Description: In ports are the links from the outside world into a system. Inside a subsystem block, there is an in port corresponding to each input port on the block. A signal that arrives at an input port on a subsystem block flows out of the corresponding in port within that block. The imports within a subsystem block must be numbered consecutively, starting with1.

3. Out Port

Out1

Purpose: provide a link to an external output and for linearization.

Description: The Out port block provides a mechanism for labelling a system's outputs. In a subsystem, output ports correspond to outputs on the subsystem block.

4. Scope:
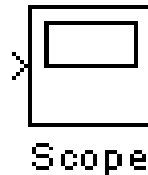
Scope

Purpose: Display signals during simulation.

Description: While the simulation is running, the Scope block displays the output of the block driving it. Opening a scope block produces a scope window. The title of this window matches the name of the block.

5. Voltage Measurement:
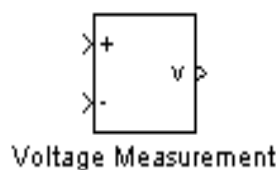
Voltage Measurement

Purpose: Measure a voltage in a circuit.

Description: The Voltage Measurement block is used to measure the instantaneous voltage between two electric nodes.

6.Current Measurement:
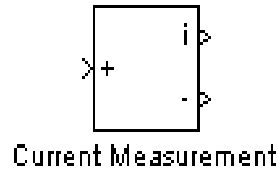
Current Measurement

Purpose: Measure a current in a circuit

Description: The Current Measurement block is used to measure the instantaneous current flowing in any electrical block or connection line.

7. MOSFET:
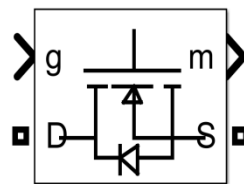
Description:MOSFET and internal diode in parallel with a series RC snubber circuit. When a gate signal is applied the MOSFET conducts and acts as a resistance in both directions. If the gate signal falls to zero when current is negative, current is transferred to the antiparallel diode.

8. Diode:
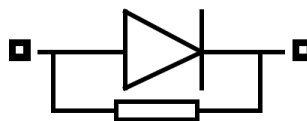
Description: Piece-wise linear model of a diode. If the voltage across the diode is bigger than the Forward voltage V_f, then the diode behaves like a linear resistor with low On resistance R_{on} plus a series voltage source. If the voltage across the diode is less than the Forward voltage, then the diode behaves like a linear resistor with low Off conductance G_{off}.

8. MUX:

Description: Split vector signals into scalars or smaller vectors. Check 'Bus Selection Mode' to split bus signals.

9. Inductor:

Description: Models a linear inductor. The relationship between voltage V and current I is $V = L\frac{dI}{dt}$ where L is the inductance in henries (H).

10. Capacitor:
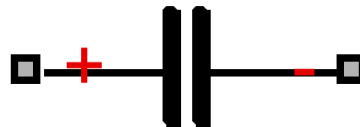
Description: Models a linear capacitor. The relationship between voltage V and current I is $I = C\frac{dv}{dt}$ Where C is the capacitance in farads.

11. Resistor:

Description: The voltage-current (V-I) relationship for a linear resistor is V=IR, where R is the constant resistance in ohms.

CHAPTER-5

MATLAB RESULTS

5.1 Mode-1 Operation:
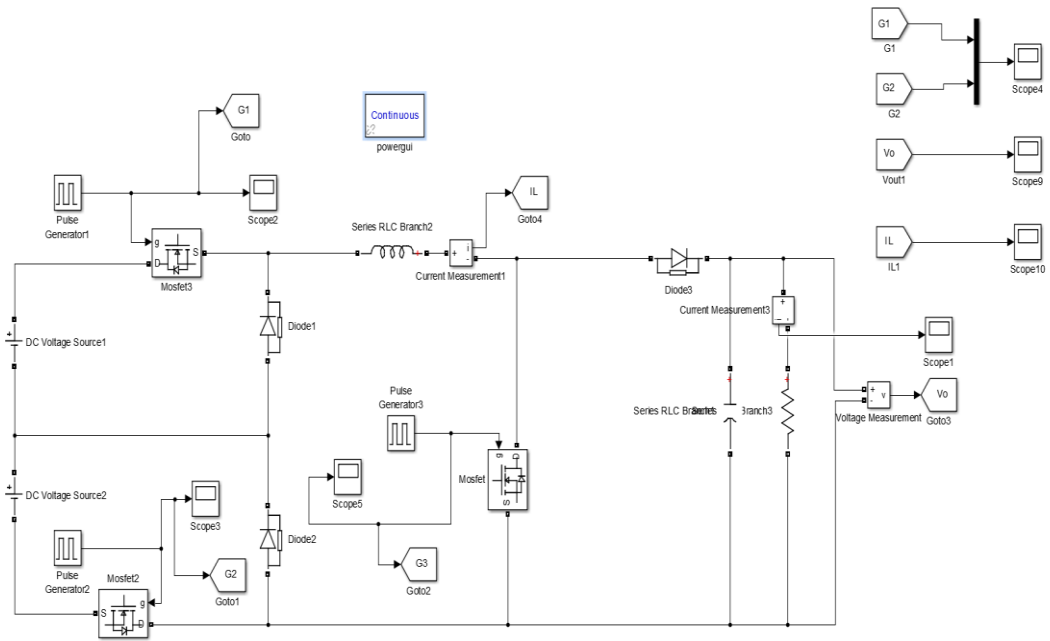
Figure 5.1: MATLAB Circuit for mode-1
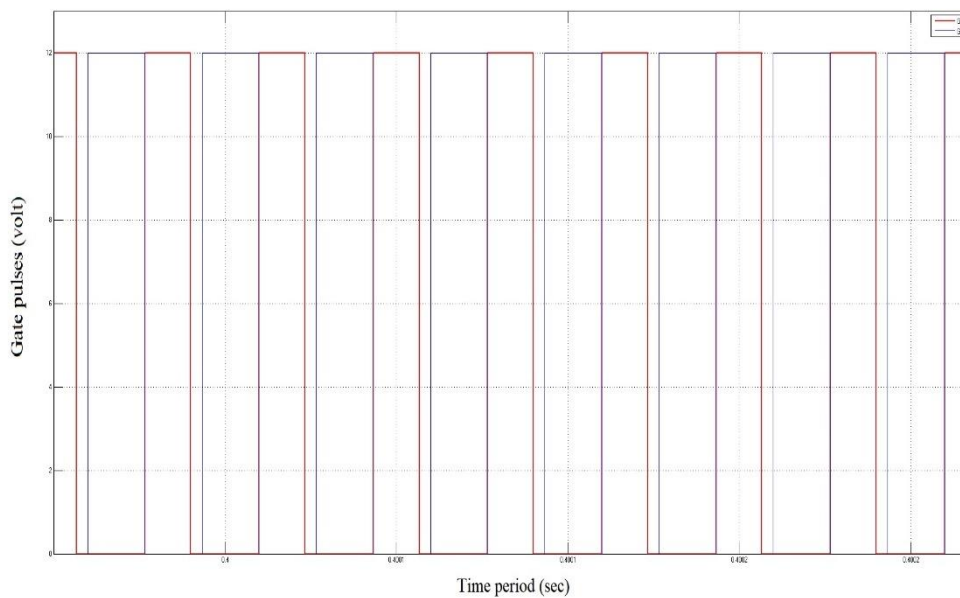
(a):Gate pulses for mode-1
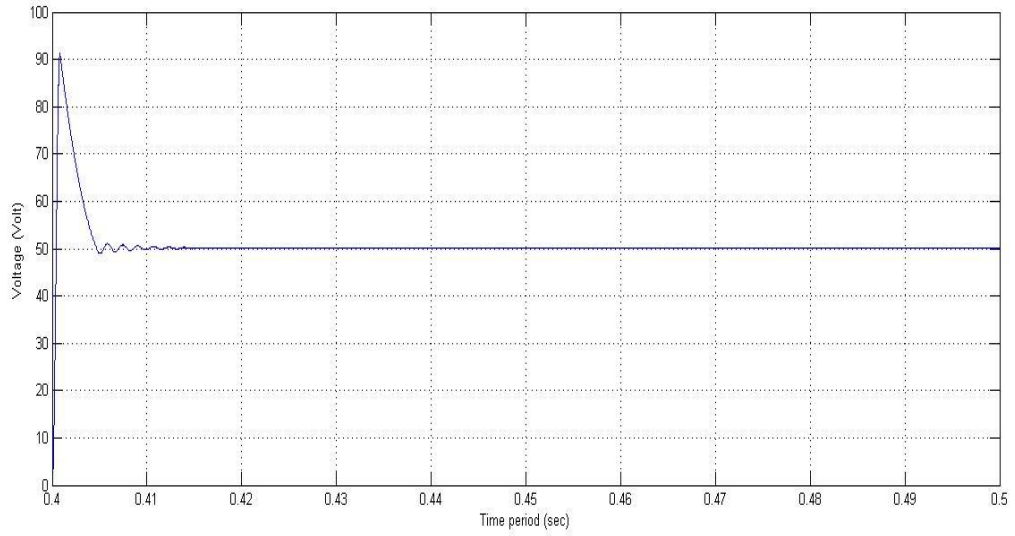
(b): Output voltage of mode-1
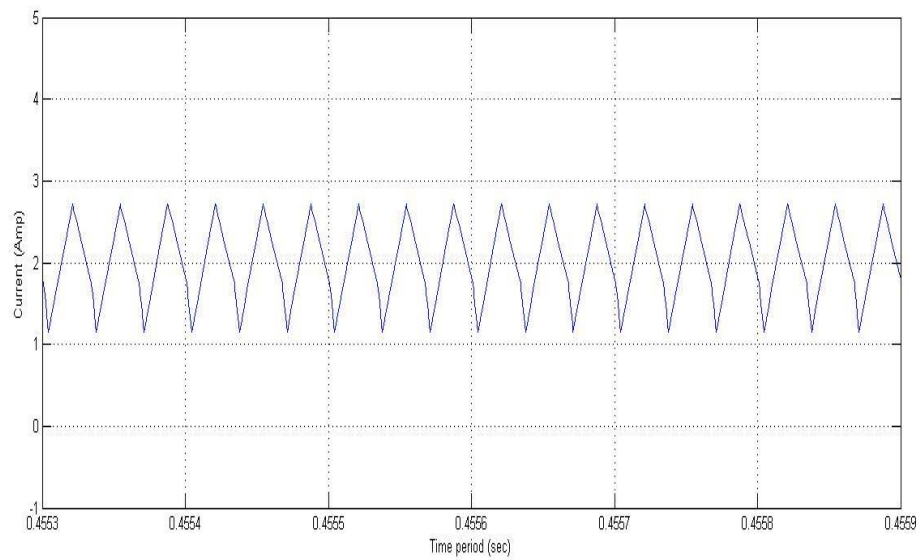
(c) Inductor current of mode-1

Figure 5.2: The simulation wave forms of mode-1(V_{in1}=30V,V_{in1}=80V,$G_{s1} = 0.4, G_{s2} = 0.5, G_{s3} =$0)

5.2 Mode-2 Operation:
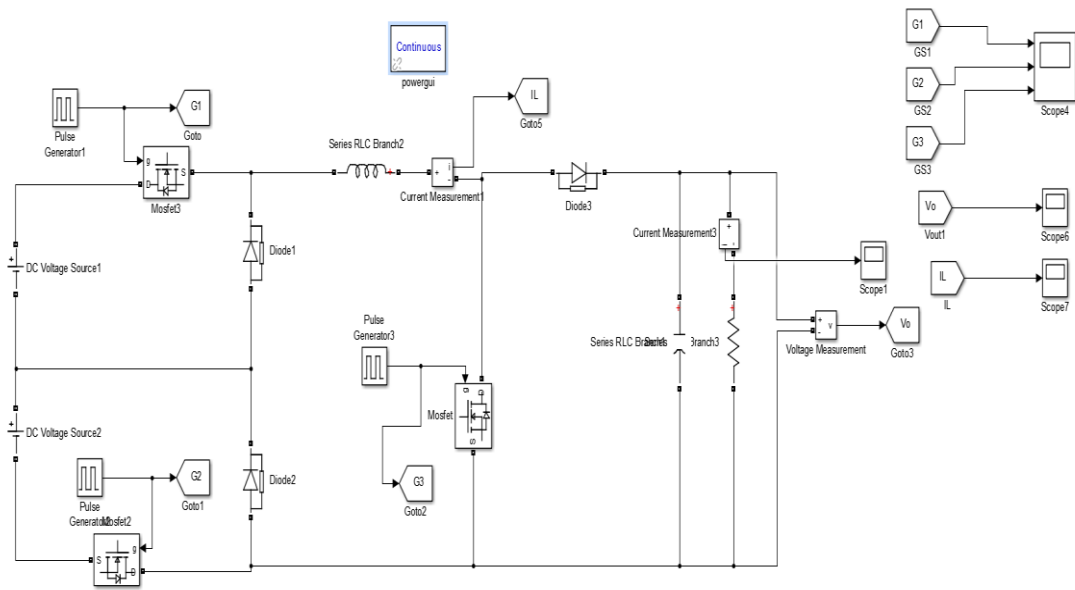
Figure 5.3: MAT lab Circuit for mode-2
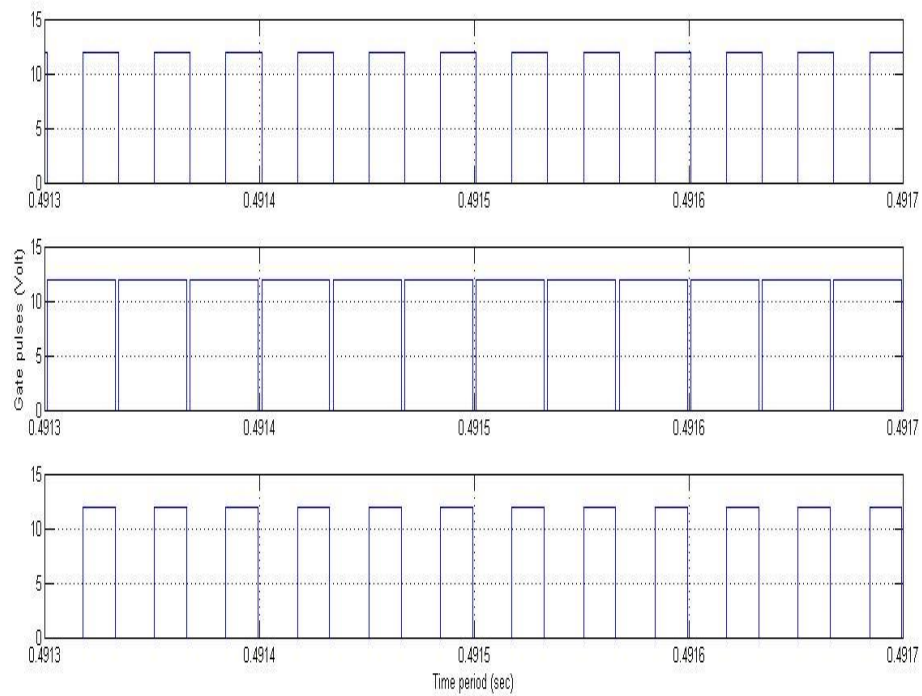
(a): Gate pulses for mode-2
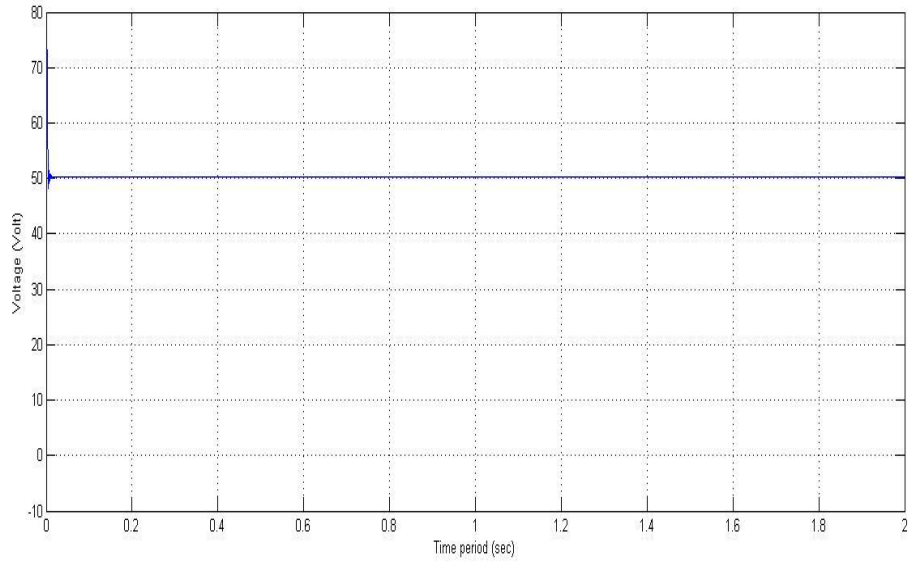
(b): Output voltage of mode-2
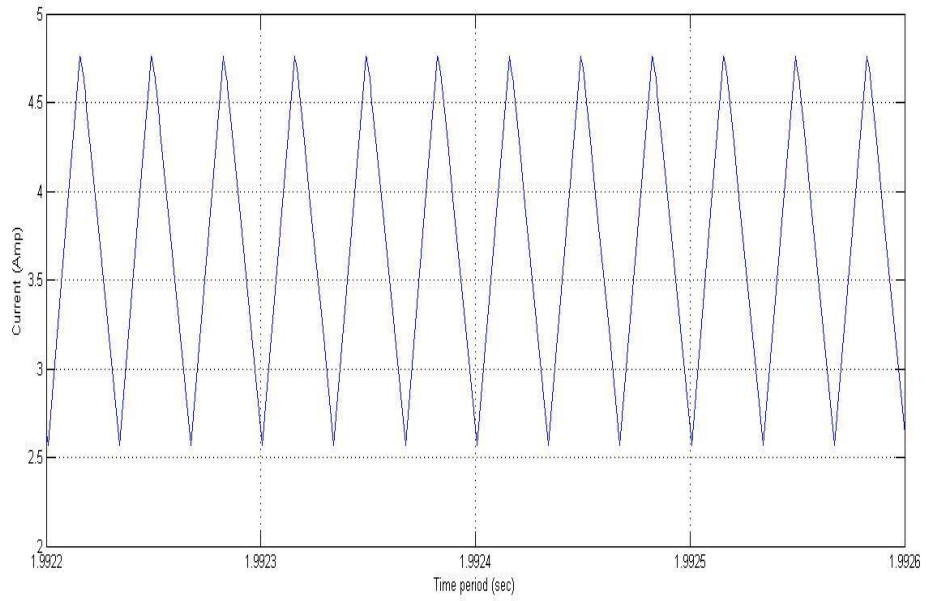
(c): Inductor current of mode-2

Figure 5.4: The simulation wave forms of mode-2 (V_{in1}=30V,V_{in1}=15V,$G_{s1} =$ 0.5, $G_{s2} = 0.95, G_{s3}$ =0.45)

5.3 Fault Tolerance Mode :

5.3.1 Boost operation:
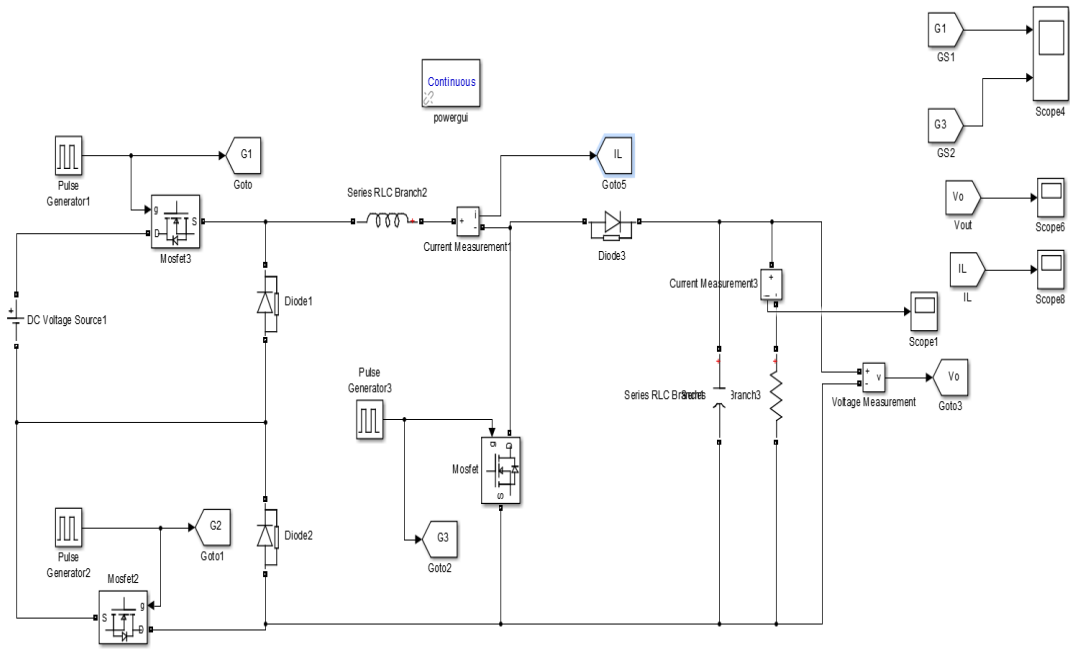
Figure 5.5: MATLAB Circuit For Fault Tolerance Mode(boost)
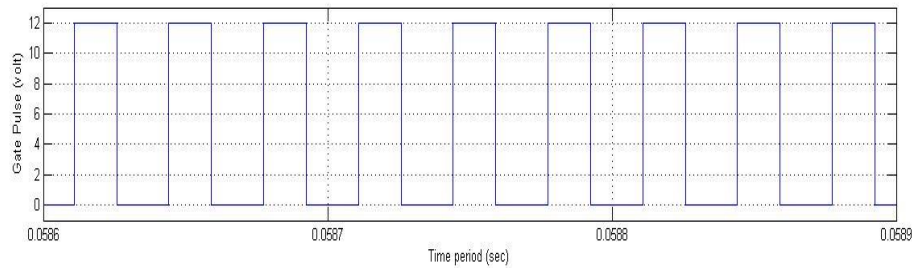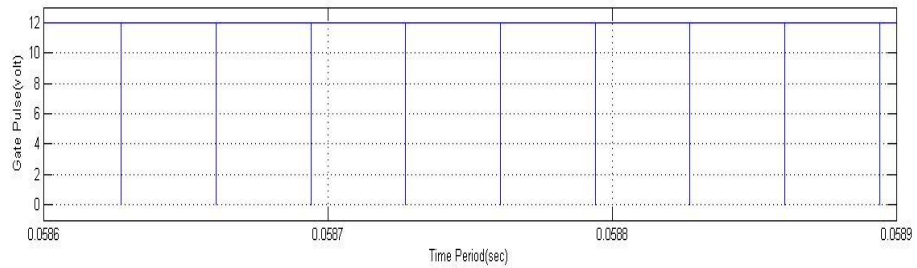
(a): Gate pulses for Fault Tolerance Mode(boost)
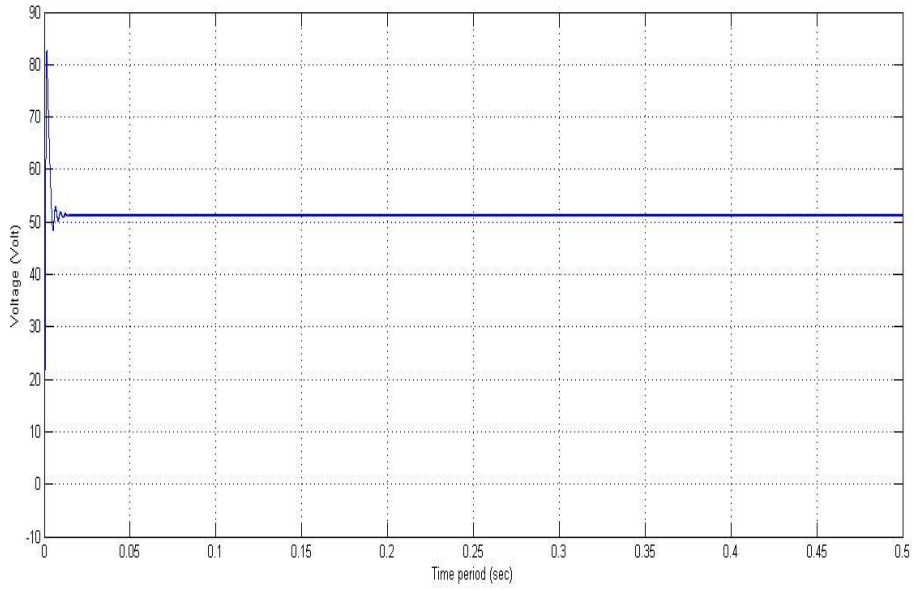
(b) Output voltage of Fault Tolerance Mode(boost)
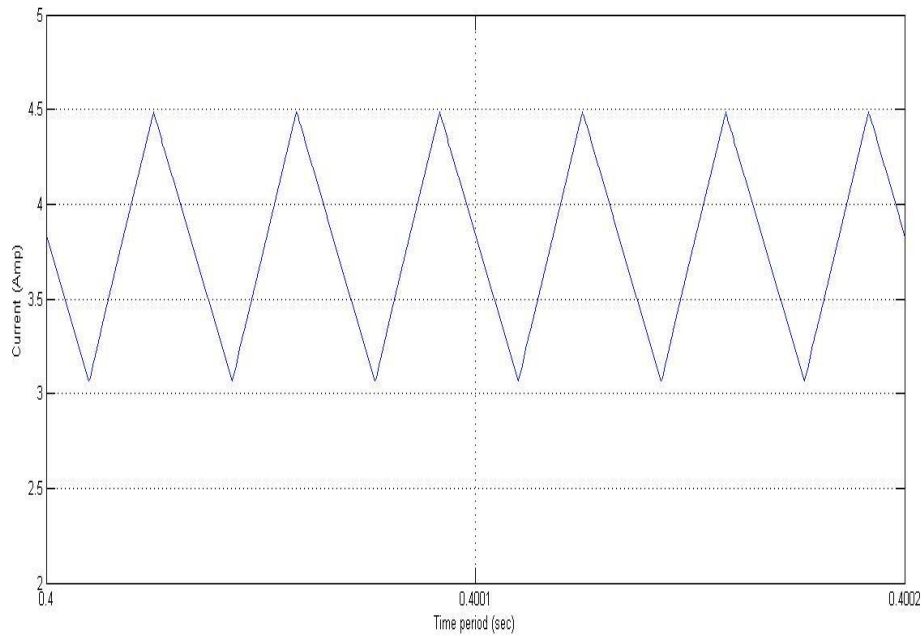
(c): Inductor current of Fault Tolerance Mode (boost)

Figure 5.6: The simulation wave forms of fault tolerant mode (boost)

(V_{in1}=30V,V_{in1}=0V,$G_{s1} = 1, G_{s2} = 0, G_{s3}$ =0.45)

5.3.2 Buck operation:
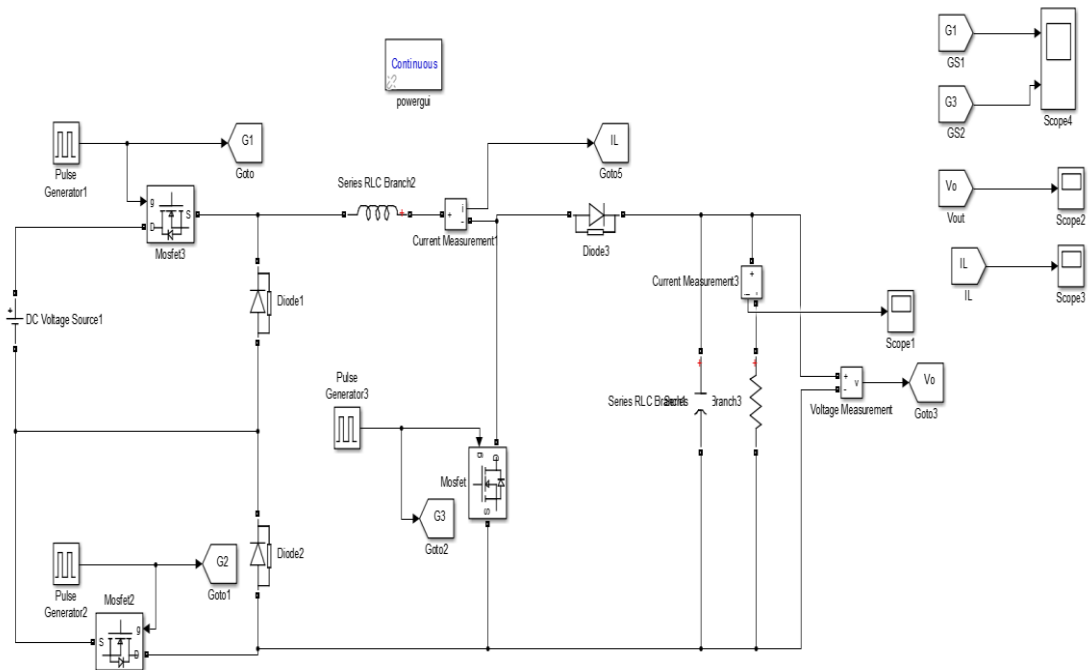
Figure 5.7: MAT lab Circuit for Fault Tolerance Mode (buck)
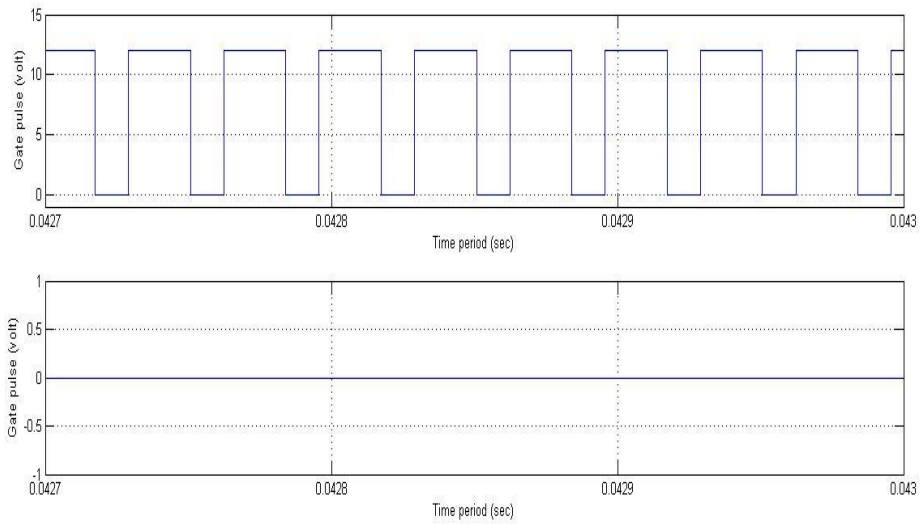
(a): Gate pulses for Fault Tolerance Mode(buck)
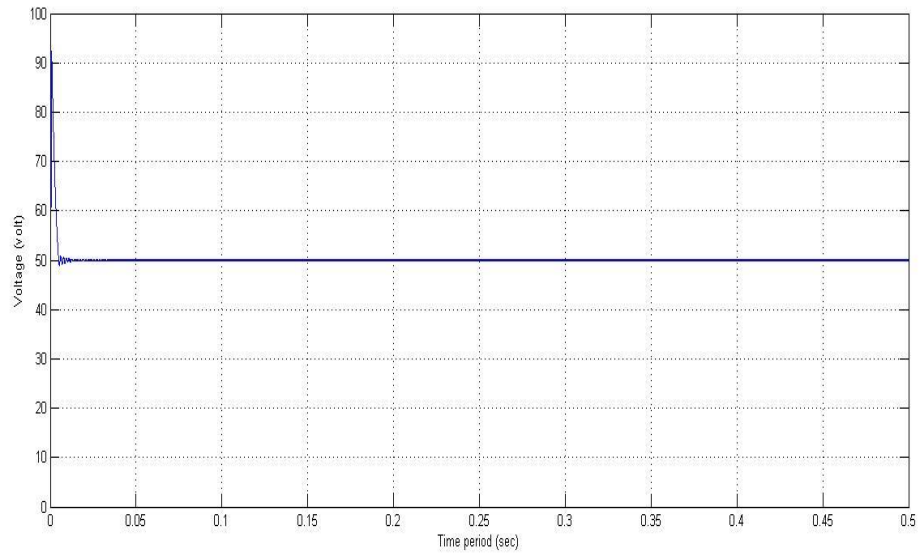
(b): Output voltage of Fault Tolerance Mode(buck)
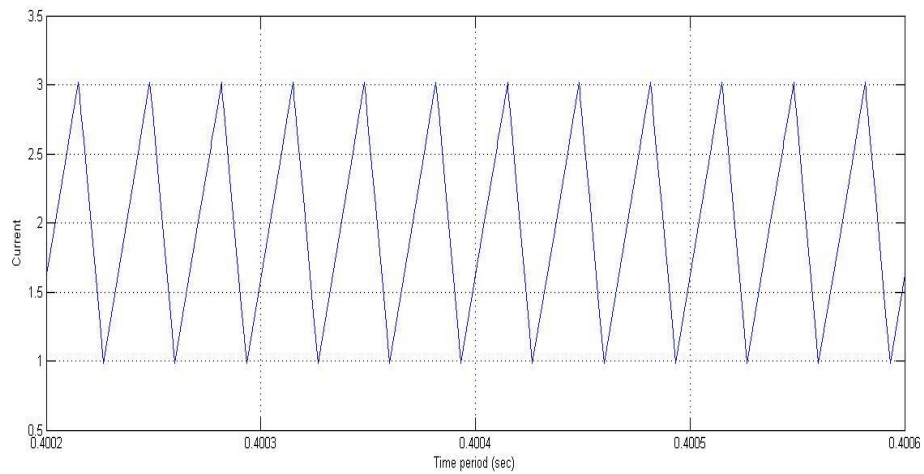
(c) Inductor current of Fault Tolerance Mode (buck)

Figure 5.8: The simulation wave forms of fault tolerant mode (buck)

(V_{in1}=30V,V_{in1}=0V,$G_{s1} = 0.65, G_{s2} = 0, G_{s3}$ =0)

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CHAPTER-6
CONCLUSION AND FUTURE SCOPE

A double-input dc-dc converter is proposed for wide-input- voltage-range applications. It is suitable for distributed power systems with two renewable energy sources such as wind-photovoltaic complementary power generation systems. The converter has two input ports, and the input sources can deliver energy to the load individually or simultaneously. Since the converter can work in two modes, a wide input range is feasible. A modulation strategy is introduced that allows the converter to smoothly transfer from mode I to mode II. Furthermore, if one of the input sources is powered off, the converter can work as a boost or buck circuit to maintain a stable output voltage**.**

However the study of different multi-input DC–DC converter topologies suggests that there is no single topologywhich can handle the entire goals of cost, reliability, flexibility andmodularity single handed. Efforts are continued to make multi-inputconverters and their control schemes more efficient and cost effectivefor integration of renewable energy sources and other applications.

FUTURE SCOPE:

Renewable energy sources are expected to be the major share-holder in future power generation industry. Efficient and reliable power electronics interface is required. Several power electronics converters have been presented in the above study to independently address the issues like high multiinput–multioutput inter-face, high efficiency, reliability, low cost, minimum number of components and less power loss, but no single circuitry is available which can collectively address these issues. Further research is required to develop a circuitry which can provide a good match between instantaneously changing sources and variable loads.

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POWER FACTOR IMPROVEMENT IN ZETA CONVERTER FOR BLDC MOTOR

Submitted in partial fulfillment of the requirements for award of the degree of

MASTER OF TECHNOLOGY

In

POWER INDUSTRIAL DRIVES

Submitted by

D.LIKHITHA **19U41D4207**

Under the Esteemed Guidance of
Mr. A.V. CHIRANJEEVI
Assistant Professor, Dept. of EEE

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2020

CERTIFICATE

This is to certify that the project work entitled "POWER FACTOR IMPROVEMENT IN ZETA CONVERTER FOR BLDC MOTOR" has been carried out by D.LIKHITHA (19U41D4207) submitted in the partial fulfillment of the requirement for the award of the degree of MASTER OF TECHOLOGY for POWER AND INDUSTRAL DRIVES during the academic year 2019-2021.

Mr.A.**V.CHIRANJEEVI**   **Mr. A. KRISHNA NAG MTech, (PID)**

(ASSISTANT PROFESSOR)   **(ASSOCIATE PROFESSOR)**

(PROJECT GUIDE)   (HEAD OF THE DEPARTMENT)

EXTERNAL EXAMINER

DECLARATION

I hereby declare that the dissertation entitled ""POWER FACTOR IMPROVEMENT IN ZETA CONVERTER FOR BLDC MOTOR" was carried out and written by me under the guidance of Mr. A. V.CHIRANJEEVI**,** Assistant Professor, Department of Electrical and Electronics Engineering, Dadi Institute of Engineering & Technology. This work has not been previously formed the basis for the award of any degree of diploma or certificate nor has been submitted elsewhere for the award of any degree or diploma.

BY

D.LIKHITHA   (19U41D4207)

ACKNOWLEDGEMENT

CONTENTS

ABSTRACT

In the recent years, usage of variable speed driving systems has been increasing in various applications like automobile industries, domestic applications etc., It leads to the development of permanent magnet brushless DC motor (PMBLDCM). For this motor diode bridge rectifier is generally used for AC to DC conversion to meet the demand of electrical machinery with the goal of providing continuous, harmonic less source of energy. In a conventional scheme of diode bridge rectifier with high value of dc-link capacitor fed BLDC motor drive, a high amount of harmonic current is drawn at AC mains. This combination draws peak current and leads to a very highly distorted supply current and very low power factor at AC mains. So, there is a need for improved power factor converters which are less expensive and reliable. For this purpose, ZETA converter is used. The speed of BLDC motor is controlled by varying dc-link voltage of the voltage source inverter (VSI) feeding BLDC motor. The ZETA converter is designed to operate in discontinuous inductor current mode. Thus, utilizing a voltage follower approach which requires a single voltage sensor for DC link voltage control and power factor correction operation. There by ZETA converter acts as inherent power factor corrector.

KEYWORDS: ZETA Converter, BLDC Motor, Voltage Source Inverter (VSI), Diode Bridge Rectifier (DBR), Power factor improvement.

LIST OF FIGURES

LIST OF ABBREVIATIONS

Acronym	Abbreviation
AC	Alternating Current
API	Application Programming interface
BLDC	Brush Less DC Motor
CICM	Continuous Inductor Current Mode
CSI	Current Source Inverter
DBR	Diode Bridge Rectifier
DC	Direct Current
DICM	Discontinuous Inductor Current Mode
DSP	Digital signal processor
EMF	Electromotive Force
IEC	International Electrotechnical Commission
IGBT	Insulated Gate Bipolar Transistor
MOSFET	Metal Oxide Semiconductor Field Effect Transistor
PF	Power Factor
PFC	Power Factor Correction
PFCC	Power Factor Correction Converter
PMBLDCM	Permanent Magnet Brushless DC Motor
PWM	Pulse Width Modulation
SEPIC	Single Ended Primary Inductor current
SMPS	Switch Mode Power Supply
SRM	Switched Reluctance Motor
THD	Total Harmonic Distortion
UPF	Unity Power Factor
UPS	Uninterrupted Power Supply
VSI	Voltage Source Inverter

LIST OF TABLES

CHAPTER-1

INTRODUCTION

Brushless DC (BLDC) motor is an ideal motor for low and medium power applications because of its high efficiency, high energy density, high torque/inertia ratio, low maintenance requirement and a wide range of speed control. It is a three-phase synchronous motor with three phase windings on the stator and permanent magnets on the rotor. It is also known as electronically commutated motor as there are no mechanical brushes and commutator assembly, rather an electronic commutation based on rotor position sensed by Hall-Effect position sensor is used. It finds applications in a wide range of household appliances, industrial tools, heating, ventilation and air conditioning and many others.

The requirement of improved power quality at ac mains is becoming essential and increasingly important. A limit on the allowable harmonic current drawn from ac mains is imposed by international power quality standards such as IEC 61000-3-2 which in-turn limits the total harmonic distortion (THD) of supply current and power factor (PF) at ac mains. Hence, this recommends the use of improved power quality converters for achieving a unity PF (UPF) at ac mains with limited amount of harmonic distortion in the supply current. In a conventional scheme of diode bridge rectifier (DBR) with high value of dc-link capacitor fed BLDC motor drive, a high amount of harmonics current is drawn at ac mains. This combination draws peaky current and leads to a very highly distorted supply current and very low PF at ac mains. Fig. 1a shows the conventional DBR fed BLDC motor drive. A very high THD of supply current, that is, 65.9% and a very low PF, that is, 0.72 is achieved at ac mains, which is not under the acceptable limits of IEC-61000-3-2.

Many single-phase power factor correction (PFC) converters are reported in the literature for feeding the BLDC motor drive. Two-stage PFC converters have been in wide practice which use two different converters for PFC and dc-link voltage control. Generally, a boost converter is used of first stage for PFC followed by a second stage which depends on the type of application and voltage level required for that particular application. It requires higher number of components and thus has

higher losses associated with it. Moreover, two different controllers for PFC and dc–dc conversion stage are required, which increase the system cost and complexity. Single-stage PFC converters, as the name suggests, require a single converter for performing both tasks of voltage control as well as PFC operation.

1.1 CONVENTIONAL DIODE BRIDGE RECTIFIER FED BLDC MOTOR DRIVE

The most conventional scheme of feeding the BLDC motor is by using a PFC boost converter. A constant dc-link voltage is maintained at the dc-link capacitor of the voltage source inverter (VSI) feeding the BLDC motor. The speed control is achieved by using the pulse width modulation (PWM)-based switching of VSI, which has high switching losses corresponding to the PWM switching frequency. This allows the operation of VSI in fundamental frequency switching for achieving an electronic commutation of BLDC motor. However, this scheme utilises a higher number of sensors for controlling the stator current of the BLDC motor. Hence, this type of scheme finds application in higher end drives for precise speed control and is not suitable for low power, low cost household type appliances.
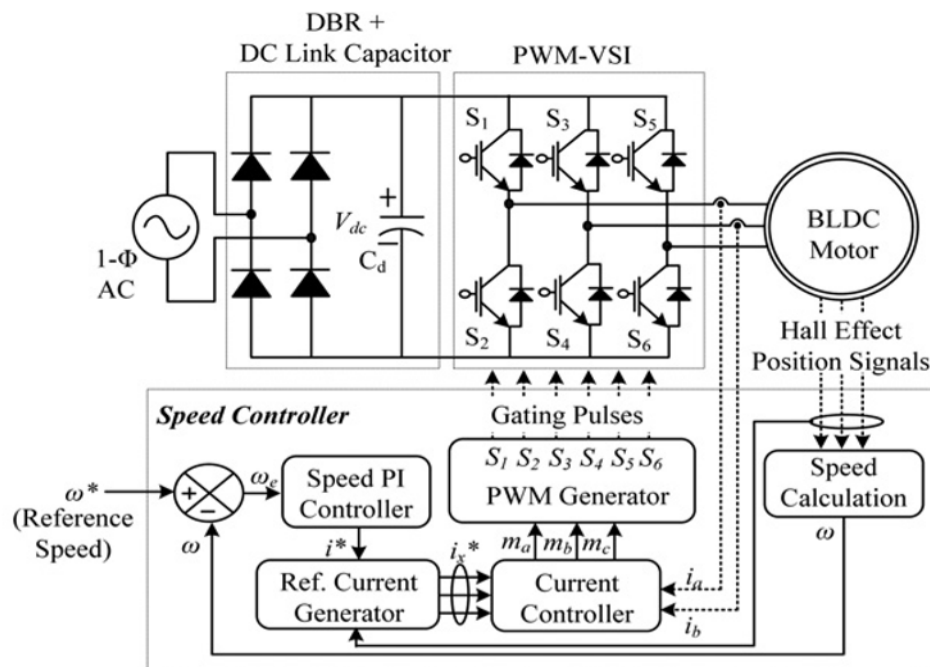
Fig.1.1 Conventional Diode Bridge Rectifier fed BLDC motor drive

Moreover, sensor reduction in a PFC-based BLDC motor drive is required for reducing the cost of complete drive. The PFC converter can be designed to operate in continuous inductor current mode (CICM) or discontinuous inductor current mode (DICM) operation. The PFC converter operating in CICM using a current multiplier approach requires sensing of dc-link voltage (V_{dc}), supply voltage (v_s) and input current (i_{in}). An inherent PFC is achieved in PFC converter operating in DICM using a voltage follower approach; and it requires sensing of dc-link voltage (V_{dc}), hence requiring a single voltage sensor.

Proper selection of a PFC converter is required for achieving a wide range of speed control of BLDC motor by varying the dc-link voltage. A widely used boost PFC converter is not suitable for this application because of its limitation of boosting the voltage higher than input voltage. Hence the operation of BLDC motor cannot be performed at lower speeds. A PFC-based zeta converter is used for this application because of its capability of bucking and boosting the voltage and its operation as an excellent PF corrector.

CHAPTER -2

CONVERTERS

2.1 DC-DC CONVERTERS

2.1.1 Introduction

Any type of power converter whether it is AC to DC or DC to AC converter takes electrical power in one form and converts it in to another form. A DC to DC converter is an electronic circuit which by electronic switching transforms a DC source voltage from one level to another.

Significance of DC-DC Conversion

why DC to DC converters are needed? It can be explained as follows for example consider electronic switch mode converters used in cell phones and laptop computers. These devices are powered using rechargeable batteries. This battery has to power all the components in the cellular phone or laptop such as display, USB devices etc. Each of these components may be operating at different voltages and current levels. DC to DC converters step up or step-down DC voltage level so that it will be suited to the requirement of interest.

Also, as the stored power drains with time, the battery voltage declines. By providing feedback from the output stage, DC to DC converters can be made to compensate this lowered battery voltage.

Often the input to these DC to DC converters is an uncontrolled DC voltage forms a diode rectifier which is unregulated. The input to DC to DC converters is unregulated not due to poor rectification of diode rectifier but due to fluctuations in

line voltage. These line fluctuations gets reflected in the output which makes it unregulated. The DC to DC converters converts these unregulated DC input voltages into controlled DC output at desired voltage level. They can be thought to be analogous to transformers which step up or step-down AC currents or voltages.

DC-DC converters are high-frequency power conversion circuits that use high-frequency switching and inductors, transformers, and capacitors to smooth out switching noise into regulated DC voltages. Closed feedback loops maintain constant voltage output even when changing input voltages and output currents. At 90% efficiency, they are generally much more efficient and smaller than linear regulators. Their disadvantages are noise and complexity.

2.1.2 Types of DC-DC Converter

There are different kinds of DC-DC converters. A variety of the converters are included here:

A. The BUCK converter

B. The BOOST converter

C. The BUCK-BOOST converter

D. The ĆUK converter

E. The SEPIC converter

F. The ZETA converter

2.1.3 Study of DC-DC Converters

There are various types of DC-DC converters. The above list of converters are non-isolated DC-DC converters. A DC-DC converter is an electronic circuit that converts a source of direct current (DC) from one voltage level to another.

(A) BUCK Converter

The buck converter is a commonly used in circuits that steps down the voltage level from the input voltage according to the requirement. It has the advantages of simplicity and low cost. Figure 2.1 shows a buck converter. The operation of the Buck

converter starts with a switch that is open (so no current flow through any part of circuit) When the switch is closed, the current flows through the inductor, slowly at first, but building up over time. When the switch is closed the inductor pulls current through the diode, and this means the voltage at the inductors "output" is lower than it first was. This is the very basic principle of operation of buck circuit.
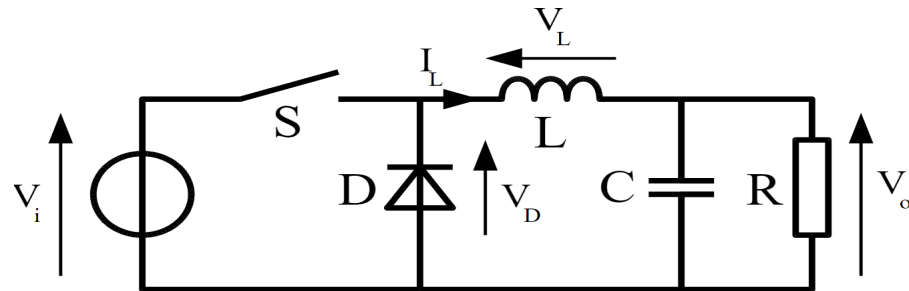
Fig 2.1 Schematic of Buck Converter

Circuit Analysis

Analysis of the buck converter begins by making these assumptions:

The circuit is operating in the steady state.

The inductor current is continuous (always positive).

The capacitor is very large, and the output voltage is held constant at voltage Vo. This restriction will be relaxed later to show the effects of finite capacitance.

The switching period is T, the switch is closed for time DT and open for time (1-D)T .

The key to the analysis for determining the voltage V_o is to examine the inductor current and inductor voltage first for the switch closed and then for the switch open. The net change in inductor current over one period must be zero for steady state operation. The average inductor voltage is zero. There are two types of operational mode for this circuit a) Continuous Conduction Mode and b) Discontinuous Conduction Mode. They are described below.

Continuous Conduction Mode

A buck converter operates in continuous mode if the current through the inductor (I_L) never falls to zero during the commutation cycle. In this mode, the operating principle is described by the chronogram in Figure 2.1.

<center>(a) ON State   (b) OFF State</center>
<center>Fig 2.2 ON and OFF state of Buck converter</center>

Figure 2.2 shows the two circuit configurations of a buck converter: (a) On-state, when the switch is closed, and(b) Off-state, when the switch is open

When the switch S is closed (On-state, shown in Figure 2.2(a)), the voltage across the inductor is $V_L = V_i - V_o$. The current through the inductor rises linearly. As the diode is reverse-biased by the voltage source V, no current flows through it.

When the switch S is open (off state, shown in Figure 2.2(a)), the diode is forward biased. The voltage across the inductor is $V_L = - V_o$ (neglecting diode drop) and Current (I_L) decreases.

The energy stored in inductor L is $\quad E = \frac{1}{2} L \times I_L^2$

Therefore, it can be seen that the energy stored in L increases during On-time (as (I_L) increases) and then decreases during the Off-state (as (I_L) decreases). L is used to transfer energy from the input to the output of the converter. The rate of change of I_L can be calculated from:

$$V_L = L \frac{dI_L}{dt}$$

With V_L equal to ($V_i - V_o$) during the On-state and to $- V_o$ during the Off-state. Therefore, the increase in current during the On-state is given by:

<center>7</center>

$$\Delta I_{Lon} = \int_0^{ton} \frac{V_L}{L} dt = \frac{(V_i - V_o)}{L} t_{on}; \qquad \{t_{on} = DT\}$$

Identically, the decrease in current during the Off-state is given by:

$$\Delta I_{Loff} = \int_{ton}^{toff} \frac{V_L}{L} dt = -\frac{V_o}{L} t_{off}; \qquad \{t_{off} = T\}$$

If we assume that the converter operates in steady state, the energy stored in each component at the end of a commutation cycle T is equal to that at the beginning of the cycle. That means that the current I_L is the same at t=0 and at t=T (see Figure3).So we can write from the above equations:

$$\frac{(V_i - V_o)}{L} t_{on} - \frac{V_o}{L} t_{off} = 0$$

It is worth noting that the above integrations can be done graphically: In Figure 2.3, ΔI_{Lon} is proportional to the area of the yellow surface, and ΔI_{Loff} to the area of the orange surface, as these surfaces are defined by the inductor voltage (red) curve. As these surfaces are simple rectangles, their areas can be found easily: $(V_i - V_o)t_{on}$ for the yellow rectangle and $-V_o t_{off}$ for the orange one. For steady state operation, these areas must be equal. As can be seen on figure 2.4, $t_{on} = DT$ and $t_{off} = (1 - D)T$. D is a scalar called the duty cycle with a value between 0 and 1. This yield:

$$\left(V_i - V_o\right)DT - V_o(1 - D) = 0$$

$$\Rightarrow V_o - DV_i = 0$$

$$\Rightarrow D = \frac{V_o}{V_i}$$

From this equation, it can be seen that the output voltage of the converter varies linearly with the duty cycle for a given input voltage. As the duty cycle D is equal to the ratio between t_{on} and the period T, it cannot be more than 1. Therefore, $V_o \leq V_i$. This is why this converter is referred to as step-down converter. So, for example, stepping 12 V down to 3 V (output voltage equal to a fourth of the input voltage) would require a duty cycle of 25%, in our theoretically ideal circuit.
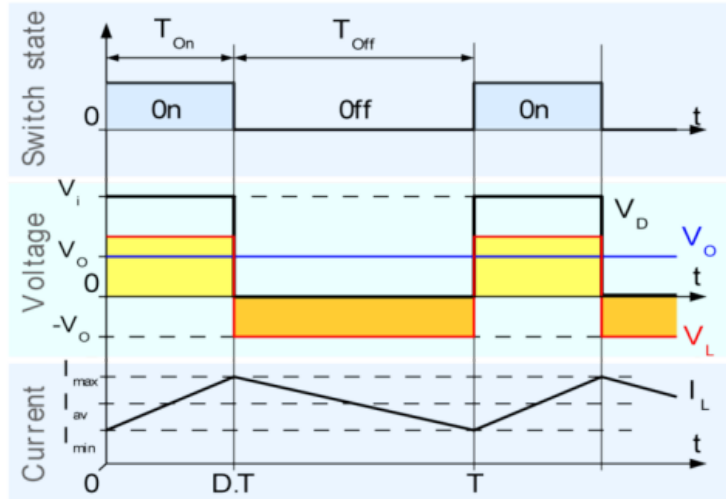
Fig 2.3: Evolution of the voltages and currents with time in an ideal buck converter operating in continuous mode

Discontinuous Conduction Mode

In some cases, the amount of energy required by the load is small enough to be transferred in a time lower than the whole commutation period. In this case, the current through the inductor falls to zero during part of the period. The only difference in the principle described above is that the inductor is completely discharged at the end of the commutation cycle (figure 2.4). This has, however, some effect on the previous equations.
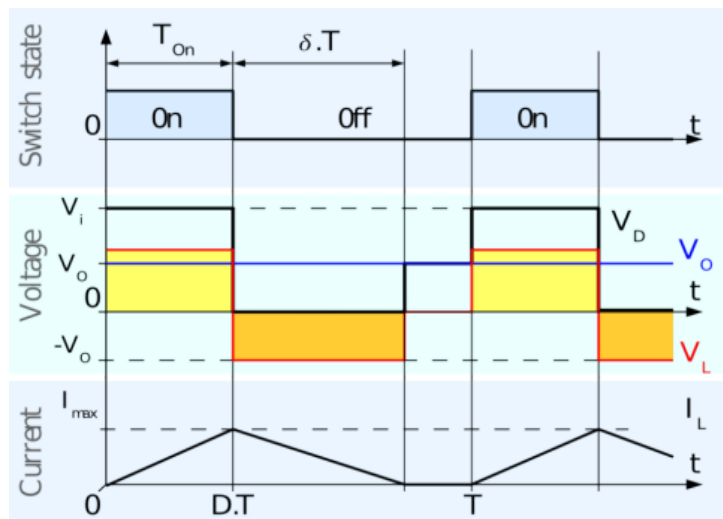
Fig. 2.4: Evolution of the voltages and currents with time in an ideal buck converter operating in discontinuous mode.

We still consider that the converter operates in steady state. Therefore, the energy in the inductor is the same at the beginning and at the end of the cycle (in the case of discontinuous mode, it is zero). This means that the average value of the inductor voltage (V_L) is zero; i.e., that the area of the yellow and orange rectangles in figure 2.4 are the same. This yield:

$$\left(V_i - V_o\right)DT - V_o \delta T = 0$$

So the value of δ is:

$$\delta = \frac{(V_i - V_o)}{V_o} D$$

The output current delivered to the load (I_o) is constant; as we consider that the output capacitor is large enough to maintain a constant voltage across its terminals during a commutation cycle. This implies that the current flowing through the capacitor has a zero average value. Therefore, we have:

$$\overline{I_L} = I_o$$

Where $\overline{I_L}$ is the average value of the inductor current. As can be seen in figure 2.4, the inductor current waveform has a triangular shape. Therefore, the average value of I_L can be sorted out geometrically as follow:

$$\overline{I_L} = \left(\frac{1}{2} I_{Lmax} DT + \frac{1}{2} I_{Lmax} \delta T\right)\frac{1}{T}$$

$$= \frac{I_{Lmax}(D+\delta)}{2}$$

$$= I_o$$

The inductor current is zero at the beginning and rises during t_{on} up to I_{Lmax}. That means that I_{Lmax} is equal to:

$$I_{Lmax} = \frac{(V_i - V_o)}{L} DT$$

Substituting the value of I_{Lmax} in the previous equation leads to:

$$I_o = \frac{(V_i - V_o)DT(D+\delta)}{2L}$$

And substituting δ by the expression given above yields:

$$I_o = \frac{(V_i - V_o)DT(D + \frac{V_i - V_o}{V_o}D)}{2L}$$

This expression can be rewritten as:

$$V_o = V_i \frac{1}{\frac{2LI_o}{D^2 V_i T} + 1}$$

It can be seen that the output voltage of a buck converter operating in discontinuous mode is much more complicated than its counterpart of the continuous mode. Furthermore, the output voltage is now a function not only of the input voltage (V_i) and the duty cycle D, but also of the inductor value (L), the commutation period (T) and the output current (I_o).

(B) BOOST Converter

A boost converter (step-up converter) is a power converter with an output DC voltage greater than its input DC voltage. It is a class of switching mode power supply (SMPS) containing at least two semi-conductor switches (a diode and a transistor) and at least one energy storage element. Filters made of capacitors (sometimes in combination with inductors) are normally added to the output of the converter to reduce output voltage ripple. A boost converter is sometimes called a step-up converter since it "steps up" the source voltage. Since power (P=VI) must be conserved, the output current is lower than the source current.

The boost converter has the same components as the buck converter, but this converter produces an output voltage greater than the source. "Boost" converters start their voltage conversion with a current flowing through the inductor (switch is closed). Then they close the switch leaving the current no other path to go than through a diode (functions as one-way valve) The current then wants to slow really fast and the only way it can do this is by increasing it's voltage (akin to pressure) at the end that connects to the diode, and switch. If the voltage is high enough it opens

the diode, and one through the diode, the current can't flow back. This is the very basic concept of boost converter.

Circuit Analysis

Analysis of the boost converter begins by making these assumptions:

The circuit is operating in the steady state.

The inductor current is continuous (always positive).

The capacitor is very large, and the output voltage is held constant at voltage Vo. This restriction will be relaxed later to show the effects of finite capacitance.

The switching period is T, the switch is closed for time DT and open for time (1-D)T.

The components are ideal.

The two modes of operations i.e., On and Off of boost converter is discussed below.

Operating Principle

The key principle that drives the boost converter is the tendency of an inductor to resist changes in current. When being charged it acts as a load and absorbs energy (somewhat like a resistor); when being discharged it acts as an energy source (somewhat like a battery). The voltage it produces during the discharge phase is related to the rate of change of current, and not to the original charging voltage, thus allowing different input and output voltages.
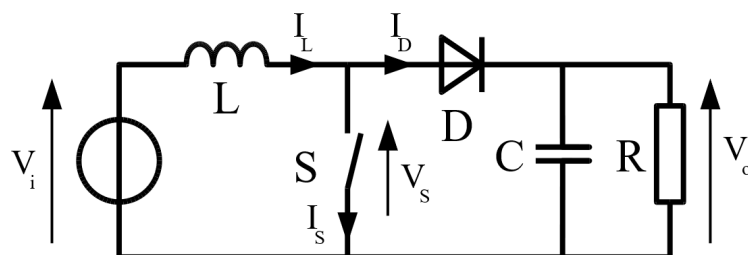
Figure. 2.5 Schematic of Boost converter

The basic principle of a Boost converter consists of 2 distinct states (Figure 6):

in the On-state, the switch S (see figure 2.6(a)) is closed, resulting in an increase in the inductor current;

in the Off-state, the switch S (see figure 2.6(b)) is open and the only path offered to inductor current is through the fly back diode D, the capacitor C and the load R. These results in transferring the energy accumulated during the On-state into the capacitor.

The input current is the same as the inductor current as can be seen in figure 2.26(b) So it is not discontinuous as in the buck circuit and the requirements on the input filter are relaxed compared to a buck converter.
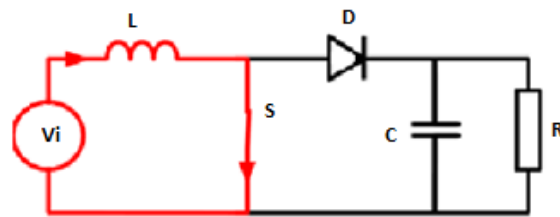
(a) ON state
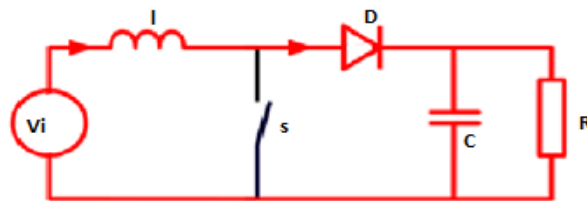
(b) OFF state

Figure. 2.6 The two configurations of a boost converter, depending on the state of the switch.

Continuous Conduction Mode

When a boost converter operates in continuous mode, the current through the inductor (I_L) never falls to zero. Figure 2.7 shows the typical waveforms of currents and voltages in a converter operating in this mode. The output voltage can be calculated as follows, in the case of an ideal converter (i.e. using components with an ideal behaviour) operating in steady conditions:
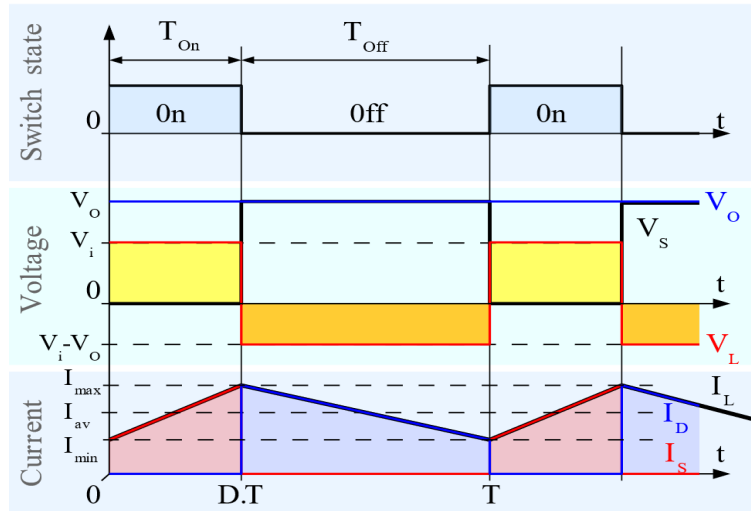
Fig. 2.7 Waveforms of current and voltage in a boost converter operating in continuous mode.

During the On-state, the switch S is closed, which makes the input voltage (V_i) appear across the inductor, which causes a change in current (I_L) flowing through the inductor during a time period (t) by the formula:

$$\frac{\Delta I_L}{\Delta t} = \frac{V_i}{L}$$

At the end of the On-state, the increase of I_L is therefore:

$$\Delta I_{Lon} = \frac{1}{L} \int_0^{DT} V_i \, dt = \frac{DT}{L} V_i$$

D is the duty cycle. It represents the fraction of the commutation period T during which the switch is On. Therefore, D ranges between 0 (S is never on) and 1 (S is always on).

During the Off-state, the switch S is open, so the inductor current flows through the load. If we consider zero voltage drop in the diode, and a capacitor large enough for its voltage to remain constant, the evolution of I_L is:

$$V_i - V_o = L \frac{dI_L}{dt}$$

Therefore, the variation of I_L during the Off-period is:

$$\Delta I_{Loff} = \int_{DT}^{T} \frac{\left(V_i - V_o\right)dt}{L} = \frac{\left(V_i - V_o\right)(1-D)T}{L}$$

As we consider that the converter operates in steady-state conditions, the amount of energy stored in each of its components has to be the same at the beginning and at the end of a commutation cycle. In particular, the energy stored in the inductor is given by:

$$E = \frac{1}{2}LI_L^2$$

So, the inductor current has to be the same at the start and end of the commutation cycle. This means the overall change in the current (the sum of the changes) is zero:

$$\Delta I_{Lon} + \Delta I_{Loff} = 0$$

Substituting ΔI_{Lon} and ΔI_{Loff} by their expressions yields:

$$\Delta I_{Lon} + \Delta I_{Loff} = \frac{DT}{L}V_i + \frac{(V_i - V_o)(1-D)T}{L}$$

This can be written as:

$$\frac{V_o}{V_i} = \frac{1}{1-D}$$

Which in turns reveals the duty cycle to be:

$$D = 1 - \frac{V_i}{V_o}$$

From the above expression it can be seen that the output voltage is always higher than the input voltage (as the duty cycle goes from 0 to 1), and that it increases with D, theoretically to infinity as D approaches 1. This is why this converter is sometimes referred to as a step-up converter.

Discontinuous Conduction Mode

Fig. 2.8 Waveforms of current and voltage in a boost converter operating in discontinuous mode.

In some cases, the amount of energy required by the load is small enough to be transferred in a time smaller than the whole commutation period. In this case, the current through the inductor falls to zero during part of the period. The only difference in the principle described above is that the inductor is completely discharged at the end of the commutation cycle (see waveforms in figure 2.8). Although slight, the difference has a strong effect on the output voltage equation. It can be calculated as follows:

As the inductor current at the beginning of the cycle is zero, its maximum value I_{Lmax} (at t= DT) is

$$I_{Lmax} = \frac{V_i DT}{L}$$

During the off-period, I_L falls to zero after δT:

$$I_{Lmax} + \frac{\left(V_i - V_o\right)\delta T}{L} = 0$$

Using the two previous equations, δ is:

$$\delta = \frac{V_i D}{V_o - V_i}$$

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The load current I_o is equal to the average diode current ($\overline{I_D}$). As can be seen on figure 2.8, the diode current is equal to the inductor current during the off-state. Therefore, the output current can be written as:

$$I_o = \overline{I_D} = \frac{I_{Lmax}}{2}\, \delta$$

Replacing I_{Lmax} and δ by their respective expressions yields:

$$I_o = \frac{V_i DT}{2L} \cdot \frac{V_i D}{V_o - V_i} = \frac{V_i^2 D^2 T}{2L(V_o - V_i)}$$

Therefore, the output voltage gain can be written as follows:

$$\frac{V_o}{V_i} = 1 + \frac{V_i D^2 T}{2LI_o}$$

Compared to the expression of the output voltage for the continuous mode, this expression is much more complicated. Furthermore, in discontinuous operation, the output voltage gain not only depends on the duty cycle, but also on the inductor value, the input voltage, the switching frequency, and the output current.

(C) BUCK-BOOST Converter

Another basic switched mode converter is the buck-boost converter. The output of the buck-boost converter can be either higher or lower than the input voltage. Assumption made about the operation of this circuit is same as it was for the previous converter circuits.

Principle of Operation
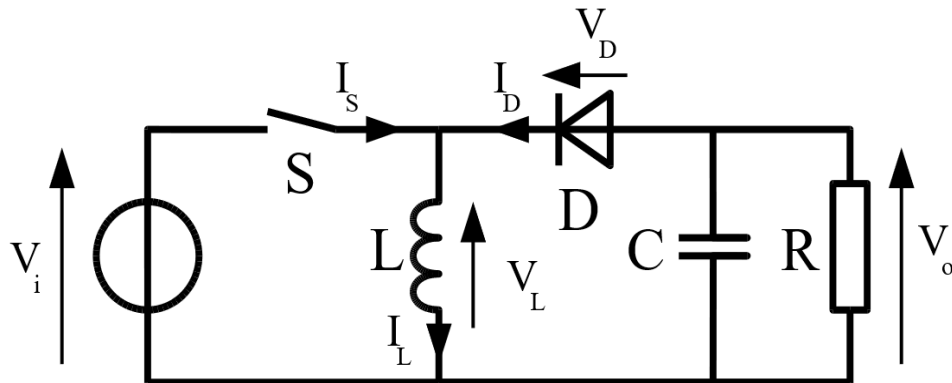
Figure. 2.9 Schematic of a buck–boost converter.

Figure 2.10 shows the two operating states of a buck–boost converter. When the switch is turned-on, the input voltage source supplies current to the inductor, and the capacitor supplies current to the resistor (output load). When the switch is opened, the inductor supplies current to the load via the diode D.
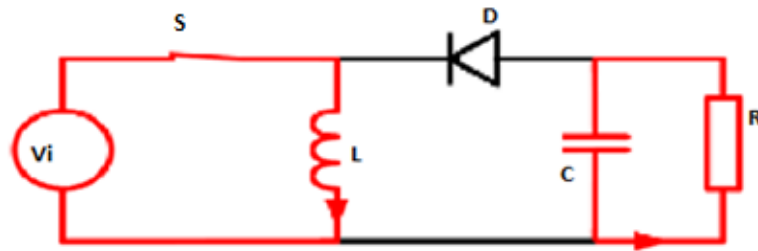
(a) ON state buck-boost converter
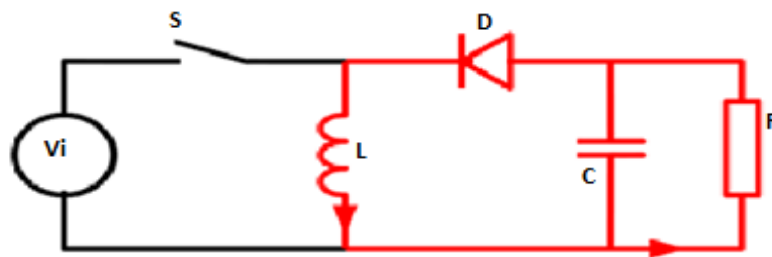
(b) OFF state buck-boost converter

Figure. 2.10 The two configurations of a buck-boost converter, depending on the state of the switch.

The basic principle of the buck–boost converter is fairly simple (Figure 2.10):

while in the On-state, the input voltage source is directly connected to the inductor (L). This results in accumulating energy in L. In this stage, the capacitor supplies energy to the output load.

while in the Off-state, the inductor is connected to the output load and capacitor, so energy is transferred from L to C and R. Compared to the buck and boost converters, the characteristics of the buck–boost converter are mainly:

Polarity of the output voltage is opposite to that of the input;

The output voltage can vary continuously from 0 to $-\infty$ (for an ideal converter). The output voltage ranges for a buck and a boost converter are respectively 0 to V_i and V_i to ∞.

The circuit has two main mode of operations. They are described below.

Continuous Conduction Mode

If the current through the inductor L never falls to zero during a commutation cycle, the converter is said to operate in continuous mode. The current and voltage waveforms in an ideal converter can be seen in Figure 2.11.

Fig 2.11 Waveforms of current and voltage in a buck–boost converter operating in continuous mode.

From $t = 0$ to $t = DT$, the converter is in On-State, so the switch S is closed. The rate of change in the inductor current (I_L) is therefore given by

$$\frac{dI_L}{dt} = \frac{V_i}{L}$$

At the end of the On-state, the increase of I_L is therefore:

$$\Delta I_{Lon} = \int_0^{DT} dI_L = \int_0^{DT} \frac{V_i}{L} dt = \frac{V_i DT}{L}$$

D is the duty cycle. It represents the fraction of the commutation period T during which the switch is On. Therefore, D ranges between 0 (S is never on) and 1 (S is always on).

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During the Off-state, the switch S is open, so the inductor current flows through the load. If we assume zero voltage drop in the diode, and a capacitor large enough for its voltage to remain constant, the evolution of I_L is:

$$\frac{dI_L}{dt} = \frac{V_o}{L}$$

Therefore, the variation of I_L during the Off-period is:

$$\Delta I_{Loff} = \int_0^{(1-D)T} dI_L = \int_0^{(1-D)T} \frac{V_o \, dt}{L} = \frac{V_o(1-D)T}{L}$$

As we consider that the converter operates in steady-state conditions, the amount of energy stored in each of its components has to be the same at the beginning and at the end of a commutation cycle. As the energy in an inductor is given by:

$$E = \frac{1}{2}LI_L^2$$

it is obvious that the value of I_L at the end of the Off state must be the same as the value of I_L at the beginning of the On-state, i.e. the sum of the variations of I_L during the on and the off states must be zero:

$$\Delta I_{Lon} + \Delta I_{Loff} = 0$$

Substituting ΔI_{Lon} and ΔI_{Loff} by their expressions yields:

$$\Delta I_{Lon} + \Delta I_{Loff} = \frac{V_i DT}{L} + \frac{V_o(1-D)T}{L} = 0$$

This can be written as:

$$\frac{V_o}{V_i} = \left(\frac{-D}{1-D}\right)$$

This in return yields that:

$$D = \frac{V_o}{V_o - V_i}$$

From the above expression it can be seen that the polarity of the output voltage is always negative (as the duty cycle goes from 0 to 1), and that its absolute value increases with D, theoretically up to minus infinity as D approaches 1. Apart from the polarity, this converter is either step-up (as a boost converter) or step-down (as a buck converter). This is why it is referred to as a buck–boost converter.

Discontinuous Conduction Mode

In some cases, the amount of energy required by the load is small enough to be transferred in a time smaller than the whole commutation period. In this case, the current through the inductor falls to zero during part of the period. The only difference in the principle described above is that the inductor is completely discharged at the end of the commutation cycle (see waveforms in figure 2.12). Although slight, the difference has a strong effect on the output voltage equation. It can be calculated as follows:

Fig 2.12 Waveforms of current and voltage in a buck–boost converter operating in discontinuous mode.

As the inductor current at the beginning of the cycle is zero, its maximum valueI_{Lmax} (at $t = DT$) is

$$I_{Lmax} = \frac{V_i DT}{L}$$

During the off-period, I_L falls to zero after δT:

$$I_{Lmax} + \frac{V_o \delta T}{L} = 0$$

Using the two previous equations, δ is:

$$\delta = \frac{V_i D}{V_o}$$

The load current I_o is equal to the average diode current (I_D). As can be seen on figure 2.12, the diode current is equal to the inductor current during the off-state. Therefore, the output current can be written as:

$$I_o = \overline{I_D} = \frac{I_{Lmax}}{2}\delta$$

Replacing I_{Lmax} and δ by their respective expressions yields:

$$I_o = -\frac{V_i DT}{2L} \cdot \frac{V_i D}{V_o} = -\frac{V_i^2 D^2 T}{2LV_o}$$

Therefore, the output voltage gain can be written as:

$$\frac{V_o}{V_i} = -\frac{V_i D^2 T}{2LI_o}$$

Compared to the expression of the output voltage gain for the continuous mode, this expression is much more complicated. Furthermore, in discontinuous operation, the output voltage not only depends on the duty cycle, but also on the inductor value, the input voltage and the output current.

(D) ĆUK Converter

The Ćuk converter is used for getting the output voltage with different polarity. That means output voltage magnitude can be either larger or smaller than the input, and there is a polarity reversal on the output.

The inductor on the input acts as a filter for the dc supply, to prevent large harmonic current. Unlike the previous converter topologies where energy transfer is associated with the inductor. Energy transfer for the Ćuk converter depends on the capacitor C1. The primary assumptions for this circuit analysis are as before. It also has two modes of operation which are described below.

Operating Principle

A non-isolated Ćuk converter comprises two inductors, two capacitors, a switch (usually a transistor), and a diode. Its schematic can be seen in figure 2.13. It is

an inverting converter, so the output voltage is negative with respect to the input voltage.
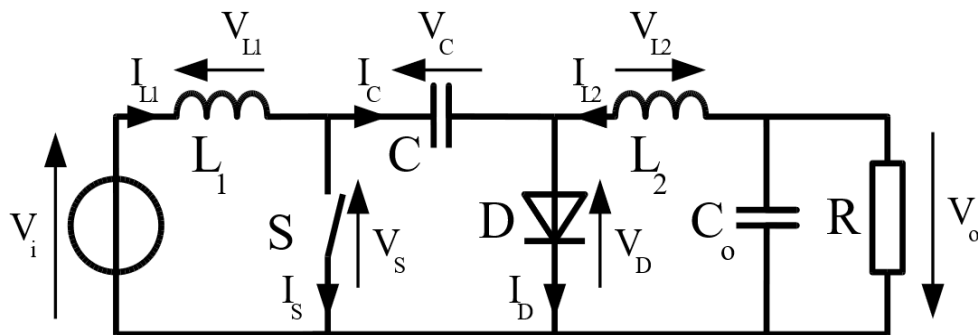
Fig 2.13 Schematic of a non-isolated Ćuk converter.

The capacitor C is used to transfer energy and is connected alternately to the input and to the output of the converter via the commutation of the transistor and the diode (see figures 2.14(a) and 2.14(b)).

The two inductors L_1 and L_2 are used to convert respectively the input voltage source (V_i) and the output voltage source (C_o) into current sources. Indeed, at a short time scale an inductor can be considered as a current source as it maintains a constant current. This conversion is necessary because if the capacitor were connected directly to the voltage source, the current would be limited only by (parasitic) resistance, resulting in high energy loss. Charging a capacitor with a current source (the inductor) prevents resistive current limiting and its associated energy loss.

As with other converters (buck converter, boost converter, buck-boost converter) the Ćuk converter can either operate in continuous or discontinuous current mode. However, unlike these converters, it can also operate in discontinuous voltage mode (i.e., the voltage across the capacitor drops to zero during the commutation cycle).
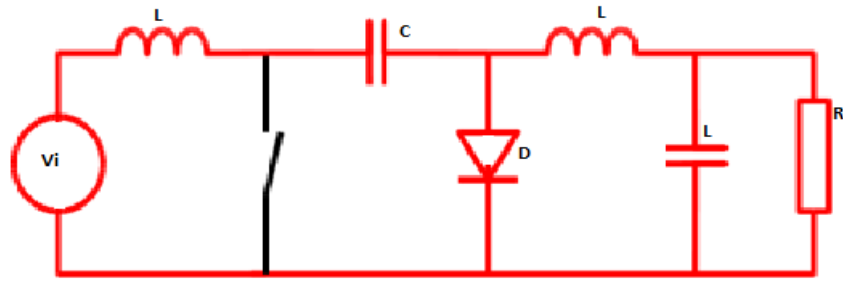
(a) ON state
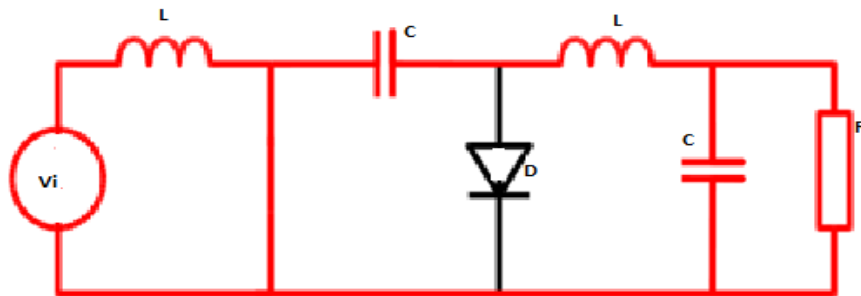
(b) OFF state

Figure 2.14: The two operating states of a non-isolated Ćuk converter.
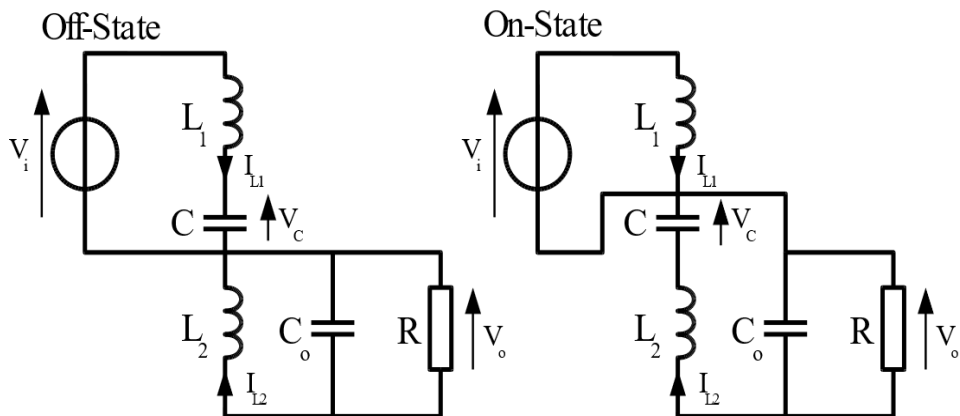
Fig 2.15 The two operating states of a non-isolated Ćuk converter.

In this figure, the diode and the switch are either replaced by a short circuit when they are on or by an open circuit when they are off. It can be seen that when in the Off state, the capacitor C is being charged by the input source through the inductor L_1.

When in the On state, the capacitor C transfers the energy to the output capacitor through the inductance L_2.

Continuous Conduction Mode

In steady state, the energy stored in the inductors has to remain the same at the beginning and at the end of a commutation cycle. The energy in an inductor is given by:
$$E = \frac{1}{2}LI_L^2$$

This implies that the current through the inductors has to be the same at the beginning and the end of the commutation cycle. As the evolution of the current through an inductor is related to the voltage across it:

$$V_L = L\frac{dI_L}{dt}$$

it can be seen that the average value of the inductor voltages over a commutation period have to be zero to satisfy the steady-state requirements.

If we consider that the capacitors C and C_o are large enough for the voltage ripple across them to be negligible, the inductor voltages become:

in the off-state, inductor L_1 is connected in series with V_i and C (see figure 15). Therefore $VL_1 = V_i - V_c$. As the diode D is forward biased (we consider zero voltage drop), L_2 is directly connected to the output capacitor. Therefore $VL_2 = V_o$.

in the on-state, inductor L_1 is directly connected to the input source. Therefore $VL_1 = V_i$. Inductor L_2 is connected in series with C and the output capacitor, so $VL_2 = V_o + V_c$.

The converter operates in on-state from $t = 0$ to $t = DT$ (D is the duty cycle), and in off state from DT to T (that is, during a period equal to $(1 - D)T$). The average values of VL_1 and VL_2 are therefore:

$$\overline{V_{L1}} = DV_i + (1 - D)(V_i - V_c) = (V_i - (1 - D)V_c)$$

$$\overline{V_{L2}} = D(V_0 + V_c) + (1 - D) - V_o = (V_0 + DV_c)$$

As both average voltage have to be zero to satisfy the steady-state conditions we can write, using the last equation:

$$V_c = \frac{V_o}{D}$$

So the average voltage across L_1 becomes:

$$\overline{V_{L1}} = \left(V_i + (1 - D)\frac{V_o}{D}\right) = 0$$

Which can be written as:

$$\frac{V_o}{V_i} = \frac{D}{1-D}$$

It can be seen that this relation is the same as that obtained for the Buck-boost converter.

Discontinuous Conduction Mode

Like all DC-DC converters Ćuk converters rely on the ability of the inductors in the circuit to provide continuous current, in much the same way a capacitor in a rectifier filter provides continuous voltage. If this inductor is too small or below the "critical inductance", then the current will be discontinuous. This state of operation is usually not studied too much depth, as it is not used beyond a demonstrating of why the minimum inductance is crucial.

The minimum inductance is given by:

$$L_{1min} = \frac{(1-D)^2 R}{2Df_s}$$

Where f_s is the switching frequency.

(E) SEPIC Converter

The **single-ended primary-inductor converter** (**SEPIC**) is a type of DC/DC converter that allows the electrical potential (voltage) at its output to be greater than,

less than, or equal to that at its input. The output of the SEPIC is controlled by the duty cycle of the control transistor.

A SEPIC is essentially a boost converter followed by a buck-boost converter, therefore it is similar to a traditional buck-boost converter, but has advantages of having non-inverted output (the output has the same voltage polarity as the input), using a series capacitor to couple energy from the input to the output (and thus can respond more gracefully to a short-circuit output), and being capable of true shutdown: when the switch is turned off, its output drops to 0 V, following a fairly hefty transient dump of charge.

SEPICs are useful in applications in which a battery voltage can be above and below that of the regulator's intended output. For example, a single lithium ion battery typically discharges from 4.2 volts to 3 volts; if other components require 3.3 volts, then the SEPIC would be effective.

Circuit Operation

The schematic diagram for a basic SEPIC is shown in Figure 2.16. As with other switched mode power supplies (specifically DC-to-DC converters), the SEPIC exchanges energy between the capacitors and inductors in order to convert from one voltage to another. The amount of energy exchanged is controlled by switch S1, which is typically a transistor such as a MOSFET. MOSFETs offer much higher input impedance and lower voltage drop than bipolar junction transistors (BJTs), and do not require biasing resistors as MOSFET switching is controlled by differences in voltage rather than a current, as with BJTs.
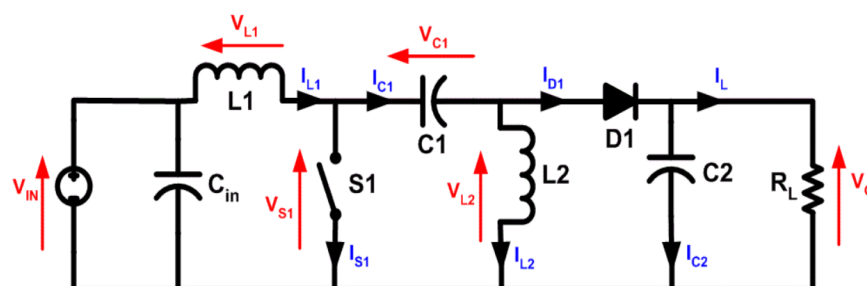
Figure 2.16 Schematic of SEPIC

Continuous Conduction Mode

A SEPIC is said to be in continuous-conduction mode ("continuous mode") if the current through the inductor L_1 never falls to zero. During a SEPIC's steady-state operation, the average voltage across capacitor C_1 (V_{c1}) is equal to the input voltage (V_{in}). Because capacitor C_1 blocks direct current (DC), the average current through it (I_{c1}) is zero, making inductor L_2 the only source of DC load current. Therefore, the average current through inductor L_2 (I_{L2}) is the same as the average load current and hence independent of the input voltage.

Looking at average voltages, the following can be written:

$$V_{IN} = V_{L1} + V_{C1} + V_{L2}$$

Because the average voltage of V_{C1} is equal to V_{IN}, $V_{L1} = -V_{L2}$. For this reason, the two inductors can be wound on the same core. Since the voltages are the same in magnitude, their effects of the mutual inductance will be zero, assuming the polarity of the windings is correct. Also, since the voltages are the same in magnitude, the ripple currents from the two inductors will be equal in magnitude.

The average currents can be summed as follows (average capacitor currents must be zero):

$$I_{D1} = I_{L1} - I_{L2}$$

When switch S1 is turned on, current I_{L1} increases and the current I_{L2} goes more negative. (Mathematically, it decreases due to arrow direction.) The energy to increase the current I_{L1} comes from the input source. Since S1 is a short while closed, and the instantaneous voltage V_{L1} is approximately V_{IN}, the voltage V_{L2} is approximately $-V_{C1}$. Therefore, the capacitor C_1 supplies the energy to increase the magnitude of the current in I_{L2} and thus increase the energy stored in L_1. The easiest way to visualize this is to consider the bias voltages of the circuit in a d.c. state, then close S1.
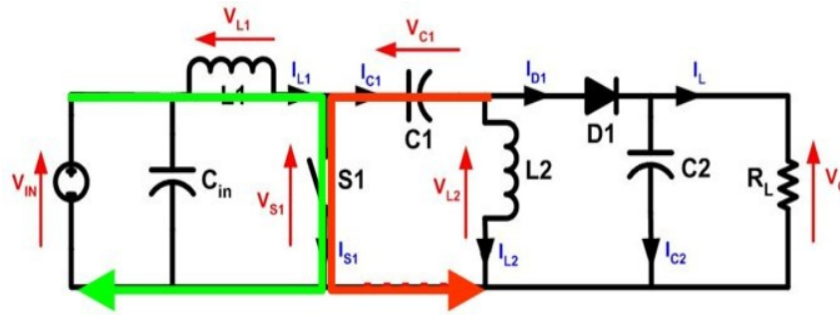
Figure 2.17 With S1 closed current increases through L_1 (green) and C_1 discharges

increasing current in L_2 (red)

When switch S1 is turned off, the current I_{C1} becomes the same as the current I_{L1}, since inductors do not allow instantaneous changes in current. The current I_{L2} will continue in the negative direction, in fact it never reverses direction. It can be seen from the diagram that a negative I_{L2} will add to the current I_{L1} to increase the current delivered to the load. Using Kirchhoff's Current Law, it can be shown that $I_{D1} = I_{L1} - I_{L2}$. It can then be concluded, that while S1 is off, power is delivered to the load from both L_2 and L_1. C_1, however is being charged by L_1 during this off cycle, and will in turn recharge L_2 during the on cycle.
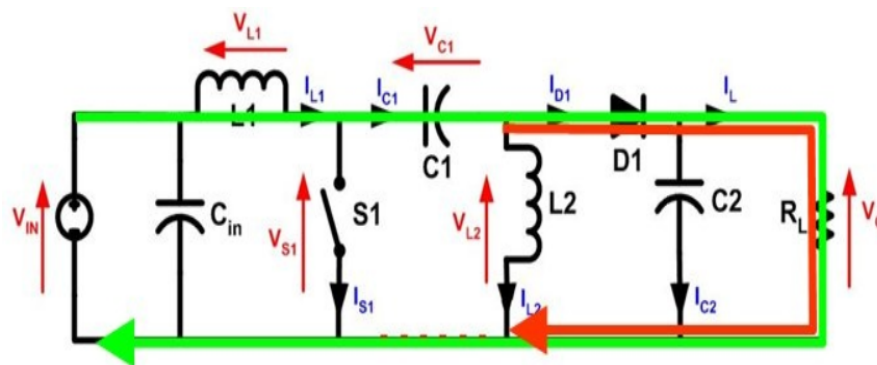
Figure 2.18 With S1 open current through L_1 (green) and current through L_2 (red)

produce current through the load

Because the potential (voltage) across capacitor C_1 may reverse direction every cycle, a non-polarized capacitor should be used. However, a polarized tantalum or electrolytic capacitor may be used in some cases, because the potential (voltage)

across capacitor C_1 will not change unless the switch is closed long enough for a half cycle of resonance with inductor L_2, and by this time the current in inductor L_1 could be quite large.

The capacitor C_{in} is required to reduce the effects of the parasitic inductance and internal resistance of the power supply. The boost/buck capabilities of the SEPIC are possible because of capacitor C_1 and inductor L_2. Inductor L_1 and switch S1 create a standard boost converter, which generates a voltage (V_{S1}) that is higher than V_{IN}, whose magnitude is determined by the duty cycle of the switch S1. Since the average voltage across C_1 is V_{IN}, the output voltage (V_O) is $V_{S1} - V_{IN}$. If V_{S1} is less than double V_{IN}, then the output voltage will be less than the input voltage. If V_{S1} is greater than double V_{IN}, then the output voltage will be greater than the input voltage.

The evolution of switched-power supplies can be seen by coupling the two inductors in a SEPIC converter together, which begins to resemble a Fly back converter, the most basic of the transformer-isolated SMPS topologies.

Discontinuous Conduction Mode

A SEPIC is said to be in discontinuous-conduction mode or discontinuous mode if the current through the inductor L_2 is allowed to fall to zero.

(F) Zeta Converter

A Zeta Converter is a fourth-order DC-DC Converter made up of two inductors and two capacitors and capable of operating in either step-up or step-down mode.

Operation of Zeta Converter

The PFC zeta converter is designed to operate in DICM, such that the current in input side inductor (I_{Li}) becomes discontinuous, whereas the current in output side inductor (I_{Lo}) and the voltage across intermediate capacitor (V_{c1}) remain in continuous conduction for a complete switching cycle. Figs. 2.19-2.21 shows the three different

modes of operation of a PFC zeta converter in a complete switching cycle and its associated waveforms are shown in Fig. 2.22. Three different modes of operation are as follows.

Mode I ($0 < t < t_1$): As shown in Fig. 2.19, when switch (S_w) is turned on, the input side inductor (L_i) and the output side inductor (L_o) start charging. The intermediate capacitor (C_1) discharges in this mode of operation and charges the dc-link capacitor as shown in Fig. 2.22. Therefore, the voltage across intermediate capacitor (V_{c1}) decreases and the dc-link voltage (V_{dc}) increases in this mode of operation.
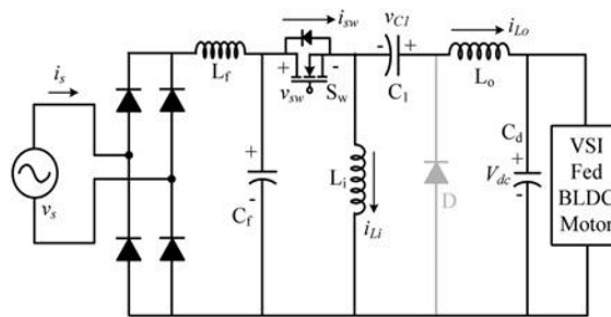
Fig. 2.19 Mode I operation of Zeta converter in DICM

Mode II ($t_1 < t < t_2$): When the switch (S_w) is turned 'off', the energy stored in the input and the output inductors (L_i and L_o) starts discharging to intermediate capacitor (C_1) and the dc-link capacitor (C_d) as shown in Fig. 2.20. The diode (D) starts conducting in this mode of operation. Hence, the voltage across the intermediate capacitor (V_{c1}) and dc-link voltage increases in this mode of operation as shown in Fig. 2.22.
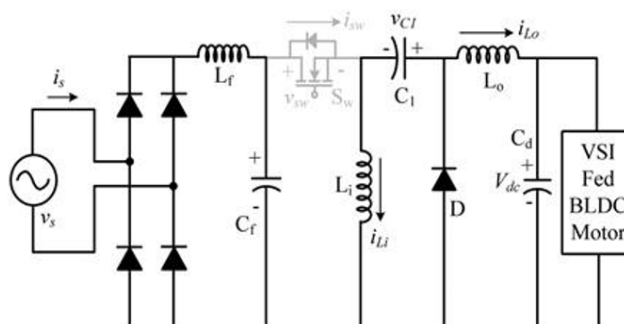
Fig. 2.20 Mode II operation of Zeta converter in DICM

Mode III ($t_2 < t < t_3$): This is the discontinuous conduction mode of operation, that is, the current in input inductor (I_{Li}) reaches zero and becomes negative as shown in Fig. 2.21.
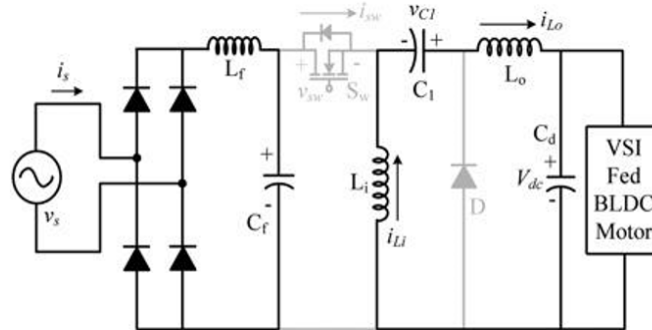
Fig. 2.21 Mode III operation of Zeta converter in DICM

The dc-link capacitor supplies the required energy to the VSI feeding BLDC motor; hence the dc-link voltage (V_{dc}) starts decreasing in this mode of operation as shown in Fig. 2.22.
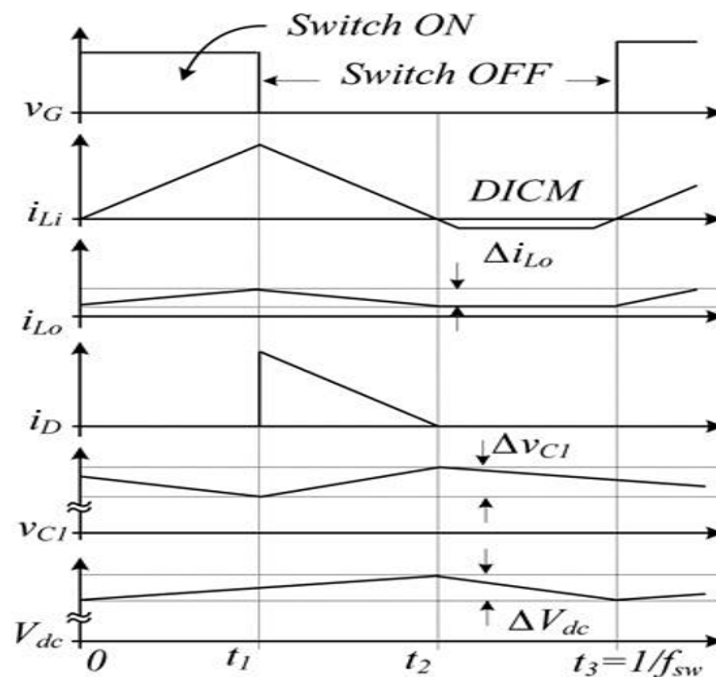
Fig. 2.22 Waveforms of Zeta converter in DICM

2.1.4 Applications of DC-DC Converters

DC/DC converters are used for converting from one DC power level to another DC power level. However, in most cases of commercial fields and industries, power source is AC. In this case, DC/DC converters cannot operate standalone. Operating together with other circuits, such as rectifiers as shown in Fig. 2.23, DC/DC converters are very useful in many applications like,
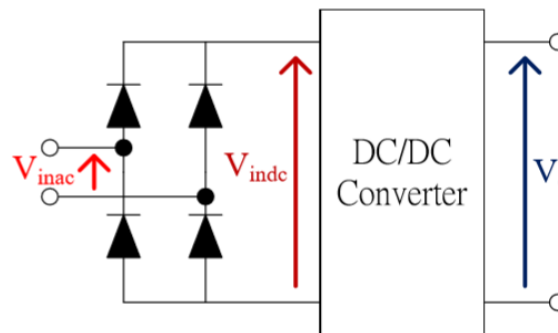
Fig. 2.23 Block diagram of DC/DC converter with a rectifier

DC power supplies (for DC or AC input, usually called switched-mode power supplies (SMPS))

Battery chargers

Power factor correction converters (PFCC)

Motor drives (DC drives, brushless DC drives, switched reluctance motor (SRM) drives, etc)

Electric brakes

Electric Vehicles

2.2 DIODE BRIDGE RECTIFIER

Most of the apparatus we use are AC devices. They require AC power for their operation. We do not have much devices which works on DC supplies. But with the advancement of electronics the DC is gaining its importance as these this device gives an efficient method for AC to DC conversion. Earlier, we used synchronous converter but the conversion process is quite lossy and inefficient. But now electronic devices such as diodes are used for conversion AC to DC. We require DC supply for DC

devices Such as computer, battery charger, Etc. All this is possible with the advancement of semiconductor technology.

Now rectifier is a process of conversion to DC to AC. It is the second stage of conversion process. It converts the AC voltage waveform to a rectified voltage. Now, we have other types of rectification methods that can also be used. So, we may think why should we need this method if other methods are available? The answer to this question is that it provides certain advantages such as no centre tap transformer need, high transformer utilization factor, so for the advantages it provides compared to other methods, it is used.

A full wave bridge rectifier is a type of rectifier which will use four diodes or more than that in a bridge formation. A full wave bridge rectifier system consists of

1. Four Diodes
2. Load

Diode bridge rectifier configuration using four number of diodes is depicted as shown in figure 2.24.
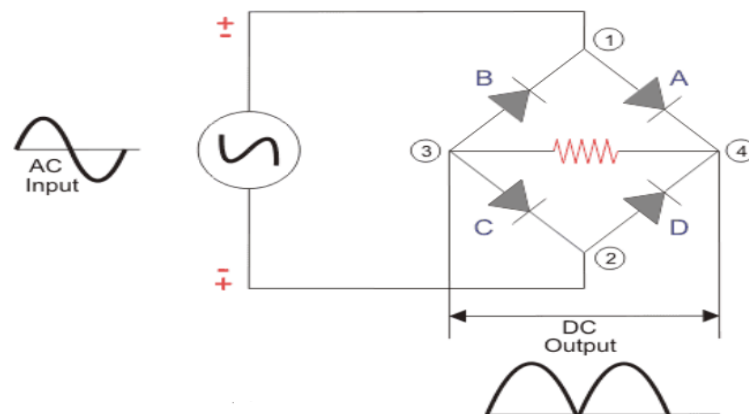
Fig. 2.24 Circuit diagram of Diode Bridge Rectifier

2.2.1 Principle of Operation

During Positive Half Cycle:

We apply an AC across the bridge. During the positive half-cycle, the terminal 1 becomes positive, and terminal 2 becomes negative. This will cause the

diodes A and C to become forward-biased, and the current will flow through it. Meanwhile diodes B and D will become reverse-biased and block current through them. The current will flow from 1 to 4 to 3 to 2.
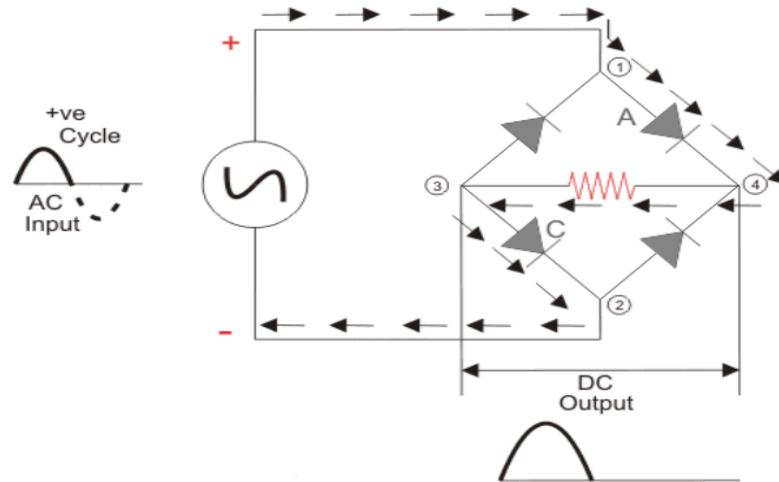
Fig.2.25 Conduction path of Current in Positive Half cycle

During Negative Half Cycle:

During the negative half-cycle, the terminal 1 will become negative, and terminal 2 will become positive. This will cause the diodes B and D to become forward-biased and will allow current through them. At the same time, diodes A and C will be reverse-biased and will block the current through them. The current will flow from 2 to 4 to 3 to 1.
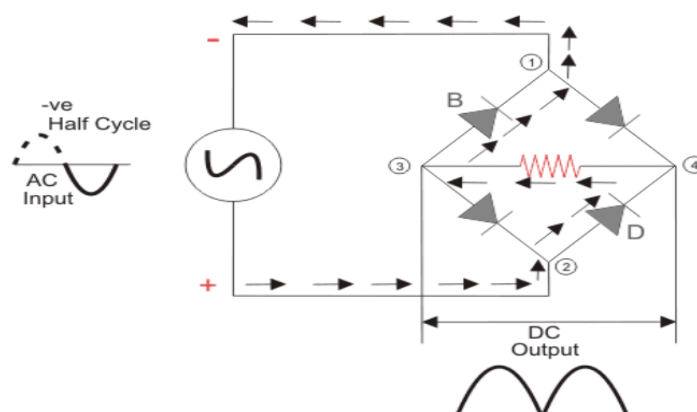
Fig.2.26 Conduction path of Current in Negative Half cycle

35
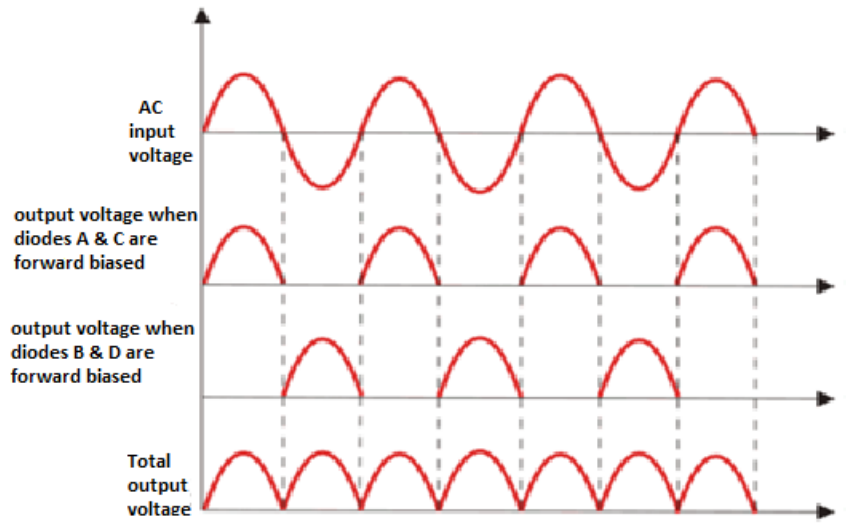
Fig. 2.27 Voltage waveforms of Diode Bridge Rectifier

2.2.2 Filter Circuit

We get a pulsating DC voltage with a lot of ripples as the output of the full wave bridge rectifier. We cannot use this voltage for practical applications. So, to convert the pulsating DC voltage to pure DC voltage, we use a filter circuit as shown above. Here we place a capacitor across the load. The working of the capacitive filter circuit is to short the ripples and block the DC component so that it flows through another path and
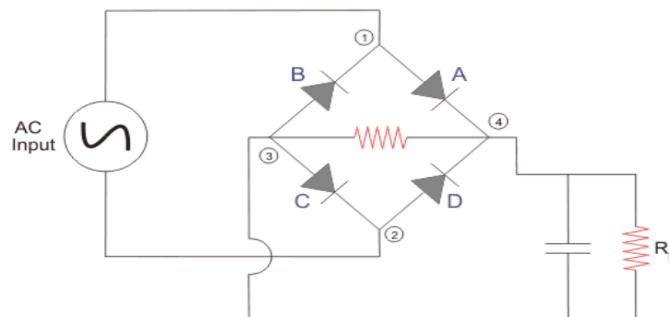
Fig.2.28 Circuit diagram of Diode Bridge Rectifier with Filter

that is through the load. During the half-wave, the diodes A and C conduct. It charges the capacitor immediately to the maximum value of the input voltage. When the rectified pulsating voltage starts decreasing and less than the capacitor voltage, the capacitor starts discharging and supplies current to the load. This discharging is slower when compared to the charging of the capacitor, and it does not get enough time to discharge entirely and the charging starts again in next pulse of the rectified voltage waveform. So around half of the charge present in the capacitor gets discharged. During the negative cycle, the diodes B and D start conducting, and the above process happens again. This causes, the current continues to flow through the same direction across the load.
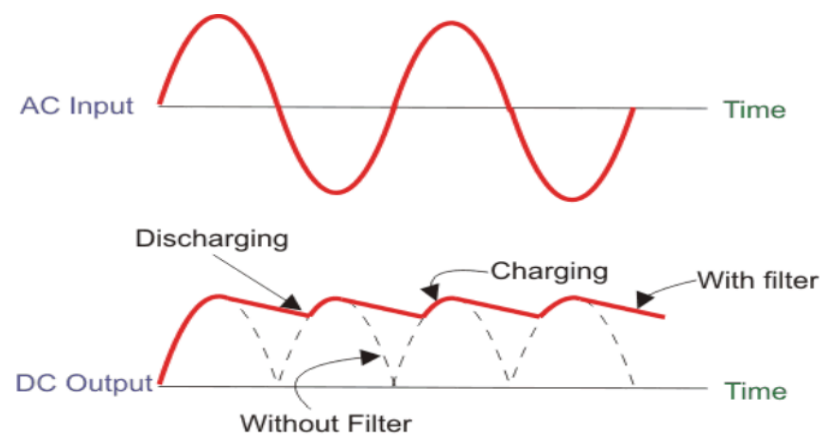
Fig.2.29 Voltage waveform of Diode Bridge Rectifier with & without Filter

2.2.3 Advantages of Diode Bridge Rectifier

1. Double rectification efficiency then half wave rectifier.
2. Low ripple voltage and higher frequency, so simple filter circuits required.
3. Higher TUF then centre tapped rectifier.
4. No centre tap transformer is required.
5. PIV or Peak Inverse Voltage is one half that of centre tap.

2.3 VOLTAGE SOURCE INVERTER

2.3.1 Introduction

Inverters are static power converters that produce an AC output waveform from a DC power supply. They are applied in adjustable AC speed drives, Uninterruptible Power Supplies (UPS), shunt active power filter, etc. For sinusoidal AC outputs, the magnitude, frequency, and phase should be controllable. If a DC input is a voltage source, then the inverter is called a Voltage Source Inverter (VSI). Similarly, in case of a Current Source Inverter (CSI), the input to the circuit is a current source. The VSI circuit has a capability of controlling AC output voltage, whereas the CSI directly controls AC output current. Sketch of output voltage waveforms by an ideal VSI, should be independent of load connected at the output.

According to a number of phases, inverters are classified into two types

    1. Single Phase Voltage Source Inverter

    2. Three Phase Voltage Source Inverter

2.3.2 Single Phase Voltage Source Inverter

Single phase inverters are basic inverters which produce a square shape AC output with a DC input. These inverters have simple on-off control logic and obviously they operate at much lower frequencies. Due to a capacity of low power, they are widely used in power supplies and single-phase UPS. They can be divided into two categories.

    A. Half bridge Single Phase Voltage Source Inverter

    B. Full bridge Single Phase Voltage Source Inverter.

2.3.2(A) Half Bridge Voltage Source Inverter

Figure 2.30 shows a circuit topology of a Half-Bridge VSI, where two large capacitors are required to provide a neutral point O, such that each capacitor maintains a constant voltage ($V_1 = V_2 = V_{dc}/2$). Due to reason that the current harmonics produced by the operation of the inverter are low-order harmonics, a set of large capacitors (C_1 and C_2) are required. In this topology, it has a single leg with two power switches Q_1 and Q_2.

According to Figure 2.30, it is clear that both switches cannot be ON simultaneously, because both are directly connected across the DC link source. If two switches conduct at the same time, a short circuit across the DC link voltage source V_{dc} would be produced. There are two defined switching states (States 1 and 2). In

order to avoid the short circuit across the DC bus and the undefined AC output voltage condition, the modulating technique should make sure that at any moment either the top or the bottom switch of the inverter leg is on.

In a half bridge topology, the input DC voltage is split in two equal parts (V_1 and V_2) through an ideal and loss-less capacitive potential divider. The half bridge topology consists of one leg (one pole) of switches whereas the full bridge topology has two such legs. Each leg of the inverter consists of two series connected power electronic switches (Q_1 and Q_2) shown in the Figure 2.30.

Fig 2.30 Circuit topology of half bridge inverter

Each of these switches consists of an IGBT type controlled switch across which, an uncontrolled diode is put in anti-parallel approach. These switches are capable of conducting bi-directional current, but they have to obstruct only one polarity of voltage. In a half bridge topology, the single-phase load is connected between the mid-point of the input DC supply and the junction point of the two switches. These points are marked as 'O' and 'A' respectively.

2.3.2(B) Full Bridge Voltage Source Inverter

Figure 2.31 shows the power topology of a full bridge VSI. This inverter is similar to the half bridge inverter; however, a second leg provides the neutral point to the load. As in the half bridge inverter, both switches Q_1 and Q_2 or Q_3 and Q_4 in a

single leg cannot be on simultaneously because a short circuit across the dc link voltage source V_{dc} would be occurred.

In a full bridge inverter, there are four defined (states 1, 2, 3, and 4) switching states. The undefined condition should be avoided so as to be always capable of defining the AC output voltage. It can be observed that the AC output voltage can acquire values up to the DC link value V_{dc} which is twice that obtained with half bridge voltage source inverter topologies. Output voltage is denoted as V_{AB} taken from the load.

Fig 2.31 Circuit diagram of full bridge voltage source inverter

The single-phase full bridge circuit shown in Figure 4.2 is similar to that of two half bridge circuits sharing the same DC bus. The full bridge circuit has two voltages (V_{AO} and V_{BO}), which are similar to the pole voltage (V_{AO}) of the half bridge circuit. Both (V_{AO}) and (V_{BO}) of the full bridge circuit are square waves but they will have some phase difference.

2.3.3 Three Phase Voltage Source Inverter

From the section 2.3.2(B), it can be understood that the single-phase voltage source inverters can manage only low power applications. For high power applications, three phase voltage source inverters are preferred to provide three phase voltage source in addition to that the magnitude, phase and frequency of voltages should be controlled.

The typical three-phase VSI topology is shown in Figure 2.32 and middle points of the inverter legs are connected to three phase RL load. There are the eight valid switch states. The switches of any leg of the inverter (S_1 and S_4, S_3 and S_6 or S_5

and S_2) cannot be switched on simultaneously. Because it would result in short circuit across the DC link voltage supply. Similarly, the switches of any leg of the inverter cannot be switched off simultaneously to avoid undefined states in the VSI and thus undefined ac output line voltages.
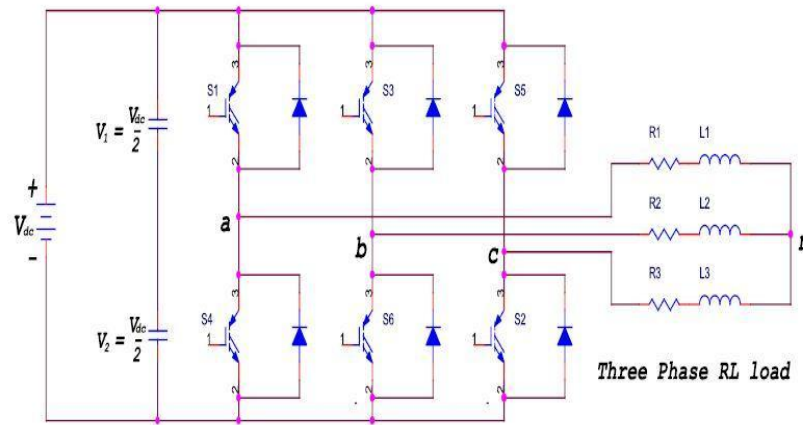
Fig 2.32 Circuit topology of three phase voltage source inverter

Two of eight valid states (7 and 8) are called as zero switch states to produce zero AC line voltages. In this case, the AC line currents freewheel through either the upper or lower components. The remaining states are called as non-zero switch states to produce non-zero AC output voltages. The resulting AC output line voltages consist of discrete values of voltages that are V_{dc}, 0, and $-V_{dc}$.

Table 2.1 Switching states and output voltage of three phase VSI

State	Switching state	Output voltage		
		V_a	V_b	V_{ab}
1	S_1 , S_2 and S_6 are ON	$-V_{dc}$	0	V_{dc}
2	S_2 , S_3 and S_1 are ON	$-V_{dc}$	V_{dc}	0
3	S_3 , S_4 and S_2 are ON	0	V_{dc}	$-V_{dc}$
4	S_4 , S_5 and S_3 are ON	V_{dc}	0	$-V_{dc}$
5	S_5 , S_6 and S_4 are ON	V_{dc}	$-V_{dc}$	0
6	S_6 , S_1 and S_5 are ON	0	$-V_{dc}$	V_{dc}
7	S_1 , S_3 and S_5 are ON	0	0	0
8	S_4 , S_6 and S_2 are ON	0	0	0

CHAPTER -3

BLDC MOTOR

3.1 INTRODUCTION

A Permanent Magnet Brushless DC motor (PMBLDCM) consists of a permanent magnet rotor and a three-phase stator winding. PMBLDC motors are electronically commutated, and do not use the brushes for commutation. Three hall sensors detect the rotor position, and commutation is based on these sensor inputs. The permanent magnet of the motor rotates and the three phase stator windings remain static. The brush-commutator assembly is replaced by an electronic controller. With rapid development in the field of microelectronics and power switches, the most adjustable speed drives are realized with AC machines.

Brushless DC (BLDC) motors are widely used in many industrial, aerospace applications and domestic appliances due to their high efficiency, excellent control accuracy and high torque to weight ratio. BLDC motor is asynchronous motor with permanent magnets on the rotor and armature windings on the stator. It is like a DC motor turned inside out, so that the field is on the rotor and the armature is on the stator. The Brushless DC motor is basically a permanent magnet AC motor whose torque-current characteristics are similar to the DC motor. Instead of commutating the armature current using brushes and mechanical commutator, the electronic commutation system is used. Because of their brushless nature, the problems associated with the brush and the commutator arrangement like sparking and wearing out of the commutator-brush arrangement are eliminated. Due to the simplified structure, BLDC motors are more rugged than a DC motor and suitable for industrial environment. Having the armature on the stator makes the cooling of windings easy. The winding of BLDC motor is much easier as compared to a conventional DC motor and Induction motor. Moreover, it is very much possible to control the speed and the angle of motion of the rotor or both very precisely and accurately. Further, BLDC motor is compatible with the digital control systems and the motor characteristics can be controlled by digital systems.

3.2 PRINCIPLE OF BRUSHLESS DC MOTOR DRIVE SYSTEM

The Permanent Magnet Brushless DC Motor Drive consists of a Permanent Magnet Brushless DC Motor and an electronic commutator. The major parts of the Brushless DC Motor are a stator and a rotor.

3.2.1 Stator

The stator of a BLDC motor consists of stacked steel laminations with windings placed in the slots that are axially cut along the inner periphery as shown in Figure 3.1. The stator resembles that of an induction motor; however, the windings are concentrated on specific number of slots. Most BLDC motors have three stator windings connected in star fashion. Each of these windings is constructed with numerous interconnected coils, with one or more coils placed in the stator slots. These windings are placed over the stator periphery to form an even number of poles.
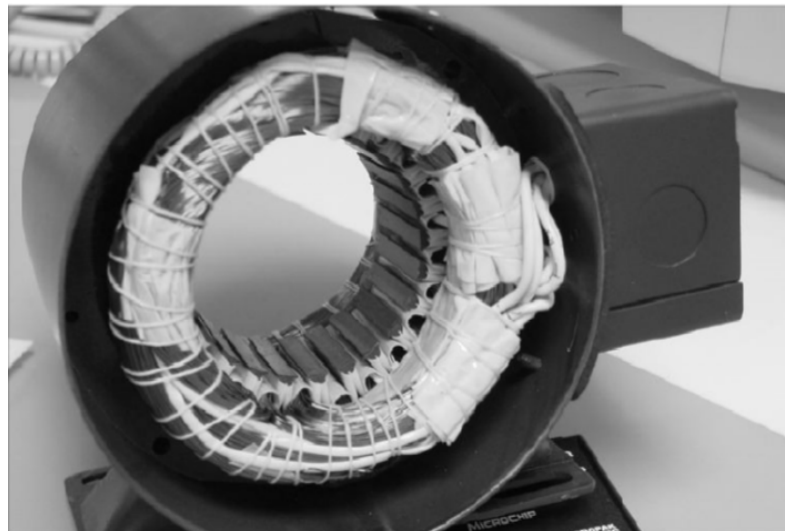
Fig. 3.1 Sectional view of BLDC motor stator

3.2.2 Rotor

The rotor is made of permanent magnets with alternate North (N) and South (S) poles according to the number of poles as shown in Figure 3.2. Based on the

required magnetic field density in the rotor, the proper magnetic material is chosen to make the rotor. Ferrite magnets are traditionally used to make the permanent magnet pole pieces. Now a day's rare earth alloy magnets are universally used for new generation motors. The ferrite magnets are less expensive but they have the disadvantage of low flux density for a given volume. In contrast, the alloy material has high magnetic density per volume and enables using a smaller rotor and stator for the same torque. The alloy magnets improve the size-to-weight ratio and give higher torque for the same size motor using ferrite magnets. Neodymium (Nd), Samarium Cobalt (SmCo) and the alloy of Neodymium, Ferrite and Boron (NdFeB) are some examples of rare earth alloy magnets used to construct the rotor.

Fig. 3.2 Four pole and eight pole rotor of BLDC motor

3.2.3 Electronic Commutator

Unlike a brushed DC motor, the commutation of a BLDC motor is controlled electronically. Conventionally a three-phase two-level voltage source inverter is used as an electronic commutation system for a three-phase permanent magnet BLDC motor. To rotate the BLDC motor, the stator windings should be energized in a sequence. It is important to know the rotor position in order to energize a specific stator winding so as to rotate the rotor for any specific direction. Rotor position is sensed using Hall Effect sensors embedded into the stator. Most BLDC motors have three Hall sensors embedded into the stator on the non-driving end of the motor. Whenever the rotor magnetic poles pass near the Hall sensors, they give a high or low

signal, indicating that the N or S pole is passing near the sensors. Based on the combination of these three Hall sensor signals, the exact sequence of commutation can be determined.

By reading the Hall Effect sensors, a 3-bit code can be obtained, with values ranging "001" (1) to "110" (6). Each code value therefore gives the information on which windings needed to be excited to turn the rotor. State '000' and '111' are considered as invalid states in commutation system for BLDC motor. The input sensor state and the corresponding drive state required for commutation and to run the rotor in a clockwise direction is given in Table 3.1. The values 1 and 0 denotes the "on" and "off" conditions of the respective power electronic switches of the voltage source inverter acting as a power electronic commutator.

Table 3.1 Hall sensor bits and drive bits for clockwise rotation in phase order

Rotor position θ (°)	Hall signals			Switching states					
	H_3	H_2	H_1	S_1	S_2	S_3	S_4	S_5	S_6
NA	0	0	0	0	0	0	0	0	0
0–60	1	0	1	1	0	0	1	0	0
60–120	0	0	1	1	0	0	0	0	1
120–180	0	1	1	0	0	1	0	0	1
180–240	0	1	0	0	1	1	0	0	0
240–300	1	1	0	0	1	0	0	1	0
300–360	1	0	0	0	0	0	1	1	0
NA	1	1	1	0	0	0	0	0	0

For a three-phase BLDC motor operation, the most common topology used as the power electronic commutation system is a three-phase buck-derived converter or a three-phase voltage source inverter (VSI). The BLDC motor commutator is shown in Figure 3.3. The three-phase inverter composed of switches that could be MOSFETs or insulated-gate bipolar transistors (IGBTs). If IGBTs is used, anti-parallel diodes need to be connected across them for carrying reverse currents, while MOSFETs use body diodes.
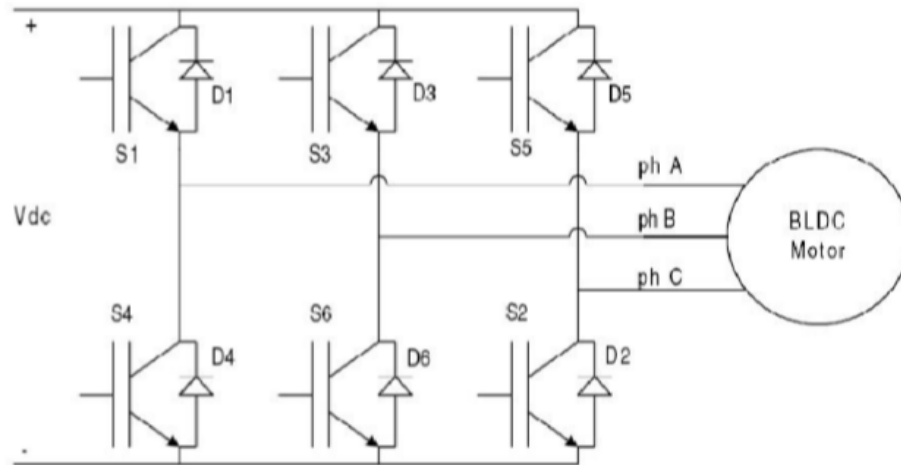
Fig. 3.3 Electronic Commutator for Brushless DC motor

The control diagram of the BLDC motor is shown in Figure 3.4. The commutation controller is basically a decoder which gives 6 gate triggering pulses based on the Hall sensor positional three-bit data. The commutation control can be performed by any digital controller like microcontroller, Field Programmable Gate Arrays (FPGA) and Digital Signal Processors (DSP). The three-phase voltage source inverter commutates the supply to the stator based on the instantaneous position of the rotor.
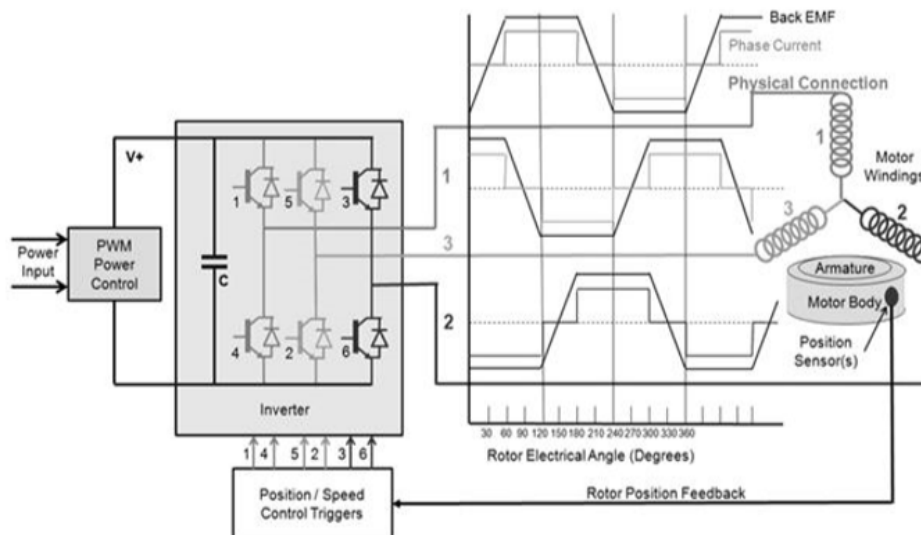
Fig. 3.4 Brushless DC motor drive control diagram

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Due to the concentrated nature of the stator windings, the back electromotive force (EMF) is in square form and not as sinusoidal for the conventional DC motors. The back EMF induced per phase of the motor winding is constant for 120°. The inductance of the stator windings causes a definite rise time and the back emf follows the trapezoidal profile. The torque developed in the BLDC Motor is proportional to its phase current and its back EMF. The back emf is directly proportional to the speed. Therefore, a variable voltage across the three phases and constant current in its stator windings maintains constant torque in a BLDC Motor under variable speed operation. In order to get constant output power and constant output torque, current is driven through a motor winding during the flat portion of the back EMF waveform. Only two switches are turned on at a time, one in high side and other in low side. Thus, for a star-connected motor winding, two phases are connected in series across the DC bus, while the third winding is open. The switches in electronic commutator are operated such that each phase carries current only during the 120° period when the back EMF is constant.
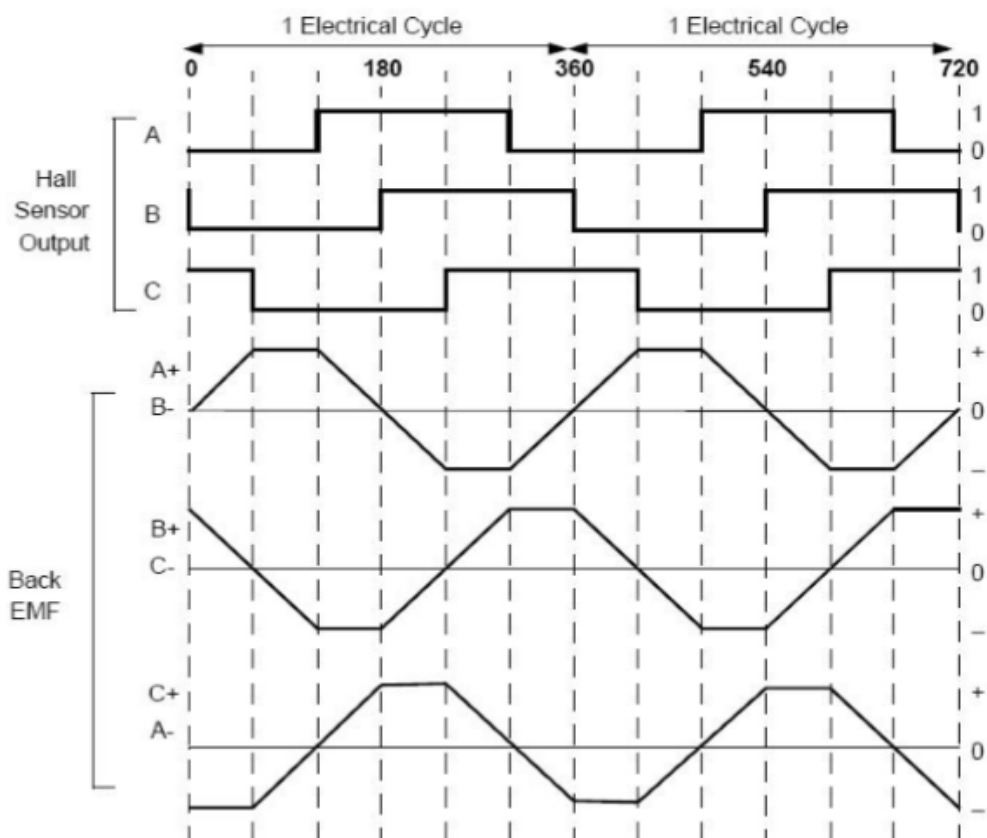
Fig. 3.5 Waveforms of Hall sensor output and Back-emf of the BLDCM

Figure 3.5 shows the Hall sensor outputs A, B, and C corresponding to the instantaneous rotor positions in digital form for one complete mechanical rotation. The back emf for the three phases is shown in trapezoidal voltage profile. For a 4-pole rotor of the motor to complete one mechanical rotation, it covers two cycles of input voltage. Moreover, the frequency at which the commutation has to be taken place is the frequency of the back emf.

The profile of the stator current waveform for the three phases and the output torque profile are presented in Figure 3.6. There are two modes of commutation applicable for the BLDC motor. They are 180° mode and 120° mode of commutation. In 180° conduction mode of commutation each phase of the stator is readily connected to the DC source. Due to the higher conduction losses in 180° mode of commutation and the difficulty of higher failure rate of the power devices, the 120° mode of commutation is prominently used in BLDC motor applications. In 120° conduction mode of commutation, each phase is open-circuited for a fraction of time in each revolution resulting in discontinuous phase current and forms different commutation-conduction patterns. The stator current is commutated for every 60° each revolution
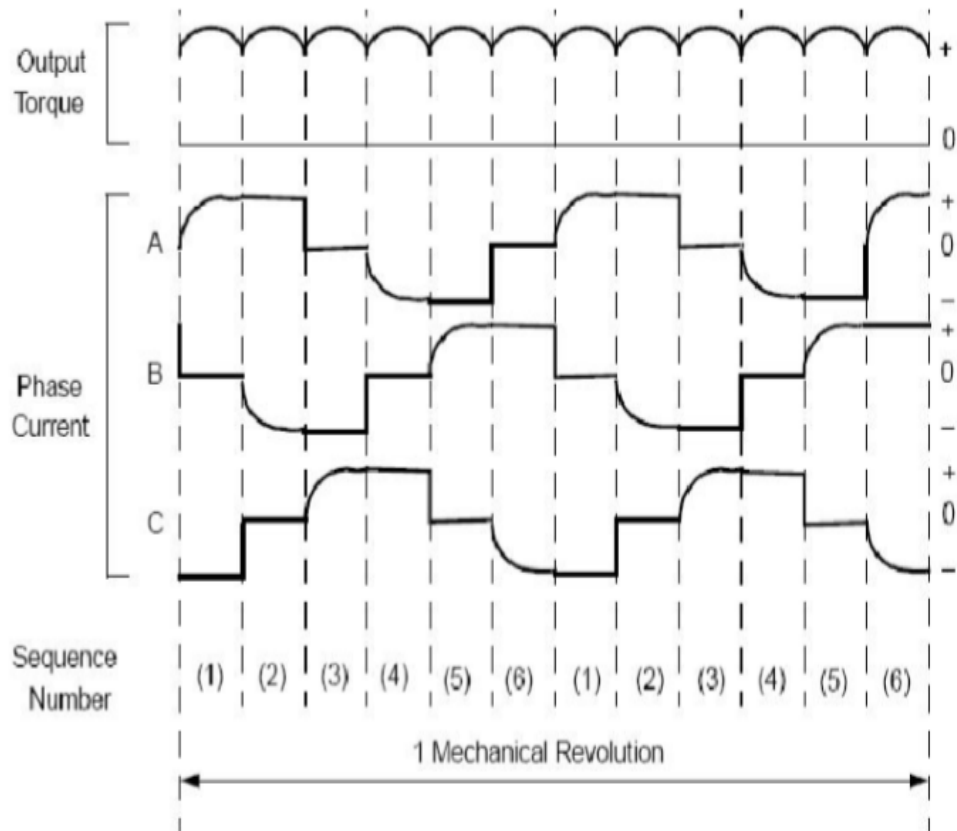
Fig. 3.6 Profile of Stator current and output torque of BLDCM

resulting in discontinuous phase current and forms different commutation-conduction patterns. The stator current is commutated for every 60° electrical and this causes transition in the current profile. This leads to ripple in torque profile which in turn causes acoustic noise and vibrations on the motor. It is very much essential to reduce the torque ripple in order to maximize the performance of the motor.

The comparison between the brushless DC motor, Brushed DC motor and the Induction motor are presented in Table 3.2

Table 3.2 Comparison of Brushless DC motor with Brushed DC motor and Induction motor

Feature	Brushless DC motor	Brushed DC motor	Induction motor
Mechanical structure	Field magnets on the rotor are permanent magnets	Field magnets on the stator or rotor are permanent magnets	Both stator and rotor are electromagnetic structure, AC lines are connected to the stator
Maintenance	Low or No maintenance	Periodic maintenance because of brushes	Low maintenance
Speed-Torque characteristics	Flat – operation at all loads with rated speed	Moderate- reduction in torque at higher speeds due to brush losses	Non-Linear
Efficiency	High	Moderate	Low
Commutation method	Using solid state switches	Mechanical contacts between brushes and commutator	Special starting circuit is required
Speed range	High- no loss in brushes	Moderate- losses in brushes	Low- Determined by AC frequency, further reduction in speed due to increase in load.
Detection of rotor position	Hall Sensors, optical encoders, etc	Automatically detected by brush and commutator	Not applicable
Direction reversal	Reversing the switching sequence	Reversing the voltage to stator or rotor	By changing the two phases of the motor
Control requirements	A controller is always required to control the commutation sequence	No controller is required for a fixed speed, controller required for variable speed.	Controller required for variable speed.
System cost	High –because of external controller requirement	Low	Low

3.3 MATHEMATICAL MODELLING OF BRUSHLESS DC MOTOR

The permanent magnet BLDC motor drive consists of a Voltage Source Inverter (VSI) as electronic commutator and a Permanent Magnet Brushless DC motor. The flux distribution in the Permanent magnet Brushless DC motor is trapezoidal in nature. Due to the non-sinusoidal distribution of flux, the model has been derived from the phase variables. Figure 3.7 shows the electrical equivalent of BLDC motor and the electronic commutation system.

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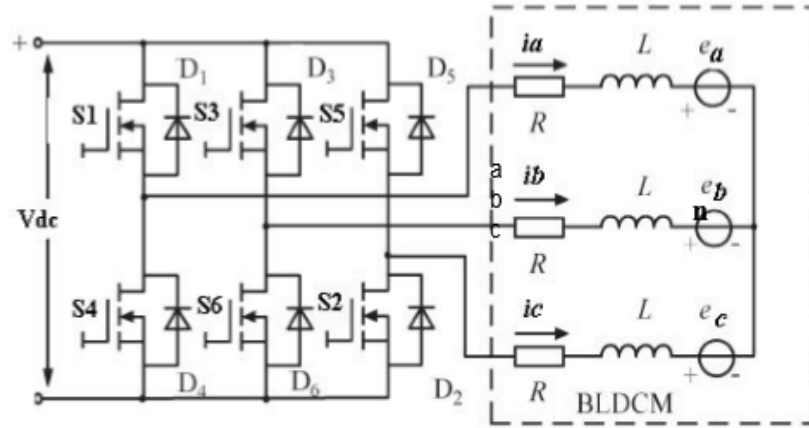
Fig. 3.7 Electrical Equivalent circuit of a BLDCM with Commutation system

The coupled circuit equations of the stator winding of the motor in terms of equivalent electrical parameters are given in below Equation

$$\left[v_a\, v_b\, v_c\right] = [R\ 0\ 0\ 0\ R\ 0\ 0\ 0\ R\,]\left[i_a\, i_b\, i_c\right] + [L\ M\ M\ M\ L\ M\ M\ M\ L\,]\frac{d}{dt}\left[i_a\, i_b\, i_c\right] + \left[e_a\, e_b\, e_c\right]$$

Where   R is the stator resistance per phase

v_a, v_b, v_c are the per phase stator voltages

i_a, i_b, i_c are the phase currents

e_a, e_b, e_c are induced back emfs for the three phases of the stator.

The stator resistance R is assumed to be equal for all the phases and the induced back emfs are assumed as trapezoidal in nature. The maximum values of induced back emf (E_m) is derived as

$$E_m = (Blv)N_s = N_s(Blr\omega_r) = N_s\varphi_a\omega_r = \lambda_m\omega_r$$

Where

N_s is the number of stator conductors in series per phase

v is the velocity, m/s

l is the length of the conductor, m

r is the radius of the rotor bore, m

ω_r is the angular velocity, rad/s

B is the flux density of the rotor field

φ_a is the total flux

λ_m is the flux linkage

The stator phase currents are constrained to be balance and $i_a + i_b + i_c = 0$ which leads to simplification of the matrix as

$$[v_a\, v_b\, v_c] = [R\,0\,0\,0\,R\,0\,0\,0\,R]\,[i_a\, i_b\, i_c] + [L\,0\,0\,0\,L\,0\,0\,0\,L]\tfrac{d}{dt}[i_a\, i_b\, i_c] + [e_a\, e_b\, e_c]$$

Based on the observation, the phase voltages are identical and are similar to the voltage equation of the DC machine. The generalized electromagnetic torque equation for BLDCM is given by below equation.

$$T_a = \frac{e_a i_a + e_b i_b + e_c i_c}{\omega_r} \qquad \text{(Nm)}$$

The instantaneous induced emfs can be written as the function of rotor position (θ_r) and the same can be expressed as follows

$$[e_a\, e_b\, e_c] = \omega_r \lambda_m [f_a(\theta_r)\, f_b(\theta_r)\, f_c(\theta_r)]$$

Where $f_a(\theta_r)$, $f_b(\theta_r)$ and $f_c(\theta_r)$ have the same shape as e_a, e_b and e_c.

In general, the electromagnetic torque of the BLDC motor can be expressed as

$$T_e = \lambda_m [f_a(\theta_r)i_a + f_b(\theta_r)i_b + f_c(\theta_r)i_c] \qquad \text{(Nm)}$$

The torque developed by the motor depends on the flux linkage between the stator and the rotor, the instantaneous stator current and the function of rotor position.

3.4 COMMUTATION TORQUE RIPPLE

The back EMF induced per phase of the motor winding is constant for 120°electrical of the complete cycle. In order to get constant output power and constant output torque, the stator current is driven through a motor winding during the flat portion of the back-emf waveform which shown in Figure3.8.
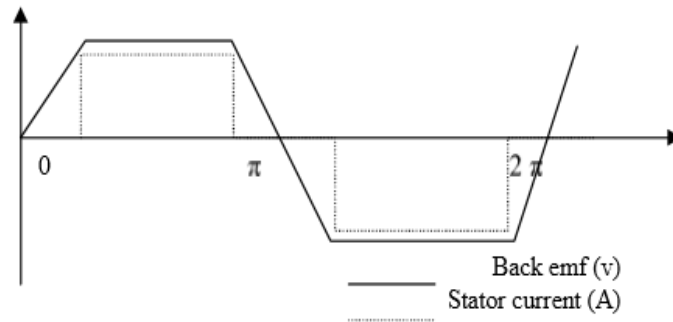
Fig. 3.8 Stator current and back emf wave form of a BLDC motor

The torque ripple during commutation can be analysed using the mathematical model of BLDCM. If the back emf is not sinusoidal, the motor suffers with torque ripple.

The steady electromagnetic torque T_{em} of the BLDC motor is given by below Equation

$$T_{em} = \frac{2 I_m E_m}{\omega_r}$$

Where I_m is the peak stator current in Ampere

E_m is the peak back-emf in Volts

ω_r is the instantaneous rotor angular velocity in rad/sec

The slopes of stator phase currents during commutation depends on the inductance (L) of the stator coil are described in the following equations

$$\frac{di_a}{dt} = -\frac{V_{dc} + 2E_m}{3L}$$

$$\frac{di_b}{dt} = -\frac{2(V_{dc} - E_m)}{3L}$$

$$\frac{di_c}{dt} = -\frac{V_{dc} - 4E_m}{3L}$$

The electromagnetic commutation torque as per below Equation and the same is used for estimating the ripple torque

$$T_{e\_com} = \frac{2E_m}{\omega_r}\left(I_m + \frac{(V_{dc} - 4E_m)}{3L}t\right)$$

The back emf E_m is proportional to speed of the motor and is given by

$$E_m = K_e \omega_r$$

Where K_e is the back emf constant, t is the commutation duration.

The difference in torque between the steady value and the commutation obtained from equation T_{e_com} and equation T_{em} gives the torque ripple equation

$$\Delta T_{e\_ripple} = 2K_e \frac{(V_{dc} - 4E_m)}{3L}t$$

It is observed that the ripple torque depends on the back emf, commutation time, and the self-inductance of the coil. This ripple torque should be the minimum in order to get the smooth torque profile of the motor.

3.5 HARMONICS

The harmonics present in the stator voltage and current inherently affect the performance of the BLDC motor. Harmonic components are mainly generated in the stator voltage and current due to

a) The power electronic commutator is present in the BLDC motor drive system.

b) Imperfections or structural imbalance of the motor (if any).

The harmonics present in the stator current causes overheating in the stator winding and produce ripple components in the torque output of the motor. This leads to power loss, which in turn reduce the efficiency of the motor. The voltage harmonics causes severe electromagnetic interference problems.

Nowadays the brushless DC motors are replacing the existing Induction motor and the brushed DC motor in many domestic and industrial applications. So, it is very much essential to analyse the possible means of improving the performance in terms of reducing the harmonics and torque ripple of the motor.

CHAPTER -4

PROPOSED CONCEPT

4.1 PROPOSED PFC ZETA CONVERTER FED BLDC MOTOR DRIVE

Fig. 4.1 shows the proposed PFC-based zeta converter feeding a BLDC motor drive and Fig. 4.2 shows a VSI feeding the BLDC motor drive. The speed of BLDC motor is controlled by varying the dc-link voltage of VSI. The PFC zeta converter is designed to operate in DICM, hence it acts as an inherent PF corrector. The complete operation of BLDC motor drive is realised using a single voltage sensor. An electronic commutation of BLDC motor is utilised for reducing the switching losses. The performance of the proposed drive is validated experimentally on a developed prototype. An improved power quality is achieved for a wide range of speed control with power quality indices within the limits of IEC 61000-3-2.
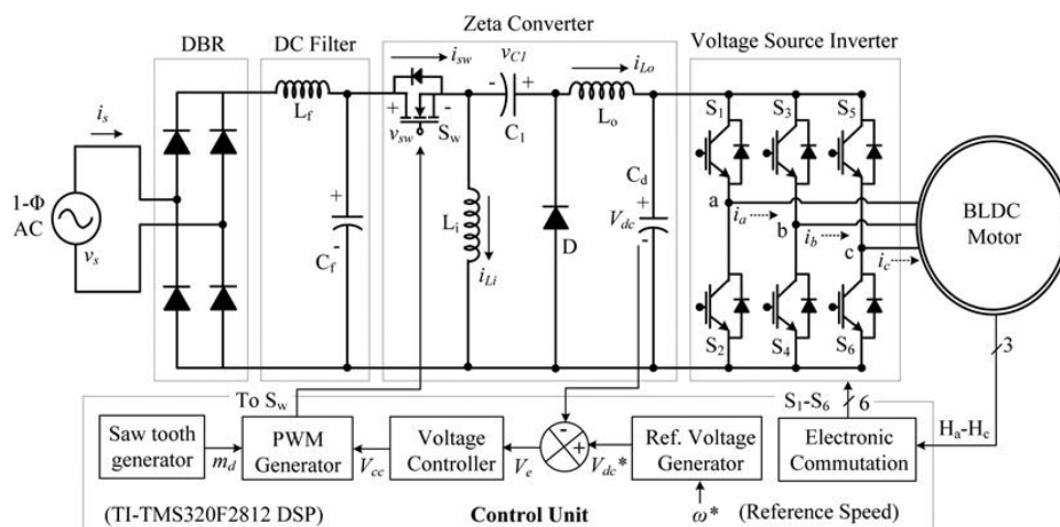
Fig. 4.1 Proposed PFC zeta converter fed BLDC motor drive
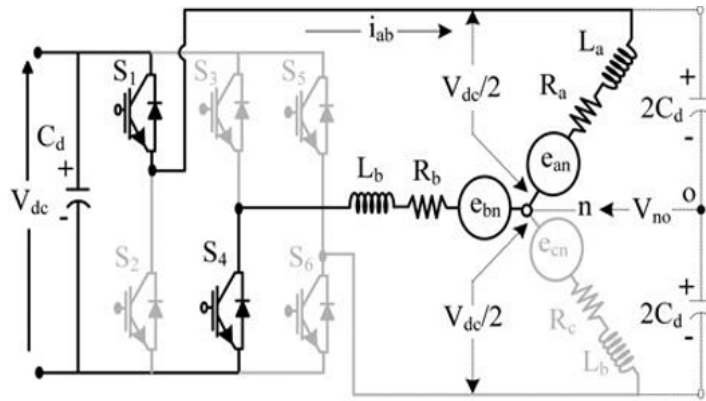
Fig. 4.2 VSI feeding BLDC motor drive

4.2 DESIGN OF PFC ZETA CONVERTER

The PFC zeta converter is designed to operate in DICM such that the current flowing in input inductor (L_i) becomes discontinuous in a switching period. A front-end converter of 300 W is designed to feed a BLDC motor of 251 W. Therefore, for a wide variation of speed, the dc-link voltage has to be controlled from a very low value ($V_{dcmin} = 50V$) to rated value ($V_{dcmax} = 200V$) of dc-link voltage.

The input voltage, V_s applied to the PFC converter as

$$V_s(t) = V_m \sin \sin \left(2\pi f_L t\right) V$$

where V_m is the peak input voltage (i.e. $\sqrt{2}V_s$ where V_s is the supply root mean square voltage), f_L is the line frequency, that is, 50 Hz.

Now, the voltage appearing after the DBR is given as

$$V_{in}(t) = |V_m \sin \sin \left(2\pi f_L t\right) V$$

The output voltage, V_{dc}, of zeta converter which is a buck-boost configuration is given as

$$V_{dc} = \frac{D}{1-D} V_{in}$$

Where D represents the duty ratio.

The duty ratio, D is calculated by substituting the expression of V_{in} from above equation as

$$D = \frac{V_{dc}}{V_{dc}+V_{in}}$$

Moreover, the speed of the BLDC motor is controlled by varying the dc-link voltage of the VSI, hence the instantaneous power, P_i at any dc-link voltage (V_{dc}) can be taken as linear function of V_{dc} as

$$P_i = \left(\frac{P_{max}}{V_{dcmax}}\right)V_{dc}$$

where V_{dcmax} represents maximum value of dc-link voltage.

4.2.1 Design of Input Inductor (L_i)

The critical value of input inductor (L_{ic}) is expressed as

$$L_{ic} = \frac{V_{in}}{2I_{in}f_s} = \frac{R_{in}D}{2f_s} = \left(\frac{V_s^2}{P_i}\right)\frac{D}{2f_s} = \left(\frac{V_s^2}{2P_if_s}\right)\frac{V_{dc}}{V_{dc}+V_{in}}$$

Where R_{in} is the input side resistance and f_s is the switching frequency which is taken as 20 kHz.

This expression exhibits a minimum value at the lowest possible value of supply voltage for which the converter is designed (V_{smin}) which is taken as 170 V. Hence the critical inductance for the two dc-link voltages (i.e. 200 and 50 V) at peak of supply voltage $\sqrt{2}V_s$ can be found as

$$L_{ic200} = \frac{V_{smin}^2}{2P_{max}f_s}\left(\frac{V_{dcmax}}{V_{dcmax}+\sqrt{2}V_{smin}}\right)$$

$$= \frac{170^2}{2\times300\times20000}\left(\frac{200}{200+170\sqrt{2}}\right) = 1.093 \text{ mH}$$

$$L_{ic40} = \frac{V_{smin}^2}{2P_{max}f_s}\left(\frac{V_{dcmax}}{V_{dcmax}+\sqrt{2}V_{smin}}\right)$$

$$= \frac{170^2}{2\times75\times20000}\left(\frac{50}{50+170\sqrt{2}}\right) = 1.658\,\text{mH}$$

Therefore, to achieve a discontinuous conduction at the worst-case scenario of maximum dc-link voltage (*i.e.* L_{ic200})the value of input inductor L_i, must be selected lower than L_{ic200}

$$L_i < L_{ic200} \Rightarrow L_i < 1.093\,\text{mH}$$

Hence the value of L_i is selected as 100 µH to achieve a guaranteed discontinuous conduction.

4.2.2 Design of Intermediate Capacitor (C_1)

The critical value of intermediate capacitance C_1 is designed for a permitted ripple voltage as

$$C_{1c} = \frac{V_{dc}D}{\Delta V_{c1}f_s R_L} = \frac{V_{dc}D}{\eta V_{c1}f_s R_L}$$

where V_{c1} is the voltage appearing across capacitor, C_1. Hence, by substituting the expressions of intermediate capacitor voltage, $V_{c1} = (V_{dc} + V_{in})$, and emulated load resistance, $R_L = V_{dc}^2/P_i$ in above equation, obtained as

$$C_{1c} = \frac{P_i}{\eta(V_{dc}+V_{in})^2 f_s}$$

The maximum value of ripple voltage across intermediate capacitor occurs at maximum value of dc-link voltage and supply voltage since $V_{c1} = (V_{dc} + V_{in})$. Hence the maximum voltage for which the converter is designed is 270 V (V_{smax}), so peak voltage is $V_{in} = 270\sqrt{2}V$. Therefore, the intermediate capacitor is calculated as

$$C_{1c} = \frac{P_{max}}{\eta(\sqrt{2V_{smax}} + V_{dcmax})^2 f_s}$$

$$= \frac{300}{0.1 \times (270\sqrt{2} + 200)^2 \times 20000} = 443.08 \text{ nF}$$

Where η is taken as 10% of V_{c1}.

Hence the intermediate capacitor of 440 nF is selected for the application.

4.2.3 Design of Output Inductor (L_o)

The critical output side inductor is designed as

$$L_o = \frac{V_{dc}(1-D)}{f_s \Delta I_{Lo}} = \frac{V_{dc}(1-D)}{f_s(\lambda I_{Lo})} = \frac{V_{dc}D}{f_s(\lambda I_{in})}$$

The above equation is rearranged as

$$L_o = \frac{V_{dc}D}{f_s \lambda I_{in}} = \frac{R_{in}V_{dc}D}{f_s \lambda V_{in}} = \left(\frac{V_s^2}{P_i}\right)\frac{V_{dc}D}{f_s \lambda V_{in}}$$

The maximum current ripple in an inductor occurs at the maximum power and for minimum value of supply voltage (i.e. $V_{smin} = 170\ V$). Hence the output inductor is calculated at the peak of supply voltage ($V_{in} = \sqrt{2}\ V_{smin}$) as

$$L_o = \left(\frac{V_{smin}^2}{P_{max}}\right)\frac{V_{dcmax}}{\lambda f_s\left(\sqrt{2V_{smin}}\right)}\left(\frac{V_{dcmax}}{V_{dcmax} + \left(\sqrt{2V_{smin}}\right)}\right)$$

$$= \frac{170^2}{300} \times \frac{200}{0.5 \times 20000 \times (170\sqrt{2})} \times \frac{200}{200 + (170\sqrt{2})} = 3.64 \text{ mH}$$

Where λ is the ripple current which is taken as 50% of I_{Lo}. Hence L_o of 3.5 mH is selected for the application.

4.2.4 Design of DC-Link Capacitor (C_d)

The value of dc-link capacitor is expressed as

$$C_d = \frac{I_{dc}}{2\omega \Delta V_{dc}} = \frac{P_i}{2\omega k V_{dc}^2}$$

where k represents the permitted ripple in dc-link voltage.

The maximum value of dc-link capacitor is achieved at minimum value of dc-link voltage with κ taken as 2% of V_{dcmin} and is calculated as

$$C_d = \frac{P_{min}}{2\omega k V_{dcmin}^2} = \frac{75}{2\times314\times0.02\times50^2} = 2388 \ \mu F$$

Hence the dc-link capacitor is selected as 2200 μF.

4.2.5 Design of DC Filter (L_f & C_f)

Moreover, a low-pass LC filter is used to avoid the reflection of higher-order harmonics in supply system. The maximum value of filter capacitance is given as

$$C_{max} = \frac{I_m}{\omega_L V_m}\tan\tan(\theta) = \frac{(P_o\sqrt{2}/V_s)}{\omega_L V_m}\tan\tan(\theta)$$

$$= \frac{(300\sqrt{2}/220)}{314\times220\sqrt{2}}\tan\tan(1°) = 344.7 \ nF$$

Where I_m and V_m are the peak of input voltage and current.

Hence a value of filter capacitor, C_f is taken as 330 nF. Now, the value of filter inductor is designed by considering source impedance (L_s) of 3.5% of the base impedance. The additional value of inductance required is given as

$$L_f = L_{req} + L_s \Rightarrow \frac{1}{4\pi^2 f_c^2 C_f} = L_{req} + 0.035\left(\frac{1}{\omega_L}\right)\frac{V_s^2}{P_i}$$

$$L_{req} = \frac{1}{4\pi^2\times2000^2\times330\times10^{-9}} - 0.035\left(\frac{1}{314}\right)\left(\frac{220^2}{300}\right) = 1.21 \ mH$$

where f_c is the cut-off frequency and is selected such that $f_L < f_c < f_s$, hence it is taken as $f_s/10$.

Hence a LC filter with inductance L_f and capacitance C_f is selected as 1.21 mH and 330 nF, respectively.

4.3 CONTROL OF PROPOSED BLDC MOTOR DRIVE

The control of the PFC zeta converter fed BLDC motor drive is classified into two parts as follows.

4.3.1 Control of Front-End PFC Converter

A voltage follower approach is used for the control of the front-end PFC converter which generates the PWM pulses for the PFC converter switch for dc-link voltage control. A single voltage control loop (voltage follower approach) is utilised for the PFC zeta converter operating in DICM. A reference dc-link voltage (V_{dc}^*) is generated as

$$V_{dc}^* = k_v \omega^*$$

where k_v is the motor's voltage constant and ω^* is the reference speed.

Reference dc-link voltage V_{dc}^* is compared with sensed dc-link voltage (V_{dc}) to generate voltage error signal (V_e) given as

$$V_e(k) = V_{dc}^*(k) - V_{dc}(k)$$

where k represents the kth sampling instant.

This error voltage signal (V_e) is given to the voltage proportional–integral (PI) controller to generate a controlled output voltage as (V_{cc})

$$V_{cc}(k) = V_{cc}(k-1) + k_p\{V_e(k) - V_e(k-1)\} + k_i V_e(k)$$

Where k_p and k_i are PI gains of the voltage PI controller.

Finally, the output of voltage controller is compared with a high frequency saw-tooth signal (m_d) to generate the PWM pulses as

$$\{if\ m_d(t) < V_{cc}(t),\ then\ S_w = 'ON'\ if\ m_d(t) \geq V_{cc}(t),\ \ then\ S_w = 'OFF'\}$$

Where S_w represents the switching signals to switch of PFC converter.

4.3.2 Control of BLDC Motor

An electronic commutation of the BLDC motor includes proper switching of VSI in such a way that a symmetrical dc current is drawn from the dc-link capacitor

for 120° and placed at the centre of each phase. Hall-Effect position sensors are used for rotor position sensing on a span of 120°. As shown in Fig. 4.2, a line current i_{ab} is drawn from the dc-link capacitor during the conduction of two switches (S_1 and S_4). The magnitude of this current depends on the applied dc-link voltage (V_{dc}), back electromotive forces (EMFs) (e_{an} and e_{bn}), resistance (R_a and R_b) and self and mutual inductance (L_a, L_b and M) of the stator windings. Table 3.1 shows the governing of different switching states of the VSI feeding a BLDC motor based on the Hall-Effect position signals ($H_a - H_c$).

CHAPTER -5

INTRODUCTION TO MATLAB & SIMULINK

5.1 INTRODUCTION TO MATLAB

MATLAB is an abnormal state specialized registering dialect and intuitive environment for calculation improvement, information perception, information investigation, and numeric calculation. Utilizing the MATLAB item, you can tackle specialized processing issues speedier than with customary programming dialects, for example, C, C++, and FORTRAN.

MATLAB is utilized as a part of extensive variety of utilizations, including flag and picture preparing, correspondences, control outline, test and estimation, money related demonstrating and investigation, and computational science. Add-on tool stash (accumulations of uncommon reason MATLAB capacities, accessible independently) extend the MATLAB environment to take care of specific classes of issues in these application zones.

MATLAB gives various elements to recording and sharing your work. You can coordinate your MATLAB code with different dialects and applications, and disseminate your MATLAB calculations and application.

5.1.1 Key Features

High-level language for technical computing.

Development environment for managing code, files, and data.

Interactive tools for iterative exploration, design, and problem solving.

Mathematical functions for linear algebra, statistics, Fourier analysis, filtering, optimization, and numerical integration.

2-D and 3-D graphics functions for visualizing data.

Tools for building custom graphical user interfaces.

Functions for integrating MATLAB based algorithms with external applications and languages, such as C, C++, Fortran, Java, COM, and Microsoft Excel.

5.2 INTRODUCTION TO SIMULINK

Simulink is a situation for multi-space reenactment and Model-Based Design for dynamic and inserted frameworks. It gives an intuitive graphical environment and an adjustable arrangement of piece libraries that let you outline, mimic, actualize, and test an assortment of time-fluctuating frameworks, including interchanges, controls, sign handling, video preparing, and picture handling.

Add-on items stretch out Simulink programming to different displaying spaces, and in addition give devices to plan, execution, and confirmation and approval errands.

Simulink is incorporated with MATLAB, giving quick access to a broad scope of instruments that let you create calculations, dissect and picture recreations, make group handling scripts, redo the displaying environment, and characterize sign, parameter, and test information

5.2.1 Key Features

Extensive and expandable libraries of predefined blocks.

Interactive graphical editor for assembling and managing intuitive block diagrams.

Ability to manage complex designs by segmenting models into hierarchies of design components.

Model Explorer to navigate, create, configure, and search all signals, parameters, properties, and generated code associated with your model.

Application programming interfaces (APIs) that let you connect with other simulation programs and incorporate hand-written code.

Embedded MATLAB™ Function blocks for bringing MATLAB algorithms into Simulink and embedded system implementations.

Simulation modes (Normal, Accelerator, and Rapid Accelerator) for running simulations interpretively or at compiled C-code speeds using fixed- or variable-step solvers.

Graphical debugger and profiler to examine simulation results and then diagnose performance and unexpected behaviour in your design.

Full access to MATLAB for analyzing and visualizing results, customizing the modelling environment, and defining signal, parameter, and test data.

Model analysis and diagnostics tools to ensure model consistency and identify modelling errors.

5.3 BLOCK DIAGRAM

A Simulink block diagram is a pictorial model of a dynamic system. It comprises of an arrangement of images, called blocks, interconnected by lines. Every block speaks to a rudimentary dynamic system that delivers a yield either consistently (a constant block) or at particular focuses in time (a discrete block). The lines represent to associations of block inputs to block outputs. Each block in a block diagram is a case of a particular kind of block. The sort of the square decides the relationship between a blocks outputs and its inputs, states, and time. A block diagram can contain any number of cases of a block expected to show a system. block speak to rudimentary element frameworks that Simulink knows how to simulate. A block contains one or a greater amount of the following:

1)   A set of inputs,

2)   A set of states, and

3)   A set of outputs

A blocks output is a component of time and the block's inputs and states (if any). The particular capacity that relates a blocks output to its inputs, states, and time relies on upon the sort of square of which the piece is an example. continuous Versus discrete Blocks Simulink's standard block set incorporates ceaseless squares and discrete block. Ceaseless pieces react persistently to consistently evolving information. Discrete blocks, by differentiation, react to changes in data just at necessary products of an altered interim called the blocks sample time. Discrete pieces hold their output steady between progressive sample time hits. Each discrete block incorporates a specimen time parameter that permits you to determine its sample rate. The Simulink block can be either continuous or discrete, contingent upon whether they are driven by continuous or discrete block. A square that can be either discrete or continuous is said to have a certain sample rate. The certain specimen time is ceaseless if any of the square's inputs are nonstop. The verifiable example time is equivalent to the most limited info test time if all the information test times are essential products of the briefest time. Something else, the information test time is equivalent to the central example time of the inputs, where the major specimen time

of an arrangement of sample times is characterized as the best whole number divisor of the arrangement of sample times.

Simulink can alternatively shading code a block diagram to show the sample times of the pieces it contains, e.g., black (continuous), maroon (constant), yellow (hybrid), red (speediest discrete), etc. The block contains block name, symbol, and piece library that contain the block, the reason for the block.

5.3.1 Simulink Block Libraries

Simulink organizes its blocks into block libraries according to their behavior:

1) The Sources library contains blocks that generate signals.
2) The Sinks library contains blocks that display or write block output.
3) The Discrete library contains blocks that describe discrete-time components.
4) The Continuous library contains blocks that describe linear functions.
5) The Math library contains blocks that describe general mathematics functions.
6) The Functions & Tables library contains blocks that describe general functions and table look-up operations.
7) The Nonlinear library contains blocks that describe nonlinear functions.
8) The Signal & Systems library contains blocks that allow multiplexing and demultiplexing, implement external input/output, pass data to other parts of the model, and perform other functions.
9) The Subsystems library contains blocks for creating various types of subsystems.
10) The Block sets and Toolboxes library contains the Extras block library of specialized blocks.

5.4 SUB SYSTEMS

Simulink permits to display a complex system as an arrangement of interconnected subsystems each of which is spoken to by a square chart. We make a subsystem utilizing Simulink's Subsystem block and the Simulink model editorial manager. We can insert subsystems with subsystems to any profundity to make

various levelled models. We can make restrictively executed subsystems that are executed just when a move happens on an activating or enabling data.

5.5 THE POWER SYSTEM BLOCK SET

Electrical power system are mixes of electrical circuits and Electro-mechanical gadgets, similar to engines and generators. Designers working in this order are every now and again tasked to enhance the execution of the system. Necessities for definitely expanded proficiency have constrained force framework creators to utilize power electronic gadgets and complex control framework ideas that duty conventional investigation apparatuses and strategies. Further convoluting the expert's part is the way that the framework is regularly so nonlinear that the best way to comprehend it is through reenactment. Area based force era from hydroelectric, steam, or different gadgets is by all account not the only utilization of force system. A typical characteristic of these frameworks is their utilization of force hardware and control frameworks to accomplish their execution targets. The Power System Block set was intended to give a present-day configuration apparatus that will permit researchers and designers to quickly and effectively assemble models that reproduce power frameworks. The blocks set uses the Simulink environment permitting a model to be assembled utilizing basic snap and drag methods. Not just can the circuit topology be drawn quickly, yet the examination of the circuit can incorporate its connections with mechanical, warm, control, and different orders. This is conceivable in light of the fact that all the electrical parts of the re-enactment interface with Simulink's broad displaying library. Since Simulink utilizes MATLAB as the computational motor, you can utilize MATLAB's tool kits as you plan your re-enactment.

The block set can be given something to do quickly. The libraries contain models of run of the mill power gear, for example, transformers, lines, machines, and power gadgets. These models are demonstrated ones originating from course readings, and their legitimacy depends on the experience of the Power Systems Testing and Simulation Laboratory of Hydro-Québec, a substantial North American utility situated in Canada. The abilities of the piece set for displaying a commonplace electrical

framework are delineated in showing records. The block set fits well with other specific logical devices you use in the power system.

CHAPTER -6

RESULTS

6.1 MATLAB RESULTS OF WITHOUT ZETA CONVERTER
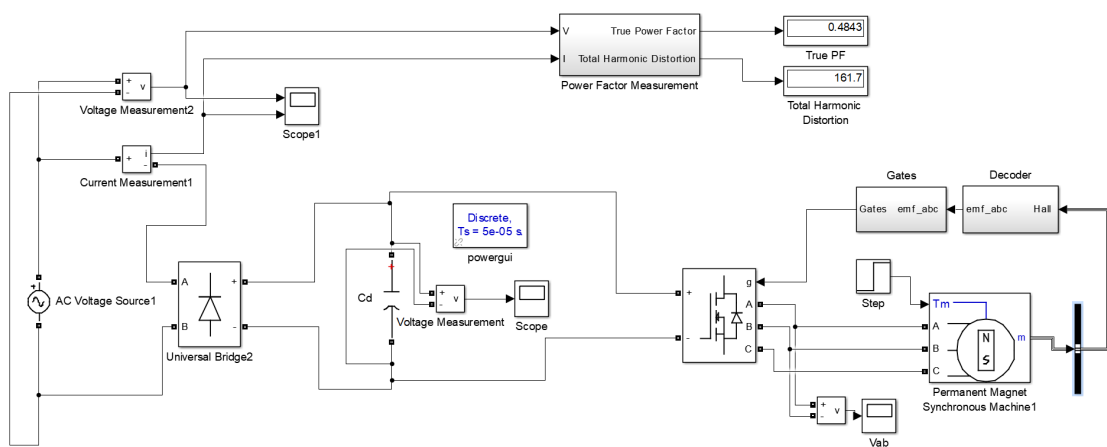
Fig.6.1.1 Conventional Diode Bridge Rectifier fed BLDC motor drive
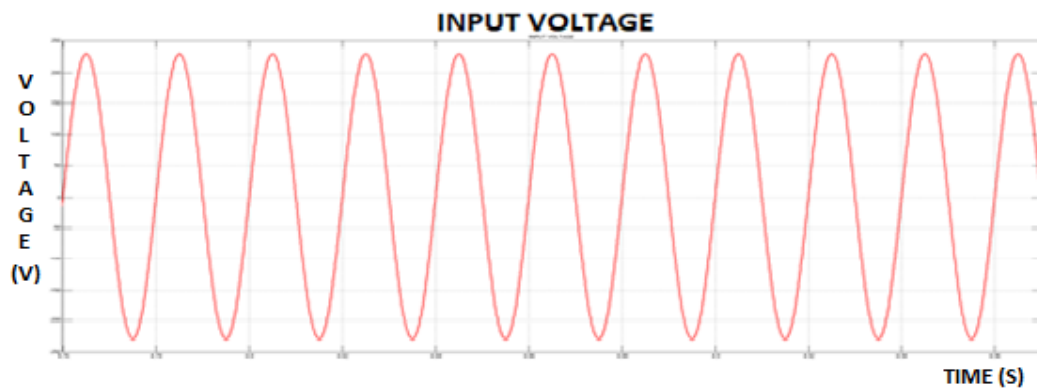
Fig.6.1.2 Input Voltage of Diode Bridge Rectifier
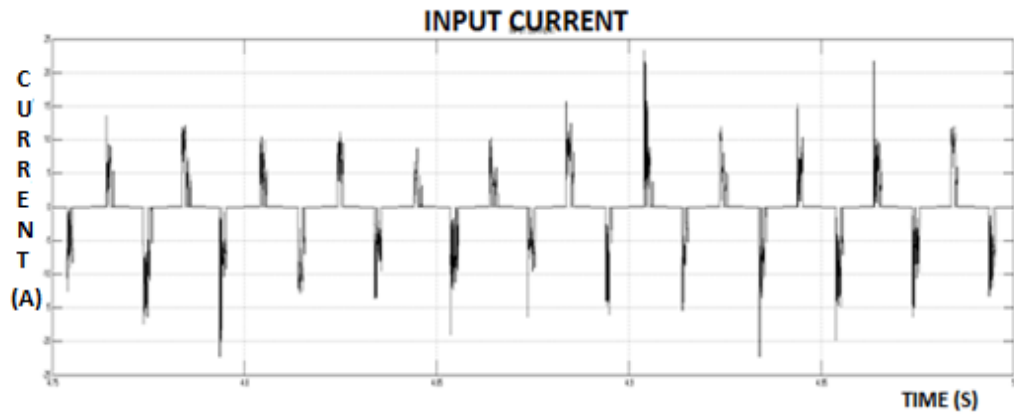
INPUT CURRENT

Fig.6.1.3 Input Current of Diode Bridge Rectifier
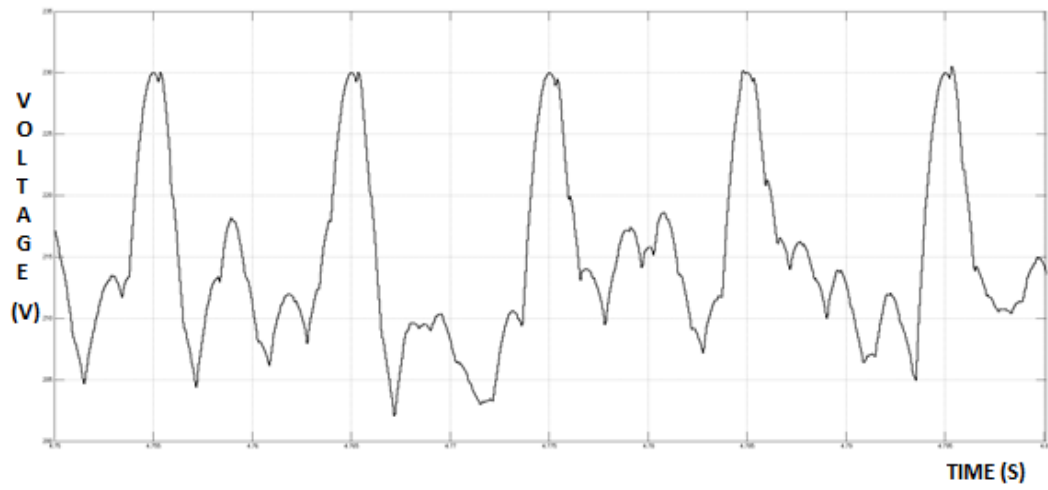
Fig.6.1.4 Rectifier Output Voltage
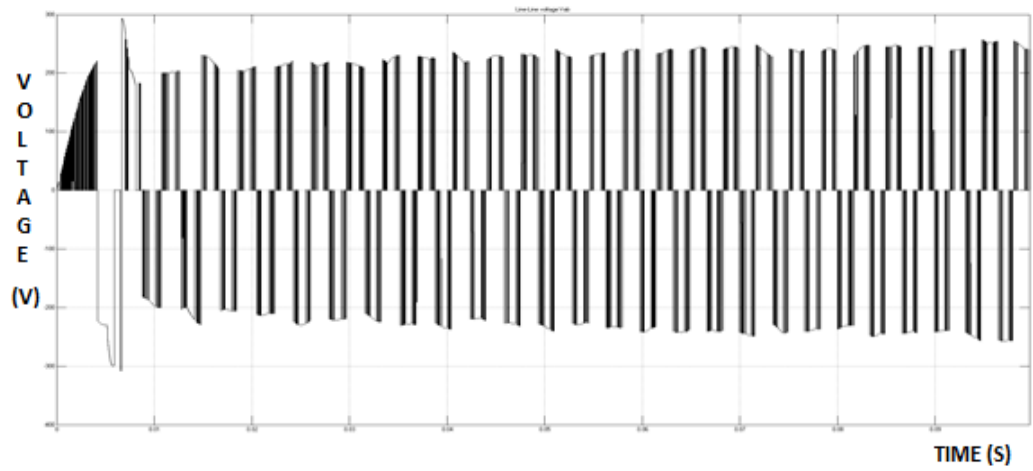
Fig.6.1.5 Inverter Output Voltage

6.2 MATLAB RESULTS OF WITH ZETA CONVERTER
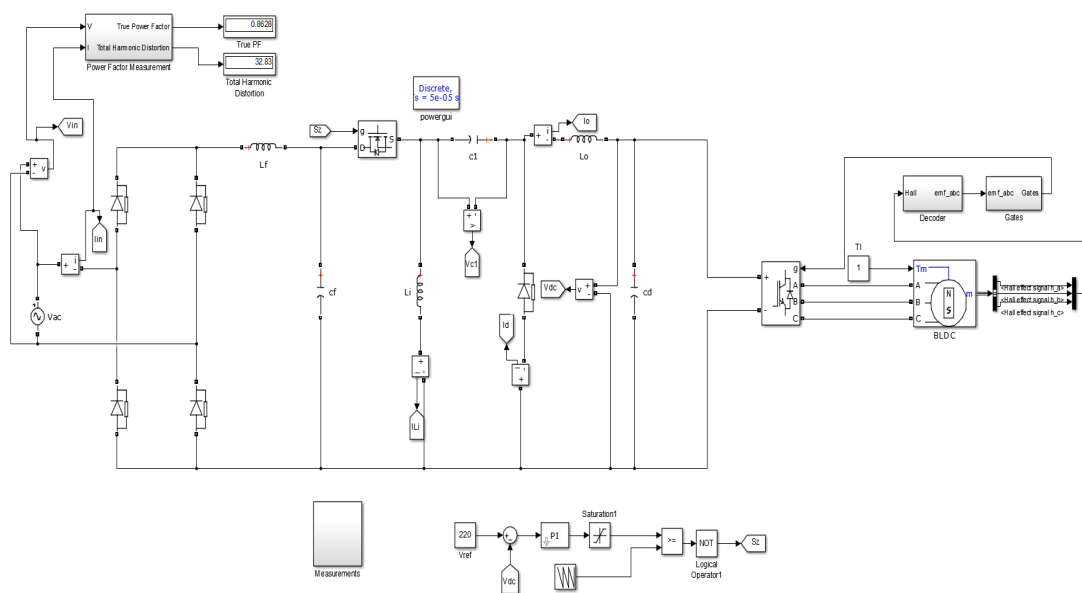
Fig.6.2.1 Proposed PFC zeta converter fed BLDC motor drive
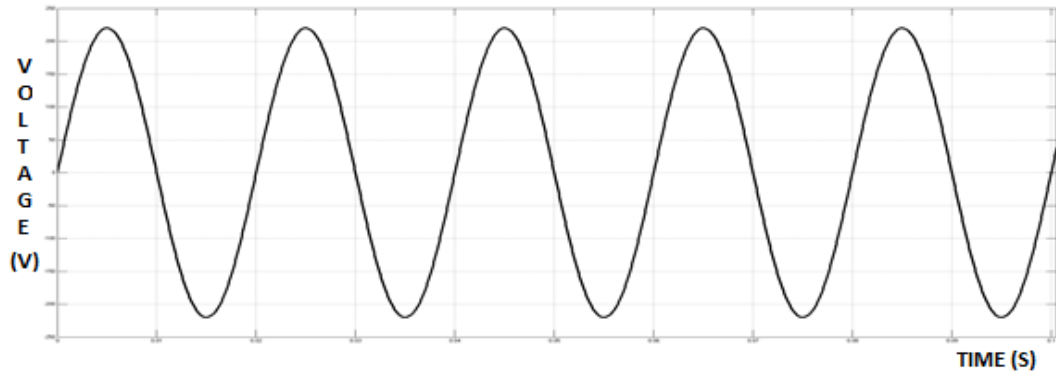
Fig.6.2.2 Input Voltage of Diode Bridge Rectifier
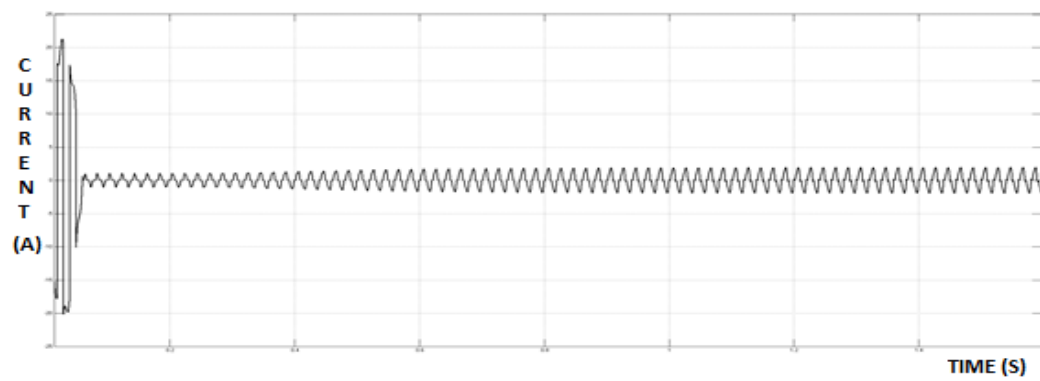
Fig.6.2.3 Input Current of Diode Bridge Rectifier
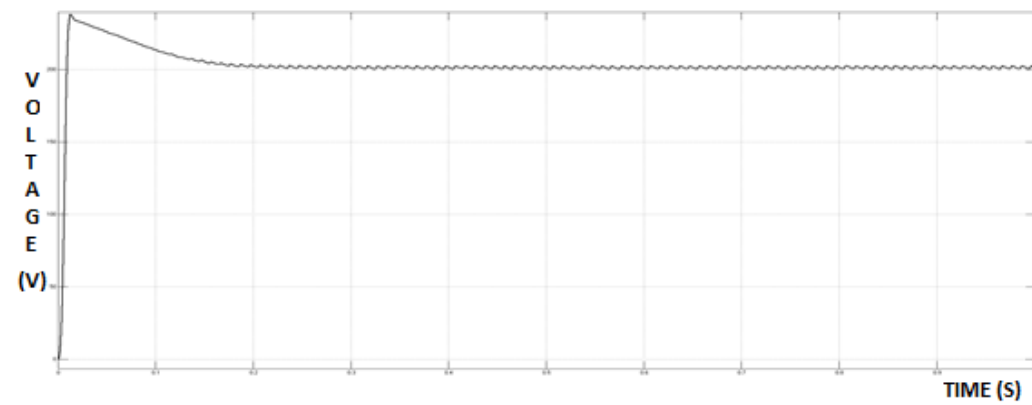
Fig.6.2.4 D.C link Voltage
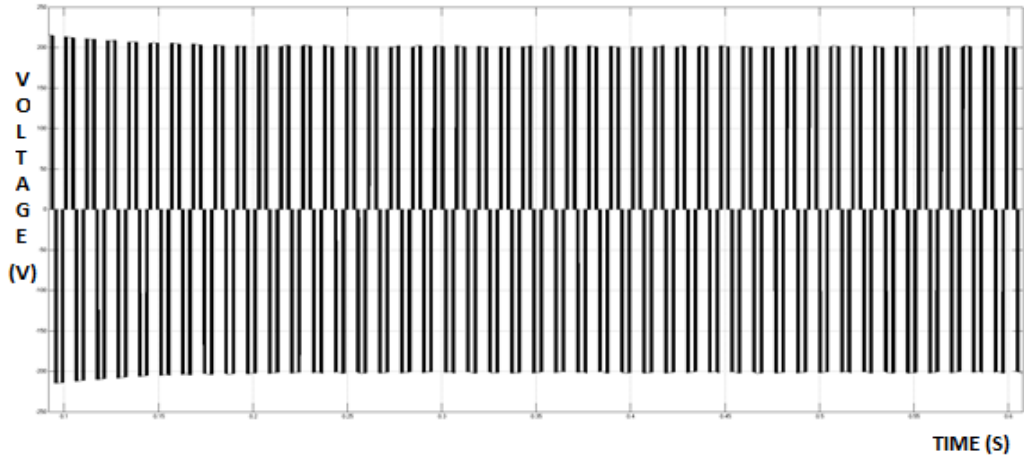
Fig.6.2.5 Inverter Output Voltage

Improvement in Power Factor

	Without zeta converter	With zeta converter
Power Factor	0.449	0.887

CHAPTER-7

CONCLUSION

A PFC zeta converter fed BLDC motor drive has been proposed for a wide range of speed control with UPF at ac mains. The speed of BLDC motor has been controlled by varying the dc-link voltage of VSI via the PFC zeta converter. The PFC

zeta converter has been designed to operate in DICM, which required a voltage follower for dc-link voltage control. A single voltage sensor has been required for the complete drive, which makes it a cost-effective solution. Moreover, low-frequency switching pulses have been used for electronically commutating the BLDC motor which offers reduced switching losses in the VSI compared with conventional scheme of PWM-based switching of VSI. The proposed drive has been designed for achieving an improved power quality at ac mains for a wide range of speed control.

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REDUCTION OF PAPR IN OFDM SIGNALS USING HYBRID PS-GW COMBINED WITH PTS

Submitted in partial fulfillment of the requirements for award

of the degree of

MASTER OF TECHNOLOGY

In

SIGNALS AND SYSTEM

Submitted by

G Siva Kumari   **19U41D4501**

Under the Esteemed Guidance of

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DADI INSTITUTE OF ENGINEERING & TECHNOLOG

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2020

CERTIFICATE

This is to certify that the project work entitled "Reduction of PAPR in OFDM Signals Using Hybrid PS-GW Combined with PTS" has been carried out by G. Siva Kumari (19U41D4501) submitted in the partial fulfillment of the requirement for the award of the degree of MASTER OF TECHOLOGY for POWER AND INDUSTRAL DRIVES during the academic year 2019-2021.

(Project Guide)   (Head of the Department)

P Amrutha B.Tech.,M.Tech   **Dr P Poorna Priya M,Tech.,Ph.D**
Assistant Professor of ECE.   Associate Professor of ECE.

EXTERNAL EXAMINER

DECLARATION

I here by declare that the dissertation entitled "Reduction of PAPR in OFDM Signals Using Hybrid PS-GW Combined with PTS" was carried out and written by me under the guidance of P AMRUTHA, Assistant Professor, Department of Electronics and Communication Engineering, Dadi Institute of Engineering & Technology. This work has not been previously formed the basis for the award of any degree of diploma or certificate nor has been submitted elsewhere for the award of any degree or diploma.

BY

G SIVA KUMARI   (19U41D4501)

ACKNOWLEDGEMENT

G SIVA KUMARI   **(19U41D4501)**

ABSTRACT

The most famous and attractive strategy used in wireless communication for huge transmission of data with higher rate was orthogonal frequency division multiplexing (OFDM) approach. Efficient methods are important for PAPR reduction in high-speed wireless communication systems. The reduction of PAPR in OFDM system has been carried out with one of the most familiar approach called Partial transmit sequences (PTS). Various techniques are already presented for reducing the PAPR, some of them are, clipping, SLM, and PTS. From that PTS is considered as an efficient method because the PAPR was reduced by PTS without causing any signal distortion. In this work, PTS along with hybridization optimization algorithm named as PS–GW will be implemented to get the minimum performance on PAPR and computational complexity. The PS–GW is a combination of both the Particle Swarm Optimization (PSO) and Grey Wolf Optimizer (GWO) which search the optimal combination of phase rotational factors efficiently. A fundamental thought in this method was that the capacity of exploitation in PSO was enhanced with the capacity of investigation in GWO to create two variations in quality. The results produced by this proposed method shows that the reduction was effectively determined in both PAPR and computational complexity. Further the same technique is applied to multiband OFDM ultra wide band signals and PAPR is observed.

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CHAPTER 1

INTRODUCTION

Wireless communication is the transfer of information over a distance without the use of electrical conductors or "wires". The distances involved may be short (a few meters as in television remote control) or long (thousands or millions of kilometers for radio communications). Wireless communication is generally considered to be a branch of telecommunications. It encompasses various types of fixed, mobile, and portable two way radios, cellular telephones, personal digital assistants (PDAs), and wireless networking.

Other examples of wireless technology include GPS units, garage door openers and or garage doors, wireless computer mice, keyboards and headsets, satellite television and cordless telephones. Wireless operations permits services, such as long range communications, that are impossible or impractical to implement with the use of wires. The term is commonly used in the telecommunications industry to refer to telecommunications systems (e.g. radio transmitters and receivers, remote controls, computer networks, network terminals, etc.) which use some form of energy (e.g. radio frequency (RF), infrared light, laser light, visible light, acoustic energy, etc.) to transfer information without the use of wires. Information is transferred in this manner over both short and long distances.

In 1895, Guglielmo Marconi opened the way for modern wireless communications by transmitting the three dot Morse code for the letter 'S' over a distance of three kilometers using electromagnetic waves. From this beginning, wireless communications has developed into a key element of modern society. From satellite transmission, radio and television broadcasting to the now ubiquitous mobile telephone, wireless communications has revolutionized the way societies function. Wireless communications and the economic goods and services that utilise it have some special characteristics that have motivated specialised studies. First, wireless communications relies on a scarce resource – namely, radio spectrum. Second, use of spectrum for wireless communications required the development of key complementary technologies; especially those that allowed higher frequencies to be utilised more efficiently. Finally, because of its special nature, the efficient use of spectrum required the coordinated development of standards. Those standards in turn played a critical role in the diffusion of technologies that relied on spectrum use.

1.1 Principles of wireless communication

Wireless communications begin with a message that is converted into an electronic signal by a device called a transmitter. There are two types of transmitters: analog and digital. An analog transmitter sends electronic signals as modulated radio waves. The analog transmitter modulates the radio wave to carry the electronic signal and then sends the modified radio signal through space. A digital transmitter encodes electronic signals by converting messages into a binary code, the series of zeros and ones that are the basis of all computer programming. The encoded electronic signal is then sent as a radio wave. Devices known as receivers decode or demodulate the radio waves and reproduce the original message over a speaker.
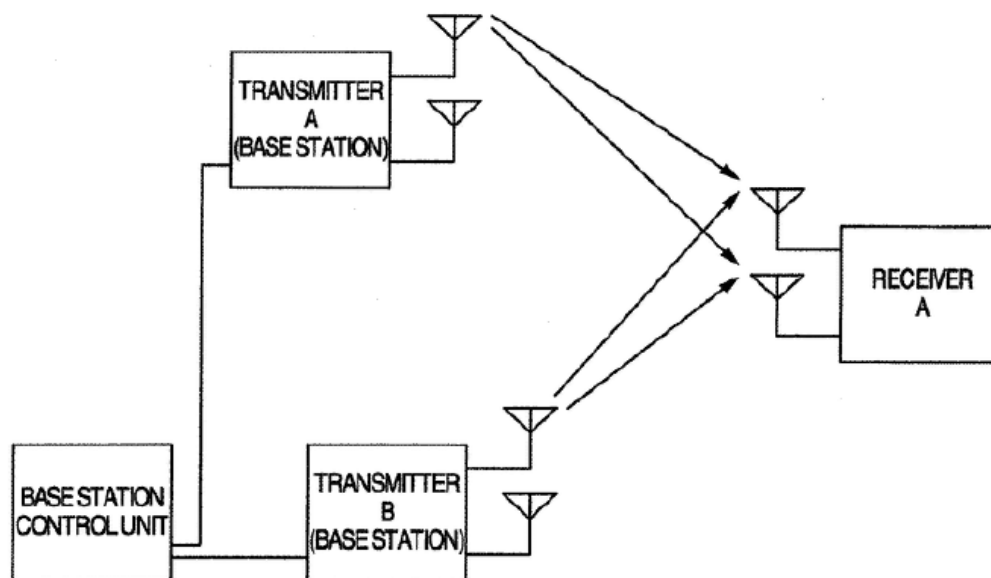
Fig 1.1. Basic Wireless Communication System

Wireless communications systems involve either one way transmissions, in which a person merely receives notice of a message, or two way transmissions, such as a telephone conversation between two people. An example of a device that only receives oneway transmission is a pager, which is a high frequency radio receiver. When a person dials a pager number, the pager company sends a radio signal to the desired pager. The encoded signal triggers the pager's circuitry and notifies the customer carrying the pager of the incoming call with a tone or a vibration, and often the telephone number of the caller. Advanced pagers can display short messages from the caller, or provide news updates or sports scores. Two way transmissions require both a transmitter and a receiver for sending and receiving signals. A

device that functions as both a transmitter and a receiver is called a transceiver. Cellular radio telephones and twoway radios use transceivers, so that backandforth communication between two people can be maintained.

Early transceivers were very large, but they have decreased in size due to advances in technology. Fixed base transceivers, such as those used at police stations, can fit on a desktop, and handheld transceivers have shrunk in size as well. Several current models of handheld transceivers weigh less than 0.2 kg (0.5 lb). Some pagers also use transceivers to provide limited response options. These brief return communication opportunities allow paging users to acknowledge reception of a page and to respond using a limited menu of options.

1.2 Types of Wireless Communication

1. Infrared Wireless Transmission" Transmission of data signals using infrared light waves". These infrared light waves are at a frequency too low for human eyes to receive and interpret. Infrared ports can be found in digital cameras, laptops, and printers as well as wireless mice.

3. Broadcast Radio

wireless transmission medium that sends data over long distances (regions, states, countries) at up to 2 megabits per second (AM/FM Radio)

3. Microwave Radio Transmission of voice and data through the atmosphere as super high frequency radio waves called microwaves. These frequencies are used to transmit messages between ground based stations and satellite communications systems.

4. Communications Satellites are microwave relay stations in orbit around the earth.

1.2.1. Infrared Wireless Transmission

Wireless infrared communications refers to the use of free space propagation of light waves in the near infrared band as a transmission medium for communication, as shown in Figure1. The communication can be between one portable communication device and another or between a portable device and a tethered device, called an access point or base station. Typical portable devices include laptop computers, personal digital assistants, and portable telephones, while the base stations are usually connected to a computer with other networked connections.
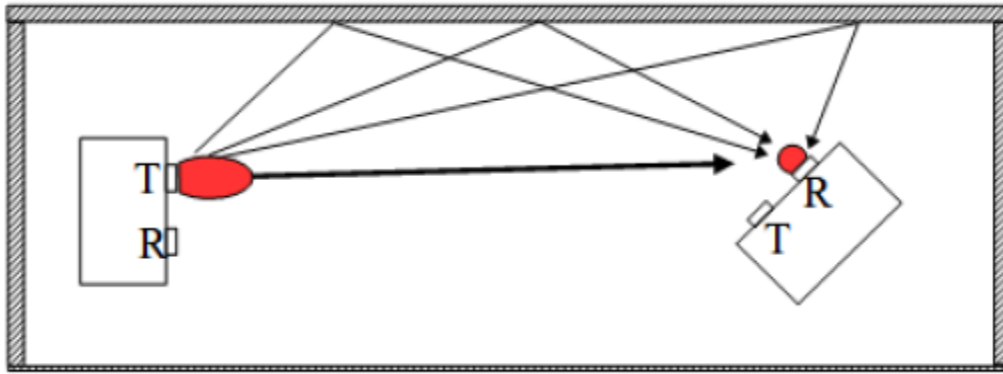
Fig 1.2 A typical wireless infrared communication system

Wireless infrared communication systems can be characterized by the application for which they are designed or by the link type, as described below.

A. Applications

The primary commercial applications are as follows:

Short term cable less connectivity for information exchange (business cards, schedules, file sharing) between two users. The primary example is IrDA systems wireless local area networks (WLANs) provide network connectivity inside buildings. This can either be an extension of existing LANs to facilitate mobility, or to establish "ad hoc" networks where there is no LAN. building to building connections for high speed network access or metropolitan or campus area networks. wireless input and control devices, such as wireless mice, remote controls, wireless game controllers, and remote electronic keys.

B. Link Type

Another important way to characterize a wireless infrared communication system is by the "link type", which means the typical or required arrangement of receiver and transmitter. Figure 2 depicts the two most common configurations: the point to point system and the diffuse system. The simplest link type is the point to point system. There, the transmitter and receiver must be pointed at each other to establish a link. The lineofsight(LOS) path from the transmitter to the receiver must be clear of obstructions, and most of the transmitted light is directed toward the receiver. Hence, point to point systems are also called directed LOS systems. The links can be temporarily created for a data exchange session between two users, or established more permanently by aiming a mobile unit at a base station unit in the LAN replacement application.

In diffuse systems, the link is always maintained between any transmitter and any receiver in the same vicinity by reflecting or "bouncing" the transmitted information bearing

light off reflecting surfaces such as ceilings, walls, and furniture. Here, the transmitter and receiver are non-directed; the transmitter employs a wide transmit beam and the receiver has a wide field of view. Also, the LOS path is not required. Hence, diffuse systems are also called non-directed non-LOS systems. These systems are well suited to the wireless LAN application, freeing the user from knowing and aligning with the locations of the other communicating devices.

Point-to-Point System   Diffuse System
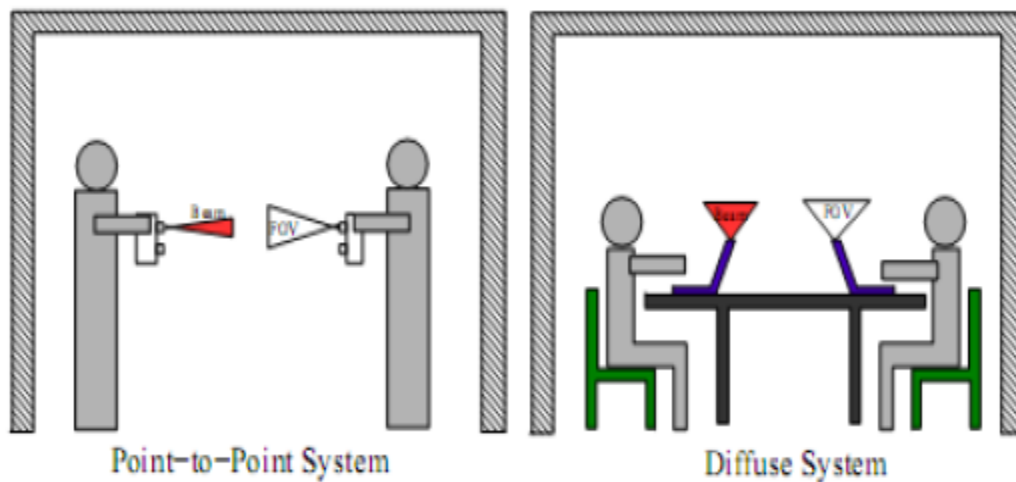
Fig.1.3 Common types of infrared communication systems

Wireless infrared communication systems enjoy significant advantages over radio systems in certain environments. First, there is an abundance of unregulated optical spectrum available. This advantage is shrinking somewhat as the spectrum available for licensed and unlicensed radio systems increases due to modernization of spectrum allocation policies.

Radio systems must make great efforts to overcome or avoid the effects of multipath fading, typically through the use of diversity. Infrared systems do not suffer from time varying fades due to the inherent diversity in the receiver. This simplifies design and increases operational reliability. Infrared systems provide a natural resistance to eavesdropping, as the signals are confined within the walls of the room. This also reduces the potential for neighbouring wireless communication systems to interfere with each other, which is a significant issue for radio based communication systems.

In band interference is a significant problem for both types of systems. A variety of electronic and electrical equipment radiates in transmission bands of current radio systems; microwave ovens are a good example. For infrared systems, ambient light, either manmade or natural, is a dominant source of noise. The primary limiting factor of infrared systems is their

limited range, particularly when no good optical path can be made available. For example, wireless communication between conventional rooms with opaque walls and doors cannot be accomplished; one must resort to using either a radio based or a wire line network to bypass the obstruction.

1.2.3. Broadcast Radio

Radio broadcasting is an audio (sound) broadcasting service, broadcast through the air as radio waves (a form of electromagnetic radiation) from a transmitter to an antenna and a thus to a receiving device. Stations can be linked in radio networks to broadcast common programming, either in syndication or simulcast or both. Audio broadcasting also can be done via cable FM, local wire networks, satellite and the Internet .
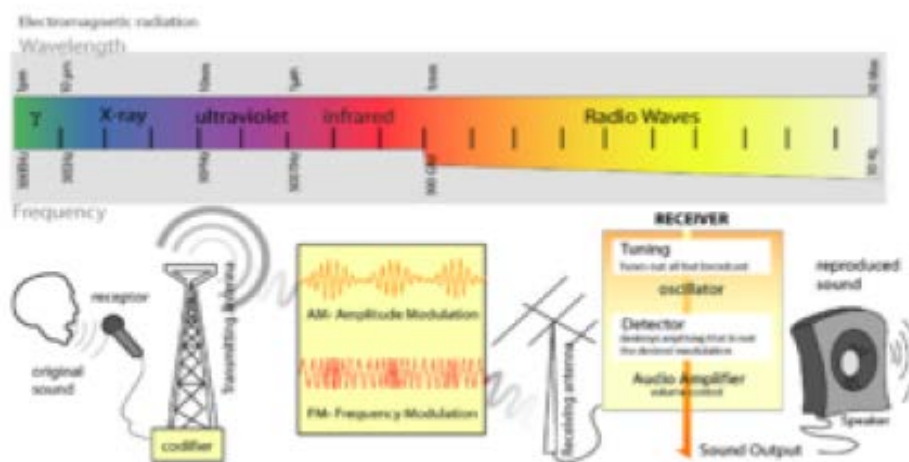
Fig 1.4 Transmission and reception schematic

The best known type of radio station is the ones that broadcast via radio waves. These include foremost AM and FM stations. There are several subtypes, namely commercial, public and non-profit varieties as well as student run campus radio stations and hospital radio stations can be found throughout the developed world. Although now being eclipsed by internet distributed radio, there are many stations that broadcast on shortwave bands using AM technology that can be received over thousands of miles (especially at night). For example, the BBC has a full schedule transmitted via shortwave. These broadcasts are very sensitive to atmospheric conditions and solar activity.

Also, many other non-broadcast types of radio stations exist. These include base stations for police, fire and ambulance networks, military base stations, dispatch base stations for taxis , trucks, and couriers , emergency broadcast systems, and amateur radio stations .

a. Shortwave

Used largely for international broadcasts by organs of state propaganda, religious organizations, militaries and others.

b. AM

AM stations were the earliest broadcasting stations to be developed. AM refers to amplitude modulation, a mode of broadcasting radio waves by varying the amplitude of the carrier signal in response to the amplitude of the signal to be transmitted.

Many countries outside of the U.S. use a similar frequency band for AM transmissions. Europe also uses the long wave band. In response to the growing popularity of FM radio stereo radio stations in the late 1980s and early 1990s, some North American stations began broadcasting in AM stereo, though this never gained popularity, and very few receivers were ever sold.

c. FM

FM refers to frequency modulation, and occurs on VHF airwaves in the frequency range of 88 to 108 MHz everywhere (except Japan and Russia) . Japan uses the 76 to 90 MHz band. Russia has two bands widely used by the Soviet Union, 65.9 to 74 MHz and 87.5 to 108 MHz worldwide standard. FM stations are much more popular in economically developed regions, such as Europe and the United States, especially since higher sound fidelity and stereo broadcasting became common in this format. FM radio was invented by Edwin H. Armstrong in the 1930s for the specific purpose of overcoming the interference (static) problem of AM radio, to which it is relatively immune. At the same time, greater fidelity was made possible by spacing stations further apart. Instead of 10 kHz apart, they are 200 kHz apart. This was far in advance of the audio equipment of the 1940s, but wide interchannel spacing was chosen to take advantage of the noise suppressing feature of wideband FM. The AM radio problem of interference at night was addressed in a different way. At the time FM was set up, the available frequencies were far higher in the spectrum than those used for AM radio by a factor of approximately 100. Using these frequencies meant that even at far higher power, the range of as given FM signal was much lower, thus its market was more local than for AM radio. The reception range at night is the same as at daytime.

The original FM radio service in the U.S. was the Yankee Network, located in New England. Regular FM broadcasting began in 1939, but did not pose a significant threat to the AM broadcasting industry. It required purchase of a special receiver. The frequencies used, 42 to 50 MHz, were not those used today. The change to the current frequencies, 88 to 108

MHz, began after the end of World War II, and it was to some extent imposed by AM radio owners so as to attempt to cripple what was by now realized to be a potentially serious threat.

FM radio on the new band had to begin from the ground floor. As a commercial venture it remained a little used audio enthusiasts' medium until the 1960s. The more prosperous AM stations, or their owners, acquired FM licenses and often broadcast the same programming on the FM station as on the AM station ("simulating"). The FCC limited this practice in the 1970s. By the 1980s, since almost all new radios included both AM and FM tuners, FM became the dominant medium, especially in cities. Because of its greater range, AM remained more common in rural environments.

d. Amateur radio

Independent "ham" radio operators, largely hobbyists, licensed by respective national bodies and assigned call signs.

e. Citizens band radio

Citizens' band radio or CB is usually unlicensed broadcasting over frequencies set aside for that purpose. It is often used by truck drivers to communicate to one another.

f. Other types of radio communication over radio waves

Radio communications have been and are used for all variety of data transmissions. The earliest radio application, Morse code, can still be heard today. Experiments in sending pictures and text date back to the early days of radio. A variety of clock signals are also broadcast. Another early use of radio was coded transmission of information by national governments in peace and war. During the Cold War the USSR and allied governments had national programs to block shortwave and other frequency transmissions by using jamming techniques. One signal known as Russian woodpecker suddenly appeared on July 4, 1976 and just as suddenly disappeared at the end of 1989, and is still something of a mystery. More and more radio frequencies are being used to send digital packets of information of varying degrees of complexity.

An early form of digital radio broadcasting was packet radio, which combines digital information with traditional radio broadcasting over the air. Digital radio broadcasting has emerged, first in Europe (the UK in 1995 and Germany in 1999), and later in the United States, France, the Netherlands, South Africa and many other countries worldwide. The most simple system is named DAB Digital Radio, for Digital Audio Broadcasting, and uses the public domain EUREKA 147 (Band III) system. DAB is used mainly in the UK and South Africa. Germany and Holland use the DAB and DAB+ systems, and France use the LBand system of DAB Digital Radio. In the United States digital radio isn't used in the same way as

Europe and South Africa instead the IBOC system is named HD Radio and owned by a consortium of private companies called iBiquity. An international nonprofit consortium Digital Radio Mondiale (DRM), has introduced the public domain DRM system. Satellite Satellite radiobroadcasters are slowly emerging, but the enormous entry costs of spacebased satellite transmitters, and restrictions on available radio spectrum licenses has restricted growth of this market. In the USA and Canada, just two services, XM Satellite Radio and Sirius Satellite Radio exist. Both XM and Sirius are owned by Sirius XM Radio, which was formed by the merger of XM and Sirius on July 29, 2008, whereas in Canada, XM Radio Canada and Sirius Canada remain separate companies.

1.2.3. Microwave Radio

Microwave radio relay is a technology for transmitting digital and analog signals, such as long distance telephone calls and the relay of television programs to transmitters, between two locations on a line of sight radio path. In microwave radio relay, radio waves are transmitted between the two locations with directional antennas, forming a fixed radio connection between the two points. Long daisy chained series of such links form transcontinental telephone and/or television communication systems.

Over-horizon- microwave radio relay, In over-horizon, or tropospheric scatter, microwave radio relay, unlike a standard microwave radio relay link, the sending and receiving antennas do not use a line of sight transmission path. Instead, the stray signal transmission, known as "tropo scatter" or simply "scatter," from the sent signal is picked up by the receiving station. Signal clarity obtained by this method depends on the weather and other factors, and as a result a high level of technical difficulty is involved in the creation of a reliable over horizon radio relay link. Over horizon radio relay links are therefore only used where standard radio relay links are unsuitable (for example, in providing a microwave link to an island).

Usage of microwave radio relay systems- During the 1950s the AT&T Communications system of TD radio grew to carry the majority of US Long Distance telephone traffic, as well as intercontinental television network signals. Similar systems were soon built in many countries, until the 1980s when the technology lost its share of fixed operation to newer technologies such as fiber-optic cable and optical radio relay links, both of which offer larger data capacities at lower cost per bit. Communication satellites, which are also microwave radio relays, better retained their market share, especially for television. At the turn of the century, microwave radio relay systems are being used increasingly in portable radio applications. The technology is particularly suited to this application because of lower

operating costs, a more efficient infrastructure, and provision of direct hardware access to the portable radio operator.

1.3 Communication Satellite

A communications satellite (sometimes abbreviated to SATCOM) is an artificial satellite stationed in space for the purpose of telecommunications.

Fig 1.5 U.S. military MILSTAR communications satellite

Modern communications satellites use a variety of orbits including geostationary orbits, Molniya orbits , other elliptical orbits and low (polar and nonpolar) Earth orbits. For fixed (pointtopoint) services, communications satellites provide a microwave radio relay technology complementary to that of submarine communication cables. They are also used for mobile applications such as communications to ships, vehicles, planes and handheld terminals, and for TV and radio broadcasting, for which application of other technologies, such as cable, is impractical or impossible.

A. Geostationary orbits

A satellite in a geostationary orbit appears to be in a fixed position to an earth based observer. A geostationary satellite revolves around the earth at a constant speed once per day over the equator The geostationary orbit is useful for communications applications because ground based antennas, which must be directed toward the satellite, can operate effectively without the need for expensive equipment to track the satellite's motion. Especially for applications that require a large number of ground antennas (such as direct TV distribution), the savings in

ground equipment can more than justify the extra cost and onboard complexity of lifting a satellite into the relatively high geostationary orbit.

B. Low Earth-orbiting satellites

A Low Earth Orbit (LEO) typically is a circular orbit about 400 kilometers above the earth's surface and, correspondingly, a period (time to revolve around the earth) of about 90 minutes. Because of their low altitude, these satellites are only visible from within a radius of roughly 1000 kilometers from the subsatellite point. In addition, satellites in low earth orbit change their position relative to the ground position quickly. So even for local applications, a large number of satellites are needed if the mission requires uninterrupted connectivity.

C. Molniya satellites

As mentioned, geostationary satellites are constrained to operate above the equator. As a consequence, they are not always suitable for providing services at high latitudes: at high latitudes, a geostationary satellite will appear low on the horizon, affecting connectivity and causing multipath (interference caused by signals reflecting off the ground and into the ground antenna).

The first satellite of the Molniya series was launched on April 23, 1965 and was used for experimental transmission of TV signal from a Moscow uplink station to downlink stations located in Siberia and the Russian Far East, in Norilsk, Khabarovsk, Magadan and Vladivostok. In November of 1967 Soviet engineers created a unique system of national TV network of satellite television, called Orbita , that was based on Molniya satellites.

1.4 Applications

- Broadcasting services: including short wave, AM and FM radio as well as terrestrial television.
- Mobile communications of voice and data: including maritime and aeronautical mobile for communications between ships, airplanes and land; land mobile for communications between a fixed base station and moving sites such as a taxi fleet and paging services, and mobile communications either between mobile users and a fixed network or between mobile users, such as mobile telephone services.
- Fixed Services : either point to point or point to multipoint services
- Satellite: used for broadcasting, telecommunications and internet, particularly over long distances.
- Amateur radio

- Professional LMR (Land Mobile Radio) and SMR (Specialized Mobile Radio) typically used by business, industrial and Public Safety entities

- Consumer Two Way Radio including FRS (Family Radio Service), GMRS (General Mobile Radio Service) and Citizens band ("CB") radios

- Consumer and professional Marine VHF radios

- Cellular telephones and pagers: provide connectivity for portable and mobile applications, both personal and business.

- Global Positioning System (GPS): allows drivers of cars and trucks, captains of boats and ships, and pilots of aircraft to ascertain their location anywhere on earth.

- Cordless computer peripherals: the cordless mouse is a common example; keyboards and printers can also be linked to a computer via wireless.

- Cordless telephone sets: these are limited range devices, not to be confused with cell phones.

- Satellite television: allows viewers in almost any location to select from hundreds of channels.

- Wireless gaming : new gaming consoles allow players to interact and play in the same game regardless of whether they are playing on different consoles. Players can chat, send text messages as well as record sound and send it to their friends.

- Security systems: Wireless technology may supplement or replace hard wired implementations in security systems for homes or office buildings.

- Television remote control: Modern televisions use wireless (generally infrared) remote control units. Now radio waves are also used.

- Cellular telephony (phones and modems): These instruments use radio waves to enable the operator to make phone calls from many locations worldwide. They can be used anywhere that there is a cellular telephone site to house the equipment that is required to transmit and receive the signal that is used to transfer both voice and data to and from these instruments.

- WiFi: WiFi (for wireless fidelity) is a wireless LAN technology that enables laptop PC's, PDA's, and other devices to connect easily to the internet. Technically known as IEEE 803.11 a,b,g,n, WiFi is less expensive and nearing the speeds of standard Ethernet and other common wirebased LAN technologies

- Wireless energy transfer: Wireless energy transfer is a process whereby electrical energy is transmitted from a power source to an electrical load that does not have a built-in power source, without the use of interconnecting wires.

1.5 Advantages

- Anywhere, Anytime Work: Through wireless communication, working professionals and mobile workers can work and access the Internet just about anywhere, anytime without the hassles of wires and network cables.

- Enhanced Productivity Workers, students, professionals and others need not be constrained by wired Internet connections or dialup connectivity. Wireless Internet connectivity options ensures that work and assignments can be completed anywhere and enhance overall productivity of all concerned.

- Remote Area Connectivity Workers, doctors and other professionals working in remote location hospitals and medical centers can keep in touch with anyone through wireless communication. Nonprofit organization volunteers working in remote and underserved areas can stay connected to the outside world with the help of wireless communication.

- On Demand Entertainment Bonanza. For those unable to keep away from their daily soap operas, reality programs, online TV shows and Internet surfing or download activities, wireless

- Emergency Alerts

Through wireless communication, many emergency situations and crisis situations can be addressed quickly. Help and other assistance can reach affected areas quickly through early alerts and warnings provided with the help of wireless communication.

1.6 Conclusion

This chapter gives the introduction to wireless communication and some advantages, disadvantages. The rest of this project is organized as follows. In Chapter 2, related work of the project i.e. literature is been presented. Chapter 3, we introduce different optimization techniques. A new PTS technique based on PS-GW for PAPR reduction in OFDM systems is discussed in Chapter 4. Simulation results are provided in chapter 5, followed by concluding remarks in Chapter 6.

CHAPTER 2

LITERATURE SURVEY

2.1 Introduction

OFDM has many well known advantages such as robustness against frequency selective fading or narrowband interference, high bandwidth efficiency, and efficient implementation [1]. Recently, it is widely used in many digital communication systems such us Digital Television (DTV), Digital Audio Broadcasting (DAB), Digital Subscriber Line (DSL) broadband internet access, standards for Wireless Local Area Networks (WLANs), standards for Wireless Metropolitan Area Networks (WMANs), and 4G mobile communications [2],[3]. The principle of OFDM is to divide a high rate information bitstream into several parallel low rate data substreams and use these substreams to modulate a number of orthogonal subcarriers by Fourier transform techniques. However, one drawback of OFDM is that the transmitted signal has a high PAPR when the subcarriers add up coherently. A high PAPR not only degrades efficiency of a linear power amplifier but also limits the application of OFDM transmission systems. Therefore, PAPR reduction in OFDM systems is an active area of research and has widely attracted the attention of researchers [2] [4].

In order to reduce the PAPR effectively, various techniques have been proposed such as clipping [5], coding [6], Tone Reservation (TR) [7], Partial Transmit Sequence (PTS) [8] and Selective Mapping (SLM) [9]. Conventional SLM techniques generate a number of sequences by altering the phase information from a sequence that consists of a fixed number of statistically independent elements, and the sequence with the lowest PAPR is chosen. Genetic algorithms (GA) [10] [11] (a type of evolutionary computing), are search techniques based on probabilities that reflect natural genetics. These algorithms are widely used to search for a global optimum in combinatorial problems due to their simplicity. In this paper, we present a new SLM-OFDM technique for improved PAPR reduction that have low complexity due to local search using a GA.

2.2 Literature Review

S. H. Han & J. H. Lee, "An overview of peak-to-average power ratio reduction techniques for multicarrier transmission," IEEE Wireless Communications Magazine, Vo. 12, No. 2, pp.56-65,Apr. 2005: High peak-to-average power ratio of the transmit signal is a major drawback of multicarrier transmission such as OFDM or DMT. This article describes some of the important PAPR reduction techniques for multicarrier transmission including amplitude

clipping and filtering, coding, partial transmit sequence, selected mapping, interleaving, tone reservation, tone injection, and active constellation extension. Also, we make some remarks on the criteria for PAPR reduction technique selection and briefly address the problem of PAPR reduction in OFDMA and MIMO-OFDM.

T. Jiang and Y. Y. Wu,"An Overview: Peak-to-Average Power Ratio Reduction Techniques for OFDM Signals," IEEE Trans. Broadcast., vol. 54, no. 2, pp. 257–268, June 2008: One of the challenging issues for Orthogonal Frequency Division Multiplexing (OFDM) system is its high Peak-to-Average Power Ratio (PAPR). In this paper, we review and analysis different OFDM PAPR reduction techniques, based on computational complexity, bandwidth expansion, spectral spillage and performance. We also discuss some methods of PAPR reduction for multiuser OFDM broadband communication systems.

Y. J. Shi, D. Z. He, W. Huang, Y. Xu, Y. F. Guan, and J. Sun, "Constellation Shifting Based on QAM with Gray Coding for PAPR Reduction of OFDM Systems," IEEE International Symposium on Broadband Multimedia Systems and Broadcasting, pp.1-3, 2013: High PAPR has long been a main drawback of OFDM systems. With the lengthening of OFDM symbol and the increasing popularity of high-order modulation, such as OFDM symbol size of 32768 and 256-QAM in DVB-T2, reducing PAPR is of growing importance. In this paper, a constellation shifting technique based on QAM with gray coding will be introduced to reduce PAPR. This technique keeps the minimum Euclidean distance of the constellation points and gray coding's benefit, costs no extra bandwidth, and consumes little extra power.

J. C. Chen and C. P. Li, "Tone reservation using near-optimal peak reduction tone set selection algorithm for PAPR reduction in OFDM systems," IEEE Signal Process. Lett., vol. 17, no. 11, pp. 933-936, Nov. 2010. This letter considers selection of the optimal peak reduction tone (PRT) set for the tone reservation (TR) scheme to reduce the peak-to-average power ratio (PAPR) of an orthogonal frequency division multiplexing (OFDM) signal. In the TR scheme, PAPR reduction performance achieved by a randomly generated PRT set is superior to that by a consecutive PRT set and that achieved by an interleaved tone set. However, the optimal PRT set requires an exhaustive search of all combinations of possible PRT sets, which is known to be a nondeterministic polynomial-time (NP)-hard and cannot be solved for the practical number of tones. Inspired by the efficiency of the cross-entropy (CE) method for finding near-optimal solutions in huge search spaces, this letter proposes the application of the CE method to search the optimal PRT set. Computer simulation results

show that the proposed CE method obtains near-optimal PRT sets and provides better PAPR performance.

J. W. Ji and G. L. Ren, "A New Modified SLM Scheme for Wireless OFDM Systems without Side Information," IEEE Signal Processing Letters, vol.20, no.11, pp.1090-1093, 2013. To avoid the transmission of side information and decrease the computational complexity in the conventional selected mapping (SLM) scheme, a novel set of conversion matrices (CMs) is proposed for the modified SLM scheme, and the signal processing scheme to remove the weighted factors on each subcarrier is also derived for wireless orthogonal frequency-division multiplexing (OFDM) systems. Computer simulations show that, without side information, the new scheme can achieve similar peak-to-average power ratio (PAPR) reduction and bit error rate (BER) performance with even lower computational complexity as compared with the available modified SLM schemes with the CMs.

S. J. Heo, H. S. Noh, J. S. No and D. J. Shin "A Modified SLM Scheme With Low Complexity for PAPR Reduction of OFDM Systems", IEEE Trans. on Broadcasting, vol. 53, no. 4, pp. 802- 808, Dec. 2007. In this paper, we propose a new peak-to-average power ratio (PAPR) reduction scheme of orthogonal frequency division multiplexing (OFDM) system, called a modified selected mapping (SLM) scheme, which considerably reduces the computational complexity with keeping the similar PAPR reduction performance compared with the conventional SLM scheme. The proposed scheme is analytically and numerically evaluated for the OFDM system specified in the IEEE 802.16 standard. For the OFDM system with 2048 subcarriers, the proposed scheme with 4 binary phase sequences can reduce the complex multiplications by 63.5% with the similar PAPR reduction compared with the SLM scheme with 16 binary phase sequences.

CHAPTER 3

OPTIMIZATION TECHNIQUES

3.1 cuckoo search

Cuckoo search (CS) is an optimization algorithm developed by Xin-she Yang and Suash Deb in 2009. It was inspired by the obligate brood parasitism of some cuckoo species by laying their eggs in the nests of other host birds (of other species). Some host birds can engage direct conflict with the intruding cuckoos. For example, if a host bird discovers the eggs are not their own, it will either throw these alien eggs away or simply abandon its nest and build a new nest elsewhere. Some cuckoo species such as the New World brood-parasitic Tapera have evolved in such a way that female parasitic cuckoos are often very specialized in the mimicry in colors and pattern of the eggs of a few chosen host species.

Cuckoo search idealized such breeding behavior, and thus can be applied for various optimization problems. It seems that it can outperform other metaheuristic algorithms in applications.

Cuckoo search (CS) uses the following representations:

Each egg in a nest represents a solution, and a cuckoo egg represents a new solution. The aim is to use the new and potentially better solutions (cuckoos) to replace a not-so-good solution in the nests. In the simplest form, each nest has one egg. The algorithm can be extended to more complicated cases in which each nest has multiple eggs representing a set of solutions.

CS is based on three idealized rules:

1. Each cuckoo lays one egg at a time, and dumps its egg in a randomly chosen nest;
2. The best nests with high quality of eggs will carry over to the next generation;
3. The number of available hosts nests is fixed, and the egg laid by a cuckoo is discovered by the host bird with a probability $p_a \in (0, 1)$. Discovering operate on some set of worst nests, and discovered solutions dumped from farther calculations.
4. The pseudo code was given in a sequential form, but Yang and Deb provides a vectorized implementation which is very efficient.[11] In the real world, if a cuckoo's egg is very similar to a host's eggs, then this cuckoo's egg is less likely to be

discovered, thus the fitness should be related to the difference in solutions. Therefore, it is a good idea to do a random walk in a biased way with some random step sizes. For Matlab implementation, this biased random walk can partly be achieved by

5. stepsize=rand*(nest(randperm(n),:)-nest(randperm(n),:));

6. new_nest=nest+stepsize.*K;

7. where K=rand(size(nest))>pa and pa is the discovery rate.

8. A standard CS matlab can be found

here http://www.mathworks.com/matlabcentral/fileexchange/29809-cuckoo-search-cs-algorithm. However, there is some controversy on whether or not this implementation truly reflects the originally published cuckoo search algorithm. The biased walk described above closely resembles another optimization algorithm, differential evolution. It was shown that this biased walk has a larger impact on the performance of the algorithm than the cuckoo search algorithm itself.

9. An object-oriented software implementation of cuckoo search was provided by Bacanin. On the other hand, a modified cuckoo search algorithm is also implemented for unconstrained optimization problems.

3.2 Ant colony Optimization

In computer science and operations research, the Ant Colony Optimization algorithm (ACO) Optimization algorithm (ACO) is a probabilistic technique for solving computational problems which can be reduced to finding good paths through graphs.

This algorithm is a member of the Ant Colony Algorithms family, in swarm intelligence methods, and it constitutes some metaheuristic optimizations. Initially proposed by Marco Dorigo in 1992 in his PhD thesis, the first algorithm was aiming to search for an optimal path in a graph, based on the behavior of ants seeking a path between their colony and a source of food. The original idea has since diversified to solve a wider class of numerical problems, and as a result, several problems have emerged, drawing on various aspects of the behavior of ants.

Application:

Ant colony optimization algorithms have been applied to many combinatorial optimization problems, ranging from quadratic assignment to protein folding or routing

vehicles and a lot of derived methods have been adapted to dynamic problems in real variables, stochastic problems, multi-targets and parallel implementations. It has also been used to produce near-optimal solutions to the travelling salesman problem. They have an advantage over simulated annealing and genetic algorithm approaches of similar problems when the graph may change dynamically; the ant colony algorithm can be run continuously and adapt to changes in real time. This is of interest in network routing and urban transportation systems.

The first ACO algorithm was called the ant system and it was aimed to solve the travelling salesman problem, in which the goal is to find the shortest round-trip to link a series of cities. The general algorithm is relatively simple and based on a set of ants, each making one of the possible round-trips along the cities. At each stage, the ant chooses to move from one city to another according to some rules:

1. It must visit each city exactly once;
2. A distant city has less chance of being chosen (the visibility);
3. The more intense the pheromone trail laid out on an edge between two cities, the greater the probability that that edge will be chosen;
4. Having completed its journey, the ant deposits more pheromones on all edges it traversed, if the journey is short;

After each iteration, trails of pheromones evaporate.

3.3 Firefly Optimization

Fireflies are unisex with the goal that each individual firefly will be pulled into different fireflies paying little mind to their opposite sex. The attractiveness and brightness are directly proportional to each other, and they both lessening as their separation increments. Along these lines for any two blazing fireflies, the less splendid one will attrack the more brilliant one. On the off chance that there is no more brilliant one than a specific firefly, it will move randomly. The brightness of a firefly is controlled by the scene of the goal work[18].

As a firefly's attractiveness is proportional to the light intensity seen by adjacent fireflies, can now define the variation of attractiveness β with the distance r by

$$\beta = \beta_0 e^{-\gamma r^2}$$

Where β_0 is attractiveness at r=0

The firefly i is attracted to another more brighter firefly j and move towards j and the sane is determined by

$$x_i^{t+1} = x_i^t + \beta_o e^{-\gamma r_{ij}^2}\left(x_j^t - x_i^t\right) + \alpha_t \epsilon_i^t$$

Where the second term $\beta_o e^{-\gamma r_{ij}^2}\left(x_j^t - x_i^t\right)$ is concern based on the attraction. The third term i.e $\alpha_t \epsilon_i^t$ is randomization with α_t being the randomization parameter, and ϵ_i^t is a vector of random numbers drawn from a Gaussian distribution or uniform distribution at time t.

3.4 Genetic Algorithm

Genetic algorithms use several mechanisms to evolve a system over the course of the run. Selection of which mechanisms to use, and the probability each will have, is a critical decision for the programmer. Since Genetic Algorithms are an iterative process, modelling either the fitness criteria or individual incorrectly can cause the program to diverge from answering the problem of interest to the programmer. However, by self-correcting over the course of a large numbers of these iterations, using assumptions and criteria based on proven theory, the algorithm has the capability of finding a set of most favorable solutions to highly complex problems that might otherwise take years of measurement and data collection.

3.4.1 Fitness Measurement

The initial item the programmer must address is how to evaluate the traits of an individual population member against the desired outcome. This is known as a "fitness measurement," and it must be performed for each individual during each consecutive generation of the run in order to be able to faithfully rank the individuals' suitability to deliver the desired result.

Defining the fitness function is the most critical step in the process. A failure to effectively shape the question at hand in a form that can be translated through a programming language into a measurement of fitness for each individual relative to each other prevents the preferential treatment of the best suited individuals to the next generation. This allows too many of the weaker members to move on and the population will continue to be characterized by linearness. Also important is the shaping of the fitness criteria based on the reality of the problem. In using a Genetic Algorithm to design and optimize an electrical or mechanical system for example, the actual performance parameters and physical limits of such a system must be faithfully reflected in the mathematics used to determine the relative ranking of the individuals. Without this fidelity to the physical world you might very well get an optimized solution to the problem posed, but that problem might not reflect the true complexity of the environment it must exist in and is therefore useless as anything other than an academic exercise. The fitness calculation may therefore be of a very complex nature.

The process is two-fold. The fitness of each individual must first be evaluated and compared to its peers, then individuals must be selected for a new population. The traits for each population member are evaluated using the fitness criteria, usually involving an analytic or numerical evaluation of a mathematical formula. The criterion must provide enough resolution that two individuals will usually have different values in order to be able to rank the entire population. For example, in the case of a simple radar antenna design problem, the fitness assessment might involve determining the antenna Gain for each individual. The traits of the individual might be those elements of Gain which are under the control of the designer: radar frequency, f, the antenna aperture efficiency, ρ_a, which is controlled by antenna shape and the physical area of the antenna, A. The fitness assessment for each member would involve using the member's traits to calculate antenna Gain in decibels, G_{dB}.

Where c is the speed of light. The resulting Gain would allow the individuals to be ranked from most fit, meaning highest Gain, to least fit. Note that the fitness criterion is not expressed as a set binary limit, such as "above 30 dB," as this limits the ranking of individuals to only two categories.

3.4.2 Population Selection

The population of any GA is composed of individuals. Each individual has discrete traits that characterize the individual and are directly applicable to the mathematics involved in determining fitness. Generally speaking, the initial population is determined Linearly for the first generation, and by the fitness assessment, selection, and creation of new individuals in subsequent generations.

Seeding

A refinement to population selection is the concept of "seeding" the initial population of a Genetic Algorithm with the results of a previous run or predetermined configurations that represent probable solutions based on known facts, problem solver experience or even the best ranked results from previous runs. Not only does the introduction of evolved, known or probable solutions cause more rapid convergence, but it also allows the GA to be adjusted between runs in order to better track toward the desired goal.

Fitness- and Rank-Proportional Selection

Once the fitness of each individual has been determined the following step in formation of a new generation involves selecting the individuals that will be allowed to contribute genetic material to the next population through one of the genetic operators, described in detail later. Individual population members are selected for membership in the next generation by their relative fitness ranking with one of several methods, two of which

are described below. Sometimes, a probability of selecting less fit individuals over more fit ones is included to retain some of the diversity of the original population, but the more fit ones must always have a higher probability of selection in order for a solution to emerge. A broader population diversity will result in slower convergence to the solutions of a problem and will require more computational resources and time, but has a greater chance of arriving at a better and perhaps unanticipated solution.

Fitness-proportional selection means that the probability of an individual being selected for continuation is weighted based on its performance during the fitness evaluation. One common method for fitness-proportional selection involves the creation of "bins," one for each individual present in the population. The size, or length, of an individual's bin is proportional to its assessed fitness. A Linear number is generated within the value range of all the bins, and the individual in whose bin this number falls is selected for inclusion in the next generation, after the application of a genetic operator. Like pitching pennies into cups of differing sizes, there is a finite probability of selection for any individual but the individuals with better fitness scores have a higher probability of selection.

A problem can arise with fitness-proportional selection when the raw fitness score values of most of the individuals are close to each other. This is particularly evident in later generations of a run, where all the individuals have begun to converge on a narrow range of solutions. The method for fixing this problem is to use rank-proportional selection. In rank-proportional selection, individuals are ranked with an integer value based on their raw fitness score, from 1 for the least fit to the population size, n, for the most fit. They are again placed in bins, but the bin size is now proportional to the integer ranking. The highest ranked individuals have the largest bins and therefore the higher probability of selection. Figure 3 illustrates this difference.
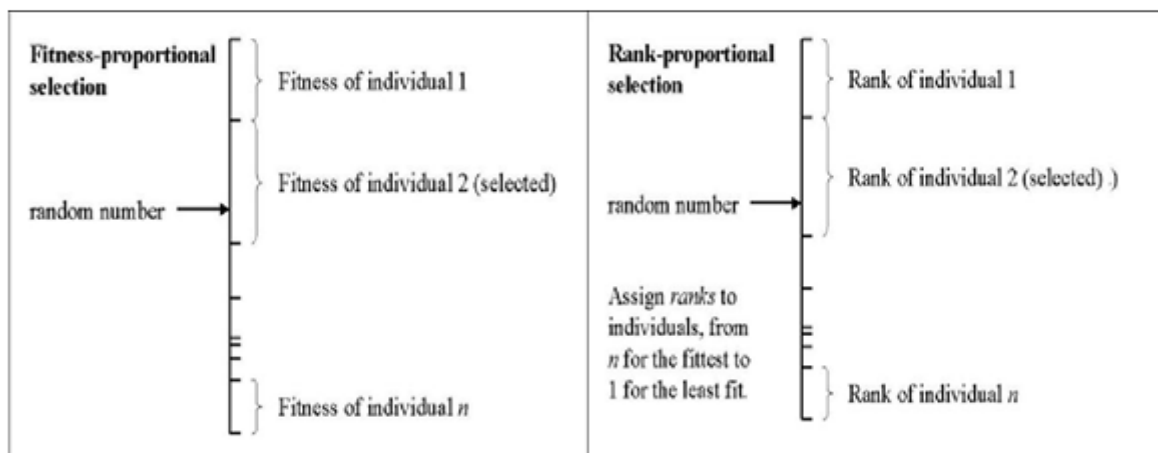
Figure 3.1. Fitness-Proportional vs. Rank- Proportional Selection

3.4.3 Generalized Genetic Operators

Another item of concern to the writer of a genetic algorithm is the method by which individual population members will be used in creation of the next generation once their fitness has been ranked. There are four methods usually used for this process: reproduction, crossover, inversion and mutation, with each of the four having potentially independent mechanisms for determining if they occur. Each is normally assigned a probability of occurring, with this probability weighted in favour the individual's fitness ranking, thereby giving traits of the most fit the best chance of survival into later generations. Using these four mechanisms, a new generation is formed and the fitness test is applied once again.

Reproduction

Reproduction, or the inclusion of an unaltered individual population member in the next generation, is the simplest process of promotion for any Genetic Algorithm. Figure 3.2 shows the reproduction to a new generation graphically. When an individual population member is selected for reproduction the traits of the member, denoted as the vector a_1 through a_n in Figure 3.2, are copied directly into an available slot for a population member in the new generation. No changes or rearrangements are made.
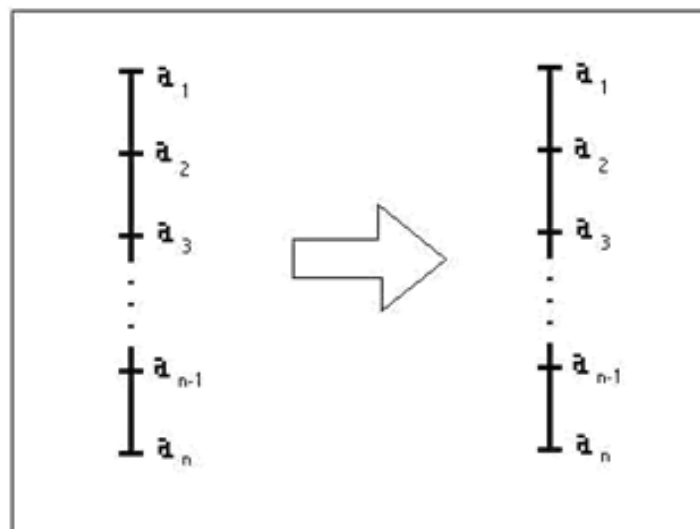
Figure 3.2 Illustration of Reproduction

The biological equivalent of this process could be seen as either survival of the individual or procreation through asexual reproduction, producing an identical copy of a single parent in the new generation. This mechanism is often assigned a significant probability of occurrence, although not as high as crossover. This same process is alternatively called copying or promotion.

b. Crossover

Crossover mimics sexual recombination in biological organisms. Starting with two parent members of the population, a number of distinct traits are swapped between mated pairs to produce two offspring, each different from the other and also from their parents, but with "genetic material" common to the family line. Crossover is also controlled by probability, again usually weighted in favour of selecting more fit individuals as parents. Like reproduction, crossover is usually assigned a relatively high probability of occurring, usually exceeding the proportion assigned the other operators. The programmer must decide on values for some specific parameters that are not required for simple reproduction. Two parents must be selected based on fitness, rather than one. The number of traits that will be crossed between mated pairs must be determined, and then a process must be included to determine which specific traits this will be. The specific traits are often selected Linearly to further promote innovative results. Figure 3.3 shows an example of the crossover operation at work.
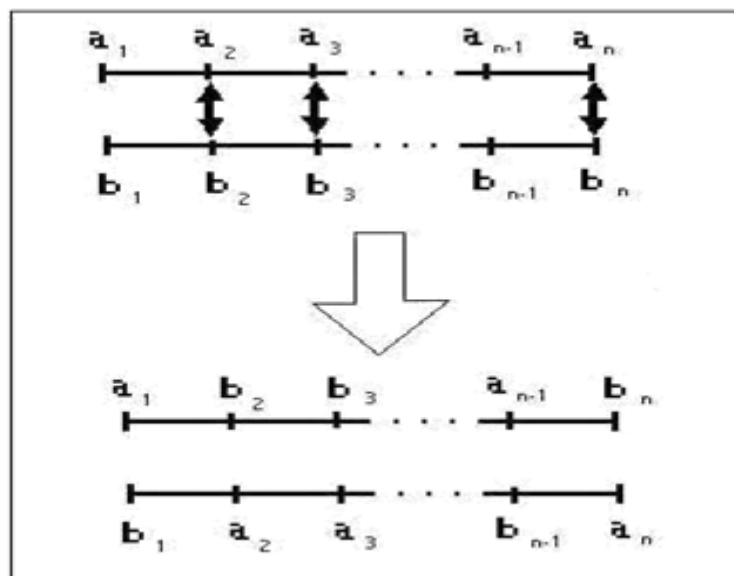
Figure 3.3Illustration of Crossover

In the case shown in Figure 3.3, an individual with traits a_1 through a_n has been selected to mate with another member with traits b_1 through b_n. The programmer has chosen to use a three point crossover, and traits with indices 2, 3 and n have been chosen to be swapped between the parents. The resulting offspring are uniquely different from each other, and each is also different from both parents. Yet both share traits with parents who were more than likely to have been ranked higher than the average in fitness. Population members whose vectors schemes have few traits may be effected little by crossover operations.

Inversion

Inversion is an unusual reproductive mechanism in Genetic Algorithms, both for its effect on the selected population entity and because it really has no corollary in biological systems. If used at all, the probability of this type of genetic operation is often set very low compared to the previously mentioned cases. A single population member is chosen at linear, again weighted toward the most-fit individuals. Again, an even number of linear indices are chosen, usually two. There is no specific reason why only two points must be used for the process, but it keeps the operation simple and avoids unnecessary Linearization of the traits. The vector is then effectively folded between traits with these two indices. This process is simplest to understand in illustration. Figure 3.4 shows a typical inversion operation.
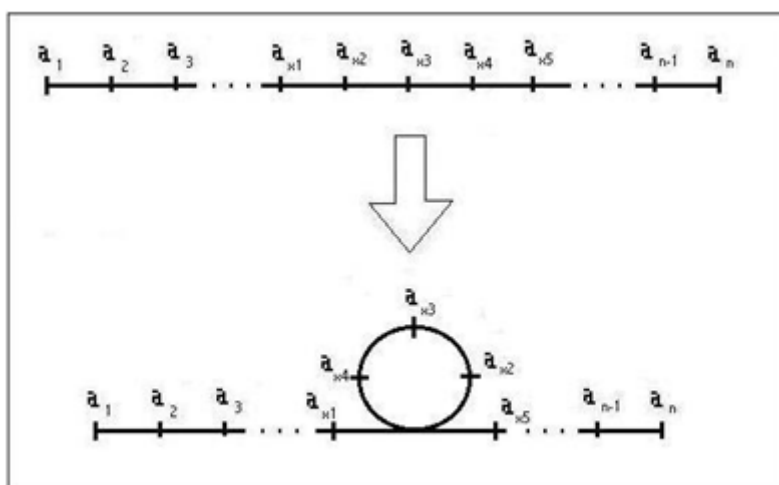
Figure3.4. Illustration of Inversion

Any possible rearrangement of traits can be accomplished by successive inversions. Also, like crossover, inversion has little effect on populations with individuals that have only a small number of character traits.

Mutation

Mutation is another probability controlled process which introduces linear changes to the characteristics of an individual member, encouraging diversity in the population as a whole and therefore increasing the chances of a unique and otherwise unexpected solution. Directly analogous to the biological process of the same name, mutation can be easily applied in two distinct ways by the designer of a Genetic Algorithm. Either the probability mechanism can be applied the same way as with the other operators, with each individual having a set probability of a mutation somewhere in the individual's traits, with another Linear process determining which trait is effected, or in a more complex manner which can have a dramatically different effect. Unlike previous operators, arguably the most effective way to

apply this genetic operator is by allowing an extremely small but non-zero probability of a linear change occurring for each trait in all individuals, rather than for the individual as a whole. The probability must be independent of whether mutation occurred in adjacent individuals, or even in an adjacent characteristic. This second method is undeniably more computationally intense.

Traits selected for mutation are replaced with a linear value within the designed limits of the attribute. Figure 4.6 shows the mutation process.
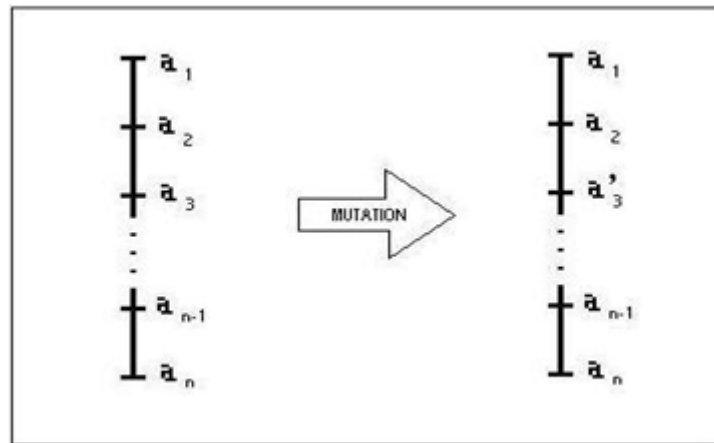
Figure 3.5 Illustration of Mutation

All the characteristic traits for this individual, as well as all other individuals in the population, will independently be tested against a small operator-selected value for the probability of mutation. When a_3 is selected for mutation, a new trait value, a_3', is chosen at Linear to replace it in the new generation.

3.4.4 Stopping the Process

The final question that must be answered by the programmer is determining when to stop the process. If an exact solution is known, the code can be designed to stop on its own when it is achieved. However the use of a Genetic Algorithm in this case would be unnecessary! Computational constraints, such as programming language and hardware, are not only factors that limit population size, individual member complexity and fitness calculation intricacy, but also may limit the allowed run time on scarce computing resources. Genetic Algorithms will rarely arrive at an exact solution anyway, regardless of the amount of time allotted, due to embedded encouragement in the process for continued population diversity. The code may include a process by which an operator or the program itself may siphon off and observe the results of the process every few generations in order to determine if the algorithm is tracking in the desired direction or has achieved a solution that is good enough to be within set error limits for the task required. Either the programmer can then

interrupt the process, or it may be programmed to jump out of the iterative loop. Other limiting factors may exist to curtail the run before the optimum solution is achieved, such as cost of constructing a physical device based on a Genetic Algorithm solution. By far the simplest way to end the run is to set a counter and run a pre-specified number of generations. At the end of these runs, the final output is all or part of the population of the final generation. Records may also be generated of previous generations, so that earlier sub-optimal solutions may be used that keep materials, labour and complexity within the available budget.

CHAPTER 4

DESIGN AND IMPLEMENTATION

4.1 OFDM System and PTS Approach

A. PAPR of OFDM Signal

The transmission of signal through the use of transceiver based on orthogonal frequency division multiplexing (OFDM) system is a typical technique which divides the effective spectrum channel to a number of orthogonal subchannels, and with equal bandwidth, each subchannel handles independently with its own data using individual subcarrier, and the OFDM signal is the sum of all independent subcarriers. In transmission systems with multicarrier signal, the input data of

binary sequences are mapped into symbols by a modulator (PSK, QPSK, QAM, etc.). Then, the N symbols

$X = [X_0, X_1, \ldots, X_{N-1}]^T$ are inserted into the IFFT block to modulate each subcarrier independently and to obtain the OFDM signal in time domain

$x = [x_0, x_1, \ldots, x_{N-1}]^T$

The complex envelope of OFDM signal in the discrete time domain with oversampled factor L (usually used L=4) can be mathematically written as

$$x[n] = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k e^{(j2\pi nk/LN)}, 0 \leq n \leq LN - 1 \qquad (1)$$

where N is the number of subcarriers and X_k is the nth complex symbol carried and transmitted by the k_{th} subcarrier.

From equation (1), the signal in time domain generated by IFFT operation consists N number of independently modulated and orthogonal subcarriers with large peak values (PAPR) when added up at the output of IDFT block. The PAPR of the OFDM signal in discrete time is defined as the ratio between the maximum power and the average power of the complex OFDM signal, and it can be defined as

$$PAPR\{x[n]\} = \frac{\max\{|x[n]|^2\}}{E\{|x[n]|^2\}}, 0 \leq n \leq LN - 1 \qquad (2)$$

where x[n] is given by (1) and E{ · } denotes the expected value (average power).

PAPR reduction techniques can be divided into two main categories [17]. The first is distortion-less techniques, which are applied prior to the IFFT stage. The second is signal distortion techniques, which are applied after the IFFT stage. Any PAPR technique presents a trade-off between a set of main performance parameters, namely: PAPR and BER.

The peak power occurs when modulated symbols are added with the same phase. It is easy to see from above that PAPR reduction may be achieved by decreasing the numerator, increasing the denominator, or both. The effectiveness of a PAPR reduction technique is measured by the complementary cumulative distribution function (CCDF), which is the probability that PAPR exceeds some threshold, i.e.: CCDF = Probability (PAPR > $p0$) (3) Where, $p0$ is the threshold.

B. PTS for OFDM

The Partial Transmit Sequence (PTS) scheme, which is one of the PAPR reduction methods, can be used in OFDM system for reducing PAPR. Fig. 1 shows the block diagram of PTS. The signal with the lowest PAPR is selected from these candidate sequence and be the transmitted signal. In order for the receiver to recover the data block of the transmitted signal, the index of the selected phase should be sent as the side information to receiver.
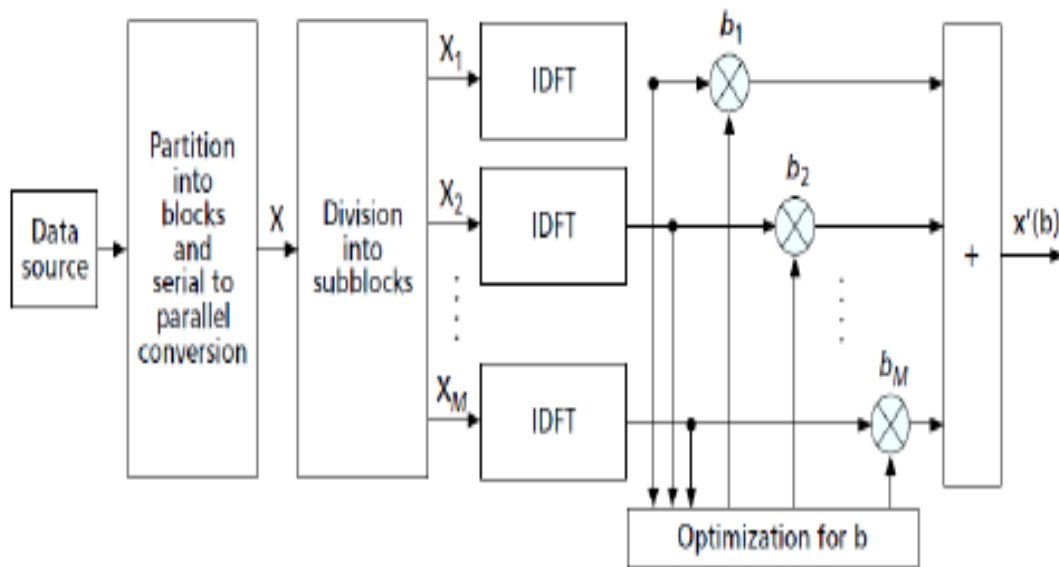
Fig 4.1. PTS System Model

The fundamental design for PTS system was exposed in Fig. 4.1. This technique separates the data blocks as several M disjoint subblocks and it is described with the vector $\{R_r\}_{r=1}^{R}$, **then**

$$M = \sum_{r=1}^{R} M_n \qquad\qquad (3)$$

The IFFT converts the separated sub-blocks as time domain partial transmit sequences and the phase weighting factors multiply these partial sequences. The main aim of the PTS approach is to minimise the PAPR value by determining an optimal weighted arrangement of the M sub-blocks. After processing combination approach, the formula for transmitted time domain signal is given as

$$m'(b) = \sum_{r=1}^{R} b_r \text{IFFT}(M_r)$$

(4)

The following equation was minimised by relating the minimised values of PAPR

$$\max_{0 \le i \le N-1} |m_i'(b)|^2$$

The PAPR value of transmitted signal was minimised by selecting the phase factors. The complexity of search was reduced by choosing the phase factors within a set of finite number of elements. Let us assume that only the B phase factors are allowed:

$$\theta_m = \left\{ \frac{2\pi l}{B}, l = 0, 1, 2, \ldots . B - 1 \right\}$$

(5)

If there was no loss in performance, then the value was set as $b1 = 1$. A set of optimal phase factors in the conventional PTS was detected by performing a searching process in B^{M-1} phase factor set. The difficulty of searching process increases exponentially due to the presence of number of sub-blocks R.

4.2 PS–GW-based PTS methodology

Though the PTS arrangement weighting factors having the range as 1 , -1, j or … it should be selected from this limits; thus we can create the solutions of hybrid PS–GW optimisation algorithm for achieving least computational complexity by means of almost the same solutions comparing to existing algorithms. So that $b = 1$, here $R1$ and $R2$ values present in between [0, 1], minimise the computational complexity. An optimal phase factors were obtained by the proposed PS–GW based PTS.

A. Particle swarm optimisation

PSO was inherently considered as a mathematical methodology to solve the optimisation problems of optimised variables. These optimised variables can be any values which provide the absolute answers without showing any restrictions. In PSO, every possible solution is denoted as a particle with 'x' position vector, 'w' represented as a phase weighting factor and velocity is represented as 'v'.

Step 1: The particle swarm initialisation:

Generate N set of phase vectors with the length of PTS subblocks; (swarm population size is represented as N.)

• Initialise the velocity vi as zero, and the size for both the velocity and position components are same;

• Particles fitness is calculated, then fix the each particle's *l*best where its objective value was found to be same as its current location, and fix the *g*best position;

Step 2: Throughout the iteration, all particles could be updated.

$$v_i(\tau + 1) = wv_i(\tau) + r_1(\xi_i^a(t) - \xi_i(t) + r_2(\xi^g(\tau) - \xi_i(\tau))$$

$$\xi_i(\tau + 1) = \xi_i(\tau) + v_i(\tau + 1)$$

$$\xi(\tau + 1) = sgn\{\xi_i(\tau + 1)\}$$

where sgn $(\cdot)$ represents the signum function

B. Grey Wolf Optimization

The Grey Wolf Optimizer (GWO) algorithm mimics the leadership hierarchy and hunting mechanism of grey wolves in nature. Four types of grey wolves such as alpha, beta, delta, and omega are employed for simulating the leadership hierarchy.

The Grey Wolf Optimizer (GWO) calculation copies the administration order and chasing mechanism of wolves. Four different of grey wolves need to be considered that are alpha, beta, delta, and omega are utilized for simulating the authority chain of command. There are three important steps in hunting- searching for prey, encircling prey and attacking the prey. These three are implemented to perform optimization technique. The three best agents are denoted as $P(\alpha), P(\beta)$ *and* $P(\delta)$. The velocities are termed as Eq (6),(7),(8)

The equations can be shown as:

$$V_\alpha = |C.P_\alpha(t) - P(t)| \qquad (6)$$

$$V_\beta = |C.P_\beta(t) - P(t)| \qquad (7)$$

$$V_\delta = |C.P_\delta(t) - P(t)| \qquad (8)$$

The position are updated as Eq (9), (10) (11):

$$P_1 = P_\alpha - B.V \qquad (9)$$

$$P_2 = P_\beta - B.V \qquad (10)$$

$$P_3 = P_\delta - B.V \qquad (11)$$

Where B and C are the vector coefficients which are calculated as Eq 10 and Eq 11

$$B = 2b.r_1 - b \qquad (12)$$

$$C = 2.r_2 \qquad (13)$$
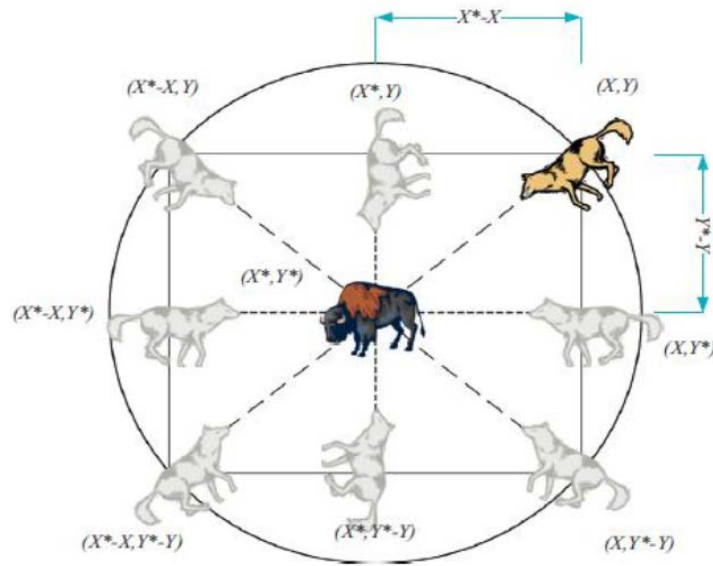
Fig 4.2 Position update of grey wolf
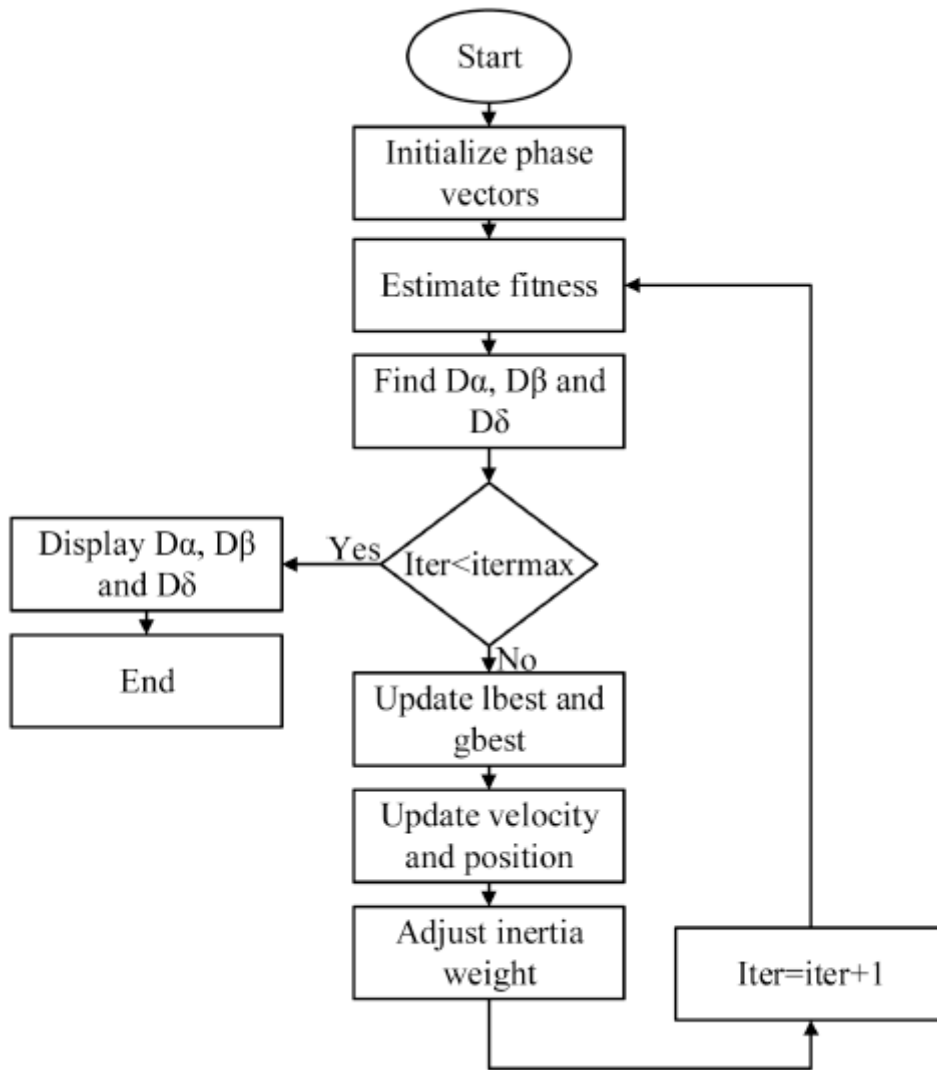
Fig. 4.3 *Flow chart for hybrid PS–GW optimisation*

Algorithm for PTS based PS-GWO

The PS-GWO based PTS algorithm is given as:

Step1: Initialise input data $I_x = I_1 I_2 I_3 \ldots \ldots \ldots \ldots I_n$

Step2: Serial bit of data converted to parallel bits

Step3. Rotating the phase of bits and applying PS-GWO for the bits

Step 4. Initialization of the search agents α, β and δ values (wolfs)

      Search process w.r.t swarms

Step5: Calculate the fitness function

Step6: Find the best position with respect to the velocities given as V_α, V_β and V_δ

Step7: Update the position of

Step8: Calculate the fitness function

Step9: update the position of V_α, V_β and V_δ w.r.t swarms

Step10. Find the best and form a unique phases

Step11. Obtain the Min PAPR signal

C. Hybrid algorithm

In this strategy, we hybridise PSO with GWO algorithm with phase vectors. The hybridisation is minimum since here the merging process is held for both variants. This process is not done in sequence since it is co-evolutionary and thus it is the parallel process. On the basis of this hybridisation, we expand the capability of exploitation within PSO through the capability of exploration in GWO to yield both variants 'strength. In PS–GW based PTS, the position of a first three agents is rationalised in this space through the above said equations. Each value in a dimension is represented as a factor in a phase factors large space. A factor set can be a place or point in this search space in which the least PAPR is best place. In the search space, each solution is a particle in PSO. To find out the optimal position, particles moves via the search space. The primary population of solutions initialises the PSO. Here, every particle is at a point of *M* dimensions in a search space (The amount of PTS sub-blocks is denoted by *M*).

In Fig. 4.3, flowchart for the hybrid algorithm is given in which the optimal phase vectors are initialised and then the fitness is evaluated. The location of prey was identified by calculating the α, β and δ values. This process is continued and compared with a previous iteration steps. If the maximum criteria are not met then the evaluation is continued until it

reaches the maximum level. In each evaluation, velocity and position are updated and the inertia constant is used for controlling both exploration and exploitation process.

Finally, the signal with minimum PAPR is chosen based on PTS with hybrid PS–GW optimisation algorithm. The signal was converted into a serial signal and the cyclic prefix was added into it. After adding cyclic prefix, the signal is transmitted through an AWGN channel and it is received by the receiver. In the receiver side, remove the cyclic prefix and demodulate the signal after accomplishing PTS recovery.

4.3 Multi Band UWB System

Ultra Wideband Technology [19] or UWB is a short range, high data rate, low power, high bandwidth wireless communication system. Federal Communications Commission (FCC) has defined UWB as any technology that makes use of bandwidth greater than 500MHz or atleast 20% of the center frequency on which the system is operating. FCC has allocated a band having a bandwidth of 7.5 GHz of unlicensed band ranging from 3.1GHz to 10.6GHz, which is already being used by other major technologies such as mobile communication, GPS, Satellite Communication, US Navy services and other major technologies. So FCC has limited the power emitted by UWB devices to below the noise threshold set by other major technologies that share the same band. The advantage is the band can be used free for UWB which otherwise the same band under major technologies would cost in crores. The maximum power limit for UWB devices is -40dBm/MHz[2] or 10nW/MHz of spectrum, which is very small as compared to WLAN which has a limit of 10mW/MHz. The power is negligible and is equivalent to noise for other system. IEEE has developed a working committee 802.15 and task group 3a for high speed PAN, where UWB is the current standard, having specified the minimum speed requirements of 110Mbps at a distance of about 10m. The speed is very high since current Bluetooth technology has a maximum practical speed of about 1Mbps.The channel capacity as shown

$$Channel\ Capacity = B.W * log2(1+SNR)$$

[19] states that due to decrease in power, SNR goes down, so Bandwidth should be very large for high channel capacity which is the advantage of UWB which has a minimum B.W of 500MHz. The power and the range is given by Friss transmission equation as shown which states that the

$$Power\ received \propto 1/Range2$$

Power is inversely proportional to range, so by using effective coding techniques range can be extended to distances larger. Currently UWB is the standard for Wireless USB which

provides a speed of 480Mbps. It is the future standard for Bluetooth as seen by Bluetooth Special Interest group IEEE 802.15.1

Single Band Technology

Fig 4.4 below shows the single carrier transmission technology. The single carrier proposal for UWB was Motorola and Path Cerva based Direct Sequence CDMA [1] technology.
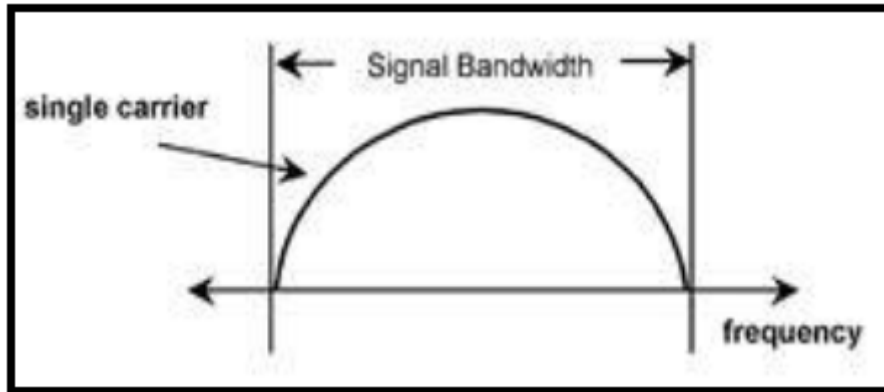
Fig: 4.4 Single Carrier Transmission

This technology works efficiently with low frequency or low bandwidth application but with bandwidth of about 7.5GHz and operating frequency well above 4 GHz with power transmission equivalent to noise, the filters, the active devices and the CMOS manufacturing process have to be tightly designed but then also with current technology non linearities will occur which would cost loss of data and retransmissions effectively decreasing the performance. The order of filter increases with bandwidth which would be huge with single carrier system.

Multi Band OFDM

Multiband is simply dividing the original given band into several sub-bands. The multiband concept in UWB is as shown in below fig.
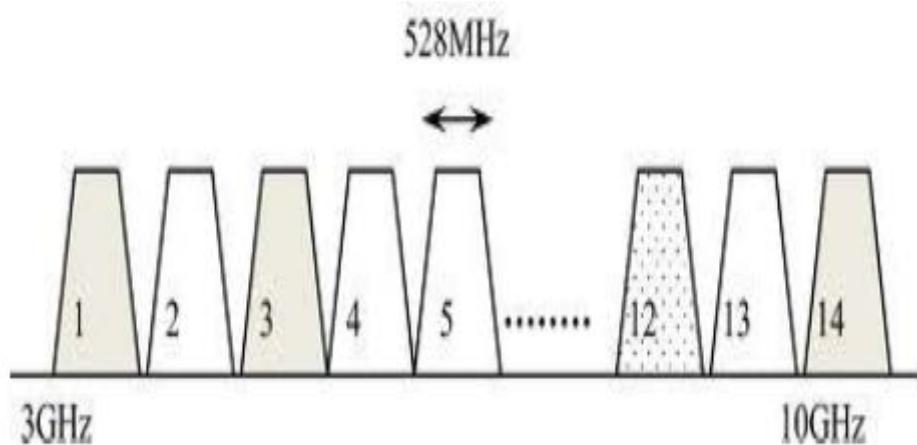
Fig: 4.5 Multiband in UWB

The 7.5GHz of band is subdivided into smaller bands and each sub-band is of 528MHz wide according to FCC definition for UWB, minimum bandwidth requirement of 500MHz. It is of two types pulse based transmission or OFDM based transmission.
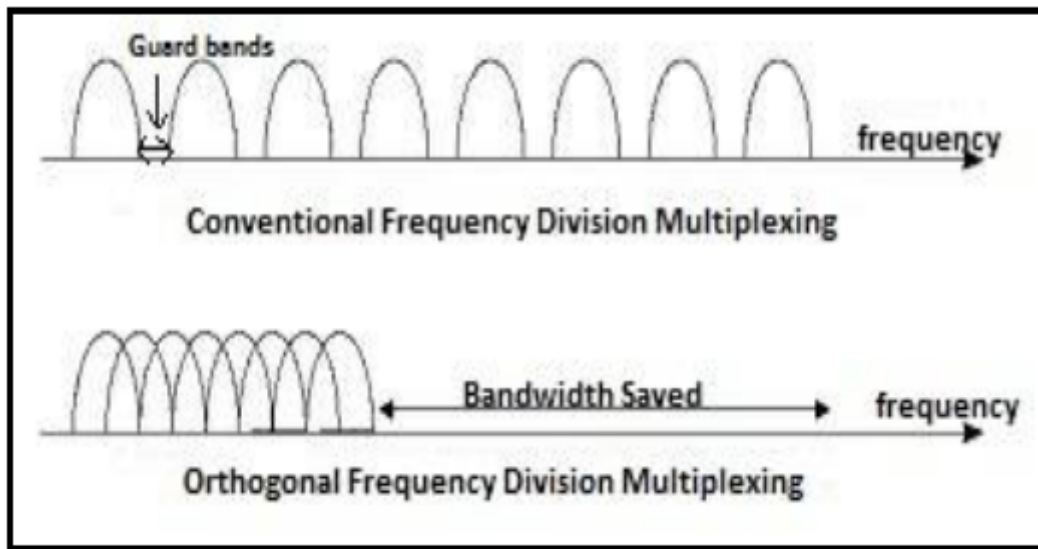
Fig: 4.6 OFDM compared to FDM for Multiband

OFDM (Orthogonal Frequency Division Multiplexing) is a multicarrier transmission technology. It works on the principal of FDM as transmitting different information on different frequency using separate carrier having separate respective frequency. But due to the limitation of not having sharper cutoff response of the filter practically there is a need of guard bands in FDM in which no information is transmitter so that interference is avoided as shown in fig above. If information is representation by say X1, X2, -----, Xn and carriers by C1, C2, ----, Cn then the FDM process is

$Y= X1*C1 +GB+ X1*C2 +GB+\cdots+GB+(Xn*Cn)$

Where GB = Guard Bandwidth. OFDM on the other hand uses an orthogonal carrier which allows overlapping of band without interfering since orthogonal vectors don't overlap and since signals are vectors it uses orthogonal carrier. The orthogonality is achieved by first dividing serial data into parallel symbol increasing effective symbol period then multiplying it by IFFT matrix since IFFT matrix is a unitary matrix its rows are orthogonal to each other and the elements of matrix are considered as carriers

$Y= X1*C1 + X1*C2 +\cdots+(Xn*Cn)$

where $C1(n) = \frac{1}{\sqrt{m}}\, e^{-j2\pi kn/m}$

where n = k = 0 to m-1, and m = length of i/p symbol.

As shown since Guard band is avoided and overlapping of frequency is allowed as shown in Fig: 4.6, a large amount of bandwidth is saved and the bandwidth is doubled nearly. In UWB OFDM is applied in each sub-band to have higher data rates.

Advantages of Multiband OFDM

a. Filter order is reduced.

With Multiband the order of the filter decreases to a lot since the band of 7.5 GHz is reduced to 528MHz each.

b. Interference is reduced easily.

External interference from ISM band 2.4GHz and UNII band 5GHz which are the neighbors to UWB band can be avoided by designing good filters having high roll off rates which is easily achievable through Multiband concept. Internal interference such as signals from GPS. Satellite and other technologies sharing the band can be avoided by unusing band having strong interference i.e. by negotiating the band between transmitters and receivers.

c. Easy design of active components.

Active component needed to design the UWB devices becomes easy as bandwidth to which the component has to react is reduced due to Multiband.

d. Multipath fading is reduced.

Since the overall symbol duration is increased in OFDM the period of symbol can be effectively made greater than delay spread time making the channel flat and multipath is avoided.

e. Power requirement is reduced.

Multiband reduces the bandwidth and OFDM increases the symbol period which reduces the no of filter orders required, no of ADC's required, which reduces the overall power dissipation which reduces the power requirement to a lot.

f. Huge Amount of Bandwidth saved.

OFDM allows the frequency spectrum to overlap with each other as shown in fig. 4.6, which doubles the bandwidth available through orthogonality concept.

Disadvantages

a. Window location Offset Error.

b. Oscillator Frequency Error.

c. High frequency transit time error.

Applications

a. Wireless USB standard.

b. Short range Video transmitter.

c. Personal Area Network.

d. Bluetooth Pico nets.

e. RFID.

f. Low data rate Wireless LAN.

CHAPTER 5

RESULTS AND DISCUSSION

Here, the PAPR values of OFDM systems were reduced by the outputs of various methods and also, by the PS–GW performance in PTS. In this proposed method, various parameters are taken to minimise the rate of PAPR in OFDM signals. There are number of simulations performed to find the enhancement of PAPR for the evaluation and comparison of sub-optimal PTS. The parameters considered for formulating the results are shown in table 5.1 below

Table 5.1 Parameter Representation

Number of samples	10,000
Number of Subcarriers	64/128/256/512
Channels	4×100
Type of modulation	QPSK
Number of Iterations	50
FFT Size	256/512/1024
Cyclic Prefix size	32``
Number of pilot tones	16
Number of subblocks	4/8/16

The proposed performance is evaluated and it is taken for various IIFT lengths. In Fig. 5.*1*, IIFT length is taken as 1024 and it gives the variation in both CCDF and PAPR (dB). Here, we compared the proposed work with alternative techniques. Among these techniques, the proposed system gives minimum PAPR. From Figs. 5.1, 5.2 and 5.3, we can show that if the IFFT length is changed to different sample size such as 1024, 512, and 256, the PAPR hit value also get reduced. Our proposed method gives 1. 9 dB for 1024 IFFT lengths, 2.4 dB for 512 IFFT lengths and 2.9 dB for 256 IIFT lengths.
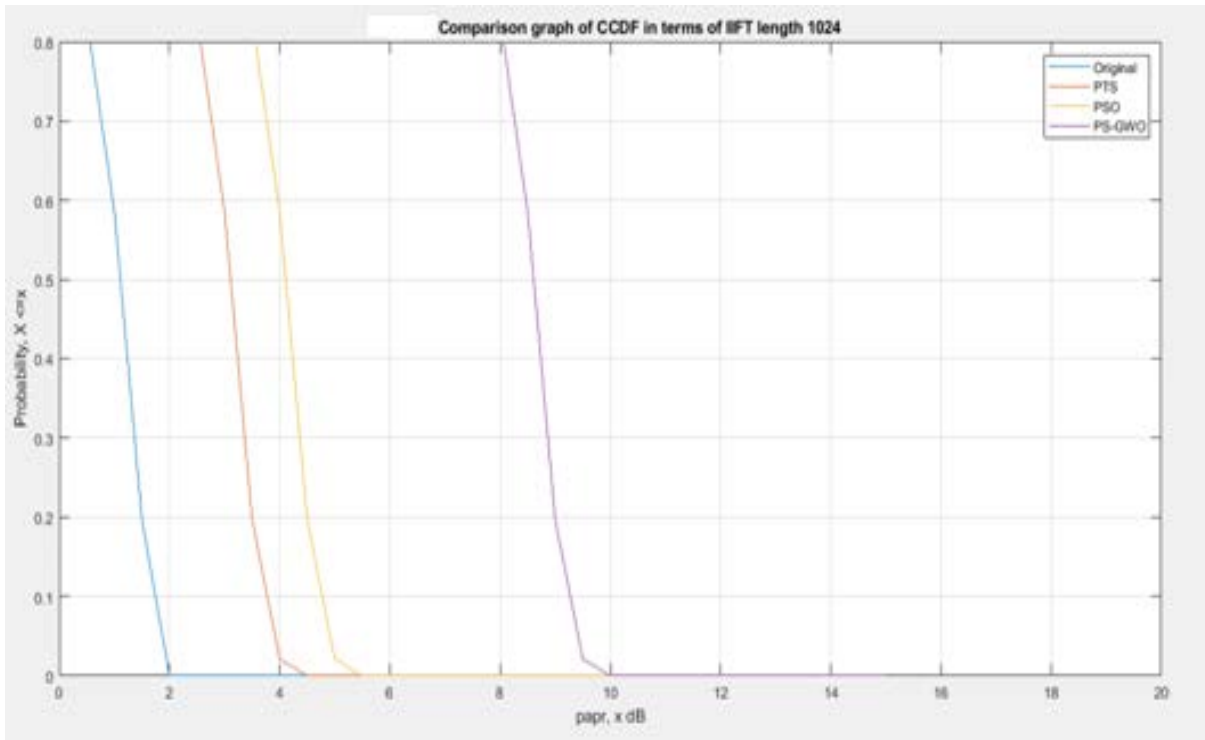
Fig 5.1 IFFT Length 1024
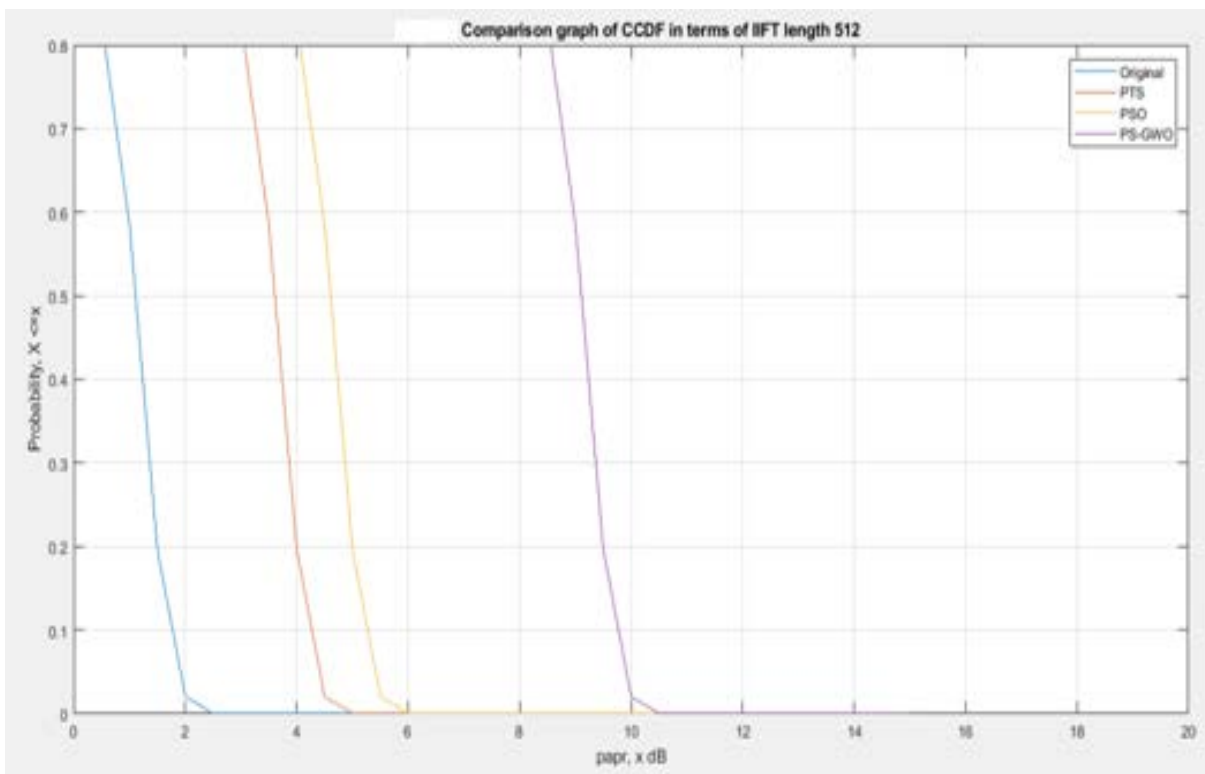
Fig 5.2 IFFT length 516
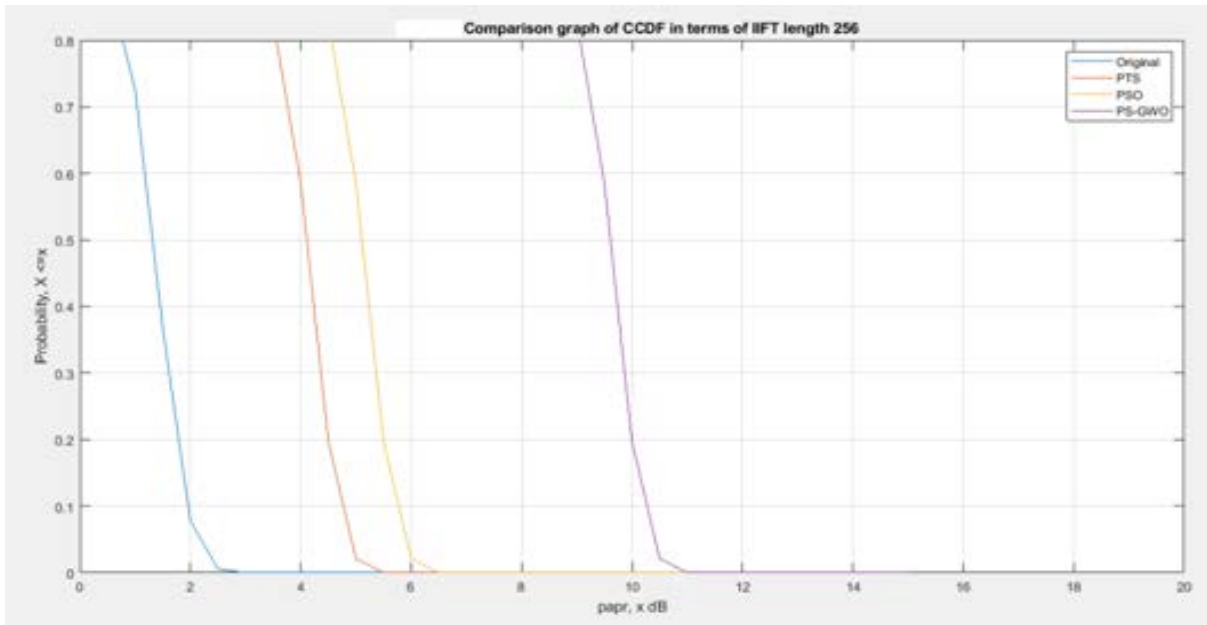
Fig 5.3 IFFT Length 256

The PAPR performance via CCDF plots is illustrated in Fig. 5.4. As shown in fig 5.4 Xaxis is considered as CCDF and Y axis as PAPR in dB. The PAPR obtained for 10^{-4} CCDF using PTS technique is 12dB and using PS-GWO PTS the PAPR obtained is 10dB. In this graph, comparison is done with original OFDM for PAPR reduction, PTS scheme and the proposed method PTS-PSGW. The figure clearly shows that the proposed approach provides better performance than the other two.
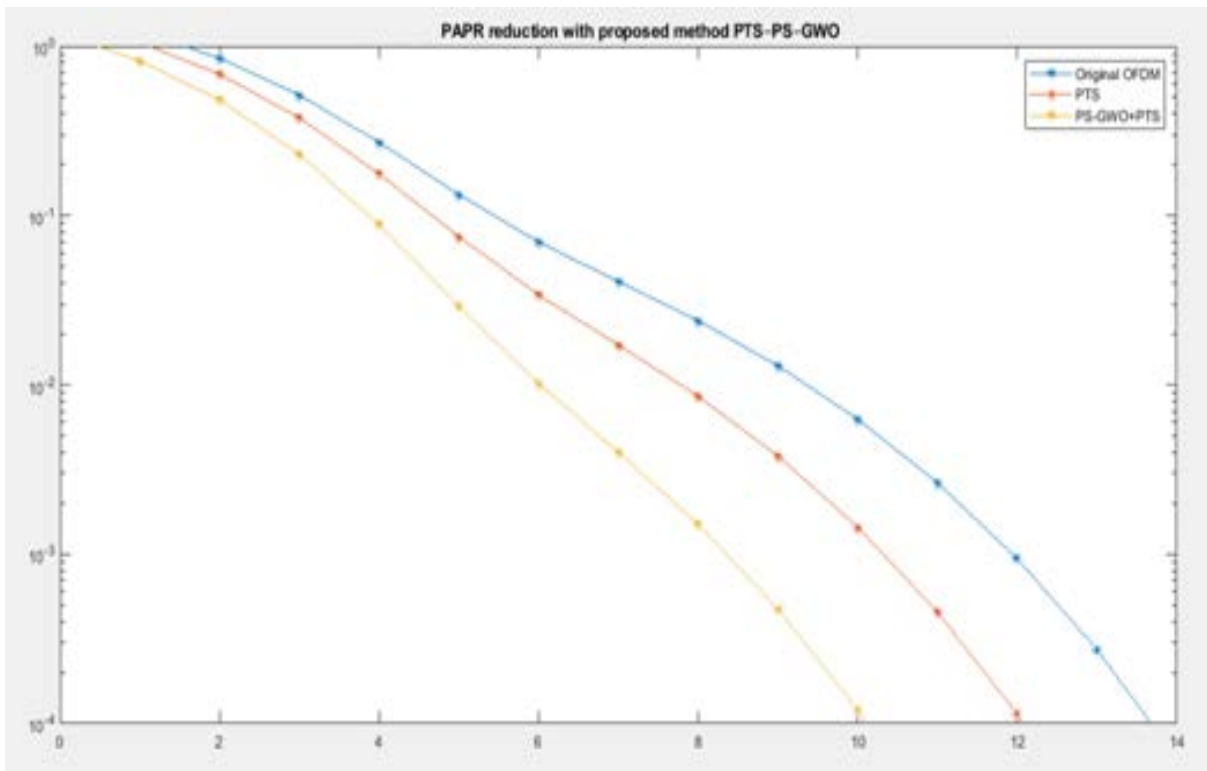
Fig 5.4 Comparison of PAPR

In Fig. 5.4, various conventional searching algorithms are considered to show the PAPR performance. The conventional algorithms are PSO, GWO, the proposed PTS-PSGW as well as PTS and original OFDM frame. The simulation of PTS, PSO, GWO is speedup with phase-weighting factors $w = \{1, -1, j, -j\}$ which optimise the modulated OFDM symbol PAPR. The hybrid proposed algorithm, chooses four phase randomly within the interval between 0 and 2π. This hybrid approach efficiently minimises the PAPR in the OFDM system.

From the fig 5.5 the PAPR values obtained for CCDF of 10^{-4} are, for original OFDM system without applying any PAPR reduction technique the PAPR value is 13.4dB, by applying PTS technique the value reduce to 10.5dB. By considering PSO-PTS techniques the value reduce to 9dB. For GWO-PTS technique PAPR value is 7.9dB. Finally our proposed method PS-GWO PTS has best PAPR with 7.2dB.
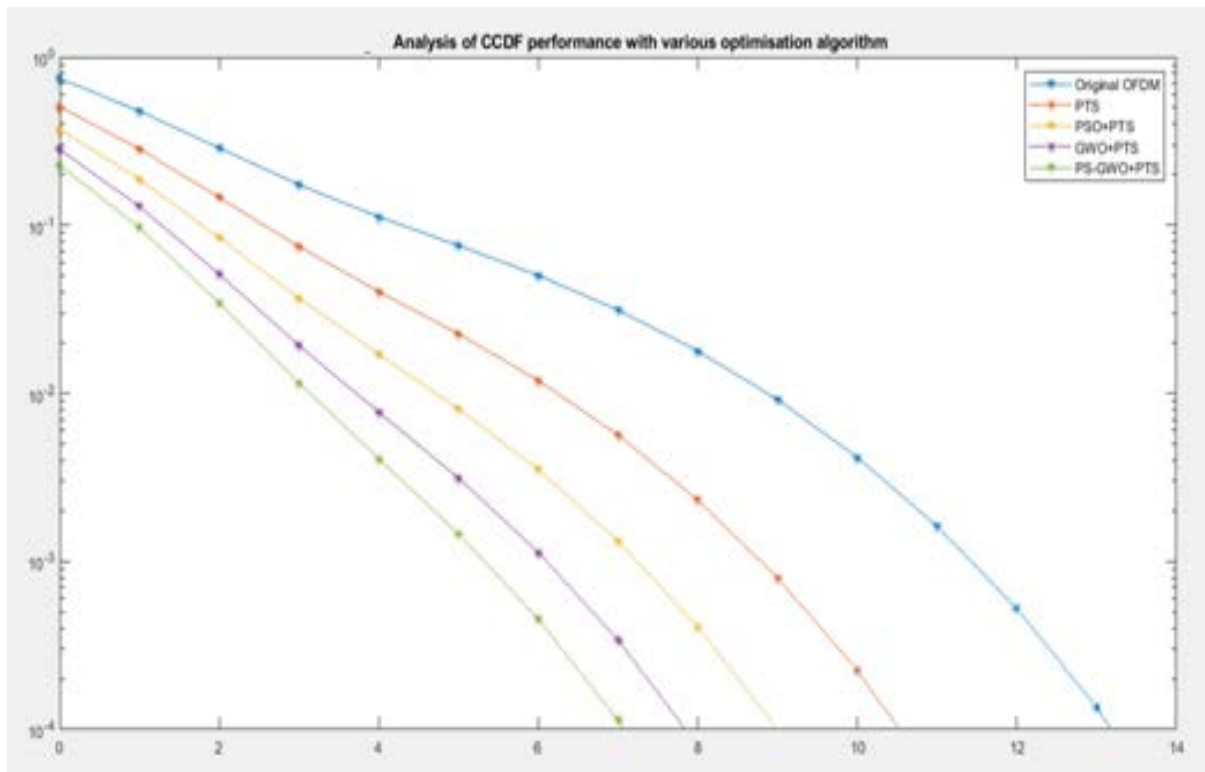
Fig 5.5 CCDF Performance

In Fig. 5.6, the hybrid optimisation based PTS based PAPR performance is analysed by varying the sub-block ($V = 2, 4, 6, 8$). When the sub-block count increases, the PAPR performance increases in the figure. Also, the sub-block maximisation does not affect the system complexity in PTS.
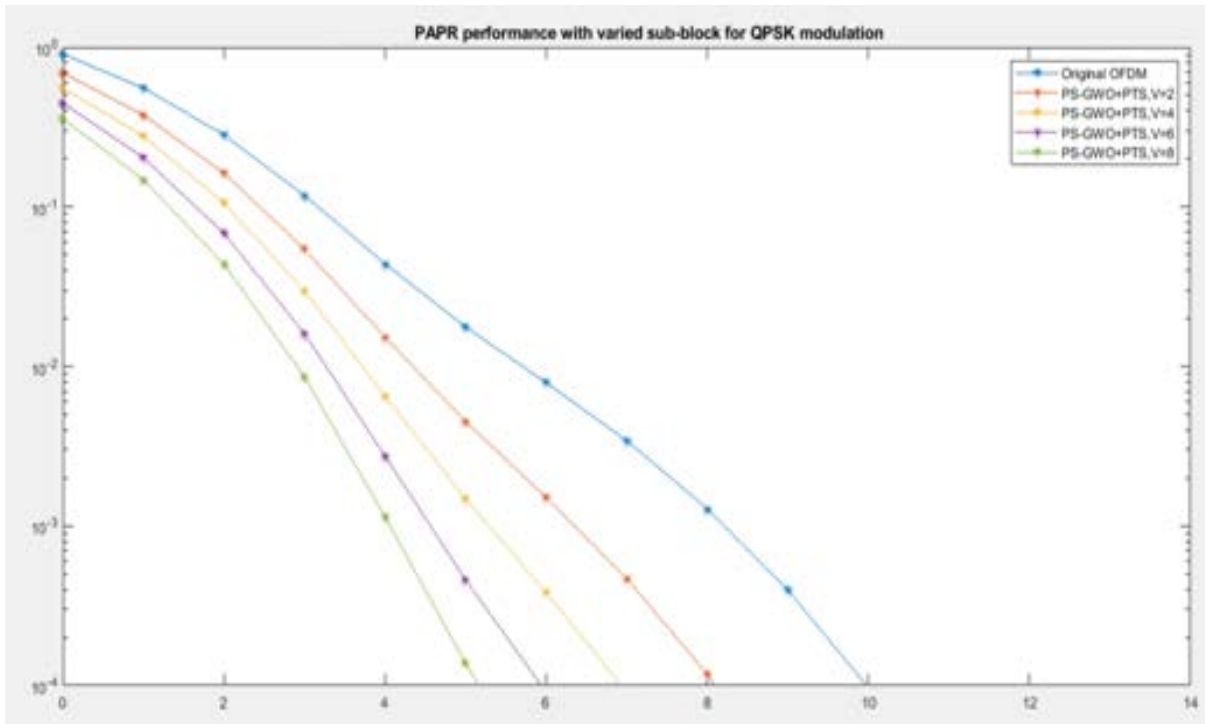
Fig 5.6 PAPR varying Subblocks

One of the important parameters for validating optimisation performance is convergence speed. The comparison between the proposed optimisation and other optimisation is illustrated in Figs. 5.7 and 5.8. By using this methodology, computational complexity is reduced by an increasing number of iteration. So in this proposed work, convergence speed also reduced with the novel optimisation algorithm.
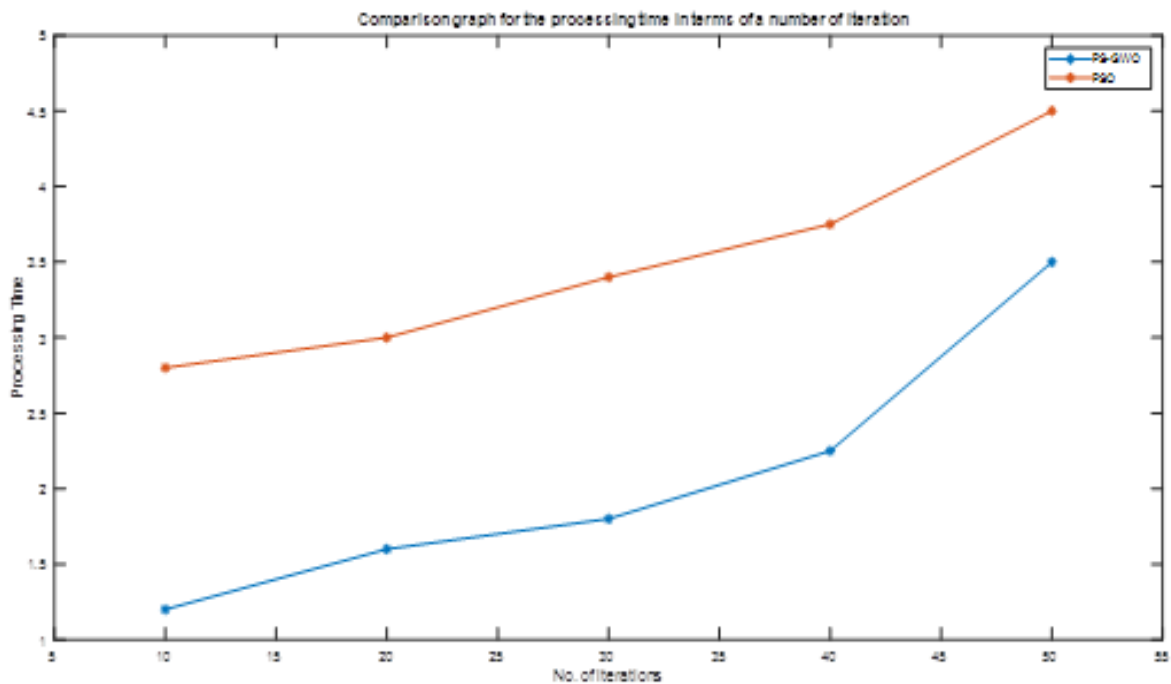
Fig 5.7 Time w.r.t Number of Iterations

However, in case of processing time referred in Fig. 5.8, time is increased when increasing the number of iteration. In this graph, we can show our proposed method yields less time than the existing one.
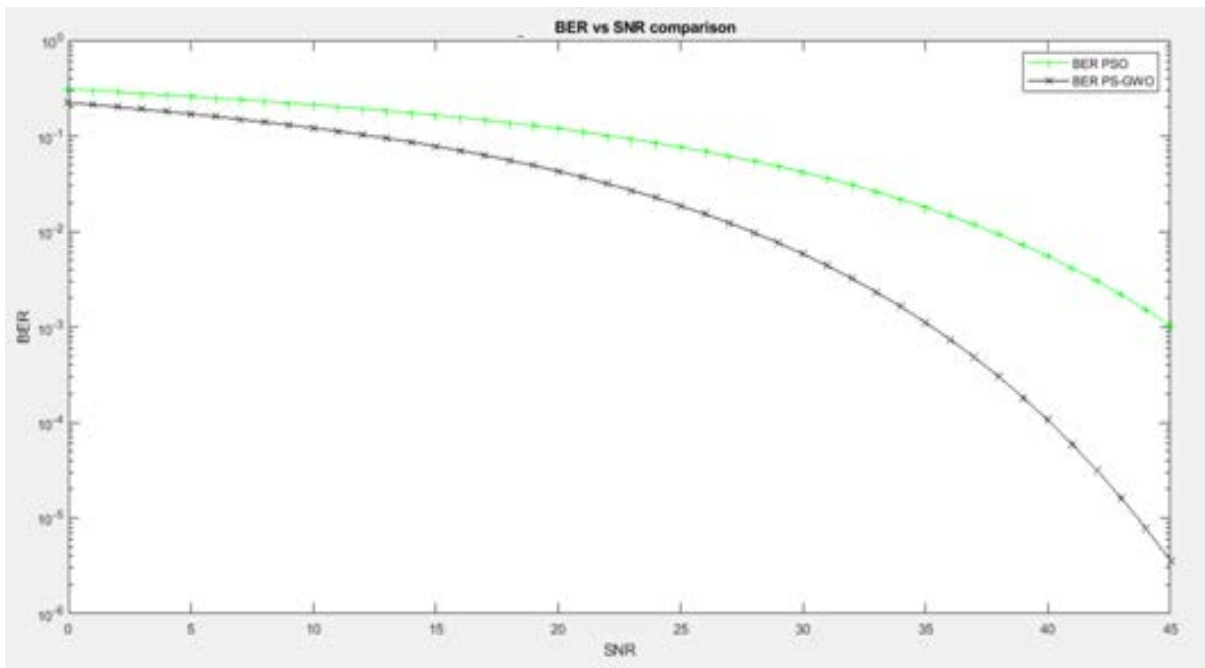
Fig 5.8 BER vs SNR

In Fig. 5.9, while increasing BER, signal-to-noise ratio is reduced. Since our proposed work yields a significant result for the IIFT length.
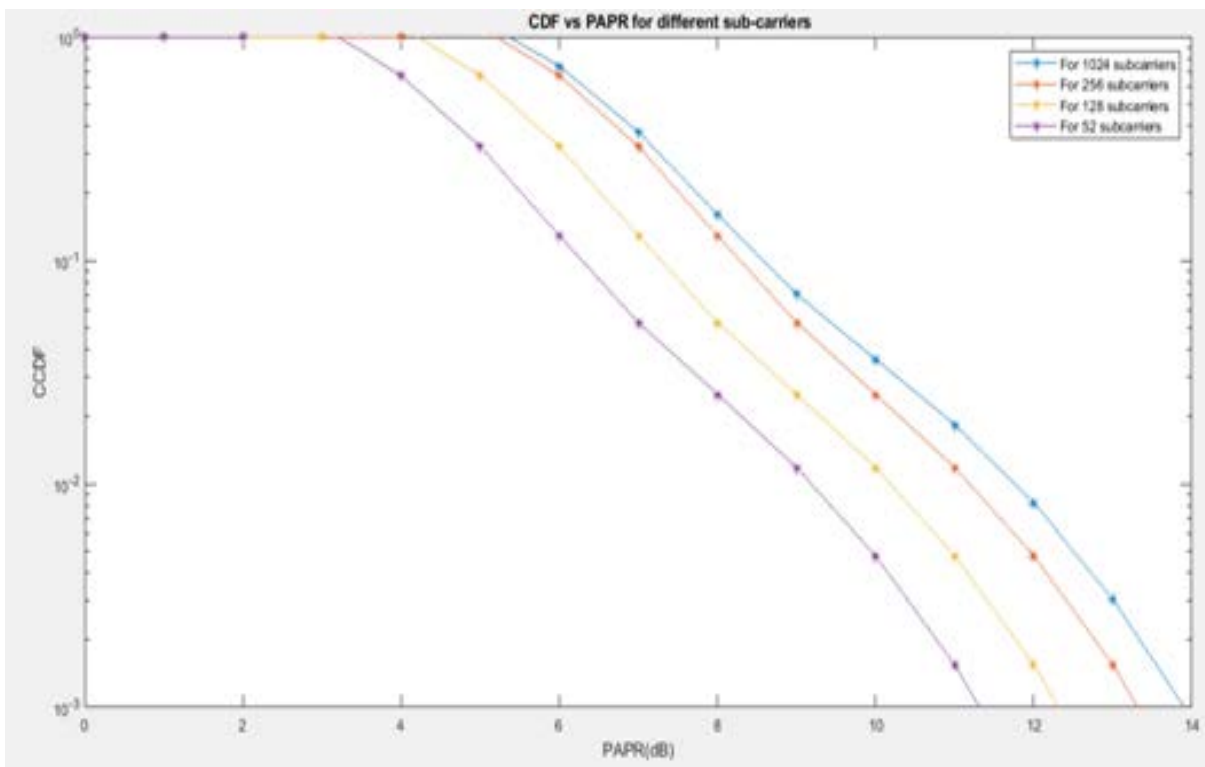
Fig 5.9 CCDF vs PAPR for different subcarriers

The performance analysis is done for different values of subcarriers such as 52 sub-carriers, 128 sub-carriers, 256 sub-carriers and 512 sub-carriers. The graph plots of CCDF vs PAPR comparison with different sub-carriers were shown in Fig 5.9. From fig 5.9 it is observed that for increase in number of subcarriers the PAPR is been increased.

The performance analysis was done for the different values of sub-blocks such as 2 sub-block, 4 sub-block, 8 sub-blocks and 16 sub-blocks. The CCDF vs PAPR comparison for different subblocks graph plots is shown in Fig 5.10
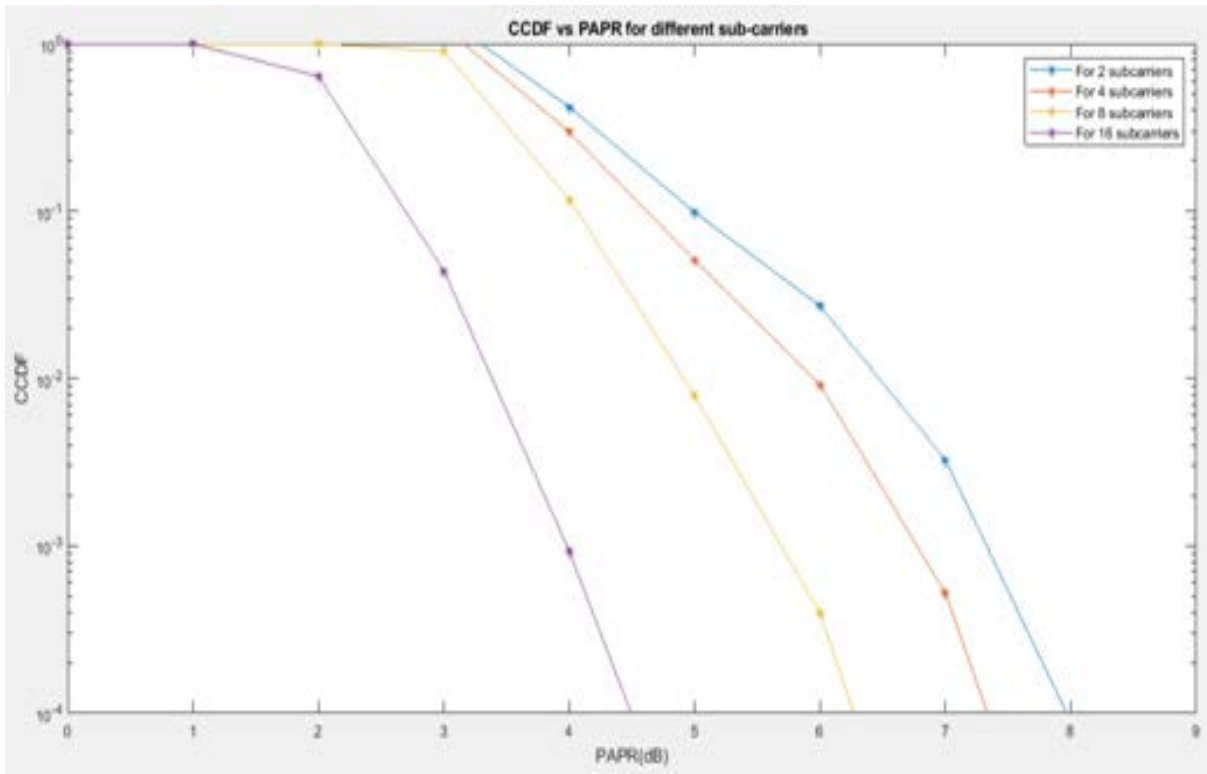
Fig 5.10 CCDF vs PAPR for different subblocks

CHAPTER 6

CONCLUSION

Enormous number of techniques like phase rotation, clipping, and coding are used to reduce PAPR. Among these, PTS and SLM are the most widely used methods to reduce a PAPR value. In a wireless communication system, by using PTS the PAPR will be reduced from the OFDM signal. The complexity while searching the optimal phase vector greatly increases as it performs the wide search randomly over the entire combination of phase vectors which are permitted. In this work, a hybrid swarm intelligence method for phase optimisation with the base of PS–GW was applied to overcome the difficulties of optimal phase vector. The superior trade-off between the computational complexity and the improved PAPR performance was provided by the proposed algorithm. This trade-off performs better by providing huge amount of sub-blocks than the PTS scheme. The proposed algorithm was compared with the conventional techniques based on some of their parameters. An efficient PAPR characteristic were obtained for an OFDM signal by the PTS-based proposed algorithm.

According to the simulation results, the proposed PS-GW optimization based PTS-OFDM output performs well compared with OFDM system PTS and PSO based OFDM. The proposed technique shows satisfying results in reducing the PAPR. The BER is reduced at the receiver end with decrease in PAPR at the transmitting end. Further the same technique is applied for MB-OFDM UWB systems and the results are compared.

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APPENDIX A
SOFTWARE DESCRIPTION
Introduction

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. MATLAB stands for matrix laboratory, and was written originally to provide easy access to matrix software developed by LINPACK (linear system package) and EISPACK (Eigen system package) projects. MATLAB is therefore built on a foundation of sophisticated matrix software in which the basic element is array that does not require pre dimensioning which to solve many technical computing problems, especially those with matrix and vector formulations, in a fraction of time.

MATLAB features a family of applications specific solutions called toolboxes. Very important to most users of MATLAB, toolboxes allow learning and applying specialized technology. These are comprehensive collections of MATLAB functions (M-files) that extend the MATLAB environment to solve particular classes of problems. Areas in which toolboxes are available include signal processing, control system, neural networks, fuzzy logic, wavelets, simulation and many others.

Typical uses of MATLAB include: Math and computation, Algorithm development, Data acquisition, Modeling, simulation, prototyping, Data analysis, exploration, visualization, Scientific and engineering graphics, Application development, including graphical user interface building.

Basic Building Blocks of MATLAB

The basic building block of MATLAB is MATRIX. The fundamental data type is the array. Vectors, scalars, real matrices and complex matrix are handled as specific class of this basic data type. The built in functions are optimized for vector operations. No dimension statements are required for vectors or arrays.

MATLAB Window

The MATLAB works based on five windows: Command window, Workspace window, Current directory window, Command history window, Editor Window, Graphics window and Online-help window.

a. Command Window

The command window is where the user types MATLAB commands and expressions at the prompt (>>) and where the output of those commands is displayed. It is opened when

the application program is launched. All commands including user-written programs are typed in this window at MATLAB prompt for execution.

b. Work Space Window

MATLAB defines the workspace as the set of variables that the user creates in a work session. The workspace browser shows these variables and some information about them. Double clicking on a variable in the workspace browser launches the Array Editor, which can be used to obtain information.

c. Current Directory Window

The current Directory tab shows the contents of the current directory, whose path is shown in the current directory window. For example, in the windows operating system the path might be as follows: C:\MATLAB\Work, indicating that directory "work" is a subdirectory of the main directory "MATLAB"; which is installed in drive C. Clicking on the arrow in the current directory window shows a list of recently used paths. MATLAB uses a search path to find M-files and other MATLAB related files. Any file run in MATLAB must reside in the current directory or in a directory that is on search path.

d. Command History Window

The Command History Window contains a record of the commands a user has entered in the command window, including both current and previous MATLAB sessions. Previously entered MATLAB commands can be selected and re-executed from the command history window by right clicking on a command or sequence of commands. This is useful to select various options in addition to executing the commands and is useful feature when experimenting with various commands in a work session.

e. Editor Window

The MATLAB editor is both a text editor specialized for creating M-files and a graphical MATLAB debugger. The editor can appear in a window by itself, or it can be a sub window in the desktop. In this window one can write, edit, create and save programs in files called M-files.

MATLAB editor window has numerous pull-down menus for tasks such as saving, viewing, and debugging files. Because it performs some simple checks and also uses color to differentiate between various elements of code, this text editor is recommended as the tool of choice for writing and editing M-functions.

f. Graphics or Figure Window

The output of all graphic commands typed in the command window is seen in this window.

g. Online Help Window

MATLAB provides online help for all it's built in functions and programming language constructs. The principal way to get help online is to use the MATLAB help browser, opened as a separate window either by clicking on the question mark symbol (?) on the desktop toolbar, or by typing help browser at the prompt in the command window. The help Browser is a web browser integrated into the MATLAB desktop that displays a Hypertext Markup Language (HTML) documents. The Help Browser consists of two panes, the help navigator pane, used to find information, and the display pane, used to view the information. Self-explanatory tabs other than navigator pane are used to perform a search.

MATLAB Files

MATLAB has three types of files for storing information. They are: M-files and MAT-files.

M-Files

These are standard ASCII text file with 'm' extension to the file name and creating own matrices using M-files, which are text files containing MATLAB code. MATLAB editor or another text editor is used to create a file containing the same statements which are typed at the MATLAB command line and save the file under a name that ends in .m. There are two types of M-files:

1. Script Files

It is an M-file with a set of MATLAB commands in it and is executed by typing name of file on the command line. These files work on global variables currently present in that environment.

2. Function Files

A function file is also an M-file except that the variables in a function file are all local. This type of files begins with a function definition line.

MAT-Files

These are binary data files with .mat extension to the file that are created by MATLAB when the data is saved. The data written in a special format that only MATLAB can read. These are located into MATLAB with 'load' command.

MATLAB System:

The MATLAB system consists of five main parts:

Development Environment:

This is the set of tools and facilities that help you use MATLAB functions and files. Many of these tools are graphical user interfaces. It includes the MATLAB desktop and Command Window, a command history, an editor and debugger, and browsers for viewing help, the workspace, files, and the search path.

MATLAB Mathematical Function:

This is a vast collection of computational algorithms ranging from elementary functions like sum, sine, cosine, and complex arithmetic, to more sophisticated functions like matrix inverse, matrix eigen values, Bessel functions, and fast Fourier transforms.

MATLAB Language:

This is a high-level matrix/array language with control flow statements, functions, data structures, input/output, and object-oriented programming features. It allows both "programming in the small" to rapidly create quick and dirty throw-away programs, and "programming in the large" to create complete large and complex application programs.

Graphics:

MATLAB has extensive facilities for displaying vectors and matrices as graphs, as well as annotating and printing these graphs. It includes high-level functions for two-dimensional and three-dimensional data visualization, image processing, animation, and presentation graphics. It also includes low-level functions that allow you to fully customize the appearance of graphics as well as to build complete graphical user interfaces on your MATLAB applications.

MATLAB Application Program Interface (API):

This is a library that allows you to write C and FORTRAN programs that interact with MATLAB. It includes facilities for calling routines from MATLAB (dynamic linking), calling MATLAB as a computational engine, and for reading and writing MAT-files.

Some Basic Commands:

pwd   prints working directory

Demo   demonstrates what is possible in Mat lab

Who   lists all of the variables in your Mat lab workspace?

Whose   list the variables and describes their matrix size

clear   erases variables and functions from memory

clear x   erases the matrix 'x' from your workspace

close   by itself, closes the current figure window

figure   creates an empty figure window

hold on holds the current plot and all axis properties so that subsequent graphing

commands add to the existing graph

hold off sets the next plot property of the current axes to "replace"

find   find indices of nonzero elements e.g.:

        d = find(x>100) returns the indices of the vector x that are greater than 100

break   terminate execution of m-file or WHILE or FOR loop

for   repeat statements a specific number of times, the general form of a FOR

        statement is:

        FOR variable = expr, statement, ..., statement END

        for n=1:cc/c;

        magn(n,1)=NaNmean(a((n-1)*c+1:n*c,1));

        end

diff   difference and approximate derivative e.g.:

        DIFF(X) for a vector X, is [X(2)-X(1) X(3)-X(2) ... X(n)-X(n-1)].

NaN   the arithmetic representation for Not-a-Number, a NaN is obtained as a

        result of mathematically undefined operations like 0.0/0.0

INF   the arithmetic representation for positive infinity, a infinity is also produced

        by operations like dividing by zero, e.g. 1.0/0.0, or from overflow, e.g. exp(1000).

save   saves all the matrices defined in the current session into the file,

        matlab.mat, located in the current working directory

load   loads contents of matlab.mat into current workspace

save filename x y z   saves the matrices x, y and z into the file titled filename.mat

save filename x y z /ascii   save the matrices x, y and z into the file titled filename.dat

load filename   loads the contents of filename into current workspace; the file can

                be a binary (.mat) file

load filename.dat   loads the contents of filename.dat into the variable filename

xlabel(' ') : Allows you to label x-axis

ylabel(' ') : Allows you to label y-axis

title(' ')   : Allows you to give title for

        plot

subplot() : Allows you to create multiple

        plots in the same window

Some Basic Plot Commands:

Kinds of plots:

plot(x,y)   creates a Cartesian plot of the vectors x & y

plot(y)   creates a plot of y vs. the numerical values of the elements in the y-vector

semilogx(x,y) plots log(x) vs y

semilogy(x,y) plots x vs log(y)

loglog(x,y)   plots log(x) vs log(y)

polar(theta,r) creates a polar plot of the vectors r & theta where theta is in radians

bar(x)   creates a bar graph of the vector x. (Note also the command stairs(x))

bar(x, y)   creates a bar-graph of the elements of the vector y, locating the bars
                according to the vector elements of 'x'

Plot description:

grid   creates a grid on the graphics plot

title('text')   places a title at top of graphics plot

xlabel('text')   writes 'text' beneath the x-axis of a plot

ylabel('text')   writes 'text' beside the y-axis of a plot

text(x,y,'text') writes 'text' at the location (x,y)

text(x,y,'text','sc') writes 'text' at point x,y assuming lower left corner is (0,0)
                and upper right corner is (1,1)

axis([xmin xmax ymin ymax]) sets scaling for the x- and y-axes on the current plot

Algebric Operations In MATLAB:

Scalar Calculations:

+   Addition

-       Subtraction

*   Multiplication

/   Right division (a/b means a ÷ b)

\   left division (a\b means b ÷ a)

^   Exponentiation

For example   3*4   executed in 'matlab' gives ans=12

                     4/5   executed in 'matlab' gives ans=0.8

Array products: Recall that addition and subtraction of matrices involved addition or subtraction of the individual elements of the matrices. Sometimes it is desired to simply multiply or divide each element of an matrix by the corresponding element of another matrix 'array operations".

Array or element-by-element operations are executed when the operator is preceded by a '.' (Period):

a .* b   multiplies each element of a by the respective element of b

a ./ b   divides each element of a by the respective element of b

a .\ b   divides each element of b by the respective element of a

a .^ b   raise each element of a by the respective b element

Matlab Working Environment:

Matlab Desktop

Matlab Desktop is the main Matlab application window. The desktop contains five sub windows, the command window, the workspace browser, the current directory window, the command history window, and one or more figure windows, which are shown only when the user displays a graphic.

The command window is where the user types MATLAB commands and expressions at the prompt (>>) and where the output of those commands is displayed. MATLAB defines the workspace as the set of variables that the user creates in a work session.

The workspace browser shows these variables and some information about them. Double clicking on a variable in the workspace browser launches the Array Editor, which can be used to obtain information and income instances edit certain properties of the variable.

The current Directory tab above the workspace tab shows the contents of the current directory, whose path is shown in the current directory window. For example, in the windows operating system the path might be as follows: C:\MATLAB\Work, indicating that directory "work" is a subdirectory of the main directory "MATLAB"; WHICH IS INSTALLED IN DRIVE C. clicking on the arrow in the current directory window shows a list of recently used paths. Clicking on the button to the right of the window allows the user to change the current directory.

MATLAB uses a search path to find M-files and other MATLAB related files, which are organize in directories in the computer file system. Any file run in MATLAB must reside in the current directory or in a directory that is on search path. By default, the files supplied with MATLAB and math works toolboxes are included in the search path. The easiest way to see which directories are soon the search path, or to add or modify a search path, is to select set path from the File menu the desktop, and then use the set path dialog box. It is good practice to add any commonly used directories to the search path to avoid repeatedly having the change the current directory.

The Command History Window contains a record of the commands a user has entered in the command window, including both current and previous MATLAB sessions. Previously entered MATLAB commands can be selected and re-executed from the command history window by right clicking on a command or sequence of commands.

This action launches a menu from which to select various options in addition to executing the commands. This is useful to select various options in addition to executing the commands. This is a useful feature when experimenting with various commands in a work session.

Using the MATLAB Editor to create M-Files

The MATLAB editor is both a text editor specialized for creating M-files and a graphical MATLAB debugger. The editor can appear in a window by itself, or it can be a sub window in the desktop. M-files are denoted by the extension .m, as in pixelup.m.

The MATLAB editor window has numerous pull-down menus for tasks such as saving, viewing, and debugging files. Because it performs some simple checks and also uses color to differentiate between various elements of code, this text editor is recommended as the tool of choice for writing and editing M-functions.

To open the editor , type edit at the prompt opens the M-file filename.m in an editor window, ready for editing. As noted earlier, the file must be in the current directory, or in a directory in the search path.

Getting Help:

The principal way to get help online is to use the MATLAB help browser, opened as a separate window either by clicking on the question mark symbol (?) on the desktop toolbar, or by typing help browser at the prompt in the command window. The help Browser is a web browser integrated into the MATLAB desktop that displays a Hypertext Markup Language(HTML) documents. The Help Browser consists of two panes, the help navigator pane, used to find information, and the display pane, used to view the information. Self-explanatory tabs other than navigator pane are used to perform a search.

APPENDIX B

CODE

```
function
[Alpha_score,Alpha_pos,Convergence_curve]=PSOGWO(SearchAgents_no,Max_iter,lb,ub,
dim,fobj)
% initialize alpha, beta, and delta_pos
Alpha_pos=zeros(1,dim);
Alpha_score=inf; %change this to -inf for maximization problems
 Beta_pos=zeros(1,dim);
Beta_score=inf; %change this to -inf for maximization problems
 Delta_pos=zeros(1,dim);
Delta_score=inf; %change this to -inf for maximization problems
 %Initialize the positions of search agents
Positions=initialization(SearchAgents_no,dim,ub,lb);
Convergence_curve=zeros(1,Max_iter);
velocity = .3*randn(SearchAgents_no,dim) ;
w=0.5+rand()/2;
l=0;% Loop counter
 % Main loop
while l<Max_iter
   for i=1:size(Positions,1)
      % Return back the search agents that go beyond the boundaries of the search space
      Flag4ub=Positions(i,:)>ub;
      Flag4lb=Positions(i,:)<lb;
      Positions(i,:)=(Positions(i,:).*(~(Flag4ub+Flag4lb)))+ub.*Flag4ub+lb.*Flag4lb;
      % Calculate objective function for each search agent
      fitness=fobj(Positions(i,:),0);
          % Update Alpha, Beta, and Delta
      if fitness<Alpha_score
        Alpha_score=fitness; % Update alpha
        Alpha_pos=Positions(i,:);
      end
```

```matlab
        if fitness>Alpha_score && fitness<Beta_score
            Beta_score=fitness; % Update beta
            Beta_pos=Positions(i,:);
        end
            if fitness>Alpha_score && fitness>Beta_score && fitness<Delta_score
            Delta_score=fitness; % Update delta
            Delta_pos=Positions(i,:);
        end
    end
    a=2-l*((2)/Max_iter); % a decreases linearly fron 2 to 0
        % Update the Position of search agents including omegas
    for i=1:size(Positions,1)
        for j=1:size(Positions,2)
            r1=rand(); % r1 is a random number in [0,1]
            r2=rand(); % r2 is a random number in [0,1]
            A1=2*a*r1-a; % Equation (3.3)
            %C1=2*r2; % Equation (3.4)
            C1=0.5;
            D_alpha=abs(C1*Alpha_pos(j)-w*Positions(i,j)); % Equation (3.5)-part 1
            X1=Alpha_pos(j)-A1*D_alpha; % Equation (3.6)-part 1
                r1=rand();
            r2=rand();
        A2=2*a*r1-a; % Equation (3.3)
            %C2=2*r2; % Equation (3.4)
            C2=0.5;
                    D_beta=abs(C2*Beta_pos(j)-w*Positions(i,j)); % Equation (3.5)-part 2
            X2=Beta_pos(j)-A2*D_beta; % Equation (3.6)-part 2
                    r1=rand();
            r2=rand();
            r3=rand();
            A3=2*a*r1-a; % Equation (3.3)
            %C3=2*r2; % Equation (3.4)
            C3=0.5;
            D_delta=abs(C3*Delta_pos(j)-w*Positions(i,j)); % Equation (3.5)-part 3
```

```matlab
            X3=Delta_pos(j)-A3*D_delta; % Equation (3.5)-part 3
                % velocity updation
        velocity(i,j)=w*(velocity(i,j)+C1*r1*(X1-Positions(i,j))+C2*r2*(X2-
Positions(i,j))+C3*r3*(X3-Positions(i,j)));
                % positions update
        Positions(i,j)=Positions(i,j)+velocity(i,j);
        end
    end
        l=l+1;
    Convergence_curve(l)=Alpha_score;
end
SearchAgents_no=3; % Number of search agents
Function_name='F1';
Max_iteration=5; % Maximum numbef of iterations
[lb,ub,dim,fobj]=Get_Functions_details(Function_name);
[Best_score,Best_pos,PSOGWO_cg_curve]=PSOGWO(SearchAgents_no,Max_iteration,lb,u
b,dim,fobj);
fobj(Best_pos,1);
```

Classification & Prediction of Chronic Kidney Disease using Machine Learning Algorithms

A Project Report submitted in partial fulfillment of the requirements for the award of the Degree of

MASTER OF TECHNOLOGY

IN

COMPUTER SCIENCE AND ENGINEERING

Submitted by

D.APOORVA BINDU PRIYA   19U41D5801

Under the Esteemed Guidance of

Dr. L. Prasanna Kumar

Professor, Head of the Department CSE

DADI INSTITUTE OF ENGINEERING & TECHNOLOGY

(Approved by A.I.C.T.E, New Delhi &Affiliated to JNTU, Kakinada)

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NH-5, Anakapalle-531002, Visakhapatnam, A.P.

2019

CERTIFICATE

This is to certify that the Project Work entitled **"Classification & Prediction of Chronic Kidney Disease using Machine Learning Algorithms"** is a bonafide work done by D APOORVA BINDU PRIYA (Reg.No: 19U41D5801) in partial fulfillment of the curriculum of Master of Technology in Computer Science & Engineering during the academic year 2020-2021.

Dr. L.PRASANNA KUMAR   **Dr. L.PRASANNA KUMAR**

(PROFESSOR)   **(PROFESSOR)**

(PROJECT GUIDE)   (HEAD OF THE DEPARTMENT)

EXTERNAL EXAMINER

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DECLARATION

I hereby declare that the project report entitled "Classification & Prediction of Chronic Kidney Disease using Machine Learning Algorithms" is entirely original and has been carried out in the presence Dr. L Prasanna Kumar, Head of the Department of CSE, DIET. This report is being submitted in partial fulfillment for the award of the Degree of Master of Technology in Computer Science & Engineering from Jawaharlal Nehru Technological University, Kakinada. We hereby state that this report is not submitted in any College / University or published at any time before.

BY

D.APOORVA BINDU PRIYA   (19U41D5801)

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I also consider it as our privilege to express our gratitude in thanking **Dr. CH.NARASIMHAM**, Principal, for providing us this opportunity to complete the Project Work.

With great solemnity and sincerity, we offer our profuse thanks to **SRI DADI RATNAKAR**, Secretary and Correspondent, for providing all the resources that greatly helped the Project Work to get successfully completed.

I sincerely thank all the staff members of the Department of Computer Science & Engineering for their sustained help in the pursuit.

D.APOORVA BINDU PRIYA   (19U41D5801)

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Abstract

The field of biosciences have progressive to a higher extent and have generated large amounts of information from Electronic Health Records. This have given rise to the acute need of knowledge generation from this enormous amount of data. Data mining methods and machine learning play a major role in this aspect of biosciences. Chronic Kidney Disease (CKD) is a condition in which the kidneys are damaged and cannot filter blood as they always do. A family history of kidney diseases or failure, high blood pressure, type 2 diabetes may lead to CKD. This is a lasting damage to the kidney and chances of getting worse by time is high. The very common problems that results due to a kidney failure are heart diseases, anemia, bone diseases, high potassium and calcium. The worst case situation leads to complete kidney failure and necessitates kidney transplant to live. An early detection of CKD can increase the quality of life to a greater extent. This calls for good prediction algorithm to predict CKD at an earlier stage. Literature shows a wide range of machine learning algorithms employed for the prediction of CKD. This paper uses data preprocessing, data transformation and various classifiers to predict CKD and also proposes best Prediction framework for CKD. The results of the framework show promising results of better prediction at an early stage of CKD.

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1. INTRODUCTION

The disability of the kidneys to perform their regular blood filtering function and others is called Chronic Kidney Disease (CKD). The term "chronic" describes the slow degradation of the kidney cells over a long period of time. This disease is a major kidney failure where the kidney sans blood filtering process and there is a heavy fluid buildup in the body. This leads to alarming increase of potassium and calcium salts in the body. Existence of high levels of these salts result in various other ailments in the body. The prime job of kidneys is to filter extra water and wastes from blood. The efficient functioning of this process is important to balance the salts and minerals present in our body. The rich balance of salts are necessary to control blood pressure, activate hormones, build red blood cells, etc. A high concentration of calcium leads to various bone diseases and cystic ovaries in women. CKD also may lead to sudden illness or allergy to certain medicines. This state is called as Acute Kidney Injury (AKI). An increased blood pressure may lead to heart problems and heart attacks. CKD in many cases leads to permanent dialysis or kidney transplants.
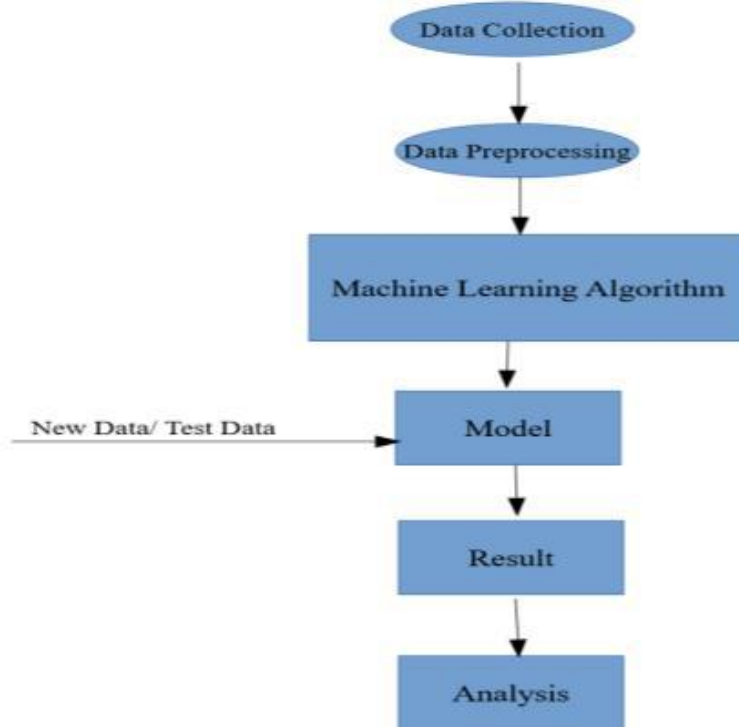
Figure 1: Stages of the Knowledge Data Discovery process

1.1 Background & Motivation

A history of kidney disease in the family also leads to high probability of CKD. Literature shows that almost one out of three people diagnosed with diabetes have CKD. Literature also

presents evidences of early identification and care of CKD can improve the quality of the patient's

life. Prediction algorithms in machine learning can be intelligently used to predict the occurrence of CKD and presents a method of early medication. The detailed review on literature shows the application of various machine learning algorithms to predict CKD. This paper tries to predict CKD using the classifiers like Decision Tree, Random Forest and Support Vector Machine and also suggested best prediction model.

The disease is called "chronic" because the damage to your kidneys happens slowly over a long period of time. The main causes are damaged blood vessels of the kidneys due to High Blood Pressure and Diabetes. The CKD is also called a chronic kidney failure where according current medical statistics the 10% of the population worldwide is affected by CKD. There were approximately 58 million deaths in the year of 2019 worldwide. According to the World Health Organization (WHO), 35 million attributed to chronic diseases. Currently it is estimated that one in five men, and one in four women aged 65 through 74 are going to be affected by CKD worldwide. Diagnosing CKD usually starts with clinical data, lab tests, imaging studies and finally biopsy. In this study, by using the machine learning techniques, we are proposing cheap, simple and non-invasive tests that can be performed easily.

1.2 Role of Machine Learning

Machine learning is a method of data analysis that automates analytical model building. It is a branch of artificial intelligence based on the idea that systems can learn from data, identify patterns and make decisions with minimal human intervention.

1.2.1 Evolution of machine learning

Because of new computing technologies, machine learning today is not like machine learning of the past. It was born from pattern recognition and the theory that computers can learn without being programmed to perform specific tasks; researchers interested in artificial intelligence wanted to see if computers could learn from data. The iterative aspect of machine learning is important because as models are exposed to new data, they are able to independently adapt. They learn from previous computations to produce reliable, repeatable decisions and results.

While many machine learning algorithms have been around for a long time, the ability to automatically apply complex mathematical calculations to big data – over and over, faster and faster – is a recent development. Here are a few widely publicized examples of machine learning applications you may be familiar with:

- The heavily hyped, self-driving Google car? The essence of machine learning.

- Online recommendation offers such as those from Amazon and Netflix? Machine learning applications for everyday life.

- Knowing what customers are saying about you on Twitter? Machine learning combined with linguistic rule creation.

- Fraud detection? One of the more obvious, important uses in our world today.

1.2.2 Importance of Machine Learning

Resurging interest in machine learning is due to the same factors that have made data mining and Bayesian analysis more popular than ever. Things like growing volumes and varieties of available data, computational processing that is cheaper and more powerful, and affordable data storage.

All of these things mean it's possible to quickly and automatically produce models that can analyze bigger, more complex data and deliver faster, more accurate results even on a very large scale. And by building precise models, an organization has a better chance of identifying profitable opportunities or avoiding unknown risks.

1.2.3 Machine Learning Applications

Artificial Intelligence is everywhere. Possibility is that you are using it in one way or the other and you don't even know about it. One of the popular applications of AI is Machine Learning, in which computers, software, and devices perform via cognition (very similar to human brain). Herein, we share few applications of machine learning.

I. Image Recognition

One of the most common uses of machine learning is image recognition. There are many situations where you can classify the object as a digital image. For digital images, the measurements describe the outputs of each pixel in the image.
- In the case of a black and white image, the intensity of each pixel serves as one measurement. So if a black and white image has N*N pixels, the total number of pixels and hence measurement is N2.
- In the colored image, each pixel considered as providing 3 measurements to the intensities of 3 main colours component i.e RGB. So N*N colored image there are 3 N2 measurements.
- For face detection – The categories might be face versus no face present. There might be a separate category for each person in a database of several individuals.
- For character recognition – We can segment a piece of writing into smaller images, each containing a single character. The categories might consist of the 26 letters of the English alphabet, the 10 digits, and some special characters.
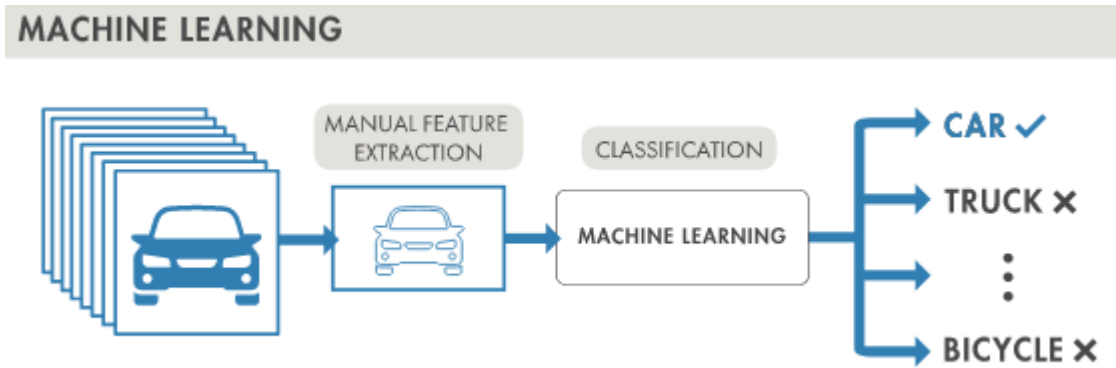
Figure 2 : Image Recognition

II. Speech Recognition

Speech recognition (SR) is the translation of spoken words into text. It is also known as "automatic speech recognition" (ASR), "computer speech recognition", or "speech to text" (STT).In speech recognition, a software application recognizes spoken words. The measurements in this application might be a set of numbers that represent the speech signal. We can segment the signal into portions that contain distinct words or phonemes.

In each segment, we can represent the speech signal by the intensities or energy in different time-frequency bands. Although the details of signal representation are outside the scope of this program, we can represent the signal by a set of real values. Speech recognition applications include voice user interfaces. Voice user interfaces are such as voice dialing; call routing, demotic appliance control. It can also use as simple data entry, preparation of structured documents, speech-to-text processing, and plane.
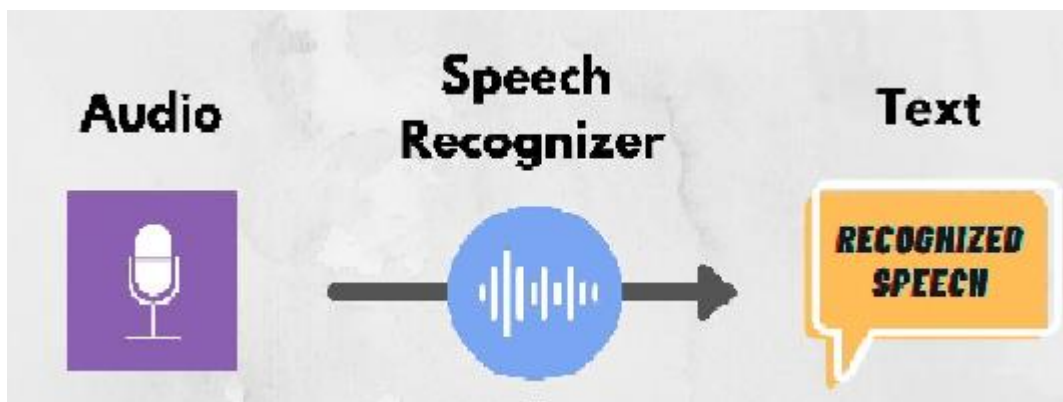
Figure 3 : Speech Recognition

III. Medical Diagnosis

ML provides methods, techniques, and tools that can help solving diagnostic and prognostic problems in a variety of medical domains. It is being used for the analysis of the importance of clinical parameters and of their combinations for prognosis, e.g. prediction of disease progression, for the extraction of medical knowledge for outcomes research, for therapy planning and support, and for overall patient management. ML is also being used for **data analysis**, such as detection of regularities in the data by appropriately dealing with imperfect data, interpretation of continuous data used in the Intensive Care Unit, and for intelligent alarming resulting in effective and efficient monitoring.

It is argued that the successful implementation of ML methods can help the integration of computer-based systems in the healthcare environment providing opportunities to facilitate and enhance the work of medical experts and ultimately to improve the efficiency and quality of medical care. In medical diagnosis, the main interest is in establishing the existence of a disease followed by its accurate identification. There is a separate category for each disease under consideration and one category for cases where no disease is present. Here, machine learning improves the accuracy of medical diagnosis by analyzing data of patients.
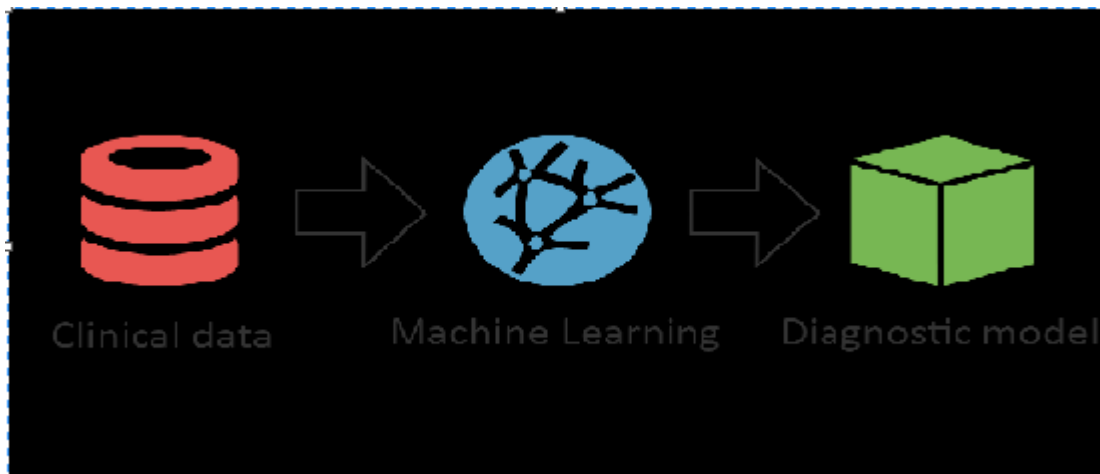
Figure 4 : Medical Diagnosis

IV. Statistical Arbitrage

In finance, statistical arbitrage refers to automated trading strategies that are typical of a short term and involve a large number of securities. In such strategies, the user tries to implement a trading algorithm for a set of securities on the basis of quantities such as historical correlations and general economic variables. These measurements can be cast as a classification or estimation problem. The basic assumption is that prices will move towards a historical average.
In the case of classification, the categories might be sold, buy or do nothing for each security. I the case of estimation one might try to predict the expected return of each security over a future

time horizon. In this case, one typically needs to use the estimates of the expected return to make a trading decision (buy, sell, etc.)

V. Learning Associations

Learning association is the process of developing insights into various associations between products. A good example is how seemingly unrelated products may reveal an association to one another. When analyzed in relation to buying behaviors of customers.

One application of machine learning- Often studying the association between the products people buy, which is also known as basket analysis. If a buyer buys 'X', would he or she force to buy 'Y' because of a relationship that can identify between them. This leads to relationship that exists between fish and chips etc. When new products launches in the market a Knowing these relationships it develops new relationship. Knowing these relationships could help in suggesting the associated product to the customer. For a higher likelihood of the customer buying it, it can also help in bundling products for a better package.

VI. Classification

A Classification is a process of placing each individual from the population under study in many classes. This is identifying as independent variables. Classification helps analysts to use measurements of an object to identify the category to which that object belong. To establish an efficient rule, analysts use data. Data consists of many examples of objects with their correct classification.

For example, before a bank decides to disburse a loan, it assesses customers on their ability to repay the loan. By considering factors such as customer's earning, age, savings and financial history we can do it. This information taken from the past data of the loan. Hence, Seeker uses to create relationship between customer attributes and related risks.

VII. Prediction

Consider the example of a bank computing the probability of any of loan applicants faulting the loan repayment. To compute the probability of the fault, the system will first need to classify the available data in certain groups. It is described by a set of rules prescribed by the analysts. Once we do the classification, as per need we can compute the probability. These probability computations can compute across all sectors for varied purposes

VIII. Extraction

Information Extraction (IE) is another application of machine learning. It is the process of extracting structured information from unstructured data. For example web pages, articles, blogs,

business reports, and e-mails. The relational database maintains the output produced by the information extraction. The process of extraction takes input as a set of documents and produces a structured data. This output is in summarized form such as excel sheet and table in a relational database.

Now-a-days extraction is becoming a key in big data industry. As we know that huge volume of data is getting generated out of which most of the data is unstructured. The first key challenge is handling of unstructured data. Now conversion of unstructured data to structured form based on some pattern so that the same can stored in RDBMS. Apart from this in current day's data collection mechanism is also getting change.

IX. Regression

We can apply Machine learning to regression as well. Assume that x= x1, x2,x3 … xn are the input variables and y is the outcome variable. In this case, we can use machine learning technology to produce the output (y) on the basis of the input variables (x).
You can use a model to express the relationship between various parameters as below:

Y=g(x) where g is a function that depends on specific characteristics of the model.

In regression, we can use the principle of machine learning to optimize the parameters. To cut the approximation error and calculate the closest possible outcome. We can also use Machine learning for function optimization. We can choose to alter the inputs to get a better model. This gives a new and improved model to work with. This is known as response surface design.

1.2.4 Introduction to Python
In technical terms, Python is an object-oriented, high-level programming language with integrated dynamic semantics primarily for web and app development. It is extremely attractive in the field of Rapid Application Development because it offers dynamic typing and dynamic binding options. Python is relatively simple, so it's easy to learn since it requires a unique syntax that focuses on readability. Developers can read and translate Python code much easier than other languages. In turn, this reduces the cost of program maintenance and development because it allows teams to work collaboratively without significant language and experience barriers.

Additionally, Python supports the use of modules and packages, which means that programs can be designed in a modular style and code can be reused across a variety of projects. Once you've developed a module or package you need, it can be scaled for use in other projects, and it's easy to import or export these modules. One of the most promising benefits of Python is that both the standard library and the interpreter are available free of charge, in both binary and source form. There is no exclusivity either, as Python and all the necessary tools are available on all major platforms. Therefore, it is an enticing option for developers who don't want to worry about paying high

development costs.

How is Python Used?

Python is a general-purpose programming language, which is another way to say that it can be used for nearly everything. Most importantly, it is an interpreted language, which means that the written code is not actually translated to a computer-readable format at runtime. Whereas, most programming languages do this conversion before the program is even run. This type of language is also referred to as a "scripting language" because it was initially meant to be used for trivial projects.

The concept of a "scripting language" has changed considerably since its inception, because Python is now used to write large, commercial style applications, instead of just banal ones. This reliance on Python has grown even more so as the internet gained popularity. A large majority of web applications and platforms rely on Python, including Google's search engine, YouTube, and the web-oriented transaction system of the New York Stock Exchange (NYSE). You know the language must be pretty serious when it's powering a stock exchange system.

Python can also be used to process text, display numbers or images, solve scientific equations, and save data. In short, it is used behind the scenes to process a lot of elements you might need or encounter on your device(s) - mobile included.

1.3 System Requirements

System Requirements comprises of Functional as well as Non-Functional requirements which are as follows :

1.3.1 Functional Requirements

In software engineering, a functional requirement defines a function of a software system or its component. A function is described as a set of inputs, the behavior, and outputs. Functional requirements may be calculations, technical details, data manipulation and processing and other specific functionality that define what a system is supposed to accomplish. Behavioral requirements describing all the cases where the system uses the functional requirements are captured in use cases. Functional requirements are supported by non-functional requirements (also known as quality requirements), which impose constraints on the design or implementation (such as performance requirements, security, or reliability). How a system implements functional requirements is detailed in the system design. In some cases a requirements analyst generates use cases after gathering and validating a set of functional requirements. Each use case illustrates behavioral scenarios through one or more functional requirements. Often, though, an analyst will begin by eliciting a set of use cases, from which the analyst can derive the functional requirements that must be implemented to allow a user to perform each use case.

Implementation of the proposed project require the following functional requirements :

INPUT: KDD dataset

OUTPUT: predictive representations of CKD detections

PROCESS: pre-process data, implementing algorithms and predicting results

STORAGE: dataset data and training dataset after algorithm implementation

- ❖ **"How"** the data should be presented in an orderly manner is seen.
- ❖ The knowledge-based and statistical models of similar projects have been taken into consideration.

Functional requirements may be calculations, technical details, data manipulation and processing and also specify what a system is supposed to be accomplished. Here register all the types of users but all the users should not be registered with same user name.

Software Requirement Specification

A Software Requirements Specification (SRS) is a complete description of the behavior of the system to be developed. It includes a set of use cases that describe all the interactions the users will have with the software. Use cases are also known as functional requirements. In addition to use cases, the SRS also contains non-functional (or supplementary) requirements. Non-functional requirements are requirements which impose constraints on the design or implementation (such as performance engineering requirements, quality standards, or design constraints).

Table : Software Requirements Specification

S.No	Requirement Number	Requirement Name	Essential /Not	Description
1	R1	Login	Essential	The user must login into the system
2	R2	Enter the values	Essential	User should enter the biotic values according to his/her body
3	R3	Prediction	Essential	He/She should get the outcome as whether they are suffering from CKD or not.

1.3.2 Non-Functional Requirements

In systems engineering and requirements engineering, a non-functional requirement is a requirement that specifies criteria that can be used to judge the operation of a system, rather than specific behaviors. Non-functional requirements are often called qualities of a system. Other terms for non-functional requirements are "constraints", "quality attributes", "quality goals" and "quality of service requirements," and "non-behavioral requirements". Qualities, that is, non-functional requirements, can be divided into two main categories:

1. Execution qualities, such as security and usability, which are observable at run time.
2. Evolution qualities, such as testability, maintainability, extensibility and scalability, which are embodied in the static structure of the software system.

- **User Interface**
    The system should provide "click" and "go" type of user interface with buttons and links that can be easily understood by the user. So that the errors in entering the data in appropriate fields can be reduced.
- **Performance**
    The system should perform its objectives efficiently and effectively as per the requirements. Response time should be very fast.
- **Security Issues**
    The system should be secured. Only authorized users can access the system. Each

user is validated by entering id and password.

- **Flexibility**

    If the organization intends to increase or extend the functionality of the software after it is deployed, that should be planned from the beginning; it influences choices made during the design, development, testing and deployment of the system.

- **Modifiability**

    Any modifications should be allowed. Only the administrator should be assigned all these responsibilities.

- **Portability**

    Portability specifies the ease with which the software can be installed on all necessary platforms, and the platforms on which it is expected to run. By using appropriate server versions released for different platforms our project can be easily operated on any operating system, hence can be said highly portable.

- **Scalability**

    Software modules can be easily integrated to our system without disturbing the existing modules or modifying the logical database schema of the existing applications. The non-functional requirements should specify the ways in which the system may be expected to scale up (by increasing hardware capacity, adding machines etc.). Our system can be easily expandable.

Hardware Requirements

The most common set of requirements defined by any operating system or software application is the physical computer resources, also known as hardware, A hardware requirements list is often accompanied by a hardware compatibility list (HCL), especially in case of operating systems.
An HCL lists tested, compatible, and sometimes incompatible hardware devices for a particular operating system or application. The following below describes the various aspects of hardware requirements used in the project:

- System: Pentium Dual Core i3.

- Hard Disk: 120 GB.

- Ram : 1 GB

- Operating system: Windows 8.

Software requirements

Software Requirements deal with defining software resource requirements and pre-requisites

that need to be installed on a computer to provide optimal functioning of an application. These requirements or pre-requisites are generally not included in the software installation package and need to be installed separately before the software is installed. The software requirements used here are:

- Coding Language : Python

- Database : MYSQL

1.4 Problem Definition

Nowadays, health care industries are providing several benefits like fraud detection in health insurance, availability of medical facilities to patients at inexpensive prices, identification of smarter treatment methodologies, and construction of effective healthcare policies, effective hospital resource management, better customer relation, improved patient care and hospital infection control. Disease detection is also one of the significant areas of research in medical. There is no automation for chronic kidney disease prediction.

1.4.1 Existing System

The existing system problem is prevailing to provide lack of quality in techniques. Basing on the number of clusters that are being formed by large datasets we need to provide the evaluation of performance of clustering techniques. So, to provide the quality of techniques by using few specific parameters.

- Required to specify the number of clusters, in advance
- Unable to handle erroneous data
- It cannot handle non-numeric data.
- It does not scale well for large data sets
- Successful diagnosis is a tedious issue to look upon and hence raises a serious issue for future therapy.
- Various classification techniques have been proposed for diagnosis, still no proper diagnosis methodology has been developed.
- Traditionally all cancers are classified based on their anatomical origin which does not gives accurate results
- Olden techniques are economically very high

1.4.2 Drawbacks of Existing System

- ❖ Manual Approach
- ❖ Requires Medical Equipments
- ❖ More Expensive
- ❖ Lack of user satisfaction
- ❖ Less Efficient
- ❖ Less Accurate

1.4.3 Proposed System

Our Aim is to predict the chronic kidney disease using the machine learning algorithms. Chronic kidney disease (CKD) means your kidneys are damaged and can't filter blood the way they should. The disease is called "chronic" because the damage to your kidneys happens slowly over a long period of time. This damage can cause wastes to build up in your body. CKD can also cause other health problems.10% of the population worldwide is affected by chronic kidney disease (CKD), and millions die each year because the doctors are unable diagnose the disease.

The system is automation for predicting the CKD. The system is a Real-world web-based application that can be used by many hospitals. It assumes variables are independent of each other. The algorithms were easy to build and works well with huge data sets. It has been used because it makes use of small training data to estimate the parameters important for classification. It performs well in multiple class prediction. When assumption of independence holds a various classifiers perform better compare to other models like logistic regression and you need less training data.

1.4.4 Objectives Of Proposed System

Machine learning has ability to deal with uncertain, fuzzy or insufficient data, which fluctuate in short period of time, robust that helps to complex and returns.
- ❖ Accuracy mostly ranges 80 to 100%.
- ❖ Helps to classify the diseases into 3 classes:-
- ◆ Diseases with either positive or negative returns which gives valuable support in making decisions, but do not specify the amount of expected and expected profit.
- ◆ System tries to predict the dieses for one or more days in advance, based on the previous data sets and on related classes.
- ◆ Concerned with modeling diseased forecasting. Predicts future values, but also have significance estimation, sensitivity analysis and other analysis of mutual dependencies.
  - ❖ Forecasting is done by various algorithms.

2. LITERATURE REVIEW

The healthcare domain is one of the prominent research fields in the current scenario with the rapid improvement of technology and data. It is difficult to handle the huge amount of data of the patients. There are a lot of procedures for the treatment of multiple diseases across the world. Machine Learning is an emerging approach that helps in prediction, diagnosis of a disease.

M. P. N. M. Wickramasinghe.et al(1) presents a methodology to control the disease using a suitable diet plan. In this research classifiers are constructed using different algorithms like Multiclass Decision Jungle, Multiclass Decision Forest, Multiclass Neural Network and Multiclass Logistic Regression. An allowable potassium zone is predicted depending on the blood potassium levels of the patient. The classification algorithms recommend a diet place based on the predicted potassium zone.

H. A. Wibawa.et al(2) proposed and evaluated Kernel-based Extreme Learning Machine(ELM) to predict Chronic Kidney Disease. Performance of four kernels-based ELM, namely RBF-ELM, Linear-ELM, Polynomial-ELM, Wavelet-ELM are compared with the performance of standard ELM. The above methodologies were compared on metrics of sensitivity and specificity. Radial Basis Function – Extreme Learning Machine (RBF-ELM) showed higher prediction rates.

CKD increases the risk factors of CardioVascular Disease (CVD) like hypertension, diabetes mellitus, dyslipidemia, and metabolic syndrome. CKD also leads to End Stage Renal Disease (ESRD) which has no cure. *U. N. Dulhare.et al*(3) extracted action rules based on stages but also predicted CKD by using naïve bayes with OneR attribute selector which helps to prevent the advancing of chronic renal disease to further stages.

It is said that the median survival time of past due-stage patients is simplest approximately three years. Evaluating exactly the condition of sufferers is of incredible importance as it might substantially assist to decide appropriate care, medications or medical interventions wished, which amongst them have a complicated interrelationship and have an impact on the final results of the person patient. *H. Zhang.et al*(4) investigated the performance of Artificial Neural Network (ANN) models while applying to the survivability prediction on Chronic Kidney Disease (CKD) patients.

Dialysis or Kidney transplant stays the only option for a patient with End Stage Renal Disease (ESRD). The progression of the disease can be slowed down or even stopped in a favourable case by early prediction of CKD and proper treatments with diet. *J. Aljaaf et al.,* (5) concluded that application of machine learning algorithms with predictive analytics proves to be an intelligent solution for early prediction of the disease.

Data mining models project ensemble techniques called Boosting which enhances the prediction of a model. AdaBoost and LogitBoost are generally used to compare the performance of classification algorithms. *Arif-Ul-Islam. et al*(6) analyzed the performance of boosting algorithms for detecting CKD and derived rules illustrating relationship among the various attributes of CKD. The paper used Ant-Miner machine learning algorithm along with Decision tree to derive rules.

Datamining methods are used to generate decisions by elicitating hidden information from chronic disease datasets. This calls of storage and manipulation of large amounts of structured, unstructured and semi structured data. The role of big data in for the same is very important. *G. Kaur.et al*(7) predicted chronic kidney disease using various data mining algorithms in Hadoop environment. Classifiers like KNN (K-Nearest Neighbor) and SVM (Support Vector Machine) are used in the research.

Levels of creatinine, sodium, urea in blood play an important role in deciding the survival prediction or the need for kidney transplantation in patients undergoing dialysis and becoming worser.*V.Ravindra.et al*(8) used simple K-means algorithm to elicit knowledge about the interaction between many of these CKD parameters and patient survival. He concluded that the clustering procedure predicts the survival period of the patients who undergo the dialysis procedure.

For CKD prediction, *R.Devika et al*(9) examined the performance of Naive Bayes, K-Nearest Neighbour (KNN) and Random Forest classifiers based on accuracy, preciseness and execution time for. *P.Panwong.et al*(10) created a classification model for predicting transitional interval of Kidney disease stages 3 to 5 and also used Decision tree, K-nearest neighbor, Naïve Bayes and Artificial neural networks for eliciting the knowledge and creating classification model with the selected set of attributes.

S.Vijayarani.at.al (11) predicted kidney diseases by using Support Vector Machine (SVM) and Artificial Neural Network (ANN). The research compared the performance of the above two algorithms on accuracy and execution time. *Misir R, et al*(12) used feature selection algorithms to identify set of features that efficiently predict kidney diseases. The reduced feature set results in reduced costs, saves time and reduced uncertainty.

Kidney damage due to diabetes is chronic and a slow process, but has significant effects on the patient. High glucose levels in blood disturbs the kidney from functioning effectively. *Bharathiet.al*(16) has applied association rule mining to predict diabetes mellitus in a given dataset by generating summarization rules.

3. OVERVIEW OF MACHINE LEARNING ALGORITHMS

Machine learning (ML) is the study of computer algorithms that can improve automatically through experience and by the use of data. It is seen as a part of artificial intelligence. Machine learning algorithms build a model based on sample data, known as "training data".

3.1 Decision Tree

Decision Tree one of the algorithm, is used to solve regression and classification problems. The general objective of using Decision Tree is to create a model that predicts classes or values of target variables by generating decision rules derived from training data sets. Decision tree algorithm follows a tree structure with roots, branches and leaves. The attributes of decision making are the internal nodes and class labels are represented as leaf nodes. Decision Tree algorithm is easy to understand compared with other classification algorithms.The Decision trees algorithm consists of two parts: nodes and rules (tests). We construct the tree. In which each node reflect a test on an attribute the basic idea of this algorithm is to draw a flowchart diagram that contains a root node on top. All other (non-leaf) nodes represent a test until you reach a leaf node (final result). Decision tree algorithms have been widely used in data mining applications below are some important reasons that why decision trees are used in the area of data mining and classification.

Decision trees create user-friendly rules. They are considered one of easy to understand algorithms to the end user in Data mining. They show effective association among the dataset attributes and represent in an easy-to-understand form. Decision trees provide a clear indication of important attributes. Decision trees require less computation. They require less computation compared to other classification algorithms. When we implementing decision trees to detect breast cancer then leaf nodes are divided into two categories: Benign or Malignant. Rules will be established among the chosen data set attributes in order to determine if the tumor is benign or malignant.
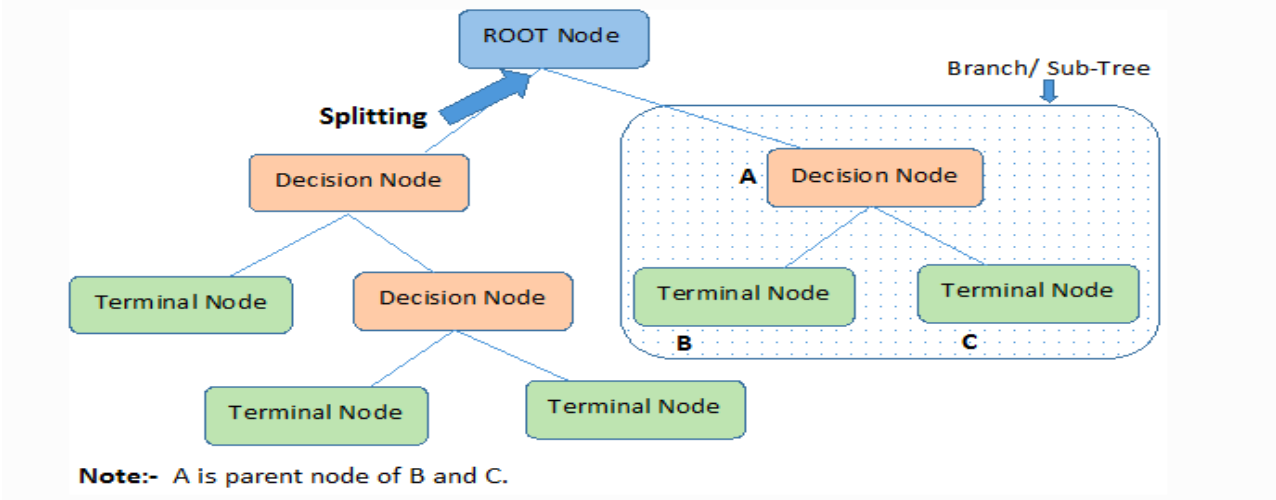
3.2 Random Forest

Random forest is a type of supervised machine learning algorithm based on ensemble learning. Ensemble learning is a type of learning where you join different types of algorithms or same algorithm multiple times to form a more powerful prediction model. The random forest algorithm combines multiple algorithm of the same type i.e. multiple decision trees, resulting in a forest of trees, hence the name "Random Forest".

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The random forest algorithm can be used for both regression and classification tasks.

Random Forest Algorithm

The following are the basic steps involved in performing the random forest algorithm:

1. Pick N random records from the dataset.
2. Build a decision tree based on these N records.
3. Choose the number of trees you want in your algorithm and repeat steps 1 and 2.
4. In case of a regression problem, for a new record, each tree in the forest predicts a value for Y (output). The final value can be calculated by taking the average of all the values predicted by all the trees in forest. Or, in case of a classification problem, each tree in the forest predicts the category to which the new record belongs. Finally, the new record is assigned to the category that wins the majority vote.

Advantages of using Random Forest

- As with any algorithm, there are advantages and disadvantages to using it. In the next two sections we'll take a look at the pros and cons of using random forest for classification and regression.
- The random forest algorithm is not biased, since, there are multiple trees and each tree is **trained on a subset of data. Basically, the random forest algorithm relies on the power of** "the crowd"; therefore the overall biasedness of the algorithm is reduced.
- This algorithm is very stable. Even if a new data point is introduced in the dataset the overall algorithm is not affected much since new data may impact one tree, but it is very hard for it to impact all the trees.

- The random forest algorithm works well when you have both categorical and numerical features.
- The random forest algorithm also works well when data has missing values or it has not been scaled well (although we have performed feature scaling in this article just for the purpose of demonstration).

Disadvantages of using Random Forest

- A major disadvantage of random forests lies in their complexity. They required much more computational resources, owing to the large number of decision trees joined together.

- Due to their complexity, they require much more time to train than other comparable algorithms.

3.3 Support Vector Machine

"Support Vector Machine" (SVM) is a supervised machine learning algorithm which can be used for both classification and regression challenges. However, it is mostly used in classification problems. In this algorithm, we plot each data item as a point in n-dimensional space (where n is number of features you have) with the value of each feature being the value of a particular coordinate. Then, we perform classification by finding the hyper-plane that differentiate the two classes very well (look at the below snapshot). Support Vectors are simply the co-ordinates of individual observation. Support Vector Machine is a frontier which best segregates the two classes (hyperplane/ line).
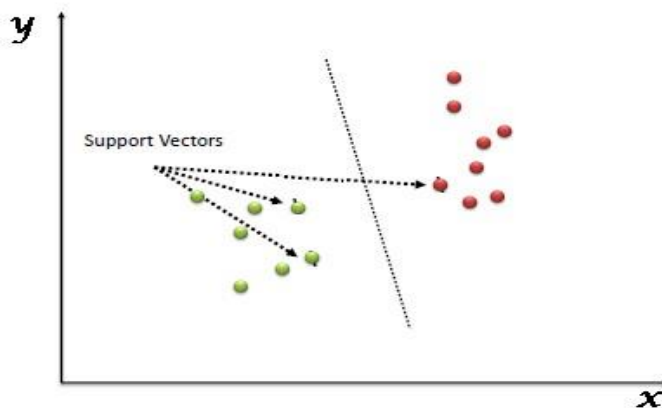
Figure 6 s: Example for Support Vector Machine

SVM Algorithm

To understand the algorithm of SVM, consider two cases:

Separable case – Infinite boundaries are possible to separate the data into two classes. In the separable case, infinite boundaries are possible. The boundary that gives the largest distance to the nearest observation is called the optimal hyperplane. The optimal hyperplane ensures the fit and

robustness of the model. Hyperplane depends on support points called the closest points. Generalization capacity of SVM increases as the number of support points decreases.

Non Separable case – Two classes are not separated but overlap with each other. If two classes are not perfectly separated but overlap. A term measuring the classification error must add to each of the following two conditions:

For every i, $y_i(a.x_i + b) \geq 1$ (correct separation)
$1/2 \|a\|2$ is minimal (greatest margin)

Define these condition for each observation x_i on the wrong side of the boundary. By measuring the distance separating it from the boundary of the margin on the side of its class.
This distance is then normalized by dividing it by the half-margin $1/\|a\|$, giving a term i, called the slack variable. An error in the model is an observation for which $\xi > 1$. The sum of all the ξ_i represents the set of classification errors.
So, the previous two constraints for finding the optimal hyperplane become:

For every i, $y_i(a.x_i + b) \geq 1–\xi_i$
$1/2 \|a\|2 + \delta\Sigma_i \xi_i$ is minimal
The quantity δ is a parameter that penalizes errors. It controls the adaptation of the model to the errors. As this increases and sensitivity to errors rise, adaptation also increases.

In SVMs, the process of restructuring data is known as transformation and does it with the help of a function. Refer this function as the transformation function and represented by the symbol (Φ). Technically, the transformation functions map the dot product of data points to a higher dimensional place.

Another way of handling the non separable case is to move to a space having a high enough dimension for there to be a linear separation. Search for a nonlinear transformation for moving from original space to a higher dimensional space. But choose one which has a scalar product.

Pros and Cons associated with SVM
Pros

- It works really well with clear margin of separation ☐It is effective in high dimensional spaces.

- It is effective in cases where number of dimensions is greater than the number of samples.
- It uses a subset of training points in the decision function (called support vectors), so it is also memory efficient.

Cons

- It doesn't perform well, when we have large data set because the required training time is higher
- It also doesn't perform very well, when the data set has more noise i.e. target classes are overlapping
- SVM doesn't directly provide probability estimates, these are calculated using an expensive five-fold cross-validation. It is related SVC method of Python scikit-learn library.

3.4 K-Nearest Neighbour

K - Nearest Neighbor (KNN) is a very simple, easy to understand, versatile and one of the topmost machine learning algorithms. KNN used in the variety of applications such as finance, healthcare, political science, handwriting detection, image recognition and video recognition. In Credit ratings, financial institutes will predict the credit rating of customers. In loan disbursement, banking institutes will predict whether the loan is safe or risky. In political science, classifying potential voters in two classes will vote or won't vote. kNN algorithm used for both classification and regression problems. kNN algorithm based on feature similarity approach.

KNN Algorithm

In KNN, K is the number of nearest neighbors. The number of neighbors is the core deciding factor. K is generally an odd number if the number of classes is 2. When K=1, then the algorithm is known as the nearest neighbor algorithm. This is the simplest case. Suppose P1 is the point, for which label needs to predict. First, you find the one closest point to P1 and then the label of the nearest point assigned to P1.
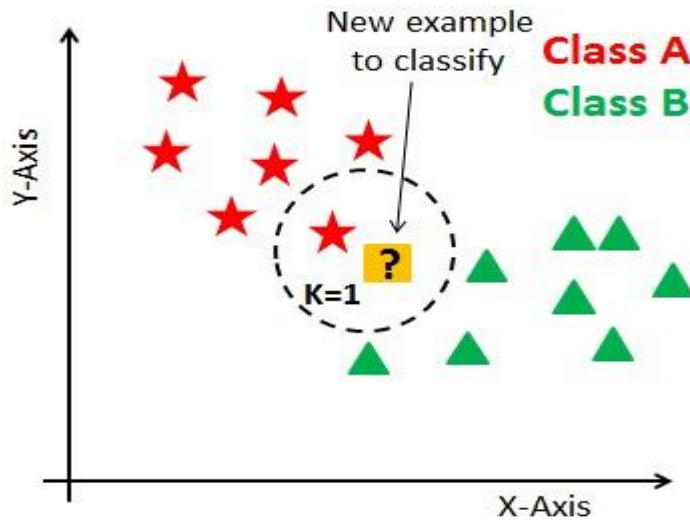
Figure 7 : Example for KNN

Suppose P1 is the point, for which label needs to predict. First, you find the k closest point to P1 and then classify points by majority vote of its k neighbors. Each object votes for their class and the class with the most votes is taken as the prediction. For finding closest similar points, you find the distance between points using distance measures such as Euclidean distance, Hamming distance, Manhattan distance and Minkowski distance.

KNN has the following basic steps:
1. Calculate distance
2. Find closest neighbors
3. Vote for labels
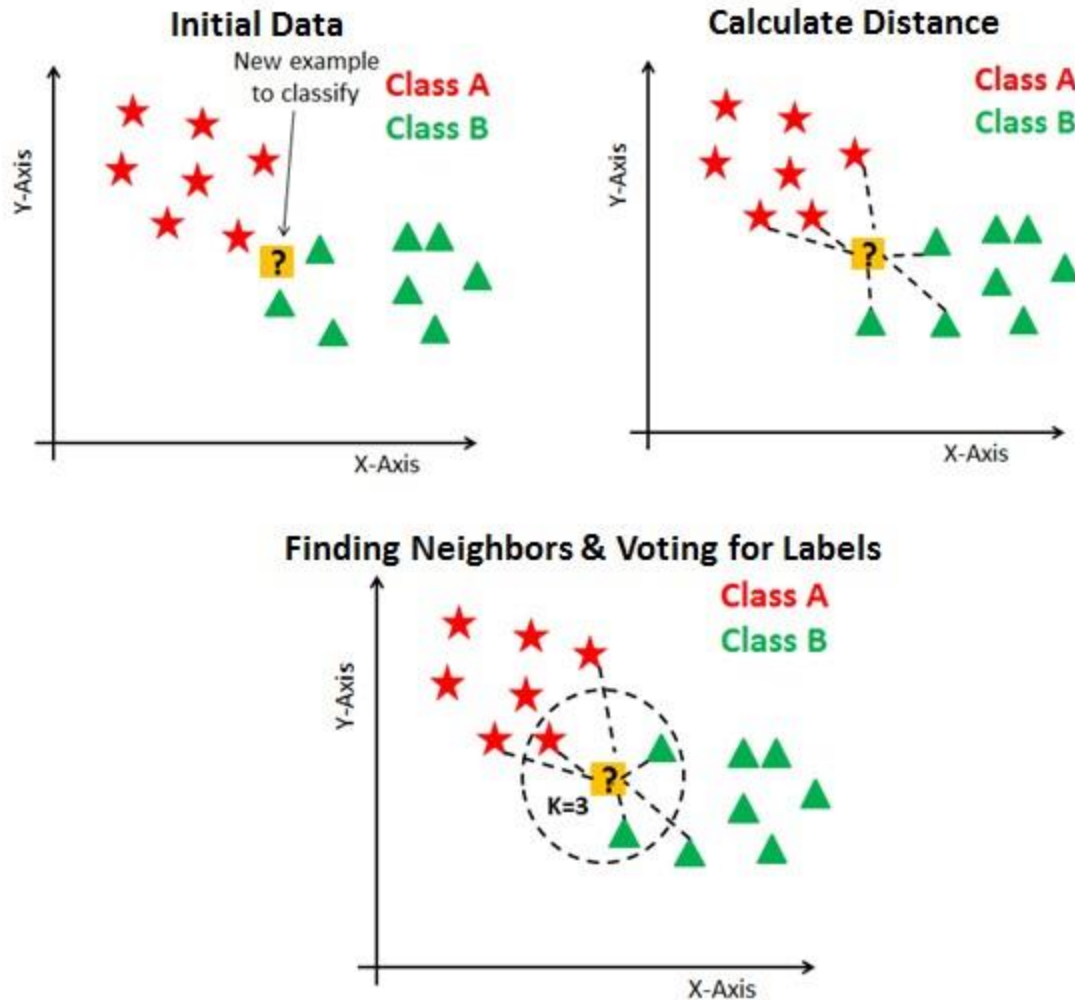
Figure 8 : KNN Algorithm

Advantages and Disadvantages of KNN

Pros

- The training phase of K-nearest neighbor classification is much faster compared to other classification algorithms. There is no need to train a model for generalization, that is why KNN is known as the simple and instance-based learning algorithm.
- KNN can be useful in case of nonlinear data. It can be used with the regression problem.
- Output value for the object is computed by the average of k closest neighbors value.

Cons

The testing phase of K-nearest neighbor classification is slower and costlier in terms of time and memory. It requires large memory for storing the entire training dataset for prediction. KNN requires scaling of data because KNN uses the Euclidean distance between two data points to find nearest neighbors. Euclidean distance is sensitive to magnitudes. The features with high magnitudes will weight more than features with low magnitudes.

3.5 Logistic Regression

Logistic regression is another technique borrowed by machine learning from the field of statistics.

Logistic Function

Logistic regression is named for the function used at the core of the method, the logistic function.

The logistic function, also called the sigmoid function was developed by statisticians to describe properties of population growth in ecology, rising quickly and maxing out at the carrying capacity of the environment. It's an S-shaped curve that can take any real-valued number and map it into a value between 0 and 1, but never exactly at those limits.

$$1 / (1 + e\text{^-value})$$

Where 'e' is the base of the natural logarithms (Euler's number or the EXP() function in your spreadsheet) and value is the actual numerical value that you want to transform. Below is a plot of the numbers between -5 and 5 transformed into the range 0 and 1 using the logistic function.
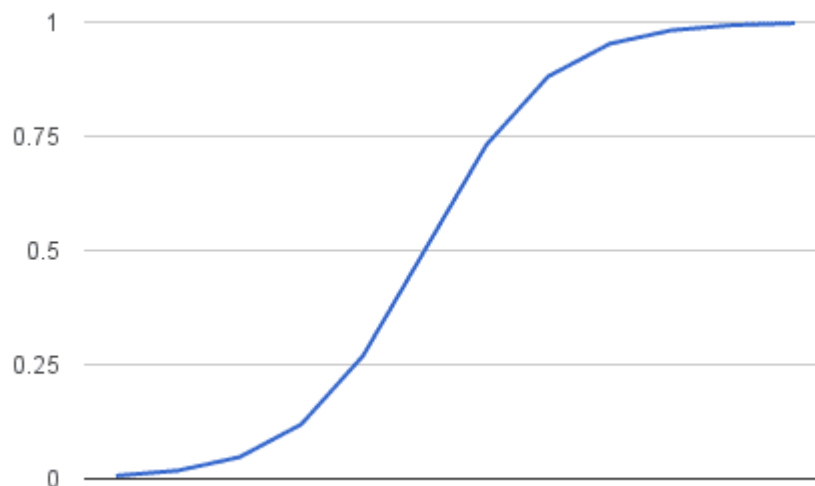
Figure 9 : Logistic Regression

Representation Used for Logistic Regression

Logistic regression uses an equation as the representation, very much like linear regression.

Input values (x) are combined linearly using weights or coefficient values (referred to as the Greek capital letter Beta) to predict an output value (y). A key difference from linear regression is that the output value being modeled is a binary values (0 or 1) rather than a numeric value.

Below is an example logistic regression equation:

$$y = e^{(b0 + b1*x)} / (1 + e^{(b0 + b1*x)})$$

Where y is the predicted output, b0 is the bias or intercept term and b1 is the coefficient for the single input value (x). Each column in your input data has an associated b coefficient (a constant real value) that must be learned from your training data.

The actual representation of the model that you would store in memory or in a file are the coefficients in the equation (the beta value or b's).

3.6 Voting Classifier

A Voting Classifier is a machine learning model that trains on an ensemble of numerous models and predicts an output (class) based on their highest probability of chosen class as the output. It simply aggregates the findings of each classifier passed into Voting Classifier and predicts the output class based on the highest majority of voting. The idea is instead of creating separate dedicated models and finding the accuracy for each them, we create a single model which trains by these models and predicts output based on their combined majority of voting for each output class.

Voting Classifier supports two types of votings.

1. **Hard Voting:** In hard voting, the predicted output class is a class with the highest majority of votes i.e the class which had the highest probability of being predicted by each of the classifiers. Suppose three classifiers predicted the *output class(A, A, B)*, so here the majority predicted *A* as output. Hence *A* will be the final prediction.

2. **Soft Voting:** In soft voting, the output class is the prediction based on the average of probability given to that class. Suppose given some input to three models, the prediction probability for class *A = (0.30, 0.47, 0.53)* and *B = (0.20, 0.32, 0.40)*. So the average for class *A is 0.4333* and *B is 0.3067*, the winner is clearly class *A* because it had the highest probability averaged by each classifier.

Classification Accuracy

Accuracy of the constructed classifier model can be calculation using the following equation.

$$Accuracy = \frac{TP+TN}{TP+TN+FP+FN} \quad (1)$$

Where,

TP = Observation is positive an predicted is also positive

TN=Observation is negative and predicted is also negative

FP = Observation is negative but predicted is positive

FN = Observation is positive but predicted is negative

Conclusion

The taxonomy or way of organizing machine learning algorithms is useful because it forces us to think about the roles of the input data and the model preparation process and select one that is the most appropriate for our problem in order to get the best result.

4. DESIGN

4.1 Introduction

There are several reasons to identify the design goals of any system. These goals will help to design the system in an efficient manner. There are several criteria to identify these goals. Some of the criteria were explained below:

1. **Performance criteria**

    a) **Response time:** The response time of the method is very low because the system simple design developed on the high performance system.
    b) **Throughput:** The throughput of the system is high.
    c) **Memory:** Memory used by the system is very low.

2. **Dependability criteria**

    a) **Robustness:** the system should be designed to work efficiently on images of any type of formats without any problem.
    b) **Availability:** the system should be ready to accept command from user at any point of time.
    c) **Fault Tolerance:** the system should not allow the user to work with fault input. It displays error messages foe every specific fault occurred.

3. **Maintenance criteria**

    a) **Portability:** The system should work on all the platforms like linux, windows, android .
    b) **Readability:** the code generated should be able to understand the purpose of the project, so as to make the user to make the modifications easily.
    c) **Traceability:** the code generated should be easy to map with the functions with the operations selected by the user.

4. **End-user criteria**

    a) **Utility:** the system should be made to operate on al inputs of end-user under any kind of circumstances. It should complete all the commands or instructions given by user without any interruptions.
    b) **Usability:** the interface of the user is to be defined with all options which make the work of the end-user easier.

4.2 System Architecture
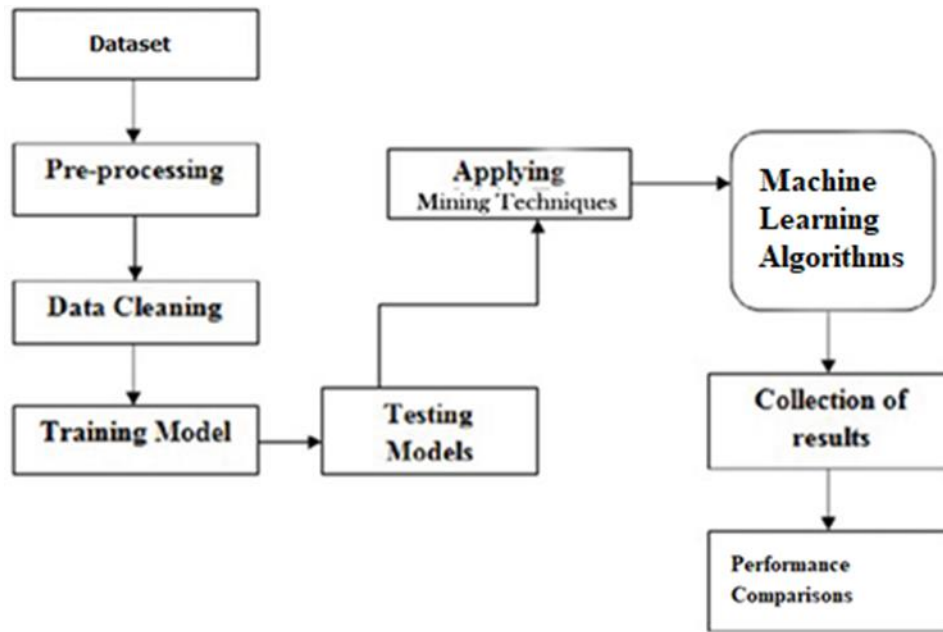
Figure 10 : System Architecture

System design or architecture is the process, which involves conceiving planning and carrying out the plan by generating the necessary reports and inputs. In other words design phase acts as a bridge between the software requirement specification and implementation phase, which satisfies those requirements. System Design is the transformation of the analysis model into a system design model.

5. IMPLEMENTATION

5.1 Introduction

Knowledge discovery is an important application of datamining which involves various stages of processing. The application of datamining algorithms are facilitated by pre-processing the data collected from multiple sources. Data preparation or pre-processing involves cleaning, extracting and transforming data to suitable formats. The key factors of knowledge representation are identified from a larger feature set. Later various classification or pattern evaluation algorithms are applied for knowledge discovery.

The paper tries to propose a datamining framework for knowledge discovery on the CKD datasets. Large amounts of CKD datasets are collected. Data preparation and pre-processing is done using the traditional methods of data mining process. Three machine learning algorithms namely Decision tree, Random Forest and Support Vector machines are used to predict the early occurrence of CKD. The goodness of each algorithm is analysed.

5.2 Description of Dataset

The clinical data of 400 records considered for analysis has been taken from UCI Machine Learning Repository. The data obtained after cleaning and removing missing values is 220. There are 25 attributes in the dataset. The numerical attributes include age, blood pressure, blood glucose random, blood urea, serum creatinine, sodium, potassium, hemoglobin, packaged cell volume, WBC count, RBC count. The nominal attributes include specific gravity, albumin and sugar. It also includes RBC, pus cell and pus cell clumps, bacteria, hypertension, diabetes mellitus, coronary artery disease, appetite, pedal edema, anemia and class. Number of Instances: 400 Number of Attributes: 25 Class: {CKD, NOTCKD} Missing Attribute Values: yes Class Distribution: [63% for CKD] [37% for NOTCKD]

The most popular R Programming Data analytics tool has been used to construct the prediction framework.

	age	bp	sg	al	su	rbc	pc	pcc	ba	bgr	bu	sc	sod
1	48	80	1.020	1	0	?	normal	notpresent	notpresent	121	36	1.2	?
2	7	50	1.020	4	0	?	normal	notpresent	notpresent	?	18	0.8	?
3	62	80	1.010	2	3	normal	normal	notpresent	notpresent	423	53	1.8	?
4	48	70	1.005	4	0	normal	abnormal	present	notpresent	117	56	3.8	111
5	51	80	1.010	2	0	normal	normal	notpresent	notpresent	106	26	1.4	?
6	60	90	1.015	3	0	?	?	notpresent	notpresent	74	25	1.1	142

Figure 11 : Chronic Kidney Disease Dataset

Algorithm:

Input: Chronic Kidney Disease Dataset

Output: Hıgh Accuracy prediction Framework

Step1: Input data

Step2: Pre-process the data

    Step 2.1: Convert Categorical values to numerical values

    Step 2.2: Replace numerical missing values by Mean

    Step2.3: Replace Categorical missing values by Mode

Step3: Construct Classifier Models

    Step3.1: Construct Decision Tree Model

    Step3.2: Construct Random Forest Model

    Step3.3: Construct SVM model

    Step3.4: Construct KNN Model

    Step3.5: Construct Voting Classifier Model

    Step3.6: Construct Linear Regression Model

Step 4: Check the accuracy of the constructed models using confusion matrix

Step 5: Decide the best prediction model for CKD.

5.2.1 Data preprocessing

   Data preparation requires approximately 80% of time. Once data is gathered, it needs to be preprocessed, cleaned, constructed, and formatted in a style that SVM comprehends and is able to work with. DM tools should be used to analyze collected real-time data.

Sources of Missing Values

    Before we dive into code, it's important to understand the sources of missing data. Here's some typical reasons why data is missing:

  -User forgot to fill in a field.
  -Data was lost while transferring manually from a legacy database.
  -There was a programming error.
  -Users chose not to fill out a field tied to their beliefs about how the results would be used or interpreted.

As you can see, some of these sources are just simple random mistakes. Other times, there can be a deeper reason why data is missing. It's important to understand these different types of missing data from a statistics point of view. The type of missing data will influence how you deal with filling in the missing values.

Let us now see how we can handle missing values (say NA or NaN) using Pandas.

```
# import the pandas library
import pandas as pd
importnumpy as np
df = pd.DataFrame(np.random.randn(5, 3), index=['a', 'c', 'e', 'f',
'h'],columns=['one', 'two', 'three'])
df = df.reindex(['a', 'b', 'c', 'd', 'e', 'f', 'g', 'h'])
printdf
```

Using reindexing, we have created a DataFrame with missing values. In the output, NaN means Not a Number.

Check for Missing Values

To make detecting missing values easier (and across different array dtypes), Pandas provides the isnull() and notnull() functions, which are also methods on Series and DataFrame objects −

Example 1

```
import pandas as pd
importnumpy as np
df = pd.DataFrame(np.random.randn(5, 3), index=['a', 'c', 'e', 'f',
'h'],columns=['one', 'two', 'three'])
df = df.reindex(['a', 'b', 'c', 'd', 'e', 'f', 'g', 'h'])
printdf['one'].isnull()
```

Its output is as follows −

Table 1 : Missing values

A	False
B	True
C	False
D	True
E	False
F	False
G	True
H	False

Name: one, dtype: bool

Cleaning / Filling Missing Data

Pandas provides various methods for cleaning the missing values. The fillna function can "fill in" NA values with non-null data in a couple of ways, which we have illustrated in the following sections.

Replace NaN with a Scalar Value

The following program shows how you can replace "NaN" with "0".

```
import pandas as pd
importnumpy as np
df = pd.DataFrame(np.random.randn(3, 3), index=['a', 'c', 'e'],columns=['one',
'two', 'three'])
df = df.reindex(['a', 'b', 'c'])
printdf
print ("NaN replaced with '0':")
printdf.fillna(0)
```

Example 2
```
import pandas as pd
importnumpy as np
df = pd.DataFrame(np.random.randn(5, 3), index=['a', 'c', 'e', 'f',
'h'],columns=['one', 'two', 'three'])
df = df.reindex(['a', 'b', 'c', 'd', 'e', 'f', 'g', 'h'])
printdf.fillna(method='pad')
```

Its output is as follows −

Table 2 : Cleaning Missing Data

	one	two	three
a	0.077988	0.476149	0.965836
b	0.077988	0.476149	0.965836
c	-0.390208	-0.551605	-2.301950
d	-0.390208	-0.551605	-2.301950
e	-2.000303	-0.788201	1.510072
f	-0.930230	-0.670473	1.146615
g	-0.930230	-0.670473	1.146615

31

h	0.085100	0.532791	0.887415

Drop Missing Values

If you want to simply exclude the missing values, then use the dropna function along with the axis argument. By default, axis=0, i.e., along row, which means that if any value within a row is NA then the whole row is excluded.

Example 3
```
import pandas as pd
importnumpy as np
df = pd.DataFrame(np.random.randn(5, 3), index=['a', 'c', 'e', 'f',
'h'],columns=['one', 'two', 'three'])
df = df.reindex(['a', 'b', 'c', 'd', 'e', 'f', 'g', 'h'])
printdf.dropna()
```

Its output is as follows −

Table 3 : Drop Missing Values

	one	two	three
a	0.077988	0.476149	0.965836
c	-0.390208	-0.551605	-2.301950
e	-2.000303	-0.788201	1.510072
f	-0.930230	-0.670473	1.146615
h	0.085100	0.532791	0.887415

Replace Missing (or) Generic Values

Many times, we have to replace a generic value with some specific value. We can achieve this by applying the replace method.

Replacing NA with a scalar value is equivalent behavior of the fillna() function.

Example 4
```
import pandas as pd
importnumpy as np
df = pd.DataFrame({'one':[10,20,30,40,50,2000],
'two':[1000,0,30,40,50,60]})
printdf.replace({1000:10,2000:60})
```

Its output is as follows −

Table 4 : Replace Missing Values

	one	two
0	10	10
1	20	0
2	30	30
3	40	40
4	50	50
5	60	60

5.2.2 Splitting data into train and test datasets

In machine learning, the study and construction of algorithms that can learn from and make predictions on data is a common task. Such algorithms work by making datadriven predictions or decisions,through building a mathematical model from input data. The data used to build the final model usually comes from multiple datasets. In particular, three data sets are commonly used in different stages of the creation of the model.

The model is initially fit on a **training dataset** that is a set of examples used to fit the parameters of the model. The model is trained on the training dataset using a supervised learning method. In practice, the training dataset often consist of pairs of an input vector and the corresponding answer vector or scalar, which is commonly denoted as the target. The current model is run with the training dataset and produces a result, which is then compared with the target, for each input vector in the training dataset. Based on the result of the comparison and the specific learning algorithm being used, the parameters of the model are adjusted. The model fitting can include both variable selection and parameter estimation.

Successively, the fitted model is used to predict the responses for the observations in a second dataset called the **validation dataset**. The validation dataset provides an unbiased evaluation of a model fit on the training dataset while tuning the model's hyperparameters. Validation datasets can be used for regularization by early stopping: stop training when the error on the validation dataset increases, as this is a sign of overfitting to the training dataset. This simple procedure is complicated in practice by the fact that the validation dataset's error may fluctuate during training, producing multiple local minima. This complication has led to the creation of many ad-hoc rules for deciding when over fitting has truly begun.

Finally, the **test dataset** is a dataset used to provide an unbiased evaluation of a final model fit on the training dataset. When the data in the test dataset has never been used in training, the test dataset is also called a **holdout dataset**. Learning the parameters of a prediction function and testing it on the same data is a methodological mistake: a model that would just repeat the labels of the samples that it has just seen would have a perfect score but would fail to predict anything useful

on yet-unseen data. This situation is called **overfitting**. To avoid it, it is common practice when performing a (supervised) machine learning experiment to hold out part of the available data as a **test dataset X_test, y_test** Note that the word "experiment" is not intended to denote academic use only, because even in commercial settings machine learning usually starts out experimentally.

In scikit-learn a random split into training and test sets can be quickly computed with the **train_test_split** helper function.

We can now quickly sample a training set while holding out 40% of the data for testing (evaluating) our classifier:
X_train,X_test,y_train,y_test=train_test_split(dataset,target,test_size=0.4,random_state=0)

When evaluating different settings ("hyperparameters") for estimators, such as the (setting that must be manually set for an SVM, there is still a risk of over-fitting on the test setbecause the parameters can be tweaked until the estimator performs optimally. This way, knowledge about the test set can "leak" into the model and evaluation metrics no longer report on generalization

performance. To solve this problem, yet another part of the dataset can be held out as a so-called "validation set": training proceeds on the training set, after which evaluation is done on the validation set, and when the experiment seems to be successful, final evaluation can be done on the test set.

5.2.3 Training classifier

There are many models for machine learning, and each model has its own strengths and weaknesses. In this paper, we will focus on a simple algorithm that usually performs well in binary classification tasks, namely Decision Tree, Random Forest, Support Vector Machine, Voting Classifier, Logistic Regression and K - Nearest Neighbour.

5.3 Perform Prediction

The prediction results have been evaluated using following parameters:

Precision: It is the fraction of retrieved data that are useful for the query.
Recall: It is the fraction of data that are relevant for the query which is effectively retrieved.
F-measure: It is measure that sums up precision and recall.

In this we perform prediction for predicting the dataset which are related to the new document for the future usage. This predicted dataset is used to build a model. That predictive model is then used on current dataset to predict what will happen next or to suggest actions to take for optimal outcomes.

5.4 Accuracy Calculations

Using classifications algorithms to fit the predicted data, this would run our data over the current data and gives us the accuracy of the classification. The classification.
Accuracy is the ratio of number of correct predictions to the total number of input samples.

Accuracy = Number of correct predictions / Total number of predictions made

6. EVALUATION OF RESULTS

6.1 Testing

Testing is the process of finding differences between the expected behavior specified by system models and the observed behavior of the system.

Verification and Validation encompass a wide range of software quality assurance(SQA) activities that include formal, technical review and quality and configuration audits, performance monitoring, simulation, feasibility study, documentation, review algorithm analysis, development testing, qualification testing and installation testing.

Verification

Verification is the fundamental concept in the software design. Verification refer in the set of activities that ensure the software correctly implement a specification function validation refer to a different set of activities that ensure that software that has been built in traceable customer. Validation is nothing but the process of using software in live environment in order to find errors verification is typically done in two steps.

- Verification of the requirement verification that the software requirement definition satisfies the customer needs.

- Verification of the design: verification that the design satisfies the requirement definition.

Software reviews are one of the most important SQA activities. Review serves as a filter for the software process, removing errors while they are relatively inexpensive to find and correct. To properly verify a system, data about engineering process should be collect, eventually and disseminated,SQA helps to improve the quality of the product and the software procedure.

Testing Concepts
i.   A component is a part of the system that can be isolated for testing. A component can be an object, a group of objects, or one or more subsystems.
ii. A fault, also called bug or defect, is a design or coding mistake that may cause abnormal component behavior.
iii. An error is a manifestation of a fault during the execution of the system.
iv. A failure is a deviation between the specification of a cosmponent and its behavior. A failure is triggered by one or more errors.
v.   A test case is a set of inputs and expected results that exercise a component with the purpose of causing failures and detecting faults.

Testing Methodology

Testing is a process, which reveals in the program. It is the condition known as text cased and the major quality measure employed during software development. During testing, the program is executed with set of condition known as text cased and output evaluated to determine whether the program is performing as expected. In order to make sure that the system does not contain error, the different levels of testing strategies that are applied at different levels of testing strategies that are applied at different phases of software development are:

White Box Testing

In this, test cases are generated on the logic of each module by drawing flow graph of that module and logical decision are tested on all the cases. While white-box testing can be applied at the unit, integration and system levels of the software testing process, it is usually done at the unit level. It can test paths within a unit, paths between units during integration, and between subsystems during a system-level test.

- Guarantee that all independent paths have been executed.
- Execute all logic decision on their true and false sides.
- Execute all loops at their boundaries and within their operational bounds.
- Execute internal data structures to ensure their validity.

Black Box Testing

In this strategy, some test cases are generated as input condition that execute all function requirement for the program this testing has been uses to find error in the following categories:

- Incorrect or missing function
- Interface errors
- Error in data structure or external database access
- Performance
- Initialization

In this testing the output is checked for correctness and the logical flow of the data is not checked.

Unit Testing

Unit Testing is done on individual modules are they are completed and become executable. It is confined only to the designer requirement. A unit is the smallest testable part of software. It usually has one or a few inputs and usually a single output. In procedural programming a unit may be an individual program, function, procedure, etc.

Integration Testing

Integration testing ensures that software and subsystem work together as whole. It tests the interface of the entire module to make behave properly when integrated together.

Compilation Testing

It was a good idea to do our stress early on,because it gave us time to fix some unexpected deadlocks and stability problem that only occurred when components were exposed to very high transaction volumes.

Output Testing

The next step is output testing of the proposed system since no system would be termed as useful until it does produce the required output in the specified format. Output format is considered in two ways:

- ✓ Screen format
- ✓ Printer format

Acceptance Testing

User Acceptance Testing is a critical phase of any project and requires significant participation by the end user. It also ensures that the system meets the functional requirements. The acceptance test suite may need to be performed multiple times, as all of the test cases may not be executed within a single test iteration.

The acceptance test suite is run using predefined acceptance test procedures to direct the testers which data to use, the step-by-step processes to follow and the expected result following execution. The actual results are retained for comparison with the expected results. If the actual results match the expected results for each test case, the test case is said to pass.

The anticipated result of a successful test execution:

- Test cases are executed, using predetermined data

- Actual results are recorded

- Actual and expected results are compared, and Test results are determined.

Recovery Testing

Recovery testing is a type of non-functional testing technique performed in order to determine how quickly the system can recover after it has gone through system crash or hardware failure. Recovery testing is the forced failure of the software to verify if the recovery is successful. Recovery testing should not be confused with reliability testing, which tries to discover the specific point at which failure occurs.

Security Testing

Security testing is a process intended to reveal flaws in the security mechanisms of an information system that protect data and maintain functionality as intended. Due to the logical limitations of security testing, passing security testing is not an indication that no flaws exist or that the system adequately satisfies the security requirements.

System Testing

Involves in-housing testing of entire system before delivery to the user. It's aim is to satisfy the user, the system meet all requirement of the clients specification.

This testing is a series of different tests whose primary is to fully exercise the computer-based system. This involves:

- Implementing the system in a simulated production environment and testing it.
- Introducing errors and testing for error handling.
- Usability testing.
- Software performance testing.
- Exception handling testing.

Performance Testing

Performance testing is the process of determining the speed or effectiveness of a computer, network, software program or device. This process can involve quantitativetests done in a lab, such as measuring the response time or the number of MIPS (millions of instructions per second) at which a system functions.

Validation Testing

The system has been tested and implemented successfully and thus ensured that all requirement are listed in the software requirement specification are completely fulfilled. In case of erroneous input corresponding error message are displayed.

Executive Testing

This program was successfully loaded and executed, because of good programming there no execution errors.

Activities undertaken using Integration and System Testing

It involves testing of integrating various modules and testing their overall performance due to their integration. Integration of different modules is undertaken once they

have been coded and unit tested. During the integration and system testing phase, the modules are integrated in a planned manner and the goal of system testing is to ensure that the developed system conforms to its requirements laid out in the SRS document. System testing usually consists of three different kinds of testing activities:

- α – testing: It is the system testing performed by the development team.

- β – Testing: It is the system testing performed by a friendly set of customers.

- acceptance testing: It is the system testing performed by the customer himself after the

  product delivery to determine whether to accept or reject the delivered product. System testing is normally carried out in a planned manner according to the system test and document.

TEST CASES

S.No	Test case	Requirement Specification	Expected Ouput	Observed Output	Status P=pass F=fail
1.	Login with correct details	RS1	The user should login	The user will login	Pass
2.	Login with wrong details	RS2	The user should not login	The user will not login	Fail
3.	If the algorithm exists	RS3	The process should run on the basis of algorithm	The process will run and will show data result	Pass
4.	If the algorithm is not in proper format	RS4	It should not generate data	It will not generate data and will not show proper output	Fail
5.	By providing other than numerical format	RS5	It should not process for next	It will not process and shows error	Fail
6.	Providing valid data	RS6	It should process for next	It will generate and process data	Pass

6.2 Source Code

Importing the packages -

```
import pandas as pd
import numpy as np
import matplotlib as plt
import seaborn as sns

import numpy
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
from sklearn import preprocessing
%matplotlib inline
import warnings
warnings.filterwarnings('ignore')
from sklearn import metrics
```

Data Exploration -

```
df = pd.read_csv("kidney_disease.csv")
df.head()
```

	id	age	bp	sg	al	su	rbc	pc	pcc	ba	...	pcv	wc	rc	htn	dm	cad	appet	pe	ane	classification
0	0	48.0	80.0	1.020	1.0	0.0	NaN	normal	notpresent	notpresent	...	44	7800	5.2	yes	yes	no	good	no	no	ckd
1	1	7.0	50.0	1.020	4.0	0.0	NaN	normal	notpresent	notpresent	...	38	6000	NaN	no	no	no	good	no	no	ckd
2	2	62.0	80.0	1.010	2.0	3.0	normal	normal	notpresent	notpresent	...	31	7500	NaN	no	yes	no	poor	no	yes	ckd
3	3	48.0	70.0	1.005	4.0	0.0	normal	abnormal	present	notpresent	...	32	6700	3.9	yes	no	no	poor	yes	yes	ckd
4	4	51.0	80.0	1.010	2.0	0.0	normal	normal	notpresent	notpresent	...	35	7300	4.6	no	no	no	good	no	no	ckd

5 rows × 26 columns

```
df.shape
(400, 26)
```

Data Preprocessing -

```
columns_to_retain = ["sg", "al", "sc", "hemo",
                "pcv", "wbcc", "rbcc", "htn", "classification"]
```

#columns_to_retain = df.columns, Drop the columns that are not in columns_to_retain
df = df.drop([col for col in df.columns if not col in columns_to_retain], axis=1)

 # Drop the rows with na or missing values
df = df.dropna(axis=0)
from sklearn.preprocessing import LabelEncoder, MinMaxScaler
for column in df.columns:
    if df[column].dtype == np.number:
        continue
    df[column] = LabelEncoder().fit_transform(df[column])

df.head()

	sg	al	sc	hemo	pcv	htn	classification
0	1.020	1.0	1.2	15.4	28	1	0
1	1.020	4.0	0.8	11.3	22	0	0
2	1.010	2.0	1.8	9.6	15	0	0
3	1.005	4.0	3.8	11.2	16	1	0
4	1.010	2.0	1.4	11.6	19	0	0

Data Visualisation -

import itertools
from itertools import zip_longest
columns=df.columns[:13]
plt.subplots(figsize=(18,15))
length=len(columns)
for i,j in itertools.zip_longest(columns,range(length)):
    plt.subplot((length/2),3,j+1)
    plt.subplots_adjust(wspace=0.2,hspace=0.5)
    df[i].hist(bins=20,edgecolor='black')
    plt.title(i)

plt.show()
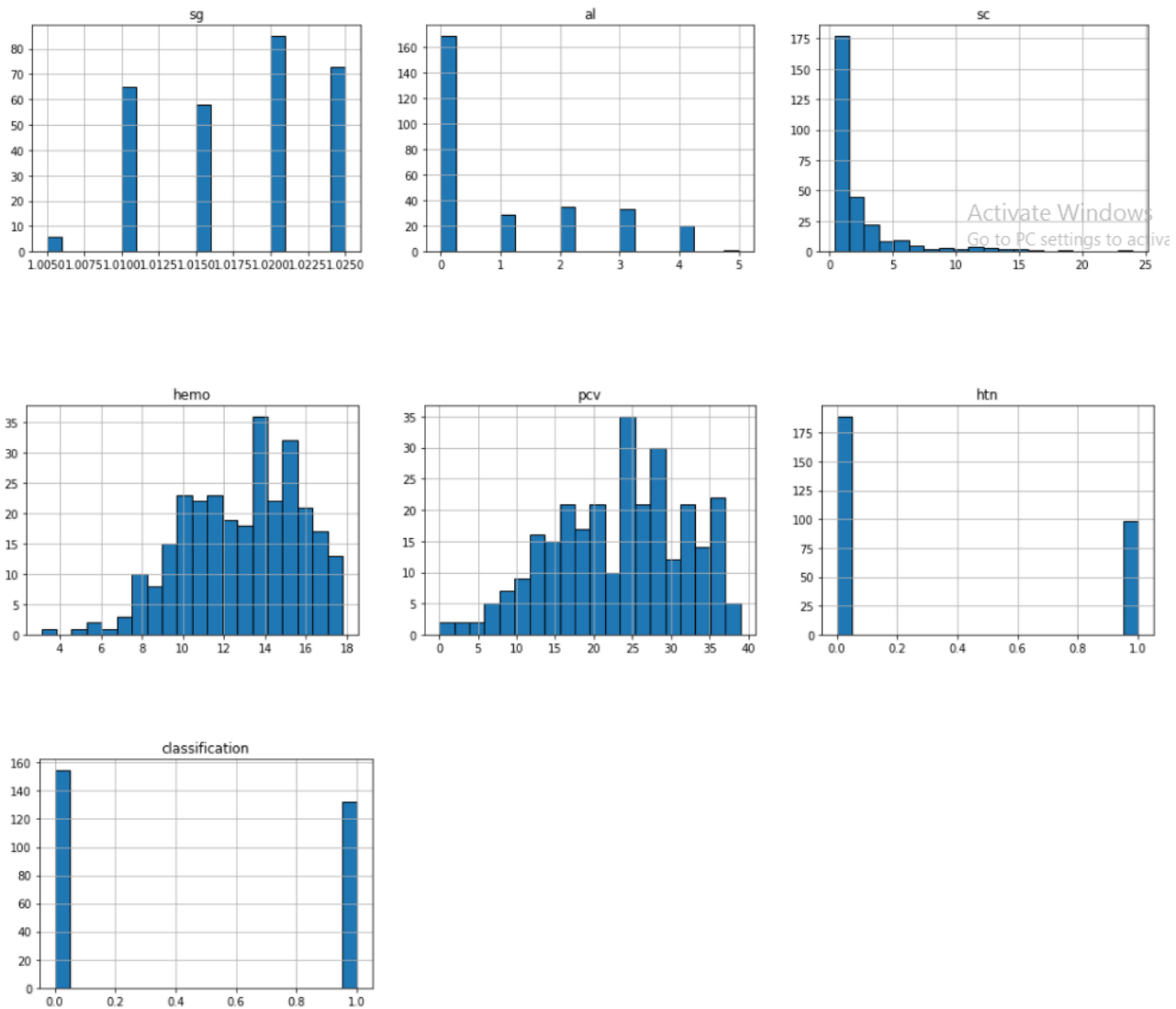
Figure 12: Data Visualization Graphs

Analysis of outcome -

```
pima1=df[df['classification']==1]
columns=df.columns[:5]
plt.subplots(figsize=(18,15))
length=len(columns)
for i,j in itertools.zip_longest(columns,range(length)):
    plt.subplot((length/2),3,j+1)
    plt.subplots_adjust(wspace=0.2,hspace=0.5)
```

```
pima1[i].hist(bins=20,edgecolor='black')
    plt.title(i)
plt.show()

df.plot(kind= 'box' , subplots=True, layout=(3,5),figsize=(14,10))

df['classification'].value_counts().plot(kind='bar', figsize=(6,6))
plt.title('Chronic Kidney Disease  - Outcome')
plt.xlabel('Target')
plt.ylabel('Frequency')
plt.show()
```
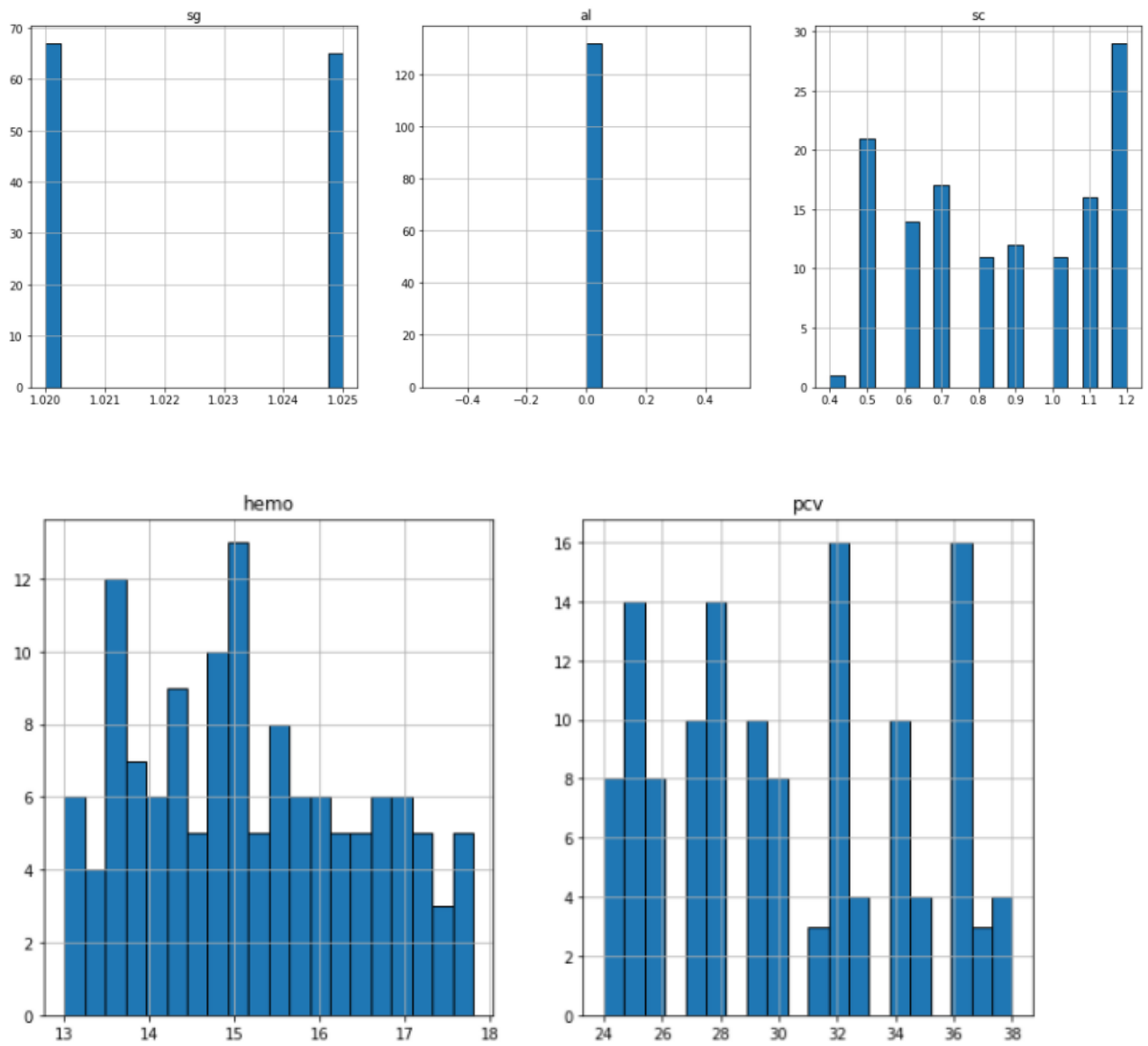

Figure 13 : Analysis Graphs

df.plot(kind= 'box' , subplots=True, layout=(3,5),figsize=(14,10))

```
sg                 AxesSubplot(0.125,0.657941;0.133621x0.222059)
al                 AxesSubplot(0.285345,0.657941;0.133621x0.222059)
sc                  AxesSubplot(0.44569,0.657941;0.133621x0.222059)
hemo               AxesSubplot(0.606034,0.657941;0.133621x0.222059)
pcv                AxesSubplot(0.766379,0.657941;0.133621x0.222059)
htn                  AxesSubplot(0.125,0.391471;0.133621x0.222059)
classification     AxesSubplot(0.285345,0.391471;0.133621x0.222059)
dtype: object
```
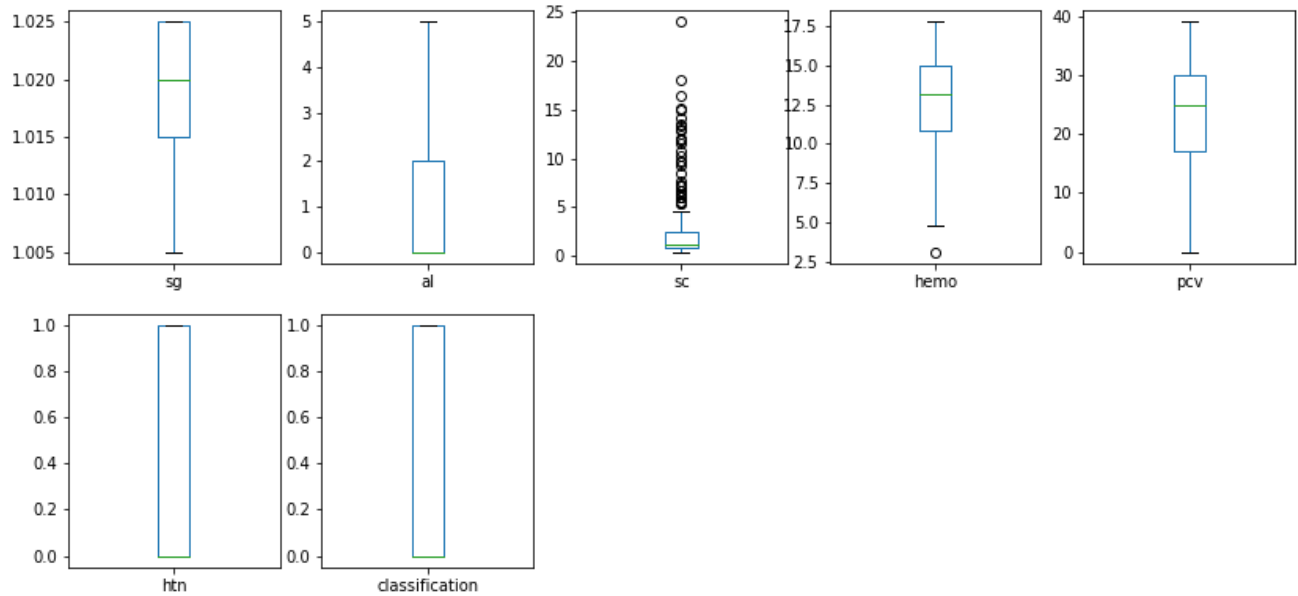

df['classification'].value_counts().plot(kind='bar', figsize=(6,6))
plt.title('Chronic Kidney Disease - Outcome')
plt.xlabel('Target')
plt.ylabel('Frequency')

plt.show()

Chronic Kidney Disease - Outcome
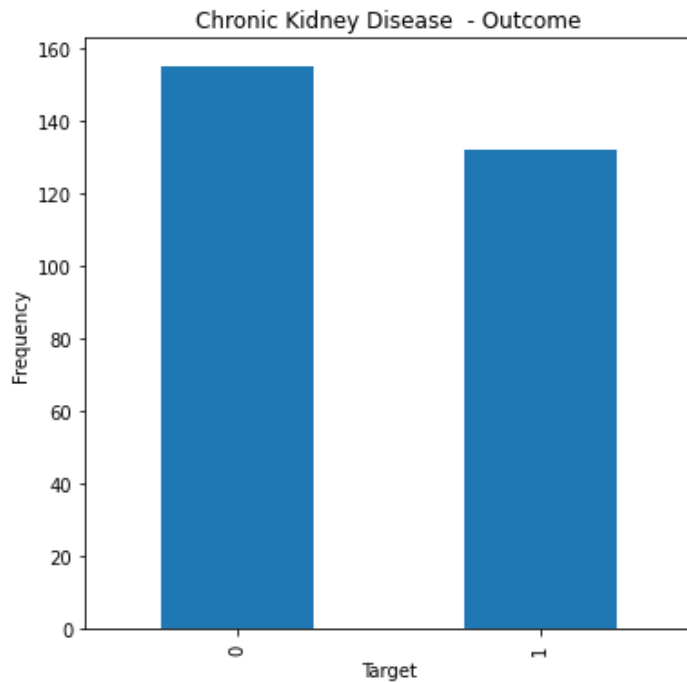
Machine Learning Algorithms -

```
from sklearn.preprocessing import MinMaxScaler
from sklearn.metrics import confusion_matrix,classification_report
from sklearn.model_selection import cross_val_score
from sklearn.metrics import classification_report
from sklearn.metrics import confusion_matrix
from sklearn.metrics import accuracy_score
from sklearn.model_selection import train_test_split
```

#Split the data into independent'X'(the features) and dependent 'y' variables (the target)
```
X = df.drop(["classification"], axis=1)
y = df["classification"]

x_scaler = MinMaxScaler()
x_scaler.fit(X)
column_names = X.columns
X[column_names] = x_scaler.transform(X)
```

#Split the data into 80% training and 20% testing & Shuffle the data before splitting
X_train, X_test, y_train, y_test = train_test_split(
      X, y, test_size= 0.2, shuffle=True)

Support Vector Machine -

```
from sklearn.svm import SVC
SVM = SVC()
SVM.fit(X_train, y_train)
predictions = SVM.predict(X_test)
val1 = (accuracy_score(y_test, predictions)*100)
print("*Accuracy score for SVM: ", val1, "\n")
print("*Confusion Matrix for SVM: ")
print(confusion_matrix(y_test, predictions))
print("*Classification Report for SVM: ")
print(classification_report(y_test, predictions))
```

```
 *Accuracy score for SVM:   100.0

 *Confusion Matrix for SVM:
 [[33  0]
  [ 0 25]]
 *Classification Report for SVM:
               precision    recall  f1-score   support

            0       1.00      1.00      1.00        33
            1       1.00      1.00      1.00        25

     accuracy                           1.00        58
    macro avg       1.00      1.00      1.00        58
 weighted avg       1.00      1.00      1.00        58
```

Random Forest Classifier -

```
from sklearn.ensemble import RandomForestClassifier
RF = RandomForestClassifier()
RF.fit(X_train, y_train)
predictions = RF.predict(X_test)
val2 = (accuracy_score(y_test, predictions)*100)
print("*Accuracy score for RF: ", val2, "\n")
print("*Confusion Matrix for RF: ")
print(confusion_matrix(y_test, predictions))
```

```
print("*Classification Report for RF: ")
print(classification_report(y_test, predictions))
```

```
 *Accuracy score for RF:  100.0

 *Confusion Matrix for RF:
 [[33  0]
  [ 0 25]]
 *Classification Report for RF:
               precision    recall  f1-score   support

            0       1.00      1.00      1.00        33
            1       1.00      1.00      1.00        25

     accuracy                           1.00        58
    macro avg       1.00      1.00      1.00        58
 weighted avg       1.00      1.00      1.00        58
```

Decision Tree Classifier -

```
from sklearn.tree import DecisionTreeClassifier
DT = DecisionTreeClassifier()
DT.fit(X_train, y_train)
predictions = DT.predict(X_test)
val3 = (accuracy_score(y_test, predictions)*100)
print("*Accuracy score for DT: ", val3, "\n")
print("*Confusion Matrix for DT: ")
print(confusion_matrix(y_test, predictions))
print("*Classification Report for DT: ")
print(classification_report(y_test, predictions))
```

```
 *Accuracy score for DT:  100.0

 *Confusion Matrix for DT:
 [[33  0]
  [ 0 25]]
 *Classification Report for DT:
               precision    recall  f1-score   support

            0       1.00      1.00      1.00        33
            1       1.00      1.00      1.00        25

     accuracy                           1.00        58
    macro avg       1.00      1.00      1.00        58
 weighted avg       1.00      1.00      1.00        58
```

K-Nearest Neighbour Classifier -

```
from sklearn.neighbors import KNeighborsClassifier
KNN = KNeighborsClassifier()
KNN.fit(X_train, y_train)
predictions = KNN.predict(X_test)
val4 = (accuracy_score(y_test, predictions)*100)
print("*Accuracy score for KNN: ", val4, "\n")
print("*Confusion Matrix for KNN: ")
print(confusion_matrix(y_test, predictions))
print("*Classification Report for KNN: ")
print(classification_report(y_test, predictions))
```

```
*Accuracy score for KNN:  100.0

*Confusion Matrix for KNN:
[[33  0]
 [ 0 25]]
*Classification Report for KNN:
              precision    recall  f1-score   support

           0       1.00      1.00      1.00        33
           1       1.00      1.00      1.00        25

    accuracy                           1.00        58
   macro avg       1.00      1.00      1.00        58
weighted avg       1.00      1.00      1.00        58
```

Logistic Regression -

```
from sklearn.linear_model import LogisticRegression
LR = LogisticRegression()
LR.fit(X_train, y_train)
predictions = LR.predict(X_test)
val5 = (accuracy_score(y_test, predictions)*100)
print("*Accuracy score for LR: ", val5, "\n")
print("*Confusion Matrix for LR: ")
print(confusion_matrix(y_test, predictions))
print("*Classification Report for LR: ")
print(classification_report(y_test, predictions))
```

```
*Accuracy score for LR:  98.27586206896551

*Confusion Matrix for LR:
[[32  1]
 [ 0 25]]
*Classification Report for LR:
              precision    recall  f1-score   support

           0       1.00      0.97      0.98        33
           1       0.96      1.00      0.98        25

    accuracy                           0.98        58
   macro avg       0.98      0.98      0.98        58
weighted avg       0.98      0.98      0.98        58
```

Voting classifier -

```
from sklearn.ensemble import VotingClassifier
from sklearn.linear_model import LogisticRegression
from sklearn.svm import SVC
from sklearn.tree import DecisionTreeClassifier
estimator = []
estimator.append(('LR',
          LogisticRegression(solver ='lbfgs',
                     multi_class ='multinomial',
                     max_iter = 200)))
estimator.append(('SVC', SVC(gamma ='auto', probability = True)))
estimator.append(('DTC', DecisionTreeClassifier()))
vot_hard = VotingClassifier(estimators = estimator, voting ='hard')
vot_hard.fit(X_train, y_train)
predictions = vot_hard.predict(X_test)
val6 = (accuracy_score(y_test, predictions)*100)
print("*Accuracy score for Voting Classifier: ", val6, "\n")
print("*Confusion Matrix for Voting CLassifier: ")
print(confusion_matrix(y_test, predictions))
print("*Classification Report for Voting Classifier: ")
print(classification_report(y_test, predictions))
```

```
*Accuracy score for Voting Classifier:  98.27586206896551

*Confusion Matrix for Voting CLassifier:
[[32  1]
 [ 0 25]]
*Classification Report for Voting Classifier:
              precision    recall  f1-score   support

           0       1.00      0.97      0.98        33
           1       0.96      1.00      0.98        25

    accuracy                           0.98        58
   macro avg       0.98      0.98      0.98        58
weighted avg       0.98      0.98      0.98        58
```

```
from sklearn import metrics
cm = metrics.confusion_matrix(y_test, predictions)
plt.imshow(cm, cmap=plt.cm.Blues)
plt.xlabel("Predicted labels")
plt.ylabel("True labels")
plt.xticks([], [])
plt.yticks([], [])
plt.title('Confusion matrix ')
plt.colorbar()
plt.show()
```


Confusion matrix
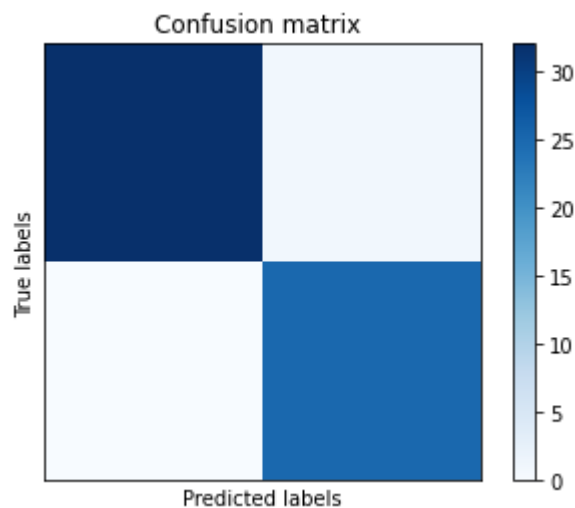
Accuracy Comparison -

```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
```

 # Bring some raw data.
```
frequencies = [val1,val2,val3,val4,val5,val6]
freq_series = pd.Series(frequencies)
x_labels = ['SVM', 'RF','DT','KNN','LR','Voting Classifier']
```

 # Plot the figure.
```
plt.figure(figsize=(12, 8))
ax = freq_series.plot(kind='bar')
ax.set_title('Evaluation of ML & DL')
ax.set_xlabel('Classifier!')
ax.set_ylabel('Accuracy Range')
ax.set_xticklabels(x_labels)

def add_value_labels(ax, spacing=5):
    """Add labels to the end of each bar in a bar chart.

    Arguments:
        ax (matplotlib.axes.Axes): The matplotlib object containing the axes
            of the plot to annotate.
        spacing (int): The distance between the labels and the bars.
    """
```
 # For each bar: Place a label
```
    for rect in ax.patches:
        # Get X and Y placement of label from rect.
        y_value = rect.get_height()
        x_value = rect.get_x() + rect.get_width() / 2
```

 # Number of points between bar and label.
```
 space = spacing
```

 # Vertical alignment for positive values
```
        va = 'bottom'
```

 # If value of bar is negative: Place label below bar
```
        if y_value < 0:
            # Invert space to place label below
            space *= -1
            # Vertically align label at top
            va = 'top'
```

 # Use Y value as label and format number with one decimal place
    label = "{:.1f}".format(y_value)

 # Create annotation
    ax.annotate(
        label,   # Use `label` as label
        (x_value, y_value),   # Place label at end of the bar
        xytext=(0, space),   # Vertically shift label by `space`
        textcoords="offset points", # Interpret `xytext` as offset in points
        ha='center',   # Horizontally center label
        va=va)   # Vertically align label differently for
                        # positive and negative values.

 # Call the function above.
add_value_labels(ax)
plt.show()
#plt.savefig("image.png")
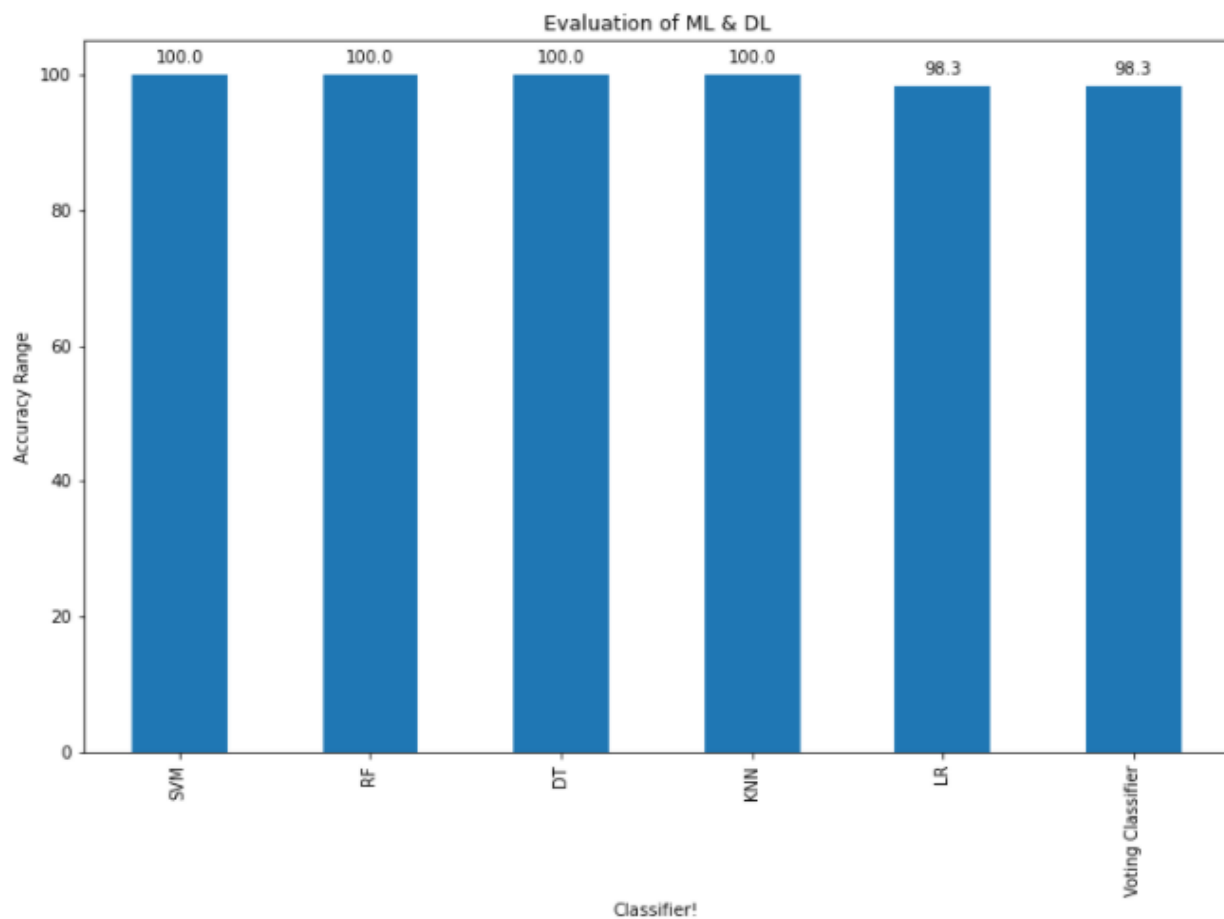
Figure 14 : Accuracy Comparison

Html code

```html
<!doctype html>
<html lang="en">
 <head>
   <!-- Required meta tags -->
   <meta charset="utf-8">
   <meta name="viewport" content="width=device-width, initial-scale=1, shrink-to-fit=no">
 <link rel="icon" href="../static/img/health.ico">
   <!-- Bootstrap CSS -->
   <link href="https://fonts.googleapis.com/css2?family=Josefin+Sans" rel="stylesheet">
   <link rel="stylesheet"
href="https://stackpath.bootstrapcdn.com/bootstrap/4.3.1/css/bootstrap.min.css" integrity="sha384-
ggOyR0iXCbMQv3Xipma34MD+dH/1fQ784/j6cY/iJTQUOhcWr7x9JvoRxT2MZw1T"
crossorigin="anonymous">
   <style>
   *{
   margin:0;
   padding:0;
   font-family: 'Josefin Sans', sans-serif;
   }
   html,
   body,
   header,
   #intro {
   height: 100%;
   }
   img {
   display: block;
   max-width: 100%;
   height: auto;
   }
   </style>
   <title>Kidney-AI</title>
 </head>
 <body>
   <header>
    <nav class="navbar navbar-expand-md navbar-dark bg-dark">
     <a class="navbar-brand" href="/home">Chronic Kidney Disease</a>
     <button class="navbar-toggler" type="button" data-toggle="collapse" data-
target="#navbarCollapse" aria-controls="navbarCollapse" aria-expanded="false" aria-
label="Toggle navigation">
```

```
      <span class="navbar-toggler-icon"></span>
    </button>
    <a style="margin-left: 65%;" class="navbar-brand" href="/about">About</a>
    <a class="navbar-brand" href="/data">Data</a>
    <a class="navbar-brand" href="/login">Sign-Out</a>
  </nav>
  <!--Mask-->
  <div id="intro" class="container-fluid view ">
    <h1 class="text-center text-capitalize pt-5">Kidney Failure Prediction Using Machine
Learning!</h1>
    <h2 class="text-center text-capitalize pt-5">Please fill up the following information!!</h2>
    <hr class="w-75 mx-auto pt-5">
    <div class="row mb-5">
      <div class="col-lg-6 col-md-6 col-12 my-auto">
        <img style="margin-top: -28%;margin-left: 15%; width: 250px;"
src="../static/images/2.jpeg" class="float-left">
        <hr class="w-75 mx-auto pt-5">
        <h1> {{ prediction_text }}</h1>
      </div>
      <div class="col-lg-6 col-md-6 col-12">
        <form action="{{ url_for('predict4')}}" method="post">
          <div class="form-group">
            <!-- TODO : Year to accept only year date picker -->
            <label for="sg">Specific Gravity</label>
            <input class="form-control" type="float" id="sg" name="sg" required="required"
placeholder="sg">
          </div>
          <div class="form-group">
            <label for="Glucose">Albumin</label>
            <input class="form-control" type="float" step="any" id="Glucose"
name="Present_Price" required="required" placeholder="Albumin">
          </div>
          <div class="form-group">
            <label for="BloodPressure">Serum Creatinine</label>
            <input class="form-control" type="float" id="BloodPressure" name="BloodPressure"
required="required" placeholder="Serum Creatinine">
          </div>
          <div class="form-group">
            <label for="Smoking">Hemoglobin</label>
            <input class="form-control" type="float" id="Smoking" name="Smoking"
required="required" placeholder="Hemoglobin">
```

```html
          </div>
        <div class="form-group">
          <label for="Alcohol">Packed Cell Volume</label>
          <input class="form-control" type="number" id="Alcohol" name="Alcohol"
required="required" placeholder="pcv">
        </div>
        <div class="form-group">
          <label for="BMI">Hypertension</label>
          <input class="form-control" type="number" id="BMI" name="BMI"
required="required" placeholder="1 or 0">
        </div>
        <button type="submit" class="btn btn-danger">Predict</button>
      </form>
    </div>
   </div>
  </div>
  <!--/.Mask-->
 </header>
 <script src='https://kit.fontawesome.com/a076d05399.js'></script>
 <!-- Optional JavaScript -->
 <!-- jQuery first, then Popper.js, then Bootstrap JS -->
 <script src="https://code.jquery.com/jquery-3.3.1.slim.min.js" integrity="sha384-
q8i/X+965DzO0rT7abK41JStQIAqVgRVzpbzo5smXKp4YfRvH+8abtTE1Pi6jizo"
crossorigin="anonymous"></script>
 <script src="https://cdnjs.cloudflare.com/ajax/libs/popper.js/1.14.7/umd/popper.min.js"
integrity="sha384-
UO2eT0CpHqdSJQ6hJty5KVphtPhzWj9WO1clHTMGa3JDZwrnQq4sF86dIHNDz0W1"
crossorigin="anonymous"></script>
 <script src="https://stackpath.bootstrapcdn.com/bootstrap/4.3.1/js/bootstrap.min.js"
integrity="sha384-
JjSmVgyd0p3pXB1rRibZUAYoIIy6OrQ6VrjIEaFf/nJGzIxFDsf4x0xIM+B07jRM"
crossorigin="anonymous"></script>

 </body>
</html>
```

6.3 Results

We can login to the portal using the existing credentials

If we do not have the credentials to login, then we can register first to the portal

After login, we can see the details regarding biotic values

Data regarding the disease

We can enter our respective biotic values in the textfields and the model can predict if we are suffering with the CKD or not.

7. CONCLUSION

This project presented a prediction algorithm to predict CKD at an early stage. The dataset shows input parameters collected from the CKD patients and the models are trained and validated for the given input parameters. Decision tree, Random Forest, KNN, Linear Regression and Support Vector Machine, Voting Classifier learning models are constructed to carry out the diagnosis of CKD.The performance of the models are evaluated based on the accuracy of prediction. The results of the research showed that SVM, Decision Tree, KNN, Random Forest Classifier model better predicts CKD in comparison to other algorithms. The comparison can also be done based on the time of execution, feature set selection as the improvisation of this research. The data distribution has properly covered the whole domain in CKD, but the general attributes like appetite, anaemia and pedal oedema are biased towards CKD. It is easy to achieve an accurate prediction using this data set but in the general context, it may lead to false positives as observed in the recall column. Further, the missing values which were completely missed at random made it impossible to achieve a perfect accuracy without filling them from a collaborative imputer instead of a constant.

Considering the medical importance of the attributes, some of them have a lesser co-relation compared to others because of the stage they appear in the patient. When training the models it makes a huge impact on the accuracy. After training the model, it clearly shows that tree structures have higher accuracy than other classification algorithms, which can be justified from the distribution of the data set since the selected attributes have a clearer separation in the class except for serum creatinine attribute. Finally, when selecting the algorithm, some trained models have a bias towards some. Considering the causes of change of the nominal values of them, it has many different possibilities apart from CKD. Therefore, it motivates to rely less on one attribute and consider more when making the decision and based on that the extra tree classifier has been selected.

Future Scope

We aim to validate our results by using big dataset or compare the results using another dataset that contains the same features. Also, in order to help in reducing the prevalence of CKD, we plan to predict if a person with CKD risk factors such as diabetes, hypertension, and family history of kidney failure will have CKD in the future or not by using appropriate dataset. In the future course of this study one can try to further improve the two-class classification accuracy by evaluating some hybrid or ensemble techniques, in addition to this a subset of features can be extracted from the complete medical data-set of chronic kidney disease of twenty four parameters (features) without effecting the performance of the classification process, so that the financial burden a patient has to bear for undergoing various clinical tests can be reduced.

References

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SEMANTIC - BASED COMPOUND KEYWORD
SEARCH OVER ENCRYPTED CLOUD DATA

A Project Report submitted in partial fulfillment of the requirements for the award of the Degree of

MASTERS OF TECHNOLOGY

IN

COMPUTER SCIENCE AND ENGINEERING

Submitted by

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Under the Esteemed Guidance of
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DADI INSTITUTE OF ENGINEERING & TECHNOLOGY

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NH-5, Anakapalle-531002, Visakhapatnam, A.P.

2021

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CERTIFICATE

This is to certify that the Project work entitled "Semantic-Based Compound Keyword Search Over Encrypted Cloud Data" is being submitted by P. RADHIKA (19U41D5804) in partial fulfillment of the Requirement for the award of the degree of MASTERS OF TECHNOLOGY for COMPUTER SCIENCE & ENGINEERING during the academic year 2020-2021.

Mr. Challa Narsimham   **Dr. L. PRASANNA KUMAR**

(Assoc. PROFESSOR)   **(PROFESSOR)**

(PROJECT GUIDE)   (HEAD OF THEDEPARTMENT)

EXTERNAL EXAMINER

DECLARATION

I hereby declare that this project work entitled "SEMANTIC – BASED COMPUND KEYWORD SEARCH OVER ENCRYPTED CLOUD DATA" has been carried out by me and contents have been presented in the form are for the award of the degree of MASTERS OF TECHNOLOGY IN COMPUTER SCIENCE AND ENGINEERING. We further declare that this dissertation has not been submitted elsewhere for any Diploma or Degree of University.

.

BY

P.RADHIKA   *(19U41D5804)*

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P. Radhika   *(19U41D5804)*

ABSTRACT

Keyword search over encrypted cloud data is essential for accessing outsourced sensitive data in cloud computing. In some circumstances, the keywords that the user searches on are only semantically related to the data rather than via an exact or fuzzy match. Hence, semantic based keyword search over encrypted cloud data becomes of paramount importance. However, existing schemes usually depends upon a global dictionary, which not only affects the accuracy of search results but also causes inefficiency in data updating. Additionally, although compound keyword search is common in practice, the existing approaches only process them as single words, which split the original semantics and achieve low accuracy. To address these limitations, we initially propose a compound concept semantic similarity (CCSS) calculation method to measure the semantic similarity between compound concepts. Next, by integrating CCSS with Locality-Sensitive Hashing Function and the secure K-Nearest Neighbor scheme, a semantic based compound keyword search(SCKS) scheme is proposed. SCKS achieves not only semantic-based search but also multi-keyword search and ranked keyword search. Additionally, SCKS also eliminates the predefined global library and can efficiently support data update. the experimental results on real world dataset indicate the SCKS introduces low overhead on computation and the search accuracy outperforms the existing
schemes.

KEYWORDS:
Semantic-Based compound keyword search(SCKS), compound concept semantic similarity(CCSS).

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION TO CLOUD COMPUTING:

Cloud computing is the use of computing resources (hardware and software) that are delivered as a service over a network (typically the Internet). The name comes from the common use of a cloud-shaped symbol as an abstraction for

the complex infrastructure it contains in system diagrams. Cloud computing entrusts remote services with a user's data, software and computation. Cloud computing consists of hardware and software resources made available on the Internet as managed third-party services. These services typically provide access to advanced software applications and high-end networks of server computers.
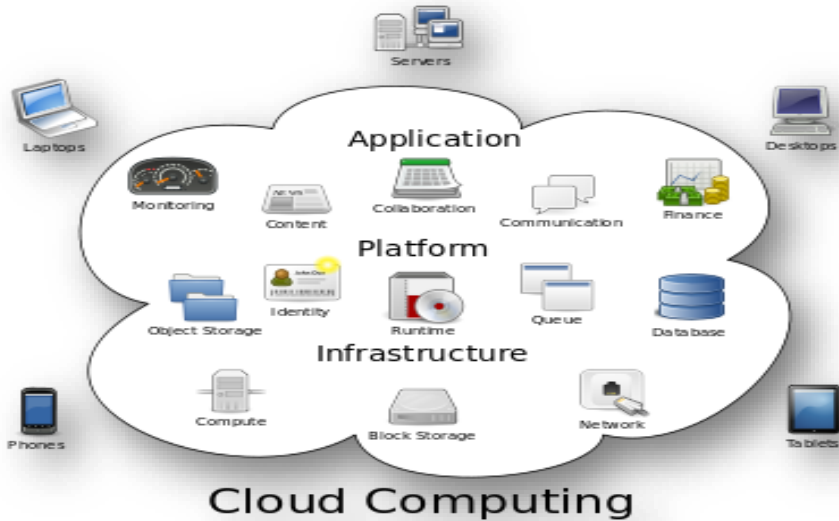
Fig.no.1.1: Structure of cloud computing

1.2 HOW CLOUD COMPUTING WORKS?

The goal of cloud computing is to apply traditional supercomputing, or high-performance computing power, normally used by military and research facilities, to perform tens of trillions of computations per second, in consumer-oriented applications such as financial portfolios, to deliver personalized information, to provide data storage or to power large, immersive computer games.

The cloud computing uses networks of large groups of servers typically running low-cost consumer PC technology with specialized connections to spread data-processing chores across them. This shared IT infrastructure contains large pools of systems that are linked together. Often, virtualization techniques are used to maximize the power of cloud computing.

1.3 CHARACTERSTICS OF CLOUD COMPUTING:

The salient characteristics of cloud computing based on the definitions provided by the National Institute of Standards and Terminology (NIST) are outlined below:

- ❖ **On-demand self-service**: A consumer can unilaterally provision computing capabilities, such as server time and network storage, as needed automatically without requiring human interaction with each service's provider.
- ❖ **Broad network access**: Capabilities are available over the network and accessed through standard mechanisms that promote use by heterogeneous thin or thick client platforms (e.g., mobile phones, laptops, and PDAs).
- ❖ **Resource pooling**: The provider's computing resources are pooled to serve multiple consumers using a multi-tenant model, with different physical and virtual resources dynamically assigned and reassigned according to consumer

demand.There is a sense of location-independence in that the customer generally has no control or knowledge over the exact location of the provided resources but may be able to specify location at a higher level of abstraction (e.g., country, state, or data center). Examples of resources include storage, processing, memory, network bandwidth, and virtual machines.

❖ **Rapid elasticity**: Capabilities can be rapidly and elastically provisioned, in some cases automatically, to quickly scale out and rapidly released to quickly scale in. To the consumer, the capabilities available for provisioning often appear to be unlimited and can be purchased in any quantity at any time.

❖ **Measured service**: Cloud systems automatically control and optimize resource use by leveraging a metering capability at some level of abstraction appropriate to the type of service (e.g., storage, processing, bandwidth, and active user accounts). Resource usage can be managed, controlled, and reported providing transparency for both the provider and consumer of the utilized service.

Fig.no.1.2:characteristics of cloud computing

1.4 SERVICE MODELS:

Cloud Computing comprises three different service models, namely Infrastructure-as-a-Service (IaaS), Platform-as-a-Service (PaaS), and Software-as-a-Service (SaaS). The three service models or layer are completed by an end user layer that encapsulates the end user perspective on cloud services. The model is shown in figure below. If a cloud user accesses services on the infrastructure layer,

for instance, she can run her own applications on the resources of a cloud infrastructure and remain responsible for the support, maintenance, and security of these applications herself. If she accesses a service on the application layer, these tasks are normally taken care of by the cloud service provider.
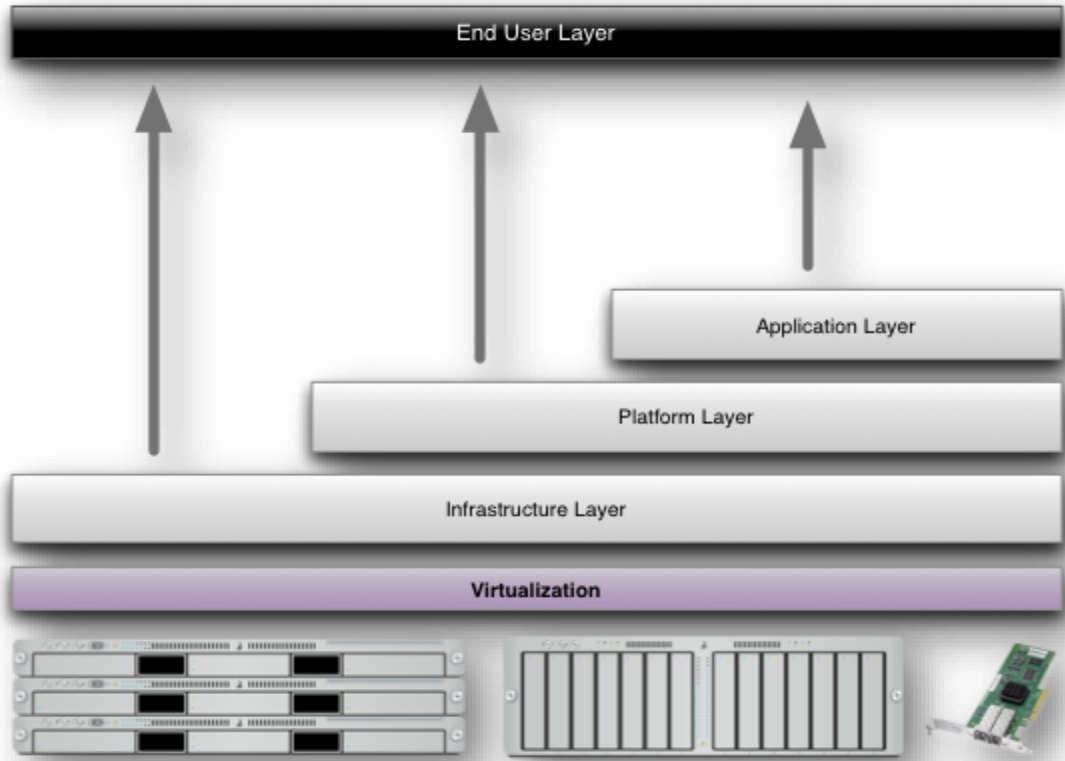
Fig.no.1.3:Structure of service models

1.5 BENEFITS OF CLOUD COMPUTING:

1. **Achieve economies of scale:** increase volume output or productivity with fewer people. Your cost per unit, project or product plummets.
2. **Reduce spending on technology infrastructure:** Maintain easy access to your information with minimal upfront spending. Pay as you go (weekly, quarterly or yearly), based on demand.
3. **Globalize your workforce on the cheap:** People worldwide can access the cloud, provided they have an Internet connection.
4. **Streamline processes:** Get more work done in less time with less people.
5. **Reduce capital costs:** There's no need to spend big money on hardware, software or licensing fees.
6. **Improve accessibility:** You have access anytime, anywhere, making your life so much easier!
7. **Monitor projects more effectively:** Stay within budget and ahead of completion cycle times.
8. **Less personnel training is needed:** It takes fewer people to do more work on a cloud, with a minimal learning curve on hardware and software issues.
9. **Minimize licensing new software:** Stretch and grow without the need to buy expensive software licenses or programs.

10. **Improve flexibility:** You can change direction without serious "people" or "financial" issues at stake.

1.6 ADVANTAGES:

1. **Price:** Pay for only the resources used.
2. **Security**: Cloud instances are isolated in the network from other instances for improved security.
3. **Performance:** Instances can be added instantly for improved performance. Clients have access to the total resources of the Cloud's core hardware.
4. **Scalability:** Auto-deploy cloud instances when needed.
5. **Uptime:** Uses multiple servers for maximum redundancies. In case of server failure, instances can be automatically created on another server.
6. **Control:** Able to login from any location. Server snapshot and a software library lets you deploy custom instances.
7. **Traffic:** Deals with spike in traffic with quick deployment of additional instances to handle the load

CHAPTER 2
LITERATURE

1) Security challenges for the public cloud

Cloud computing represents today's most exciting computing paradigm shift in information technology. However, security and privacy are perceived as primary obstacles to its wide adoption. Here, the author's outline several critical security challenges and motivates further investigation of security solutions for a trustworthy public cloud environment.

2) **A fully homomorphic encryption scheme**

We propose the first fully homomorphic encryption scheme, solving an old open problem. Such a scheme allows one to compute arbitrary functions over encrypted data without the decryption key—i.e., given encryptions $E(m1)$, ..., $E(mt)$ of $m1$, ..., $m\ t$, one can efficiently compute a compact cipher text that encrypts $f(m1, ..., m\ t)$ for any efficiently computable function f.

Fully homomorphic encryption has numerous applications. For example, it enables encrypted search engine queries—i.e., a search engine can give you a succinct encrypted answer to your (Boolean) query without even knowing what your query was. It also enables searching on encrypted data; you can store your encrypted data on a remote server, and later have the server retrieve only files that (when decrypted) satisfy some Boolean constraint, even though the server cannot decrypt the files on its own. More broadly, it improves the efficiency of secure multiparty computation. In our solution, we begin by designing a somewhat homomorphic "boos trappable" encryption scheme that works when the function f is the scheme's down decryption function. We then show how, through recursive self-embedding, boots trappable encryption gives fully homomorphic encryption.

3) Public key encryption with keyword search

We study the problem of searching on data that is encrypted using a public key system. Consider user Bob who sends email to user Alice encrypted under Alice's public key. An email gateway wants to test whether the email contains the keyword "urgent" so that it

could route the email accordingly. Alice, on the other hand does not wish to give the gateway the ability to decrypt all her messages. We define and construct a mechanism that enables Alice to provide a key to the gateway that enables the gateway to test whether the word "urgent" is a keyword in the email without learning anything else about the email. We refer to this mechanism as Public Key Encryption with keyword Search. As another example, consider a mail server that stores various messages publicly encrypted for Alice by others. Using our mechanism Alice can send the mail server a key that will enable the server to identify all messages containing some specific keyword, but learn nothing else. We define the concept of public key encryption with keyword search and give several constructions.

4) Practical techniques for searches on encrypted data

It is desirable to store data on data storage servers such as mail servers and file servers in encrypted form to reduce security and privacy risks. But this usually implies that one has to sacrifice functionality for security. For example, if a client wishes to retrieve only documents containing certain words, it was not previously known how to let the data storage server perform the search and answer the query, without loss of data confidentiality. We describe our cryptographic schemes for the problem of searching on encrypted data and provide proofs of security for the resulting crypto systems. Our techniques have a number of crucial advantages. They are provably secure: they provide provable secrecy for encryption, in the sense that the untrusted server cannot learn anything about the plaintext when only given the ciphertext; they provide query isolation for searches, meaning that the untrusted server cannot learn anything more about the plaintext than the search result; they provide controlled searching, so that the untrusted server cannot search for an arbitrary word without the user's authorization; they also support hidden queries, so that the user may ask the untrusted server to search for a secret word without revealing the word to the server. The algorithms presented are simple, fast (for a document of length n, the encryption and search algorithms only need $O(n)$ stream cipher and block cipher operations), and introduce almost no space and communication overhead, and hence are practical to use today .

5) Privacy preserving keyword searches on remote encrypted data

W e consider the following problem: a user U wants to store his files in an encrypted form on a remote file server S. Later the user U wants to efficiently retrieve some of the encrypted files containing (or indexed by) specific keywords, keeping the keywords themselves secret and not jeopardizing the security of the remotely stored files. For example, a user may want to store old e-mail messages encrypted on a server managed by Yahoo or another large vendor, and later retrieve certain messages while travelling with a mobile device.

In this paper, we offer solutions for this problem under well-defined security requirements. Our schemes are efficient in the sense that no public-key cryptosystem is involved. Indeed, our approach is independent of the encryption method chosen for the remote files. They are also incremental, in that U can submit New files which are secure against previous queries but still searchable against future queries.

CHAPTER 3
EXISTING SYSTEM

❖ A general approach to protect the data confidentiality is to encrypt the data before outsourcing.

❖ Searchable encryption schemes enable the client to store the encrypted data to the cloud and execute keyword search over cipher text domain. So far, abundant works have been proposed under different threat models to achieve various search functionality, such as single keyword search, similarity search, multi-keyword boolean search, ranked search, multi-keyword ranked search, etc. Among them, multi-keyword ranked search achieves more and more attention for its practical applicability. Recently, some *dynamic* schemes have been proposed to support inserting and deleting operations on document collection.

3.1 DISADVANTAGES OF EXISTING SYSTEM:

❖ Huge cost in terms of data usability. For example, the existing techniques on keyword-based information retrieval, which are widely used on the plaintext data, cannot be directly applied on the encrypted data. Downloading all the data from the cloud and decrypt locally is obviously impractical.

❖ Existing System methods not practical due to their high computational overhead for both the cloud sever and user.

CHAPTER 4
PRPOSED SYSTEM

- This paper proposes a secure tree-based search scheme over the encrypted cloud data, which supports multi-keyword ranked search and dynamic operation on the document collection. Specifically, the vector space model and the widely-used "term frequency (TF) × inverse document frequency (IDF)" model are combined in the index construction and query generation to provide multi-keyword ranked search. In order to obtain high search efficiency, we construct a tree-based index structure and propose a "Greedy Depth-first Search" algorithm based on this index tree.

- The secure KNN algorithm is utilized to encrypt the index and query vectors, and meanwhile ensure accurate relevance score calculation between encrypted index and query vectors.

- To resist different attacks in different threat models, we construct two secure search schemes: the basic dynamic multi-keyword ranked search (BDMRS) scheme in the known cipher text model, and the

- Enhanced dynamic multi-keyword ranked search (EDMRS) scheme in the known background model.

4.1 ADVANTAGES OF PROPOSED SYSTEM:

- Due to the special structure of our tree-based index, the proposed search scheme can flexibly achieve sub-linear search time and deal with the deletion and insertion of documents.

- We design a searchable encryption scheme that supports both the accurate multi-keyword ranked search and flexible dynamic operation on document collection.

- Due to the special structure of our tree-based index, the search complexity of the proposed scheme is fundamentally kept to logarithmic. And in practice, the proposed scheme can achieve higher search efficiency by executing our "Greedy Depth-first Search" algorithm.

CHAPTER 5

SOFTWARE REQUIREMENTS

- Operating system : Windows XP.
- Coding Language : Java.
- Data Base : MY SQL.
- IDE : Net Beans.
- Cloud : Drive HQ.
- Server : Apache Tomcat.

CHAPTER 6
SYSTEM
REQUIREMENTS

6.1 SOFTWARE ENVIRONMENT:

The Java programming language is a high-level language that can be characterized by all of the following buzzwords:

- Simple
- Architecture neutral
- Object oriented
- Portable
- Distributed
- High performance
- Interpreted
- Multithreaded
- Robust
- Dynamic
- Secure

With most programming languages, you either compile or interpret a program so that you can run it on your computer. The Java programming language is unusual in that a program is both compiled and interpreted. With the compiler, first you translate a program into an intermediate language called *Java byte codes* —the platform-independent codes interpreted by the interpreter on the Java platform. The interpreter parses and runs each Java byte code instruction on the computer. Compilation happens just once; interpretation occurs each time the program is executed. The following figure illustrates how this works.
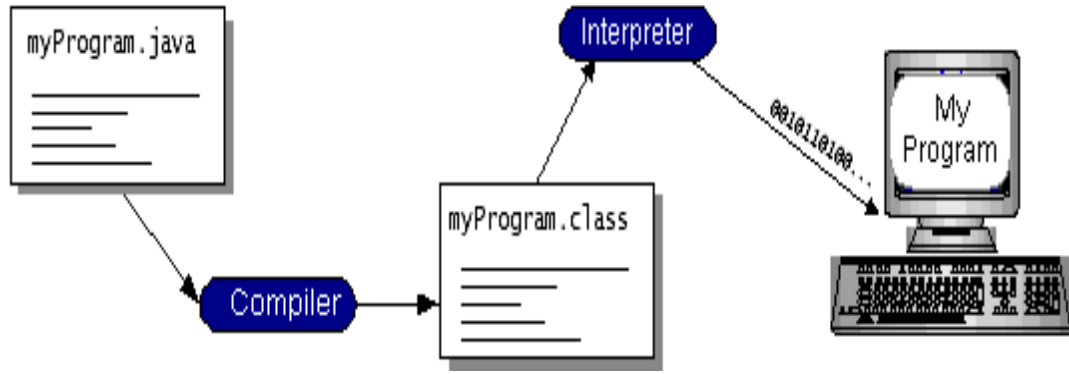
Fig.no.1.4:Architecture Of Java Programing

You can think of Java byte codes as the machine code instructions for the *Java Virtual Machine* (Java VM). Every Java interpreter, whether it's a development tool or a Web browser that can run applets, is an implementation of the Java VM. Java byte codes help make "write once, run anywhere" possible. You can compile your program into byte codes on any platform that has a Java compiler. The byte codes can then be run on any implementation of the Java VM. That means that as long as a computer has a Java VM, the same program written in the Java programming language can run on Windows 2000, a Solaris workstation, or on an iMac.
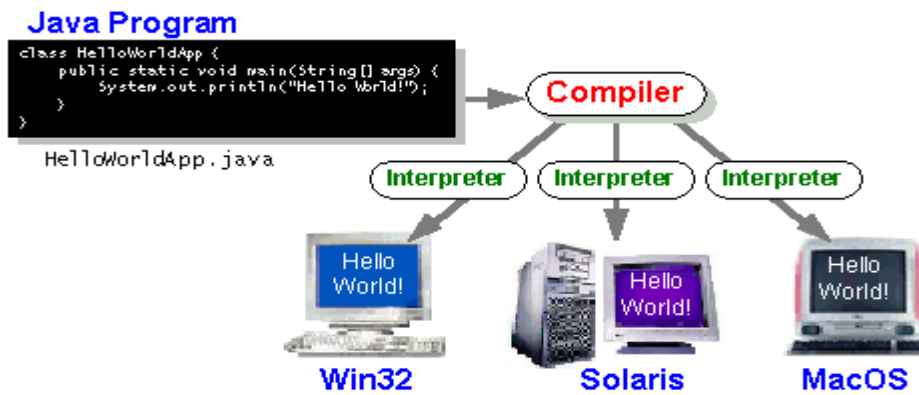
Fig.no.1.5.Detailed Architecture Of JVM

6.2 Tomcat 6.0 web server :

Tomcat is an open source web server developed by Apache Group. Apache Tomcat is the servlet container that is used in the official Reference Implementation for the Java Servlet and Java Server Pages technologies. The Java Servlet and Java Server Pages specifications are developed by Sun under the Java Community Process. Web Servers like Apache Tomcat support only web components while an application server supports web components as well as business components (BEAs Weblogic, is one of the popular application server).To develop a web application with jsp/servlet install any web server like JRun, Tomcat etc to run your application.
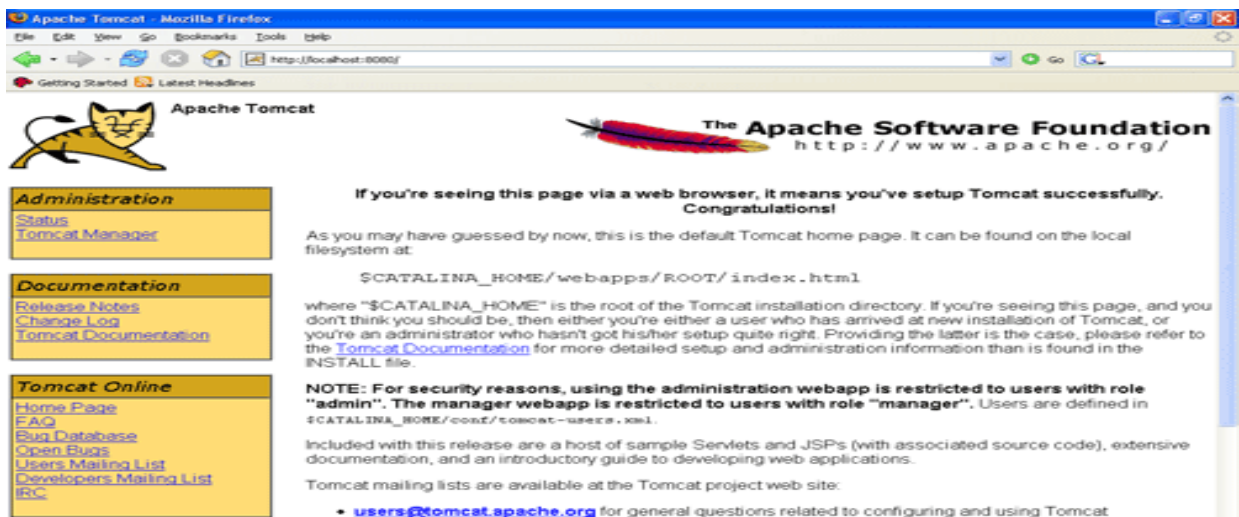
Fig.no.1.6: Tomcat Webserver

CHAPTER 7
SYSTEM DESIGN

7.1 SYSTEM ARCHITECTURE:
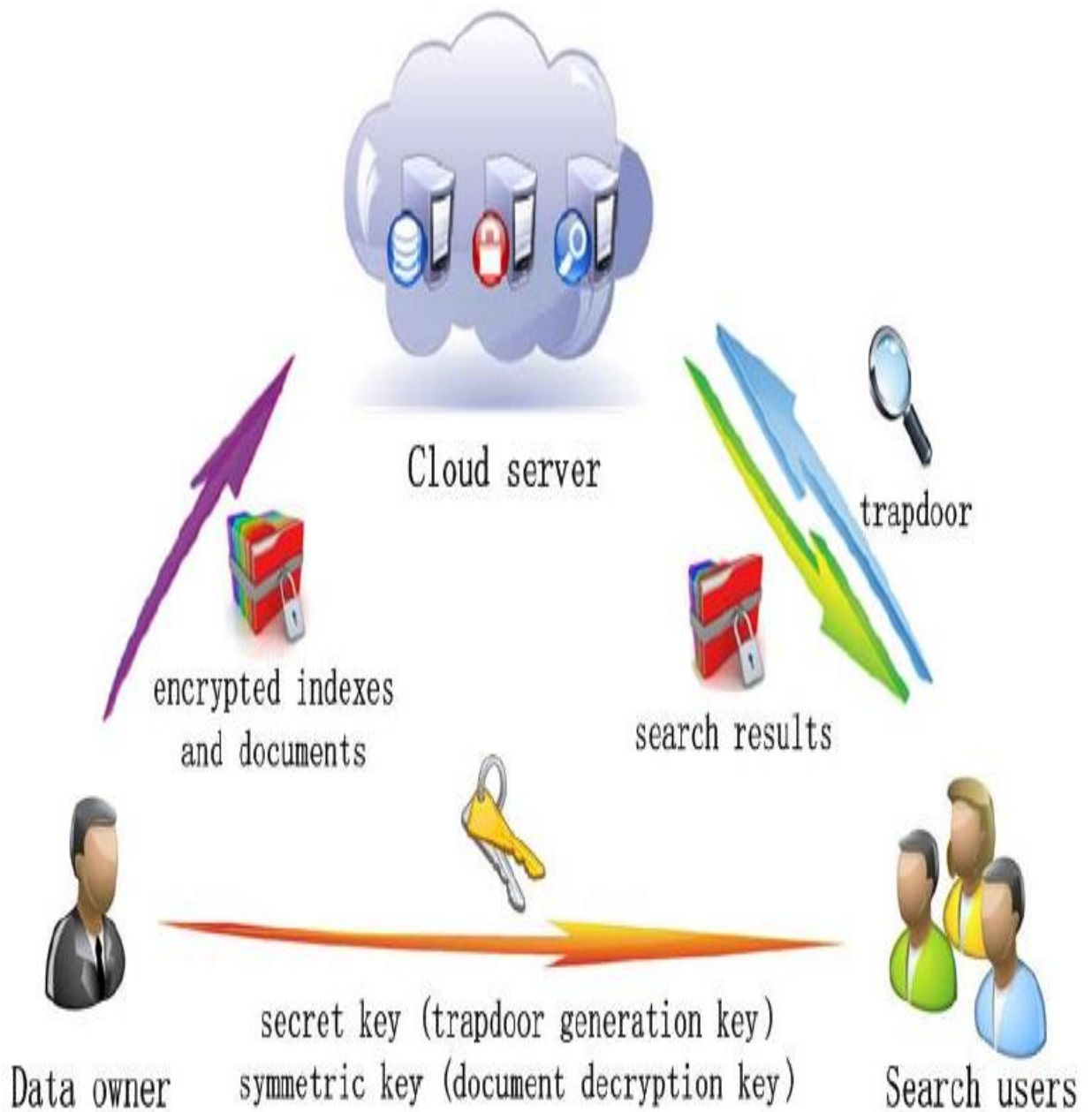
Fig.no.1.7:System Architecture

7.2 INPUT DESIGN:

The input design is the link between the information system and the user. It comprises the developing specification and procedures for data preparation and those steps are necessary to put transaction data in to a usable form for processing can be achieved by inspecting the computer to read data from a written or printed document or it can occur by having people keying the data directly into the system. The design of input focuses on controlling the amount of input required, controlling the errors, avoiding delay, avoiding extra steps and keeping the process simple. The input is designed in such a way so that it provides security and ease of use with retaining the privacy. Input Design considered the following things:

➢ What data should be given as input?
➢ How the data should be arranged or coded?
➢ The dialog to guide the operating personnel in providing input.
➢ Methods for preparing input validations and steps to follow when error occur.

7.3 OBJECTIVES:

1. Input Design is the process of converting a user-oriented description of the input into a computer-based system. This design is important to avoid errors in the data input process and show the correct direction to the management for getting correct information from the computerized system.

2. It is achieved by creating user-friendly screens for the data entry to handle large volume of data. The goal of designing input is to make data entry easier and to be free from errors. The data entry screen is designed in such a way that all the data manipulates can be performed. It also provides record viewing facilities.

3. When the data is entered it will check for its validity. Data can be entered with the help of screens. Appropriate messages are provided as when needed so that the user will not be in maize of instant. Thus the objective of input design is to create an input layout that is easy to follow

7.4 OUTPUT DESIGN:

A quality output is one, which meets the requirements of the end user and presents the information clearly. In any system results of processing are communicated to the users and to other system through outputs. In output design it is determined how the information is to be displaced for immediate need and also the hard copy output. It is the most important and direct source information to the user. Efficient and intelligent output design improves the system's relationship to help user decision-making.

1. Designing computer output should proceed in an organized, well thought out manner; the right output must be developed while ensuring that each output element is designed so that people will find the system can use easily and effectively. When analysis design computer output, they should Identify the specific output that is needed to meet the requirements.

2.Select methods for presenting information.

3.Create document, report, or other formats that contain information produced by the system.

The output form of an information system should accomplish one or more of the following objectives.

- ❖ Convey information about past activities, current status or projections of the
- ❖ Future.
- ❖ Signal important events, opportunities, problems, or warnings.
- ❖ Trigger an action.
- ❖ Confirm an action.

CHAPTER 8
SYSTEM MODELS

8.1 UML DIAGRAMS:

UML stands for Unified Modeling Language. UML is a standardized general-purpose modeling language in the field of object-oriented software engineering. The standard is managed, and was created by, the Object Management Group.

The goal is for UML to become a common language for creating models of object oriented computer software. In its current form UML is comprised of two major components: a Meta-model and a notation. In the future, some form of method or process may also be added to; or associated with, UML.

The Unified Modeling Language is a standard language for specifying, Visualization, Constructing and documenting the artifacts of software system, as well as for business modeling and other non-software systems.

The UML represents a collection of best engineering practices that have proven successful in the modeling of large and complex systems.

The UML is a very important part of developing objects oriented software and the software development process. The UML uses mostly graphical notations to express the design of software projects.

GOALS:

The Primary goals in the design of the UML are as follows:

1. Provide users a ready-to-use, expressive visual modeling Language so that they can develop and exchange meaningful models.
2. Provide extendibility and specialization mechanisms to extend the core concepts.
3. Be independent of particular programming languages and development process.
4. Provide a formal basis for understanding the modeling language.
5. Encourage the growth of OO tools market.
6. Support higher level development concepts such as collaborations, frameworks, patterns and components.

8.1.1 USE CASE DIAGRAM:

      A use case diagram in the Unified Modeling Language (UML) is a type of behavioral diagram defined by and created from a Use-case analysis. Its purpose is to present a graphical overview of the functionality provided by a system in terms of actors, their goals (represented as use cases), and any dependencies between those use cases. The main purpose of a use case diagram is to show what system functions are performed for which actor. Roles of the actors in the system can be depicted.
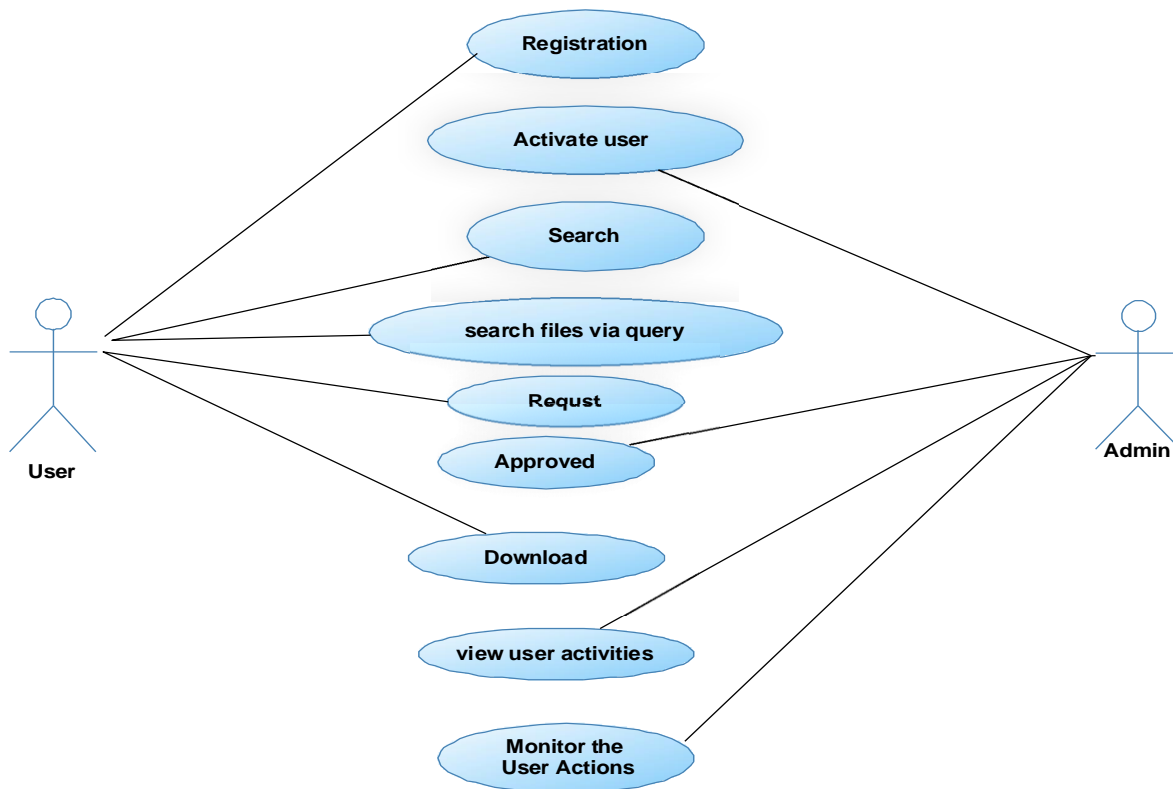
Fig.no.1.8:Use Case Diagram

8.1.2 CLASS DIAGRAM:

In software engineering, a class diagram in the Unified Modeling Language (UML) is a type of static structure diagram that describes the structure of a system by showing the system's classes, their attributes, operations (or methods), and the relationships among the classes. It explains which class contains information.

USER
FILE SEARCH QUERY
QUERY(); VIEW(); DOWNLOAD();

ADMIN
KEY LOG USER
USER_REQUESTS(); APPROVE(); MONITOR_USER(); UPLOAD();
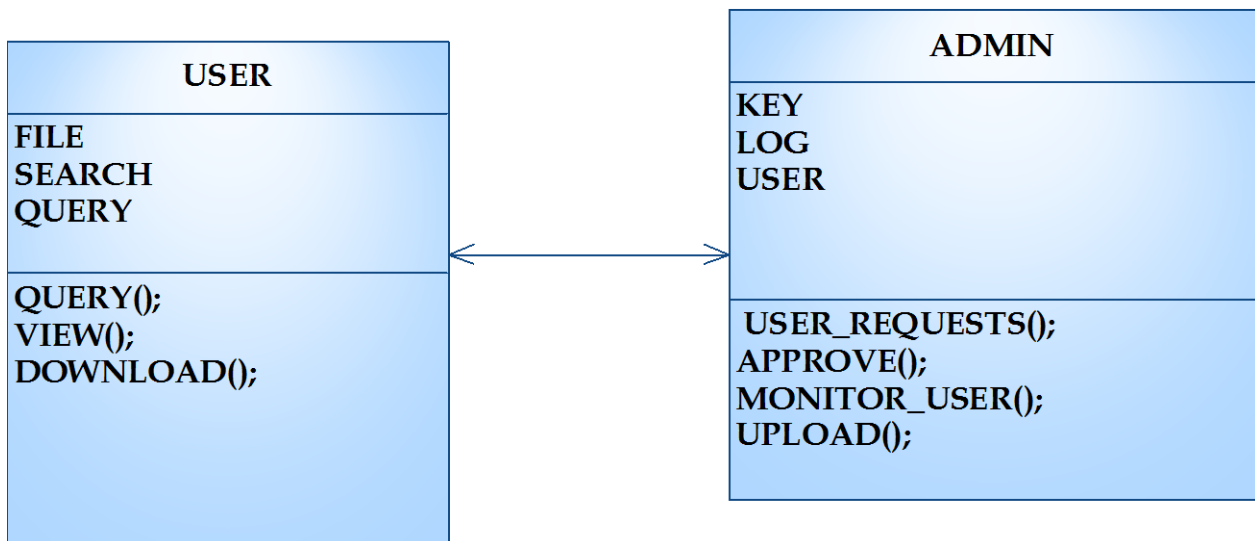
Fig.no.1.9:Class Diagram

8.1.3 SEQUENCE DIAGRAM:

A sequence diagram in Unified Modeling Language (UML) is a kind of interaction diagram that shows how processes operate with one another and in what order. It is a construct of a Message Sequence Chart. Sequence diagrams are sometimes called event diagrams, event scenarios, and timing diagrams.
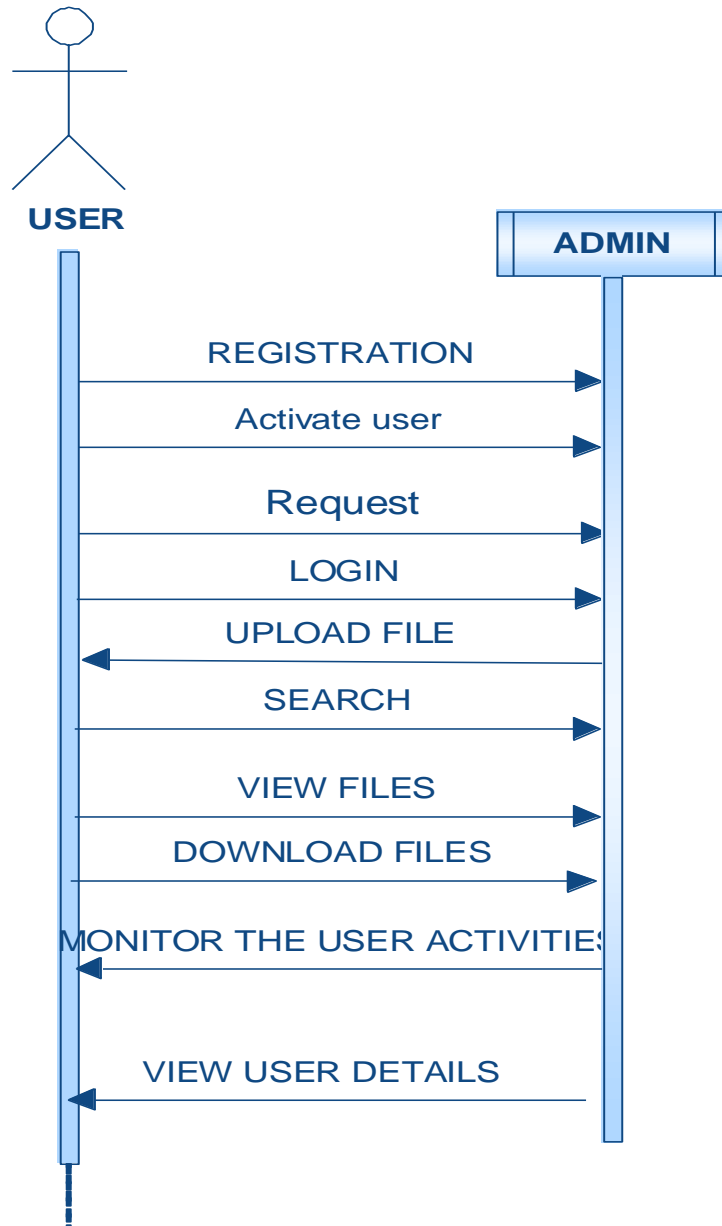
Fig.no.1.10:Sequence Diagram

8.1.4 ACTIVITY DIAGRAM:

Activity diagrams are graphical representations of workflows of stepwise activities and actions with support for choice, iteration and concurrency. In the Unified Modeling Language, activity diagrams can be used to describe the business and operational step-by-step workflows of components in a system. An activity diagram shows the overall flow of control.
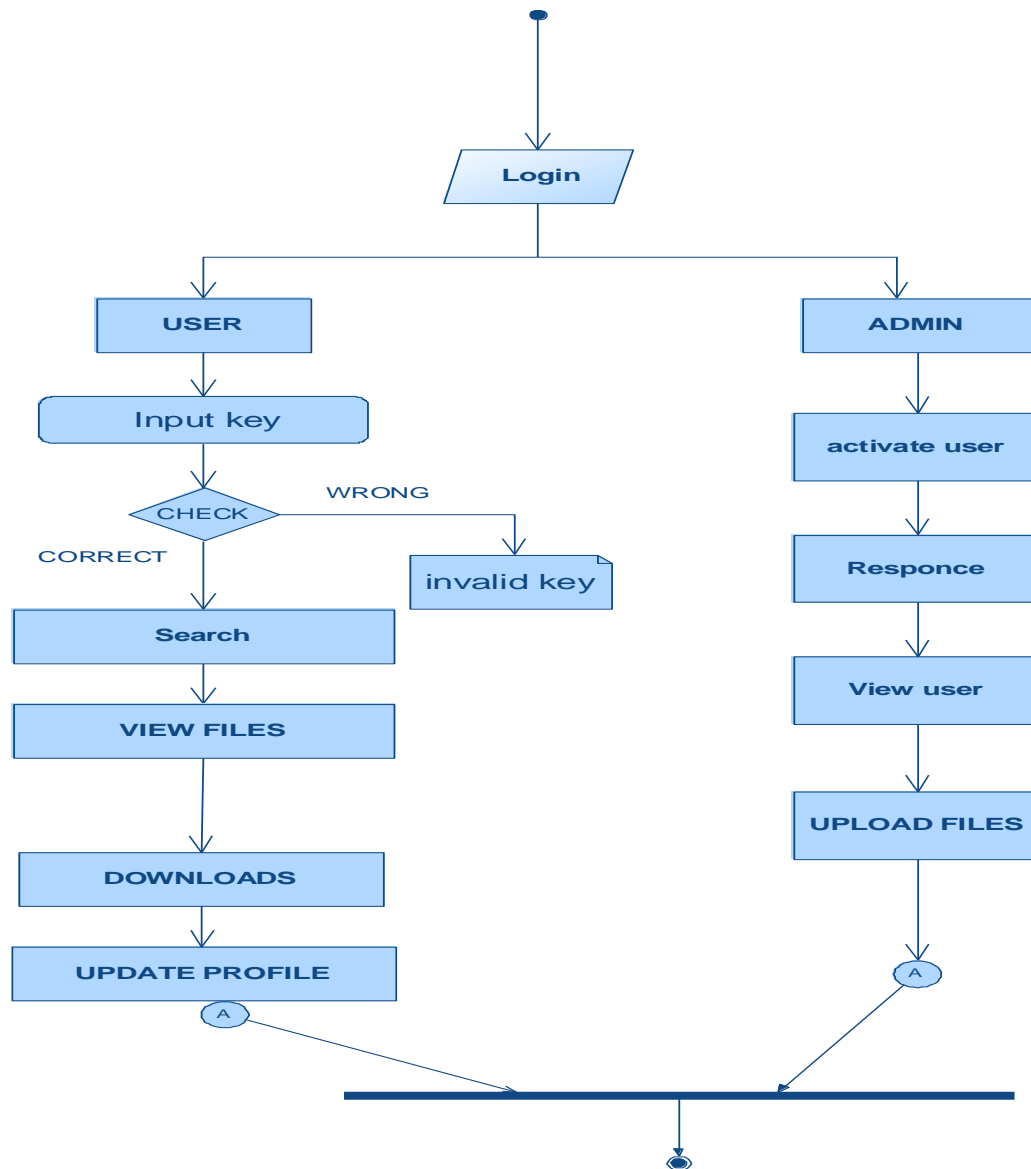
Fig.no.1.11:Activity Diagram

8.1.5 DATA FLOW DIAGRAM:

1. The DFD is also called as bubble chart. It is a simple graphical formalism that can be used to represent a system in terms of input data to the system, various processing carried out on this data, and the output data is generated by this system.
2. The data flow diagram (DFD) is one of the most important modeling tools. It is used to model the system components. These components are the system process, the data used by the process, an external entity that interacts with the system and the information flows in the system.
3. DFD shows how the information moves through the system and how it is modified by a series of transformations. It is a graphical technique that depicts information flow and the transformations that are applied as data moves from input to output.
4. 4.DFD is also known as bubble chart. A DFD may be used to represent a system at any level of abstraction. DFD may be partitioned into levels that represent increasing information flow and functional detail.
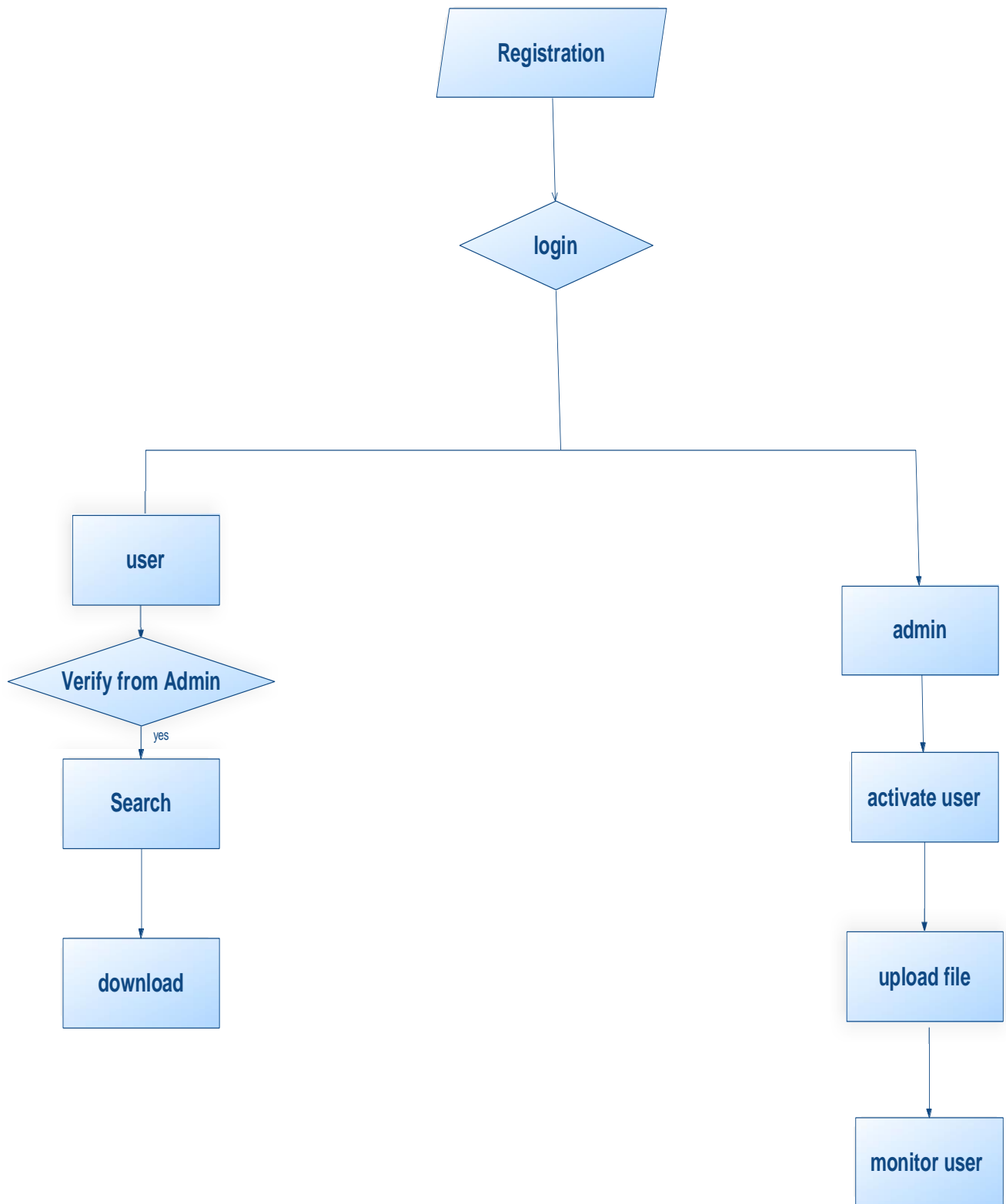
Fig.no.1.12:Data Flow Diagram

Chapter 9
SYSTEM IMPLEMENTATION

9.1 MODULES

❖ Data Owner Module
❖ Data User Module
❖ Cloud server and Encryption Module
❖ Rank Search Module

9.1.1 DATA OWNER MODULE:

This module helps the owner to register those details and also include login details. This module helps the owner to upload his file with encryption using RSA algorithm. This ensures the files to be protected from unauthorized user. Data owner has a collection of documents $F = \{f1; f2; :::; fn\}$ that he wants to outsource to the cloud server in encrypted form while still keeping the capability to search on them for effective utilization. In our scheme, the data owner firstly builds a secure searchable tree index I from document collection F, and then generates an encrypted document collection C for F. Afterwards, the data owner outsources the encrypted collection C and the secure index I to the cloud server, and securely distributes the key information of trapdoor generation and document decryption to the authorized data users. Besides, the data owner is responsible for the update operation of his documents stored in the cloud server. While updating, the data owner generates the update information locally and sends it to the server.

9.1.2 DATA USER MODULE:

This module includes the user registration login details. This module is used to help the client to search the file using the multiple key words concept and get the accurate result list based on the user query. The user is going to select the required file and register the user details and get activation code in mail email before enter the activation

code. After user can download the Zip file and extract that file. Data users are authorized ones to access the documents of data owner. With t query keywords, the authorized user can generate a trapdoor *TD* according to search control mechanisms to fetch k encrypted documents from cloud server. Then, the data user can decrypt the documents with the shared secret key.

9.1.3 CLOUD SERVER AND ENCRYPTION MODULE:

This module is used to help the server to encrypt the document using RSA Algorithm and to convert the encrypted document to the Zip file with activation code and then activation code send to the user for download. Cloud server stores the encrypted document collection *C* and the encrypted searchable tree index *I* for data owner. Upon receiving the trapdoor *TD* from the data user, the cloud server executes search over the index tree *I,* and finally returns the corresponding collection of top- k ranked encrypted documents. Besides, upon receiving the update information from the data owner, the server needs to update the index *I* and document collection *C* according to the received information. The cloud server in the proposed scheme is considered as "honest-but-curious", which is employed by lots of works on secure cloud data search

9.1.4 RANK SEARCH MODULE:

These modules ensure the user to search the files that are searched frequently using rank search. This module allows the user to download the file using his secret key to decrypt the downloaded data. This module allows the Owner to view the uploaded files and downloaded files. The proposed scheme is designed to provide not only multi-keyword query and accurate result ranking, but also dynamic update on document collections

CODING:

<u>DBCONNECTION.JAVA</u>

```java
/*
 * To change this license header, choose License Headers in Project Properties.
 * To change this template file, choose Tools | Templates
 * and open the template in the editor.
 */
packagecom.secure.kk.action;

importjava.sql.Connection;

importjava.sql.DriverManager;

/**
 *
 * @author java2
 */
public class Dbconnection {

public static Connection getConnection() {

 Connection con = null;

try {

Class.forName("com.mysql.jdbc.Driver");

con = DriverManager.getConnection("jdbc:mysql://localhost:3306/secure", "root", "root");

 } catch (Exception ex) {

ex.printStackTrace();

 }

return con;

   }
```

```
}
```

FTCON.JAVA

```java
packagecom.secure.kk.action;

importjava.io.File;

importjava.io.FileInputStream;

importorg.apache.commons.net.ftp.FTPClient;

/*

 * To change this license header, choose License Headers in Project Properties.

 * To change this template file, choose Tools | Templates

 * and open the template in the editor.

 */

/**

 *

 * @author java2

 */

public class Ftpcon {

FTPClient client = new FTPClient();

FileInputStreamfis = null;

boolean status;

publicboolean upload(File file,Stringfname) {

try {

client.connect("ftp.drivehq.com");

client.login("madhumaddy997@gmail.com", "madhu@.23");

client.enterLocalPassiveMode();

fis = new FileInputStream(file);

status = client.storeFile(" /kk/" + fname, fis);

client.logout();
```

```java
fis.close();

} catch (Exception e) {

System.out.println(e);

}

if (status) {

System.out.println("success");

return true;

 } else {

System.out.println("failed");

return false;

    }

  }

}
```

MAIL.JAVA

```java
/*

 * To change this license header, choose License Headers in Project Properties.

 * To change this template file, choose Tools | Templates

 * and open the template in the editor.

 */

packagecom.secure.kk.action;

importjava.util.Properties;

importjavax.mail.Message;

importjavax.mail.MessagingException;

importjavax.mail.PasswordAuthentication;

importjavax.mail.Session;

importjavax.mail.Transport;

importjavax.mail.internet.InternetAddress;
```

```java
importjavax.mail.internet.MimeMessage;

public class Mail {

public static booleansecretMail(String msg, String userid, String to) {

 Properties props = new Properties();

props.put("mail.smtp.host", "smtp.gmail.com");

props.put("mail.smtp.socketFactory.port", "465");

props.put("mail.smtp.socketFactory.class",

"javax.net.ssl.SSLSocketFactory");

props.put("mail.smtp.auth", "true");

props.put("mail.smtp.port", "465");

  // Assuming you are sending email from localhost

  Session session = Session.getDefaultInstance(props,

newjavax.mail.Authenticator() {

protectedPasswordAuthenticationgetPasswordAuthentication() {

return new PasswordAuthentication("madhumaddy997@gmail.com", "madhu234512");

 }

    });

System.out.println("Message   " + msg);

try {

     Message message = new MimeMessage(session);

message.setFrom(new InternetAddress(userid));

message.setRecipients(Message.RecipientType.TO,

InternetAddress.parse(to));

message.setSubject("Secret key ");

message.setText(msg);

Transport.send(message);

System.out.println("Done");
```

```java
        return true;

    } catch (MessagingException e) {

System.out.println(e);

e.printStackTrace();

return false;

        // throw new RuntimeException(e);

    }

}}
```

DECRYPTION.JAVA

```java
packagecom.secure.kk.action;

import com.sun.org.apache.xerces.internal.impl.dv.util.Base64;

importjava.io.ByteArrayOutputStream;

importjava.io.FileInputStream;

importjava.io.FileWriter;

importjava.util.Scanner;

importjavax.crypto.Cipher;

importjavax.crypto.KeyGenerator;

importjavax.crypto.SecretKey;

importjavax.crypto.spec.SecretKeySpec;

importjavax.swing.JOptionPane;

import sun.misc.BASE64Decoder;

import sun.misc.BASE64Encoder;

public class decryption {

//public static void main(String args[])

//{

//      Scanner s=new Scanner(System.in);
```

```java
//        System.out.println("Enter encrypted Text and key");

//        String text=s.next();

//        String key=s.next();

//        new decryption().decrypt(text,key);

//}


public String decrypt(String txt, String skey) {

    String decryptedtext = null;

try {

//converting string to secretkey

byte[] bs = Base64.decode(skey);

SecretKey sec = new SecretKeySpec(bs, "AES");

System.out.println("converted string to seretkey:" + sec);

System.out.println("secret key:" + sec);

 Cipher aesCipher = Cipher.getInstance("AES");//getting AES instance

aesCipher.init(Cipher.ENCRYPT_MODE, sec);//initiating ciper encryption using secretke

byte[] byteCipherText = new BASE64Decoder().decodeBuffer(txt); //encrypting data

 // System.out.println("ciper text:"+byteCipherText);

aesCipher.init(Cipher.DECRYPT_MODE, sec, aesCipher.getParameters());//initiating ciper decryption

byte[] byteDecryptedText = aesCipher.doFinal(byteCipherText);

decryptedtext = new String(byteDecryptedText);

System.out.println("Decrypted Text:" + decryptedtext);

 } catch (Exception e) {

System.out.println(e);

    }

returndecryptedtext;

}
```

```
}


DOWNLOAD.JAVA

/*

 * To change this license header, choose License Headers in Project Properties.

 * To change this template file, choose Tools | Templates

 * and open the template in the editor.

 */

packagecom.secure.kk.action;

importjava.io.BufferedReader;

importjava.io.IOException;

importjava.io.InputStream;

importjava.io.InputStreamReader;

importjava.io.PrintWriter;

importjava.sql.Connection;

importjava.sql.ResultSet;

importjava.sql.SQLException;

importjava.sql.Statement;

importjava.util.logging.Level;

importjava.util.logging.Logger;

importjavax.servlet.ServletException;

importjavax.servlet.http.HttpServlet;

importjavax.servlet.http.HttpServletRequest;

importjavax.servlet.http.HttpServletResponse;


public class download extends HttpServlet {

    /**
```

```java
 * Processes requests for both HTTP <code>GET</code> and <code>POST</code>

 * methods.

 * @param request servlet request

 * @param response servlet response

 * @throws ServletException if a servlet-specific error occurs

 * @throws IOException if an I/O error occurs

 */

protected void processRequest(HttpServletRequest request, HttpServletResponse response)

throwsServletException, IOException, SQLException {

response.setContentType("text/html;charset=UTF-8");

PrintWriter out = response.getWriter();

 /* TODO output your page here. You may use following sample code. */

String[] filedetails = request.getQueryString().split(",");

    String fname = null, fkey = null;

InputStream is = null;

 Connection con = Dbconnection.getConnection();

 Statement st = con.createStatement();

ResultSetrt = st.executeQuery("select * from files where filename='" + filedetails[0] + "' AND owner='" +
ffiledetails[1] + "'");

if (rt.next()) {

fname = rt.getString("filename");

fkey = rt.getString("file_key");

is = (InputStream) rt.getAsciiStream("data");

 } else {

out.println("error while retreiving data");

 }

BufferedReaderbr = new BufferedReader(new InputStreamReader(is));
```

```java
    String temp = null;

StringBuffersb = new StringBuffer();

while ((temp = br.readLine()) != null) {

sb.append(temp + "\n");

 }

  String content = new decryption().decrypt(sb.toString(), fkey);

response.setHeader("Content-Disposition", "attachment;filename=\"" + fname + "\"");

out.write(content);

      }

// <editor-fold defaultstate="collapsed" desc="HttpServlet methods. Click on the + sign on the left to edit the
code.">

  /**

    * Handles the HTTP <code>GET</code> method.

    * @param request servlet request

    * @param response servlet response

    * @throws ServletException if a servlet-specific error occurs

    * @throws IOException if an I/O error occurs

    */

  @Override
protected void doGet(HttpServletRequest request, HttpServletResponse response)

throwsServletException, IOException {

try {

processRequest(request, response);

    } catch (SQLException ex) {

Logger.getLogger(download.class.getName()).log(Level.SEVERE, null, ex);

    }

  }
```

```java
    /**
     * Handles the HTTP <code>POST</code> method.

     * @param request servlet request

     * @param response servlet response

     * @throws ServletException if a servlet-specific error occurs

     * @throws IOException if an I/O error occurs

     */
    @Override
protected void doPost(HttpServletRequest request, HttpServletResponserespons

throwsServletException, IOException {

try {

processRequest(request, response);

 } catch (SQLException ex) {

Logger.getLogger(download.class.getName()).log(Level.SEVERE, null, ex);

 }

  }


  /**

     * Returns a short description of the servlet.

     * @return a String containing servlet description

     */
    @Override
public String getServletInfo() {

return "Short description";

}// </editor-fold>

}
```

```java
/*
 * To change this template, choose Tools | Templates
 * and open the template in the editor.
 */
package pack;
/*
 * To change this template, choose Tools | Templates
 * and open the template in the editor.
 */
/**
 * @author JP Infotech
 */
importjava.io.UnsupportedEncodingException;
importjava.util.Properties;
importjava.util.logging.Level;
importjava.util.logging.Logger;
importjavax.mail.Authenticator;
importjavax.mail.Message;
importjavax.mail.MessagingException;
importjavax.mail.PasswordAuthentication;
importjavax.mail.Session;
importjavax.mail.Transport;
importjavax.mail.internet.InternetAddress;
importjavax.mail.internet.MimeMessage;
public class MailUtil {
private String SMTP_HOST = "smtp.gmail.com";
```

```java
private String FROM_ADDRESS = "madhumaddy997@gmail.com";

private String PASSWORD = "madhu234512";

private String FROM_NAME = "Account Information";

publicbooleansendMail(String[] recipients, String[] bccRecipients, String subject, String message) {

try {

 Properties props = new Properties();

props.put("mail.smtp.starttls.enable", "true");

props.put("mail.smtp.host", SMTP_HOST);

props.put("mail.smtp.auth", "true");

props.put("mail.smtp.port", "465");

props.put("mail.smtp.socketFactory.class","javax.net.ssl.SSLSocketFactory");

props.put("mail.debug", "false");

props.put("mail.smtp.ssl.enable", "true");

Session session = Session.getInstance(props, new SocialAuth());

 Message msg = new MimeMessage(session);

InternetAddress from = new InternetAddress(FROM_ADDRESS, FROM_NAME);

msg.setFrom(from);

InternetAddress[] toAddresses = new InternetAddress[recipients.length];

for (int i = 0; i <recipients.length; i++) {

toAddresses[i] = new InternetAddress(recipients[i]);

        }

msg.setRecipients(Message.RecipientType.TO, toAddresses);

InternetAddress[] bccAddresses = new InternetAddress[bccRecipients.length];

for (int j = 0; j <bccRecipients.length; j++) {

bccAddresses[j] = new InternetAddress(bccRecipients[j]);

        }

msg.setRecipients(Message.RecipientType.BCC, bccAddresses);
```

```java
msg.setSubject(subject);

msg.setContent(message, "text/plain");

Transport.send(msg);

return true;

  } catch (UnsupportedEncodingException ex) {

Logger.getLogger(MailUtil.class.getName()).log(Level.SEVERE, null, ex);

return false;

  } catch (MessagingException ex) {

Logger.getLogger(MailUtil.class.getName()).log(Level.SEVERE, null, ex);

return false;

    }

  }

classSocialAuth extends Authenticator {

 @Override

protectedPasswordAuthenticationgetPasswordAuthentication() {

return new PasswordAuthentication(FROM_ADDRESS, PASSWORD);

 }

   }
}
```

SIMPLE FTP CLIENT.JAVA

```java
package pack;

import java.net.*;

import java.io.*;

public class SimpleFTPClient {

 /** The URL connection object */

privateURLConnectionm_client;
```

```java
    /** The FTP host/server to be connected */

private String host;

    /** The FTP user */

private String user;

 /** The FTP user's password */

private String password;

 /** The remote file that needs to be uploaded or downloaded */

private String remoteFile;

  /** The previous error message triggered after a method is called */

private String erMesg;

   /** The previous success message after any method is called */

private String succMesg;

publicSimpleFTPClient() {

   }

 /** Setter method for the FTP host/server */

public void setHost(String host) {

this.host = host;

   }

/** Setter method for the FTP user */

public void setUser(String user) {

this.user = user;

   }

 /** Setter method for the FTP user's password */

public void setPassword(String p) {

this.password = p;

   }

public void setRemoteFile(String d) {
```

```java
this.remoteFile = d;

/** The method that returns the last message of success of any method call */

public synchronized String getLastSuccessMessage() {

if (succMesg == null) {

return "";

    }

returnsuccMesg;

  }

 /** The method that returns the last message of error resulted from any exception of any method call */

public synchronized String getLastErrorMessage() {

if (erMesg == null) {

return "";

    }

returnerMesg;

  }

public synchronized booleanuploadFile(InputStream is) {

   //public synchronized booleanuploadFile(String localfilename) {

try {

//   InputStream is = new FileInputStream(localfilename);

BufferedInputStreambis = new BufferedInputStream(is);

OutputStreamos = m_client.getOutputStream();

BufferedOutputStreambos = new BufferedOutputStream(os);

byte[] buffer = new byte[1024];

intreadCount;

while ((readCount = bis.read(buffer)) > 0) {

bos.write(buffer, 0, readCount);

}
```

```
        bos.close();

this.succMesg = "Uploaded!";

return true;

  } catch (Exception ex) {

ex.printStackTrace();

StringWriter sw0 = new StringWriter();

PrintWriter p0 = new PrintWriter(sw0, true);

ex.printStackTrace(p0);

erMesg = sw0.getBuffer().toString();

return false;

        }

    }

 /** The method to download a file and save it onto the local drive of the client in the specified absolut path

    @paramlocalfilename – the local absolute file name that the file needs to be saved as */

public synchronized booleandownloadFile(String localfilename) {

try {

InputStream is = m_client.getInputStream();

BufferedInputStreambis = new BufferedInputStream(is);

System.out.println(">>>>>>>>>>"+localfilename);

OutputStreamos = new FileOutputStream(localfilename);

BufferedOutputStreambos = new BufferedOutputStream(os);

byte[] buffer = new byte[1024];

intreadCount;

while ((readCount = bis.read(buffer)) > 0) {

bos.write(buffer, 0, readCount);

        }

bos.close();
```

```
is.close(); // close the FTP inputstream

this.succMesg = "Downloaded!";

return true;

 } catch (Exception ex) {

ex.printStackTrace();

StringWriter sw0 = new StringWriter();

PrintWriter p0 = new PrintWriter(sw0, true);

ex.printStackTrace(p0);

erMesg = sw0.getBuffer().toString()

  return false;

    }

  }


  /** The method that connects to the remote FTP server */

public synchronized boolean connect() {

try {

 URL url = new URL("ftp://" + user + ":" + password + "@" + host + "/" + remoteFile + ";type=i");

m_client = url.openConnection();

System.out.println(">>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>.."+"ftp://" + user + ":" + password + "@" +
host + "/" + remoteFile + ";type=i");

return true;

 } catch (Exception ex) {

ex.printStackTrace();

StringWriter sw0 = new StringWriter();

PrintWriter p0 = new PrintWriter(sw0, true);

ex.printStackTrace(p0);

erMesg = sw0.getBuffer().toString();
```

```java
        return false;

      }

    }

//public static SimpleFTPClientconf(){

//      SimpleFTPClient f = new SimpleFTPClient();

//      f.setHost("ftp.drivehq.com");

//      f.setUser("sabari06");

//      f.setPassword("sabari06");

//      f.setRemoteFile("onepoint.wsdl");

//      boolean connected = f.connect();

//      System.out.println(">>>" + connected);

// return f;

//}

public static void main(String arg[]) {

SimpleFTPClient f = new SimpleFTPClient();

f.setHost("ftp.drivehq.com");

f.setUser("madhumaddy997@gmail.com");

f.setPassword("madhu@.23");

f.setRemoteFile("c.txt");

boolean connected = f.connect();

    //System.out.println(">>>>>>>>>>"+f.downloadFile("D:/dd/onepoint.wsdl"));

System.out.println(">>>" + connected);

//      if (connected) {

//          // Upload a file from your local drive, lets say in "c:/ftpul/u.txt�?

//          if (f.uploadFile("D:/dd/a.txt")) // display the message of success if uploaded

//          {

//              System.out.println(f.getLastSuccessMessage());
```

```
//        } else {

//           System.out.println(f.getLastErrorMessage());

//        }

//     } else {

//        // Display any connection exception, if any

//        System.out.println(f.getLastErrorMessage());

//     }

   //  f.setRemoteFile("www.wsdl");

    /* if (connected) {

        // The downloaded file to be saved to the local drive

        // as mydl.txt and in the subfoler c:\ftpdownloads

if (f.downloadFile("/home/zeroone09/Desktop/New Folder_1/onepoint.wsdl")) // display the message of success if
uploaded

        {

System.out.println(f.getLastSuccessMessage());

        } else {

System.out.println(f.getLastErrorMessage());

        }

     } else {

        // Display any connection exception, if any

System.out.println(f.getLastErrorMessage());


     }*/

  }

}
```

 TRILPLE DES.JAVA

```
package pack;
```

```java
import java.net.*;

import java.io.*;

public class SimpleFTPClient {

  /** The URL connection object */

privateURLConnectionm_client;

   /** The FTP host/server to be connected */

private String host;

   /** The FTP user */

private String user;

   /** The FTP user's password */

private String password;

   /** The remote file that needs to be uploaded or downloaded */

private String remoteFile;

   /** The previous error message triggered after a method is called */

private String erMesg;

   /** The previous success message after any method is called */

private String succMesg;

publicSimpleFTPClient() {

   }

  /** Setter method for the FTP host/server */

public void setHost(String host) {

this.host = host;

   }

/** Setter method for the FTP user */

public void setUser(String user) {

this.user = user;

   }
```

```java
  /** Setter method for the FTP user's password */

public void setPassword(String p) {

this.password = p;

  }

public void setRemoteFile(String d) {

this.remoteFile = d;

  }

/** The method that returns the last message of success of any method call */

public synchronized String getLastSuccessMessage() {

if (succMesg == null) {

return "";

    }

returnsuccMesg;

  }

 /** The method that returns the last message of error resulted from any exception of any method call */

public synchronized String getLastErrorMessage() {

if (erMesg == null) {

return "";

    }

returnerMesg;

  }

public synchronized booleanuploadFile(InputStream is) {

  //public synchronized booleanuploadFile(String localfilename) {

try {

 //  InputStream is = new FileInputStream(localfilename);

BufferedInputStreambis = new BufferedInputStream(is);

OutputStreamos = m_client.getOutputStream();
```

```java
BufferedOutputStreambos = new BufferedOutputStream(os);

byte[] buffer = new byte[1024];

intreadCount;

while ((readCount = bis.read(buffer)) > 0) {

bos.write(buffer, 0, readCount);

        }

bos.close();

this.succMesg = "Uploaded!";

return true;

  } catch (Exception ex) {

ex.printStackTrace();

StringWriter sw0 = new StringWriter();

PrintWriter p0 = new PrintWriter(sw0, true);

ex.printStackTrace(p0);

erMesg = sw0.getBuffer().toString();

return false;

    }

  }

  /** The method to download a file and save it onto the local drive of the client in the specified absolut path

    @paramlocalfilename – the local absolute file name that the file needs to be saved as */

public synchronized booleandownloadFile(String localfilename) {

try {

InputStream is = m_client.getInputStream();

BufferedInputStreambis = new BufferedInputStream(is);

System.out.println(">>>>>>>>>>>"+localfilename);

OutputStreamos = new FileOutputStream(localfilename);

BufferedOutputStreambos = new BufferedOutputStream(os);
```

```java
byte[] buffer = new byte[1024];

intreadCount;

while ((readCount = bis.read(buffer)) > 0) {

bos.write(buffer, 0, readCount);

        }

bos.close();

is.close(); // close the FTP inputstream

this.succMesg = "Downloaded!";

return true;

    } catch (Exception ex) {

ex.printStackTrace();

StringWriter sw0 = new StringWriter();

PrintWriter p0 = new PrintWriter(sw0, true);

ex.printStackTrace(p0);

erMesg = sw0.getBuffer().toString();

return false;

    }

  }

 /** The method that connects to the remote FTP server */

ublic synchronized boolean connect() {

try {

        URL url = new URL("ftp://" + user + ":" + password + "@" + host + "/" + remoteFile + ";type=i");

m_client = url.openConnection();

System.out.println(">>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>.."+"ftp://" + user + ":" + password + "@" +
host + "/" + remoteFile + ";type=i");

return true;

 } catch (Exception ex) {
```

```java
        ex.printStackTrace();

        StringWriter sw0 = new StringWriter();

        PrintWriter p0 = new PrintWriter(sw0, true);

        ex.printStackTrace(p0);

        erMesg = sw0.getBuffer().toString();

        return false;

            }

        }

//public static SimpleFTPClientconf(){

//      SimpleFTPClient f = new SimpleFTPClient();

//      f.setHost("ftp.drivehq.com");

//      f.setUser("sabari06");

//      f.setPassword("sabari06");

//      f.setRemoteFile("onepoint.wsdl");

//      boolean connected = f.connect();

//      System.out.println(">>>" + connected);

// return f;

//}

public static void main(String arg[]) {

SimpleFTPClient f = new SimpleFTPClient();

f.setHost("ftp.drivehq.com");

f.setUser("madhumaddy997@gmail.com");

f.setPassword("madhu@.23");

f.setRemoteFile("c.txt");

boolean connected = f.connect();

    //System.out.println(">>>>>>>>>>"+f.downloadFile("D:/dd/onepoint.wsdl"));

System.out.println(">>>" + connected);
```

```java
//      if (connected) {

//          // Upload a file from your local drive, lets say in "c:/ftpul/u.txt�?

//          if (f.uploadFile("D:/dd/a.txt")) // display the message of success if uploaded

//          {

//              System.out.println(f.getLastSuccessMessage());

//          } else {

//              System.out.println(f.getLastErrorMessage());

//          }

//      } else {

//          // Display any connection exception, if any

//          System.out.println(f.getLastErrorMessage());

//      }

   //  f.setRemoteFile("www.wsdl");

    /* if (connected) {

        // The downloaded file to be saved to the local drive

        // as mydl.txt and in the subfoler c:\ftpdownloads

if (f.downloadFile("/home/zeroone09/Desktop/New Folder_1/onepoint.wsdl")) // display the message of success if
uploaded

        {

System.out.println(f.getLastSuccessMessage());

        } else {

System.out.println(f.getLastErrorMessage());

        }

    } else {

        // Display any connection exception, if any

System.out.println(f.getLastErrorMessage());
```

```
        }*/

    }

}


```

```
/*

 * To change this template, choose Tools | Templates

 * and open the template in the editor.

 */

package pack;

import com.sun.org.apache.xerces.internal.impl.dv.util.Base64;

importjava.io.ByteArrayOutputStream;

importjava.io.FileInputStream;

importjava.io.FileWriter;

importjava.util.Scanner;

importjavax.crypto.Cipher;

importjavax.crypto.KeyGenerator;

importjavax.crypto.SecretKey;

importjavax.crypto.spec.SecretKeySpec;

importjavax.swing.JOptionPane;

import sun.misc.BASE64Decoder;

import sun.misc.BASE64Encoder;

public class decryption

{

//public static void main(String args[])

//{

//      Scanner s=new Scanner(System.in);
```

```java
//        System.out.println("Enter encrypted Text and key");

//        String text=s.next();

//        String key=s.next();

//        new decryption().decrypt(text,key);

//}

public String decrypt(String txt,Stringskey)

{

    String decryptedtext = null;

        try

        {


        //converting string to secretkey

byte[] bs=Base64.decode(skey);

SecretKey sec=new SecretKeySpec(bs, "AES");

System.out.println("converted string to seretkey:"+sec);

System.out.println("secret key:"+sec)

 Cipher aesCipher = Cipher.getInstance("AES");//getting AES
instancaesCipher.init(Cipher.ENCRYPT_MODE,sec);//initiating ciper encryption using secretkey

byte[] byteCipherText =new BASE64Decoder().decodeBuffer(txt); //encrypting data

 // System.out.println("ciper text:"+byteCipherText);

aesCipher.init(Cipher.DECRYPT_MODE,sec,aesCipher.getParameters());//initiating ciper decryption

byte[] byteDecryptedText = aesCipher.doFinal(byteCipherText);

decryptedtext = new String(byteDecryptedText);

System.out.println("Decrypted Text:"+decryptedtext);

    }

catch(Exception e)

        {
```

```
System.out.println(e);

}

returndecryptedtext}
```

CHAPTER 10
TESTING

The purpose of testing is to discover errors. Testing is the process of trying to discover every conceivable fault or weakness in a work product. It provides a way to check the functionality of components, sub assemblies, assemblies and/or a finished product .It is the process of exercising software with the intent of ensuring that the Software system meets its requirements and user expectations and does not fail in an unacceptable manner. There are various types of test. Each test type addresses a specific testing requirement.

10.1 TYPES OF TESTING:

10.1.1 UNIT TESTING:

Unit testing involves the design of test cases that validate that the internal program logic is functioning properly, and that program inputs produce valid outputs. All decision branches and internal code flow should be validated. It is the testing of individual software units of the application .it is done after the completion of an individual unit before integration. This is a structural testing, that relies on knowledge of its construction and is invasive. Unit tests perform basic tests at component level and test a specific business process, application, and/or system configuration. Unit tests ensure that each unique path of a business process performs accurately to the documented specifications and contains clearly defined inputs and expected results.

10.1.2 INTEGRATION TESTING:

Integration tests are designed to test integrated software components to determine if they actually run as one program. Testing is event driven and is more concerned with the basic outcome of screens or fields. Integration tests demonstrate that although the

components were individually satisfaction, as shown by successfully unit testing, the combination of components is correct and consistent. Integration testing is specifically aimed at exposing the problems that arise from the combination of components.

10.1.3 FUNCTIONAL TESTING:

 Functional tests provide systematic demonstrations that functions tested are available as specified by the business and technical requirements, system documentation, and user manuals.

Functional testing is centered on the following items:

Valid Input : identified classes of valid input must be accepted.

Invalid   : identified classes of invalid input must be rejected.

Functions   : identified functions must be exercised.

Output   :   identified   classes   of   application   outputs   must   be exercised.

Systems/Procedures: interfacing systems or procedures must be invoked. Organization and preparation of functional tests is focused on requirements, key functions, or special test cases. In addition, systematic coverage pertaining to identify Business process flows; data fields, predefined processes, and successive processes must be considered for testing. Before functional testing is complete, additional tests are identified and the effective value of current tests is determined.

10.1.4 SYSTEM TESTING:

   System testing ensures that the entire integrated software system meets requirements. It tests a configuration to ensure known and predictable results. An example of system testing is the configuration oriented system integration test. System

testing is based on process descriptions and flows, emphasizing pre-driven process links and integration points.

White Box Testing:

White Box Testing is a testing in which in which the software tester has knowledge of the inner workings, structure and language of the software, or at least its purpose. It is purpose. It is used to test areas that cannot be reached from a black box level.

Black Box Testing:

Black Box Testing is testing the software without any knowledge of the inner workings, structure or language of the module being tested. Black box tests, as most other kinds of tests, must be written from a definitive source document, such as specification or requirements document, such as specification or requirements document. It is a testing in which the software under test is treated, as a black box .you cannot "see" into it. The test provides inputs and responds to outputs without considering how the software works.

UNIT TESTING:

Unit testing is usually conducted as part of a combined code and unit test phase of the software lifecycle, although it is not uncommon for coding and unit testing to be conducted as two distinct phases.

Test strategy and approach

Field testing will be performed manually and functional tests will be written in detail.

Test objectives

- All field entries must work properly.

- Pages must be activated from the identified link.

- The entry screen, messages and responses must not be delayed.

Features to be tested

- Verify that the entries are of the correct format

- No duplicate entries should be allowed

- All links should take the user to the correct page.

Integration Testing:

Software integration testing is the incremental integration testing of two or more integrated software components on a single platform to produce failures caused by interface defects.

The task of the integration test is to check that components or software applications, e.g. components in a software system or – one step up – software applications at the company level – interact without error.

Test Results: All the test cases mentioned above passed successfully. No defects encountered.

Acceptance Testing:

User Acceptance Testing is a critical phase of any project and requires significant participation by the end user. It also ensures that the system meets the functional requirements.

Test Results: All the test cases mentioned above passed successfully. No defects encountered.

CHAPTER 11
OUTPUT SCREENS

11.1 REGISTRATION FORM:

Fig.no.1.13:Registration Form

11.2 DATA OWNER LOGIN PAGE:
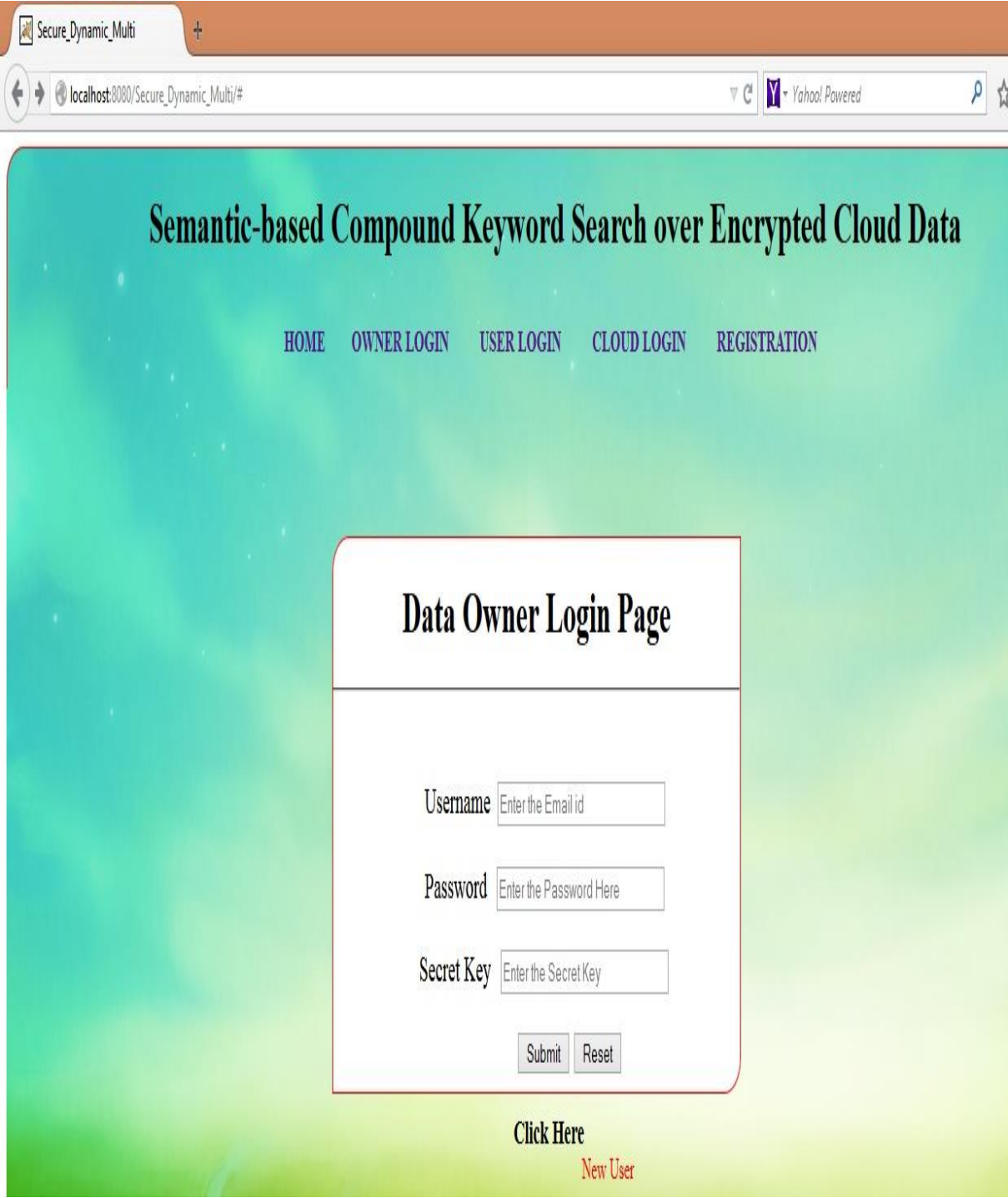
Fig.no.1.14:Data Owner Login Page

11.3 USER LOGIN PAGE:

Fig.no.1.15:User Login Page

11.4 DRIVE HQ REGESTRATION PAGE:

Fig.no.1.16:Drive HQ Registration Page

11.5 DRIVE HQ LOGIN PAGE :

Fig.no.1.17:Drive HQ Login Page

11.6 FILE DETAILS:

Semantic-based Compound Keyword Search over Encrypted Cloud Data

HOME   FILE UPLOAD   FILE DETAILS   REQUEST FILE   GRAPH   PASSWORD   LOGOUT

File Details

File Name	Keyword	File Type	Upload Date	File Size	Rank
decryption.txt	decryption	.java	2018-09-21	2077Bytes	1
hello.txt	hello	.txt	2018-09-21	72Bytes	1
hello.txt	hello	.txt	2018-09-21	72Bytes	1
hello.txt	hello	.txt	2018-09-21	72Bytes	1
hello.txt	hello	.txt	2018-09-21	72Bytes	1
mentor.chrome.txt	mentor.chrome	.txt	2018-09-21	144Bytes	0
hi.txt	hi	.txt	2018-09-22	10Bytes	1

Fig.no.1.18:File Details

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CHAPTER 12
CONCLUSION

- In this project, a secure, efficient and dynamic search scheme is proposed, which supports not only the accurate multi-keyword ranked search but also the dynamic deletion and insertion of documents.

- We construct a special keyword balanced binary tree as the index, and propose a "Greedy Depth-first Search" algorithm to obtain better efficiency than linear search.

- In addition, the parallel search process can be carried out to further reduce the time cost. The security of the scheme is protected against two threat models by using the secure KNN algorithm. Experimental results demonstrate the efficiency of our proposed scheme.

- There are still many challenge problems in symmetric SE schemes. In the proposed scheme, the data owner is responsible for generating updating information and sending them to the cloud server. Thus, the data owner needs to store the unencrypted index tree and the information that are necessary to recalculate the IDF values. Such an active data owner may not be very suitable for the cloud computing model.

- It could be a meaningful but difficult future work to design a dynamic searchable encryption scheme whose updating operation can be completed by cloud server only, meanwhile reserving the ability to support multi-keyword ranked search.

- In addition, as the most of works about searchable encryption, our scheme mainly considers the challenge from the cloud server. Actually, there are many secure challenges in a multi-user scheme. Firstly, all the users usually keep the same secure key for trapdoor generation in a symmetric SE scheme.

- In this case, the revocation of the user is big challenge. If it is needed to revoke a user in this scheme, we need to rebuild the index and distribute the new secure keys to all the authorized users. Secondly, symmetric SE schemes usually assume that all the data users are trustworthy.

- It is not practical and a dishonest data user will lead to many secure problems. For example, a dishonest data user may search the documents and distribute the decrypted documents to the unauthorized ones.

CHAPTER 13

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APPENDIX

ELLIPTIC CURVE CRYPTOGRAPHY FOR SECURED TEXT ENCRYPTION

A Project Report submitted in partial fulfilment of the requirements for the award of the Degree of

MASTER OF TECHNOLOGY

IN

COMPUTER SCIENCE AND ENGINEERING

Submitted by

K. LIKHITHA   **19U41D5805**

Under the Esteemed Guidance of
Dr. M. SRINIVASA RAO
Professor, Department of CSE

DADI INSTITUTE OF ENGINEERING & TECHNOLOGY
(Approved by A.I.C.T.E, New Delhi &Affiliated to JNTU, Kakinada)

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NH-5, Anakapalle-531002, Visakhapatnam, A.P.

2021

CERTIFICATE

This is to certify that the Project work entitled "ELLIPTIC CURVE CRYPTOGRAPHY FOR SECURED TEXT ENCRYPTION" is a being submitted by K.LIKHITHA (19U41D5805), in partial fulfilment of the Requirement for the award of the degree of MASTER OF TECHNOLOGY for COMPUTER SCIENCE & ENGINEERING during the academic year 2020-21.

Dr. M . SRINIVAS RAO   **Dr. L. PRASANNA KUMAR**

PROFESSOR   **ASSOCIATE PROFESSOR**

(PROJECT GUIDE)   (HEAD OF THE DEPARTMENT)

EXTERNAL EXAMINER

DECLARATION

We hereby declare that this project work entitled "IOT BASED DRUNK DRIVER DETECTION" has been carried out by us and contents have been presented in the form are for the award of the degree of MASTER OF TECHNOLOGY IN COMPUTER SCIENCE AND ENGINEERING. We further declare that this dissertation has not been submitted elsewhere for any Diploma or Degree of University.

BY

K.LIKHITHA   (19U41D5805)

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K.LIKHITHA   (19U41D5805)

ABSTRACT

Data security is an important issue in this modern world. When a person sends a secret message to the receiver there are lots of possibilities for third parties to access the secret message .Cryptography plays a significant role in transferring messages securely.

Elliptic Curve cryptography is a public key cryptographic system where the message is encrypted using the private key of the sender and decryption is done using the sender's public key and the receiver's private key. ECC provides more security with lesser key size when compared to other cryptographic techniques.So this can be utilized in electronic devices with lesser memory and lower power consumption. The security in the mapping technique will provide double security for the text encryption.

In this project we analyzed the performance of standard NIST ECC curves like 192 bit, 224 bit, 256 bit, 384 bit, 448 bit and 512 bit.

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CHAPTER - 1
INTRODUCTION

1.1 Overview Of Cryptography :

In today's rapid growth of digital communication and electronic data exchange, many of us communicate in cyberspace without giving a second thought about security. We exchange a lot of our private information and secrets in cyberspace. Whether we like it or not, our digital footprint is in cyberspace. To be precise, whatever we communicate is often unprotected and open to cyber criminals for manipulation. There is hence an urgent need for modern cryptography to find ways to protect sensitive or confidential information. Effective encryption and decryption of data hold the key to security in cyberspace. As such, we need to convert information into an unreadable format so that it can be protected and accessed only by those authorized to do so.

Cryptography   is a crucial   instrument to protect information that is communicated using computers. Cryptography is an artistic transformation of data into an unreadable format so that only the intended recipient can understand and use it.

The goal of cryptography is to protect private communication in the public world. The assumption is that two entities wanting to communicate - Alice and Bob - are shouting their messages in a room full of people. Everyone can hear what they are saying. The goal of cryptography is to protect this communication so that only Alice and Bob can understand the content of the messages.

Cryptography is the science of using mathematics to encrypt and decrypt data. It is the art of secret writing so that the third person will not be able to understand it. It enables you to store sensitive information or transmit it across insecure networks (like the Internet) so that it cannot be read by anyone except the intended recipient.

While cryptography is the science of securing data, cryptanalysis is the science of analyzing and breaking secure communication.

ENCRYPTION :

In cryptography, encryption is the process of encoding information. This process converts the original representation of the information, known as plaintext,

into an alternative form known as ciphertext. Ideally, only authorized parties can decipher a ciphertext back to plaintext and access the original information.That's why a hacker is not able to read the data as senders use an encryption algorithm.

Today, encryption is used in the transfer of communication over the Internet for security and commerce. As computing power continues to increase, computer encryption is constantly evolving to prevent attacks.

Encryption is usually done using key algorithms.
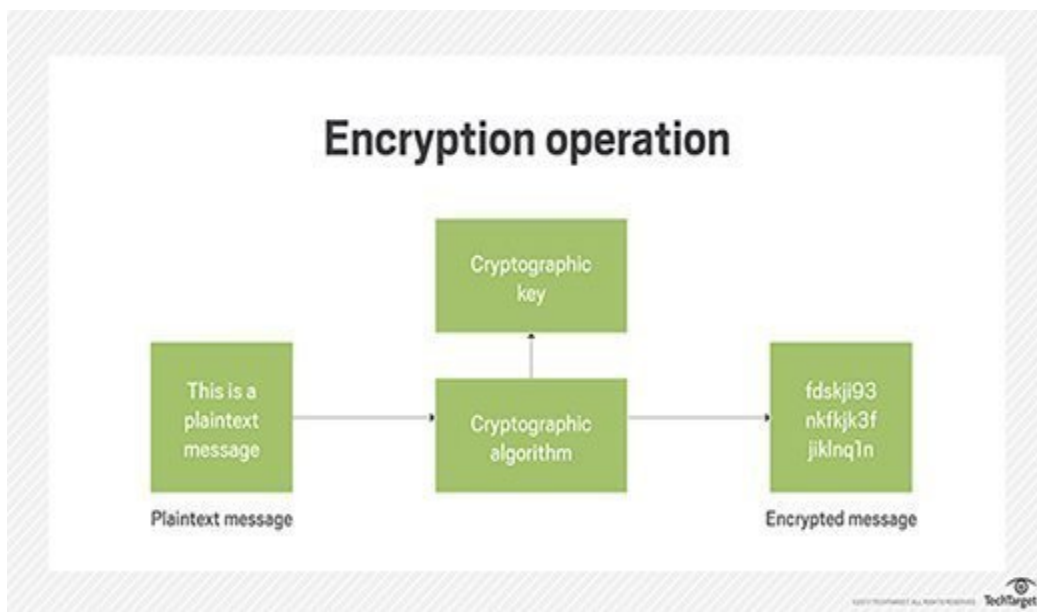
Fig 1.1 : Encryption

DECRYPTION :

The conversion of encrypted data into its original form is called Decryption. It is generally a reverse process of encryption. It decodes the encrypted information so that an authorized user can only decrypt the data because decryption requires a secret key or password.

One of the reasons for implementing an encryption-decryption system is privacy. As information travels over the Internet, it is necessary to scrutinise the access from unauthorized organisations or individuals. Due to this, the data is

encrypted to reduce data loss and theft. Few common items that are encrypted include text files, images, e-mail messages, user data and directories. The recipient of decryption receives a prompt or window in which a password can be entered to access the encrypted data. For decryption, the system extracts and converts the garbled data and transforms it into words and images that are easily understandable not only by a reader but also by a system. Decryption can be done manually or automatically. It may also be performed with a set of keys or passwords.
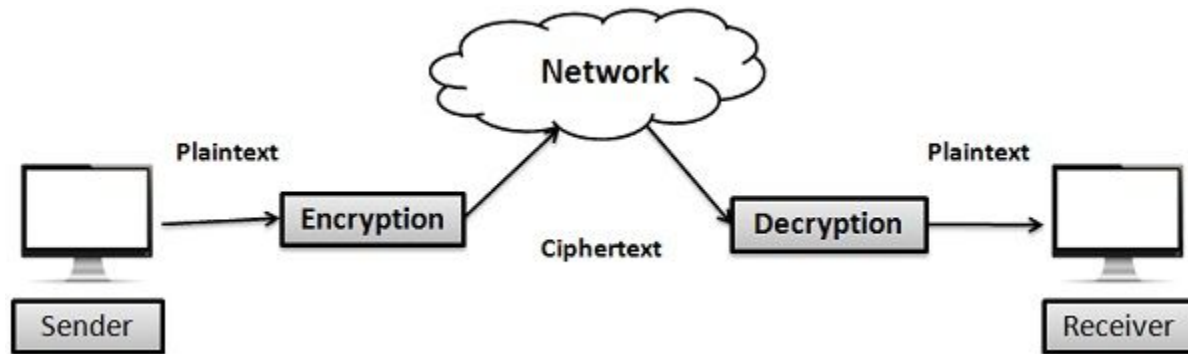
Fig 1.2 : Cryptography

Data Confidentiality, Data Integrity, Authentication and Non-repudiation are core principles of modern-day cryptography.

1) **Confidentiality** refers to certain rules and guidelines usually executed under confidentiality agreements which ensure that the information is restricted to certain people or places.The information cannot be understood by anyone for whom it was unintended.

2) **Data integrity** refers to maintaining and making sure that the data stays accurate and consistent over its entire life cycle.

3) **Authentication** is the process of making sure that the piece of data being claimed by the user belongs to it.

4) **Non-repudiation** refers to the ability to make sure that a person or a party associated with a contract or a communication cannot deny the authenticity of their signature over their document or the sending of a message.

1.2 TYPES OF CRYPTOGRAPHY :

In Cryptography the techniques which are used to protect information are obtained from mathematical concepts and a set of rule based calculations known as algorithms to convert messages in ways that make it hard to decode it. These algorithms are used for cryptographic key generation, digital signing, verification to protect data privacy, web browsing on the internet and to protect confidential transactions such as credit card and debit card transactions.

In general there are three types of cryptography. They are:

1.2.1 Symmetric Key Cryptography :

Symmetric Key Cryptography also known as Symmetric Encryption is when a secret key is leveraged for both encryption and decryption functions.

During this process, data is converted to a format that cannot be read or inspected by anyone who does not have the secret key that was used to encrypt it.

Symmetric key cryptography relies on a shared key between two parties. Asymmetric key cryptography uses a public-private key pair where one key is used to encrypt and the other to decrypt.
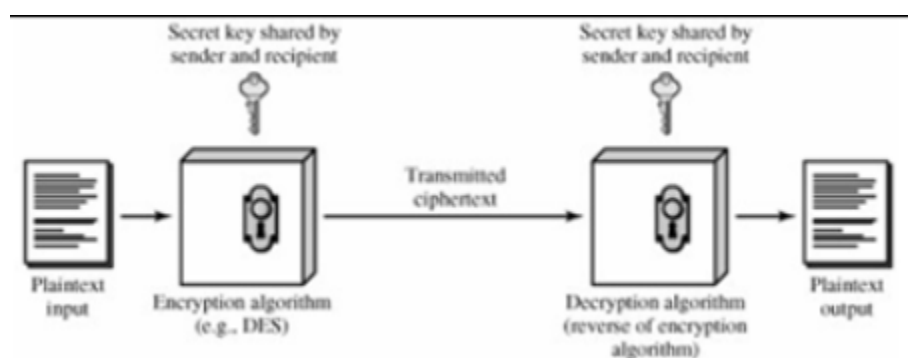
Fig 1.3 Symmetric cryptography

Symmetric key encryption uses one the following encryption types:

- ➢ **Stream ciphers:** encrypt the digits (typically bytes), or letters (in substitution ciphers) of a message one at a time.
- ➢ **Block ciphers:** encrypts a number of bits as a single unit, adding the plaintext so that it is a multiple of the block size. Blocks of 64 bits were commonly used.

Some examples of symmetric encryption algorithms include:

AES (Advanced Encryption Standard), DES (Data Encryption Standard), IDEA (International Data Encryption Algorithm), Blowfish (Drop-in replacement for DES or IDEA)

ADVANTAGES:

- ❖ Many solid state drives, which are typically extremely fast, use symmetric key encryption internally to store data and they are still faster than unencrypted traditional hard drives.
- ❖ When it uses a secure algorithm, symmetric key encryption can be extremely secure. When you use it with its most secure 256-bit key length, it would take about a billion years for a 10 petaflop computer to guess the key through a brute-force attack.

DRAWBACKS:

- ➢ Unfortunately, symmetric encryption does come with its own drawbacks. Its weakest point is its aspects of key management.
- ➢ The biggest problem with symmetric key encryption is that you need to have a way to get the key to the party with whom you are sharing data. Encryption keys aren't simple strings of text like passwords. They are essentially blocks of gibberish. As such, you'll need to have a safe way to get the key to the other party.
- ➢ When someone gets their hands on a symmetric key, they can decrypt everything encrypted with that key. When you're using symmetric encryption for two-way communications, this means that both sides of the conversation get compromised.

APPLICATIONS:

Some examples of where symmetric cryptography is used are:
- ➢ Payment applications, such as card transactions where PII needs to be protected to prevent identity theft or fraudulent charges
- ➢ Validations to confirm that the sender of a message is who he claims to be
- ➢ Random number generation or hashing

1.2.2 PUBLIC KEY CRYPTOGRAPHY:

Sometimes referred to as asymmetric cryptography. Public key cryptography is a form of Cryptosystem in which encryption and decryption are performed using different keys-Public key (known to everyone) and Private Key (Secret key). Network users receive a public and private key pair from certification authorities. If other users want to encrypt data, they get the intended recipient's public key from a public directory. This key is used to encrypt the message, and to send it to the recipient. When the message arrives, the recipient decrypts it using a private key, to which no one else has access.
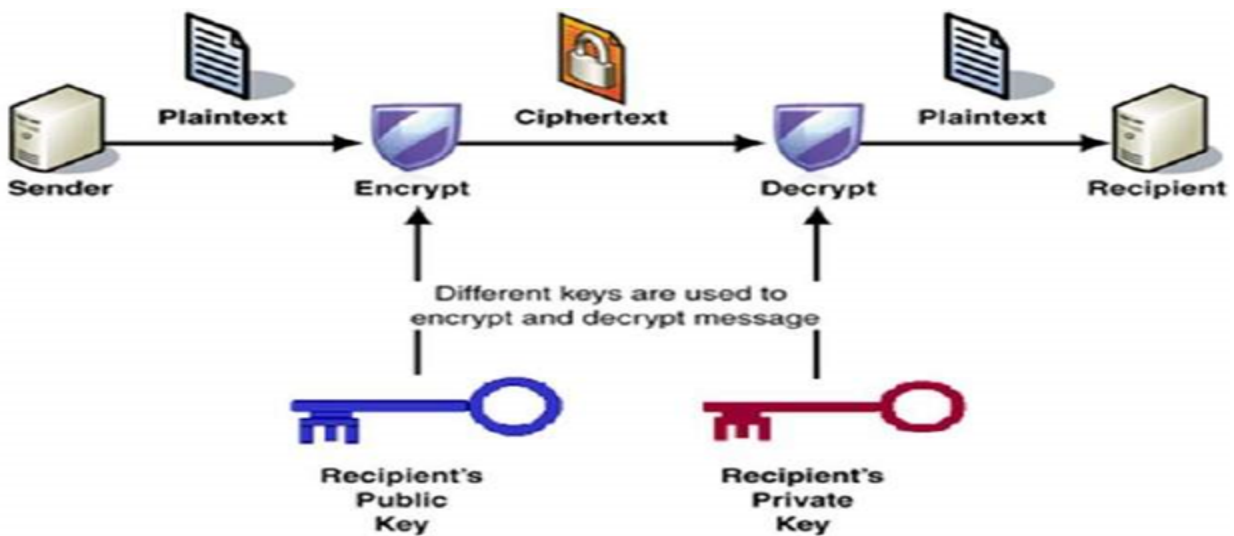
Fig 1.4 Asymmetric Cryptography

Components of public key cryptography:

Plain Text: This is the message which is readable or understandable. This message is given to the Encryption algorithm as an input.

Cipher Text: The cipher text is produced as an output of the Encryption algorithm. We cannot simply understand this message.

Encryption Algorithm: The encryption algorithm is used to convert plain text into cipher text.

Decryption Algorithm: It accepts the cipher text as input and the matching key (Private Key or Public key) and produces the original plain text

Public and Private Key: One key either Private key (Secret key) or Public Key (known to everyone) used for encryption and the other is used for decryption.

Benefits of public key cryptography:

The increased data security provided by public key cryptography is its main benefit. Public key cryptography remains the most secure protocol (over private key cryptography) because users never need to transmit or reveal their private keys to anyone, which lessens the chances of cyber criminals discovering an individual's secret key during the transmission.

Public key cryptography also provides digital signatures that cannot be repudiated. Public key cryptography requires each user to be responsible for protecting his private key, whereas private key systems require users to share secret keys and perhaps even trust third parties for transmission. With the secret key system, it is possible for senders to claim the shared secret key was compromised by one of the parties involved in the process.

Applications:
- Confidentiality can be achieved using Public Key cryptography. In this the Plain text is encrypted using the receiver public key. This will ensure that no one other than the receiver 's private key can decrypt the ciphertext.
- Digital signature is for senders authentication purpose. In this sender encrypt the plain text using his own private key. This step will make sure the authentication of the sender because the receiver can decrypt the ciphertext using the sender's public key only.

- This algorithm can be used in both Key-management and secure transmission of data.
- The most widely used public-key cryptosystem is RSA (Rivest–Shamir–Adleman). The difficulty of finding the prime factors of a composite number is the backbone of RSA.

1.2.3 HASH FUNCTIONS :

A cryptographic hash function is an algorithm that takes an arbitrary amount of data input—a credential—and produces a fixed-size output of enciphered text called a hash value, or just "hash." That enciphered text can then be stored instead of the password itself, and later used to verify the user.
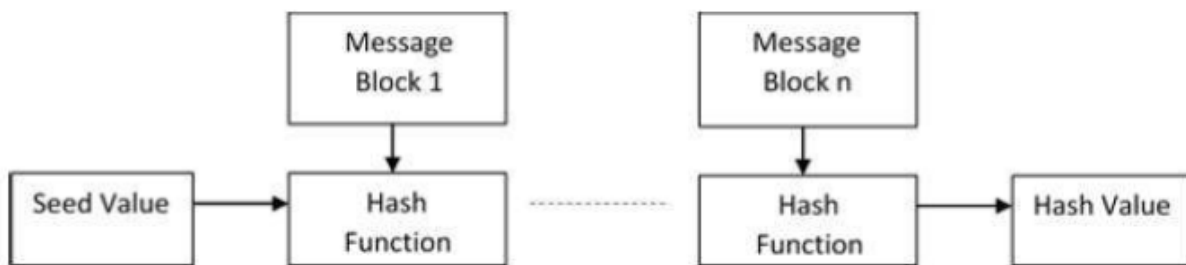
Fig 1.5 Hash Functions

Certain properties of cryptographic hash functions impact the security of password storage.

- Non-reversibility, or one-way function. A good hash should make it very hard to reconstruct the original password from the output or hash.
- Diffusion, or avalanche effect. A change in just one bit of the original password should result in change to half the bits of its hash. In other words, when a password is changed slightly, the output of enciphered text should change significantly and unpredictably.
- Determinism. A given password must always generate the same hash value or enciphered text.
- Collision resistance. It should be hard to find two different passwords that hash to the same enciphered text.

- Non-predictable. The hash value should not be predictable from the password.
- The most common cryptographic hash function is MD5. Another popular hash function is SHA-1.

Advantages

- The output always has the same length, so this can be taken into account when processing or storing the message digest.
- The output is much shorter than the input, so that processing and storing can be done much quicker.

Disadvantages

- Hash collisions are practically unavoidable. when hashing a random subset of a large set of possible keys.
- Hash tables become quite inefficient when there are many collisions.
- Hash table does not allow null values, like hash map.

1.3 APPLICATIONS OF CRYPTOGRAPHY :

1. Authentication/Digital Signatures
2. Time Stamping
3. Electronic Money
4. Encryption/Decryption in email
5. Encryption in WhatsApp
6. Encryption in Instagram
7. Sim card Authentication

CHAPTER - 2
LITERATURE SURVEY

Guerric Meurice de Dormale and Jean-Jacques Quisquater[1] explained the techniques for implementing Elliptic Curve Cryptography at a high-speed. This survey is a classification of the work available in the open literature in function of the level of efficiency and flexibility is also proposed. In particular, the subjects of reconfigurable, dedicated, generator, versatile and general purpose scalar multipliers are addressed.Elliptic Curve Cryptography (ECC) has gained increasing acceptance in the industry and the academic community and has been the subject of several standards. This interest is mainly due to the high level of security with relatively small keys provided by ECC. To sustain the high throughput required by applications like network servers, high-speed implementations of public-key cryptosystems are needed. For that purpose, hardware-based accelerators are often the only solution reaching an acceptable performance-cost ratio. The fundamental question that arises is how to choose the appropriate efficiency–flexibility tradeoff. Finally, some words about future work that should be tackled are provided.

Hamad Marzouqi,Mahmoud Al-Qutayri,Khaled Salah[2] proposed that Elliptic Curve Cryptography (ECC) is a multilayer system with increased hardware implementation complexity. A wide range of parameters and design choices affect the overall implementation of ECC systems. A variety of hardware implementations of ECC systems that vary in parameters are proposed in the literature. Implementation target, underlying finite fields, coordinate system and modular arithmetic algorithms are key design elements that impact the overall implementation outcome.They survey the various implementation approaches with the aim of providing a useful reference for hardware designers for building efficient ECC processors. Their literature review consists of four components. First, we list the design options and discuss their impact on ECC implementation. Second, we summarize different approaches and algorithms used in the literature for implementing modular arithmetic operations. Third, we review best practices in the literature for data paths and overall architectures. Fourth, we review the existing parallelism and performance enhancement techniques. In addition, it also provides comparison of the different binary extension, prime and dual 8 hardware implementations of ECC.

Young Sil Lee, Esko Alasaarela and Hoon Jae Lee[3] focus on these challenges and intend to provide some contributions to solve the problem. In order to solve these problems, we choose the Elliptic Curve Cryptography (ECC) which is one of the most famous asymmetric cryptographic algorithms. It has attracted considerable attention with the other widely used asymmetric cryptographic algorithm RSA. An elliptic curve Cryptosystem using a 160-bits key can provide the same security level with a 1024-bits RSA key .They applied symmetric algorithm to encrypt or decrypt some sensitive physiological data, and also use ECC to manage the key's distribution, update and revocation.

Neal Koblitz[4] discusses analogs based on elliptic curves over finite fields of public key cryptosystems which use the multiplicative group of a finite field. These elliptic curve cryptosystems may be more secure, because the analog of the discrete logarithm problem on elliptic curves is likely to be harder than the classical discrete logarithm problem, especially over $GF(2^n)$.And also the question of primitive points on an elliptic curve modulo p, and give a theorem on non smoothness of the order of the cyclic subgroup generated by a global point.

Nejmeddine Alimi, Younes Lahbib, Mohsen Machhout and Rached Tourki[5] proposed that Elliptic Curve Cryptography have known, in recent years, an increasing success in security applications thanks to their advantages such as a short keys size with a high security level. Their popularity has led to various implementations in terms of algorithms, curves, coordinate systems, platforms, etc. The aim of their work is first to explore actual trends of ECC-based implementations in different platforms through a review of a number of works. Secondly, to identify and gather the criteria and corresponding metrics used to evaluate the performance of these implementations. They also propose a platform for design exploration and evaluation of ECC designs.

M. A. Mohamed[6] provided a ground up survey on elliptic curve cryptography. It tailors the mathematics behind the elliptic curve to the applicability within a cryptosystem. In brief, the elliptic curve is a study of points on two-variable

polynomials of degree 3. With a curve defined over a finite field, this set of points acted by an addition operation forms a finite group structure. Also known as torsion points, they are used to represent the coded messages. Encryption and decryption transform a point into another point in the same set. Besides providing conceptual understanding, discussions are targeting the issues of security and efficiency of elliptic curve cryptosystem, highlighting subareas of research within the scope of elliptic curve cryptosystem.

R.Shanthakumari,S. Malliga[7] presentation intends to provide a new approach based on a combination of Steganography and Cryptography procedure for inserting the hidden data into a cover object and obtain high data embedding capacity with an improved security level. In this approach, the Elliptic Curve Cryptography algorithm is used to encrypt the hidden information and the encrypted data inserted into a cover object by the process of the LSB Inversion algorithm. This blend of technology has successfully reached the benchmark level of some essential properties known as data confidentiality, integrity verification, capacity and robustness which are the evidence to prove the excellent performance and effective implementation of this steganography process. This new approach intensely tested through several steganalysis attacks such as analysis of visual, histogram, and chi-square. The outcome of the experimental result shown that the stego image has delivered the strong opposition force against all attacks. The data embedding capacity has attained at an improved level compared with typical methods.

Miller V.S.[8] discussed the use of elliptic curves in cryptography. In particular,it proposes an analogue of the Diffie-Hellmann key exchange protocol which appears to be immune from attacks of the style of Western, Miller, and Adleman. With the current bounds for infeasible attack, it appears to be about 20% faster than the Diffie-Hellmann scheme over GF(p). As computational power grows, this disparity should get rapidly bigger.

Verri Lucca A., Mariano Sborz G.A., Leithardt V.R.Q., Beko M., Albenes Zeferino C., Parreira W.D.,[9] presents a systematic review of literature on ECPM implementations on both Field-Programmable Gate Array (FPGA) and

Application-Specific Integrated Circuit (ASIC). The obtained results show which methods and technologies have been used to implement ECPM on hardware and present some findings of the choices available to the hardware designers.

Darrel Hankerson, Alfred Menezes and Vanstone[10] explained practical aspects of elliptic curve cryptography,finite field arithmetic,elliptic curve arithmetic,describes state-of-the art implementation methods, and presents standardized protocols for public-key encryption, digital signatures, and key establishment. They survey the known attacks on the ECDLP, and describe the generation and validation of domain parameters and key pairs, and selected elliptic curve protocols for digital signature, public-key encryption and key establishment. We chose not to include the mathematical details of the attacks on the ECDLP, or descriptions of algorithms for counting the points on an elliptic curve, because the relevant mathematics is quite sophisticated.In particular the FIPS 186-2 standard for the Elliptic Curve Digital Signature Algorithm (ECDSA) developed by the U.S. government's National Institute for Standards and Technology (NIST).In addition, they also address some issues that arise in software and hardware implementation, side-channel attacks and countermeasures, and efficient parameter generation.

S. M. Sakharkar, R. S. Mangrulkar and M. Atique [11] tried to explore security issue in WSN. First, the constraints, security requirements and attacks with their corresponding countermeasures in WSNs are explained. Individual sensor nodes are subject to compromised security. An adversary can inject false reports into the networks via compromised nodes. Furthermore, an adversary can create a Gray hole by compromised nodes. If these two kinds of attacks occur simultaneously in a network, some of the existing methods fail to defend against those attacks. The Ad-hoc On Demand Distance (AODV) Vector scheme for detecting Gray-Hole attack and Statistical En-Route Filtering is used for detecting false report. For increasing security level, the Elliptic Curve Cryptography (ECC) algorithm is used. Simulations results obtain so far reduces energy consumption and also provide greater network security to some extent.

Jouko Teeriaho[12] shows implementation of various aspects of ECC using Mathematica To securely transfer images across the network various techniques have been developed in recent years using ECC.Teeriaho gave a very clear example

implementation of ECC-DH key exchange, ECC encryption, Elliptic Curve Digital Signature using Mathematica .

Lo'ai Tawalbeh, Moad Mowa and Walid Aljoby [13] presented two ECC based encryption on image. The first algorithm performs selective encryption on the transform coefficients during compression, whereas the second algorithm achieves perceptual encryption based on selective bit-plane encryption before compression. The results of applying ECC to multimedia encryption are presented and analysed with respect to the 32 requirements of multimedia encryption: the encryption efficiency, compression efficiency, codec compliance and security level. It is shown that ECC is highly efficient and does not affect the compression efficiency, and accordingly can meet the multimedia encryption requirements.

CHAPTER 3
EXISTING SYSTEM

3.1 DESCRIPTION :

The RSA algorithm is an asymmetric cryptography algorithm; this means that it uses a public key and a private key (i.e two different, mathematically linked keys). As their names suggest, a public key is shared publicly, while a private key is secret and must not be shared with anyone.

The RSA algorithm is named after those who invented it in 1978: Ron Rivest, Adi Shamir, and Leonard Adleman.

The idea of RSA is based on the fact that it is difficult to factorize a large integer. The public key consists of two numbers where one number is multiplication of two large prime numbers. And private key is also derived from the same two prime numbers. So if somebody can factorize the large number, the private key is compromised. Therefore encryption strength totally lies on the key size and if we double or triple the key size, the strength of encryption increases exponentially. RSA keys can be typically 1024 or 2048 bits long, but experts believe that 1024 bit keys could be broken in the near future. But till now it seems to be an infeasible task.

RSA Key generation:

An RSA key pair can be generated using Algorithm 3.1. The public key consists of a pair of integers (n, e) where the RSA modulus n is a product of two randomly generated (and secret) primes p and q of the same bitlength. The encryption exponent e is an integer satisfying $1 < e < \varphi$ and $\gcd(e, \varphi) = 1$ where $\varphi = (p-1)(q-1)$. The private key d, also called the decryption exponent, is the integer satisfying $1 < d < \varphi$ and $ed \equiv 1 \pmod{\varphi}$. It has been proven that the problem of determining the private key d from the public key (n, e) is computationally equivalent to the problem of determining the factors p and q of n; the latter is the *integer factorization problem (IFP).*

Algorithm 3.1 RSA key pair generation

INPUT: Security parameter l.

OUTPUT: RSA public key (n, e) and private key d.
1. Randomly select two primes p and q of the same bitlength l/2.
2. Compute n = pq and φ = (p−1)(q −1).
3. Select an arbitrary integer e with 1 < e <φ and gcd(e,φ) = 1.
4. Compute the integer d satisfying 1 < d <φ and ed ≡ 1 (mod φ).
5. Return(n, e,d).

RSA encryption scheme:

RSA encryption use the fact that
$$m^{ed} \equiv m \ (mod\ n) \ (3.1)$$
for all integers m. The encryption and decryption procedures for the (basic) RSA public-key encryption scheme are presented as Algorithms 3.2 and 3.3. Decryption works because cd ≡ (me)d ≡ m (mod n), as derived from expression (3.1). The security relies on the difficulty of computing the plaintext m from the ciphertext c = m^e mod n and the public parameters n and e. This is the problem of finding e^{th} roots modulo n and is assumed (but has not been proven) to be as difficult as the *integer factorization problem.*

Algorithm 3.2 Basic RSA encryption

INPUT: RSA public key (n, e), plaintext m ∈ [0,n−1].
OUTPUT: Ciphertext c.
1. Compute c = m^e mod n.
2. Return(c).

Algorithm 3.3 Basic RSA decryption

INPUT: RSA public key (n, e), RSAprivate key d, ciphertext c.
OUTPUT: Plaintext m.
1. Compute m = c^d mod n.
2. Return(m).

Alice generates her RSA keys by selecting two primes:

$$p=11 \text{ and } q=13$$

The modulus is $n=p\times q=143$.

The totient is n $\phi(n)=(p-1)\text{x}(q-1)=120$.

She chooses 7 for her RSA public key e and calculates her RSA private key using the Extended Euclidean algorithm, which gives her 103.

Bob wants to send Alice an encrypted message, M,

so he obtains her RSA public key (n, e) which, in this example, is (143, 7).

His plaintext message is just the number 9 and is encrypted into ciphertext, C, as follows:

$$\text{Me mod } n = 97 \text{ mod } 143 = 48 = C$$

When Alice receives Bob's message, she decrypts it by using her RSA private key (d, n) as follows:

$$\text{Cd mod } n = 48103 \text{ mod } 143 = 9 = =M$$

To use RSA keys to digitally sign a message, Alice would need to create a hash -- a message digest of her message to Bob -- encrypt the hash value with her RSA private key, and add the key to the message. Bob can then verify that the message has been sent by Alice and has not been altered by decrypting the hash value with her public key. If this value matches the hash of the original message, then only Alice could have sent it -- authentication and non-repudiation -- and the message is exactly as she wrote it -- integrity.

Alice could, of course, encrypt her message with Bob's RSA public key -- confidentiality -- before sending it to Bob. A digital certificate contains information that identifies the certificate's owner and also contains the owner's public key.

Certificates are signed by the certificate authority that issues them, and they can simplify the process of obtaining public keys and verifying the owner.

The computationally expensive step in any RSA operation is the modular exponentiation,e.g., computing me mod n in encryption and cd mod n in decryption. In order to increase the efficiency of encryption and signature verification, one can select a small encryption exponent e; in practice, e = 3 or e = 216 +1 is commonly chosen. The decryption exponent d is of the same bitlength as n. Thus, RSA encryption with small exponent e are significantly faster than RSA decryption.

Drawbacks:

- RSA algorithm can be very slow in cases where large data needs to be encrypted by the same computer.
- It requires a third party to verify the reliability of public keys.
- Data transferred through RSA algorithm could be compromised through middlemen who might tamper with the public key system.
- It requires a more computer power supply compared to single key encryption.
- Complexity of the algorithm i.e key is too large and calculation time is long.
- Very slow key generation.

CHAPTER 4
PROPOSED SYSTEM

4.1 ELLIPTIC CURVE CRYPTOGRAPHY :

Elliptic Curve Cryptography (ECC) is a key-based technique for encrypting data. ECC focuses on pairs of public and private keys for decryption and encryption of web traffic.

ECC, an alternative technique to RSA, is a powerful cryptography approach. It generates security between key pairs for public key encryption by using the mathematics of elliptic curves. Like all public-key cryptography, ECC is based on mathematical functions that are simple to compute in one direction, but very difficult to reverse.

In the case of ECC, this difficulty resides in the infeasibility of computing the discrete logarithm of a random elliptic curve element with respect to a publicly known base point, or the "elliptic curve discrete logarithm problem" (ECDLP). ECC can achieve the same level of security with a 164-bit key that other systems require a 1,024-bit key. Because ECC helps to establish equivalent security with lower computing power and battery resource usage. An elliptic curve is the set of points that satisfy a specific mathematical equation. The equation for an elliptic curve looks like this $y^2=x^3+ax+b$.

4.2 PRELIMINARIES :

The basic operations on the elliptic curve are Point Addition and Point Doubling which forms the building blocks of scalar multiplication. All the basic operations are performed in Projective coordinates in order to reduce the costly inversion operation.

4.2.1. Weierstrass Equation :

A **Weierstrass equation** or **Weierstrass model** over a field k is a plane curve E of the form :

$$y^2+a_1xy+a_3y = x^3+a_2x_2+a_4x+a_6$$

$$\text{with } a_1,a_2,a_3,a_4,a_6 \in k.$$

The **Weierstrass coefficients** of this model E are the five coefficients ai. These are often displayed as a list $[a_1, a_2, a_3, a_4, a_6]$.

It is common not to distinguish between the *affine* curve defined by a Weierstrass equation and its *projective closure*, which contains exactly one additional *point at infinity*, [0:1:0][0:1:0][0:1:0].

A Weierstrass model is smooth if and only if its discriminant Δ is nonzero. In this case, the plane curve EEE together with the point at infinity as base point, define an elliptic curve defined over k.

Two smooth Weierstrass models define isomorphic elliptic curves if and only if they are isomorphic as Weierstrass models.

4.2.2. Point Addition :

Let P and Q be the two points on the curve ,the addition of P and Q results in P+Q. i.e. R=P+Q .The basic operation of addition of points is by drawing a line through the points P and Q. This line intersect a point on the curve, i.e. -R. The inverse of this point is the actual result R.

To perform addition of two distinct point coordinates the following calculation is used. Figure 1(a) shows the graphical representation of point addition.

$$P(x_1, y_1) + Q(x_2, y_2) = R(x_3, y_3)$$
$$x_3 = (\lambda_2 - x_1 - x_2) \mod p$$
$$y_3 = (\lambda(x_1 - x_3) - y_1) \mod p$$
$$\text{Where}$$
$$\lambda = (y_2 - y_1)/(x_2 - x_1) \mod p$$
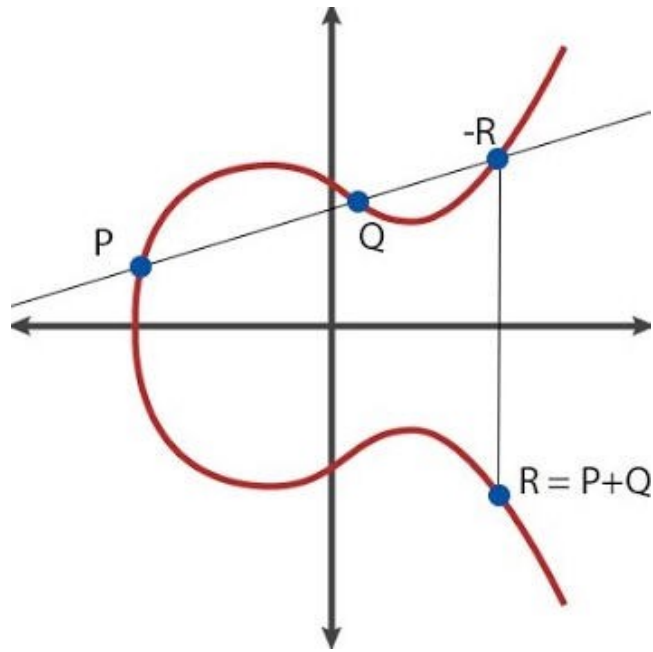
Fig 4.1 Point Addition

4.2.3. Point Inversion :

The inverse of a given point $P = (x1, y1)$ on a finite field curve is given by the point $(x1, -y1)$ which can be called as -P.
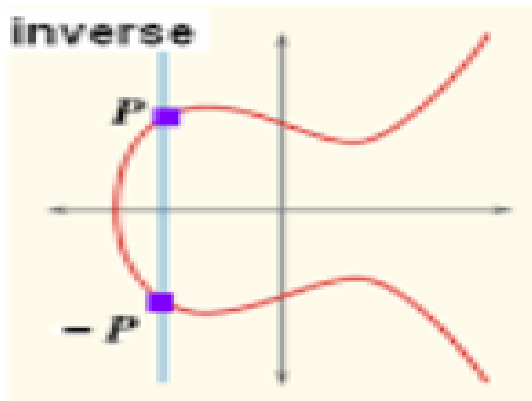
Fig 4.2 Point Inversion

4.2.4. Point Multiplication :

Multiplication is repeated addition of the base coordinate point. Many algorithms have been developed to perform point multiplication swiftly.

$$kP = P + P + P + \cdots + k \text{ times}$$

4.2.5. Point Subtraction :

To perform point subtraction, get a mirror coordinate of the subtracted point along x -axis and perform point addition on the resulting coordinate and the other coordinate. Figure shows graphical representation of point subtraction.

$$P(x\,1\,,\,y\,1\,) - Q(x\,2\,,\,y\,2\,) = P(x\,1\,,\,y\,1\,) + Q(x\,2\,,\,-y\,2\,)$$
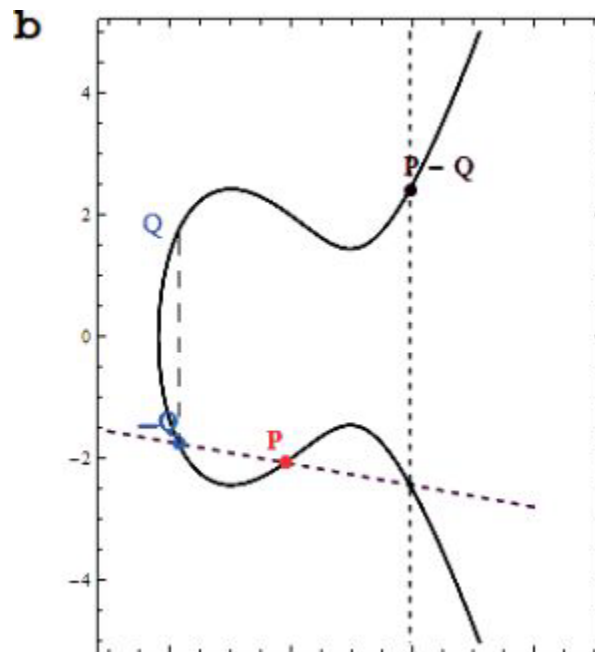
Fig 4.3 Point Subtraction

4.2.6. Point Doubling :

Let P be a Point on the curve ,Doubling results in R=2P.The computation is pictorially given by drawing a tangent on the point P. The Point obtained by intersection of this line is -R. The inverse of this point result in the actual point R.

Point doubling is performed to add up two points which are the same i.e they have the same coordinate value.Figure 1(c) shows graphical representation of point doubling .

$$P(x_1, y_1) + Q(x_2, y_2) = R(x_3, y_3)$$
$$x_3 = (\lambda^2 - 2x_1) \bmod p$$
$$y_3 = (\lambda(x_1 - x_3) - y_1) \bmod p$$
$$\lambda = (3x_1^2 + a)/2y_1 \bmod p$$
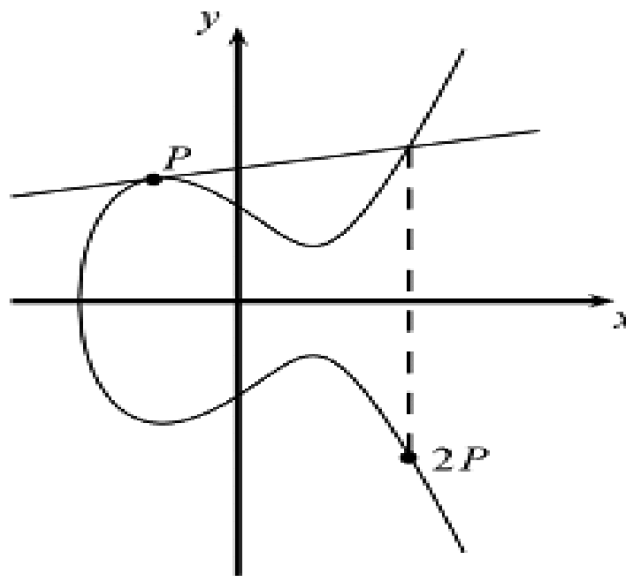
Fig 4.4 Point Doubling

Algorithm 1: Point Doubling ($y^2 = x^3 + ax + b$), Jacobian Coordinates

---

1. If $P = \infty$ then
2. Return (∞)
3. $B \leftarrow 4 * X_1 * Y_1^2$
4. $A \leftarrow 3 * X_1^2 + a * Z_1^4$
5. $X_3 \leftarrow A^2 - 2 * B$
6. $Y_3 \leftarrow A * (B - X_3) - 8 * Y_1^4$
7. $Z3 \leftarrow 2 * Y_1 * Z_1$
8. Return ($X_3 : Y_3 : Z_3$)

4.2.7. Projective Coordinates :

Here two dimensional affine points are converted into three dimensional Projective Coordinates. This has considerably reduced the number of inversions.

If (x, y) be the affine point on the curve, then the Projective Coordinate of this point can be denoted as (X,Y,Z) and $Z \neq 0$.

The projective form of the Weierstrass equations can be obtained by replacing x with X/Z^c and y by Y / Z^d and clearing the denominators.

Algorithm2: Point Addition on Affine-Jacobian Coordinates

---

1. If $Q = \infty$ then Return $(X_1 : Y_{,1} : Z_1)$
2. If $P = \infty$ then Return $(x_2 : y_2 : 1)$
3. $T_1 \leftarrow Z_1^2$
4. $T_2 \leftarrow T_1 * Z_1$
5. $T_1 \leftarrow T_1 * x_2$
6. $T_2 \leftarrow T_2 * y_2$
7. $T_1 \leftarrow T_1 - X_1$
8. $T_2 \leftarrow T_2 - Y_1$
9. If $T1 = 0$ then
10. If $T2 = 0$ then
11. Use algorithm 1 to compute $(X_3 : Y_3 : Z_3) = 2(x2 : y2 : 1)$
    Return $(X_3: Y_3: Z_3)$
12. Else Return (∞)
13. $Z_3 \leftarrow Z_1 * T_1$
14. $T_3 \leftarrow T_1^2$
15. $T_4 \leftarrow T_3 * T_1$
16. $T_3 \leftarrow T_3 * X_1$
17. $X_3 \leftarrow T_2^2$
18. $X_3 \leftarrow X_3 - T_4$
19. $X_3 \leftarrow X_3 - 2*T_3$

20. $T_3 \leftarrow T_3 - X_3{}^2$
21. $Y_3 \leftarrow T_2 * T_3$
22. $T_4 \leftarrow Y_1 * Y_4$
23. $Y_3 \leftarrow Y_3 - T_4$
24. Return $(X_3 : Y_3 : Z_3)$

The most commonly used projective coordinate system are:

Standard Coordinate: c= 1 and d = 1

Jacobian Coordinate: c= 2 and d = 3

Lopez-Dahab (LD) Coordinate: c=1 and d=2

4.3 Encryption and Decryption using ECC :

By definition, asymmetric encryption works as follows: if we encrypt data by a private key, we will be able to decrypt the ciphertext later by the corresponding public key.

Let Alice and Bob be the two communicating parties. The communicating parties agree upon the Elliptic curve equation and a Generator (G).

$$y\,2 = \{x\,3 + ax + b\}\,mod\,[\,p]$$

Suppose Alice wants to encrypt a message ' Pm' and send it to Bob. The cipher text is given by

$$Pc = [kG,\ Pm+kPb\ ]$$

where 'k' is a random integer and

' Pb ' is the public key of Bob computed using the private key of Bob 'nB ',

Pb = nBG.

Bob 44 decrypts the cipher message as message [Pm+kPb-nBkG].

Since Pb=nBG, kPb and nBkG cancel each other and ' Pm' remains, which is the message sent by Alice.

4.4 Comparison Of RSA and ECC Key Size :

The biggest differentiator between ECC and RSA is key size compared to cryptographic strength.Both key types share the same important property of being asymmetric algorithms (one key for encrypting and one key for decrypting).

However, ECC can offer the same level of cryptographic strength at much smaller key sizes - offering improved security with reduced computational requirements.

ECC Key Size (bits)	RSA Key Size(bits)	Key Size Ratio
160	1024	1:7
224	2048	1:10
256	3072	1:12
384	7680	1:20
521	15360	1:30

Fig 4.5 Comparision of key size

As you can see in the chart above, ECC is able to provide the same cryptographic strength as an RSA-based system with much smaller key sizes. For example, a 256 bit ECC key is equivalent to RSA 3072 bit keys (which are 50% longer than the 2048 bit keys commonly used today).
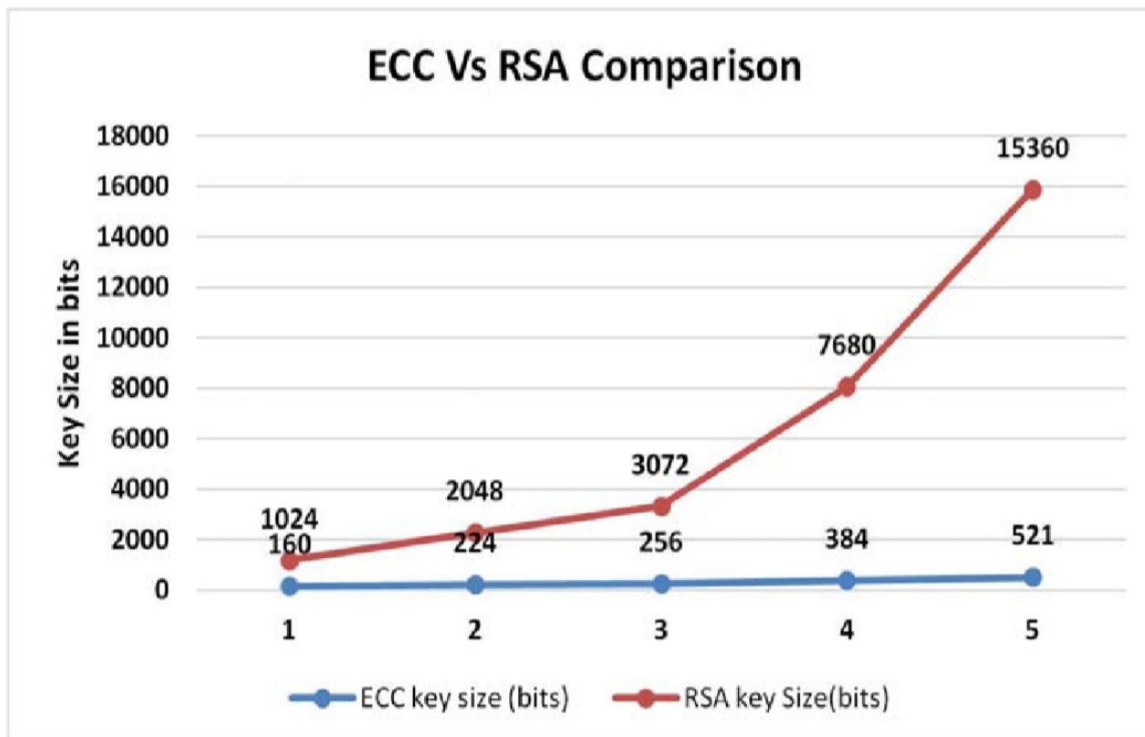
Fig 4.6 Graphical representation for comparision of key size

4.5 Advantages of ECC:

➢ Smaller keys, ciphertexts and signatures.
➢ Very fast key generation.
➢ Fast signatures.
➢ Moderately fast encryption and decryption.
➢ Signatures can be computed in two stages, allowing latency much lower than inverse throughput.
➢ Good protocols for authenticated key exchange (FH-ECMQV et a l)
➢ Special curves with bilinear pairings allow new-fangled crypto .
➢ Binary curves are really fast in hardware.

CHAPTER 5
HARDWARE REQUIREMENTS

HARDWARE REQUIREMENTS:

5.1 Processor :

The Core i5 processor is available in multiple speeds, ranging from 1.90 GHz up to 3.80 GHz, and it features 3 MB, 4 MB or 6 MB of cache. It utilizes either the LGA 1150 or LGA 1155 socket on a motherboard. Core i5 processors are most often found as quad-core, having four cores. However, a select few high-end Core i5 processors feature six cores.

Intel Core i5 is a 64-bit dual-core mid-range performance x86 mobile micro-processor introduced by Intel in late 2015. Developed and manufactured by Intel, the Core i5 is a computer processor, available as dual-core or quad-core. It can be used in both desktop and laptop computers, and is one of three types of processors in the "i" series (also called the Intel Core family of processors).

Fabricated on a 14 nm process based on the Sky lake microarchitecture, this processor operates at 2.30 GHz with a turbo boost of upto 2.80 GHz. The i5-6200U has a TDP of 15W with a configurable TDP-down of 7.5 W (800 MHz) and a configurable TDP-up of 25 (2.4 GHz). This chip incorporates the HD Graphics 520 GPU operating at 300 MHz with a burst frequency of 1 GHz. This processor supports up to 32 GB of non-ECC dual-channel DDR4-2133 memory. The most common type of RAM used with a Core i5 processor is DDR3 1333 or DDR3 1600, however, higher performance RAM can be used as well (if the motherboard supports it).

Power usage varies for the Core i5 processors:
- · Slower speeds (1.90 GHz to 2.30 GHz) use 11.5 W of power 47
- · Medium speeds (2.60 GHz to 3.10 GHz) use 15 W, 25 W, 28 W or 37W of power
- Faster speeds (3.20 GHz to 3.80 GHz) use 35 W, 37 W, 45 W, 47W, 65 W or 84 W of power.

Core i5 processors are commonly found in desktop computers for most

everyday use and some higher performance needs. Some laptop computers feature Core i5 processors as well, to provide improved performance for heavier usage needs. At the lower speeds, battery usage is pretty conservative and can reach up to five hours or usage on a single charge. However, at higher speeds, battery usage is higher and may result in up to three hours or so of usage per charge.

5.2. RAM: 4GB

5.3 Speed: 2.1GHz

CHAPTER 6

SOFTWARE REQUIREMENTS

6.1 Operating System :

Windows 10 is a series of personal computer operating systems produced by Microsoft as part of its Windows NT family of operating systems. It is the successor to Windows 8.1, and was released to manufacturing on July 15, 2015, and broadly released for retail sale on July 29, 2015. Windows 10 receives new builds on an ongoing basis, which are available at no additional cost to users, in addition to additional test builds of Windows 10 which are available to Windows Insiders. Devices in enterprise environments can receive these updates at a slower pace, or use long-term support milestones that only receive critical updates, such as security patches, over their ten-year lifespan of extended support.

One of Windows 10's most notable features is support for universal apps, an expansion of the Metro-style apps first introduced in Windows 8. Universal apps can be designed to run across multiple Microsoft product families with nearly identical code including PCs, tablets, smart phones, embedded systems, Xbox One, Surface Hub and Mixed Reality. The Windows user interface was revised to handle transitions between a mouse oriented interface and a touch screen-optimized interface based on available input devices particularly on 2-in-1 PCs, both interfaces include an updated Start menu which incorporates elements of Windows 7's traditional Start menu with the tiles of Windows 8. Windows 10 also introduced the Microsoft Edge, web browser, a virtual desktop system, a window and desktop management feature called Task View, support for fingerprint and face recognition login, and new security features for enterprise environments.

Windows 10 received mostly positive reviews upon its original release in July 2015. Critics praised Microsoft's decision to provide a desktop-oriented interface in line with previous versions of Windows, contrasting the tablet-oriented approach of 8, although Windows 10's touch-oriented user interface mode was criticized for containing regressions upon the touch-oriented interface of Windows 8. Critics also praised the improvements to Windows 10's bundled software over Windows 8.1, Xbox Live integration, as well as the functionality and capabilities of the Cortana

personal assistant and the replacement of Internet Explorer with Microsoft Edge. However, media outlets have been critical of changes to operating system behaviors, including mandatory update installation, privacy concerns over data collection performed by the OS for Microsoft and its partners and the adware-like tactics used to promote the operating system on its release.

Windows 10 makes more consistent the user experience and functionality between different classes of device, and addresses shortcomings in the user interface that were introduced in Windows 8. Windows 10 Mobile, the successor to Windows Phone 8.1, shares some user interface elements and apps with its PC counterpart.

6.2 Programming Environment : JAVA

Java is a recently developed, concurrent, class-based, object-oriented programming and runtime environment, consisting of:

- A programming language
- An API specification
- A virtual machine specification

Using BigInteger :

BigInteger class is used for mathematical operations which involve very big integer calculations that are outside the limit of all available primitive data types.

Declaration :

int a, b;

BigInteger A, B;

Initialization:

a = 54;

b = 23;

A = BigInteger.valueOf(54);

B = BigInteger.valueOf(37);

And for Integers available as string you can initialize them as:

A = new BigInteger("54");

B = new BigInteger("123456789123456789");

Some constant are also defined in BigInteger class for ease of initialization :

A = BigInteger.ONE;

// Other than this, available constant are BigInteger.ZERO

// and BigInteger.TEN

Mathematical operations:

int c = a + b;

BigInteger C = A.add(B);

Other similar function are subtract() , multiply(), divide(), remainder()

But all these function take BigInteger as their argument so if we want these operation with integers or string convert them to BigInteger before passing them to functions as shown below:

String str = "123456789";

BigInteger C = A.add(new BigInteger(str));

int val = 123456789;

BigInteger C = A.add(BigInteger.valueOf(val));

Extraction of value from BigInteger:

int x = A.intValue();   // value should be in limit of int x

long y = A.longValue(); // value should be in limit of long y

String z = A.toString();

CHAPTER 7
IMPLEMENTATION

7.1 Mapping:

The proposed method shows a new mapping technique for mapping the message into affine points on the curve. For performing Elliptic curve encryption and decryption both the sender and the receiver must the following:
- The Elliptic curve chosen E(Fp).i.e. For a finite field curve :
$$y^2 = x^3 + ax + b \pmod{p},$$
    the parameters are a, b and p where p is the prime number.
- The base point with order N.
- The order in which the mapped HEXADECIMAL encryption is performed.

The mapping method proposed in this project converts Message M into ASCII values and converts these ASCII into HEXADECIMAL and grouping of HEXADECIMAL into a finite set of input size. Reverse the order of the HEXADECIMAL value obtained. These results are encrypted using the Scalar multiplication algorithm and converted into cipher text.

Transform the plain text into ASCII values

↓

Convert the ASCII values into HEXADECIMAL values

↓

Group the HEX values to form affine points

↓

Reverse the order before encryption

Transform ASCII to plain text

↑

Convert the HEXADECIMAL to ASCII values

↑

Convert the affine points to HEX values

↑

Decrypt the message and reverse the order
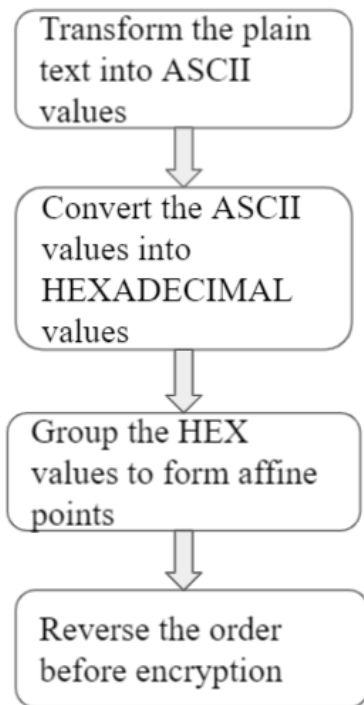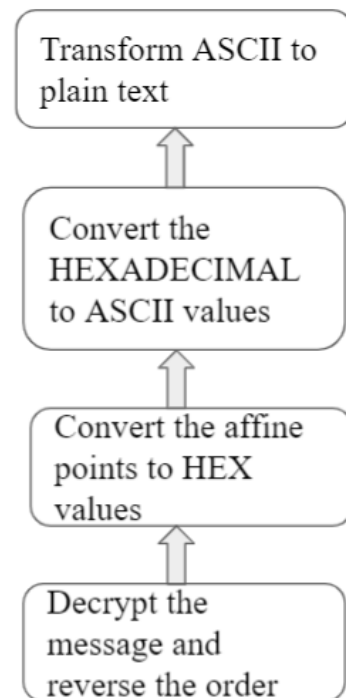
Fig 7.1 Encryption   **Fig 7.2 Decryption**

7.2 Encryption and Decryption:

Code:

Elliptic Curve cryptography is a public Key cryptosystem we need both private key and public key. Let Alice and Bob be the communicating parties, then they should have a secured channel for communication between them. So this they need secret keys for converting the actual message into known readable format. Key generation is the important part of ECC, so we need both public key and private key. Alice will encrypt the message using Bob's public key and Bob will decrypt the message using his private key.

For Elliptic Curve Cryptography both the sender and the receiver should know the chosen Elliptic curve E(Fp).

The key Generation step is as follows:

Select a constant d $\in$ (0 to n-1), where n is the maximum limit, which is a prime number.
Generate public key Q:

$$Q=d*P$$

Where P is the point on the curve.

Encryption:

Message m is transformed into affine point M on the curve.Select k ε (0 to n-1).The plain text is transformed into two cipher text C1 and C2 and send these both cipher text.

$$C1 = k*P$$
$$C2 = M + k*Q$$

Decryption:

The d used for generating Public key is used for decryption. Decryption will return the actual message M from the cipher text C1 and C2.

$$M = C2 - d*C1$$

Where C1 and C2 are encrypted cipher texts and M is message

$$C2 - d*C1 = (M+k*Q) - d*C1$$
$$= (M+k*Q) - d*(k*P)$$
$$= (M+k*Q) - k*(d*P)$$
$$= M+k*Q-(k*Q)$$
$$= M$$

So, the message is decrypted successfully and we get the original message M.

Implementation Process:

Read the input text and convert it into ASCII values and ASCII are again converted into HEXADECIMAL values and then perform the grouping of these HEXADECIMAL values based on the size of the curve parameter. For example if we are using 192 bit NIST prime then the HEXADECIMAL is grouped to 192 bit (x, y) coordinate. But the point is that these groups perform the scalar multiplication in the reverse order of the HEXADECIMAL input obtained or either you can perform any columnar transposition for the input points x and y in order to provide security. After mapping encryption is performed. This point is termed as M which is used in the encryption process.

The Encryption point in elliptic curve Cryptography is (kP,M+kQ) . Here we will take K,G,nA,nB as inputs .Calculate kP(P+P+P......(K times) This point is the x- coordinate of Cipher point.C1 can be calculated by kP. M varies from one alphabet to another and calculates M+kQ for every alphabet.This point is called a cipher point.

The formula for decrypted points : C2-d*C1 = M

Multiply d with kP and find the negative points of that point (i.e negative point of (x,y) is (x,p-y)) and add it with cipher points i.e M+kQ .The result will be M. Again Reverse look up the Pm x coordinate so that we can get the characters

which in turn returns the original text.

Code:

Class: ECPoint.java

```java
import java.math.BigInteger;    // for large numeric calculations
import java.util.ArrayList; // dynamic array
import java.util.List;  // to store collection of elements
import java.util.Scanner;   // to read user input
import java.util.Random;    // to generate random number

class ECPoint {
    public BigInteger x;
    public BigInteger y;
    private boolean pointOfInfinity;

    public ECPoint() {
        this.x = this.y = BigInteger.ZERO;
        this.pointOfInfinity = false;
    }

    public ECPoint(BigInteger x, BigInteger y) {
        this.x = x;
        this.y = y;
        this.pointOfInfinity = false;
    }

    public ECPoint(long x, long y) {
        this.x = BigInteger.valueOf(x);
        this.y = BigInteger.valueOf(y);
        this.pointOfInfinity = false;
    }

    public ECPoint(ECPoint p) { // Copy Constructor
```

```java
      this.x = p.x;
      this.y = p.y;
      this.pointOfInfinity = p.pointOfInfinity;
   }

   public boolean equals(ECPoint point) {  // to check if 2 points are equal
      if (point == null) return false;

      if (this.pointOfInfinity == point.pointOfInfinity) return true;

      return (this.x.compareTo(point.x) | this.y.compareTo(point.y)) == 0;
   }

   public boolean isPointOfInfinity() {
      return pointOfInfinity;
   }

   public ECPoint negate() {   // (x,y) => (x,-y)
      if (isPointOfInfinity()) {
         return INFINITY;
      } else {
         return new ECPoint(x, y.negate());
      }
   }

   private static ECPoint infinity() {
      ECPoint point = new ECPoint();
      point.pointOfInfinity = true;
      return point;
   }

   public static final ECPoint INFINITY = infinity();

   @Override
   public String toString() {  // gives string representation of object
```

```java
        if (isPointOfInfinity()) {
            return "INFINITY";
        } else {
            return "(" + x.toString() + ", " + y.toString() + ")";
        }
    }

    public String toString(int radix) {
        if (isPointOfInfinity()) {
            return "INFINITY";
        } else {
            return "(" + x.toString(radix) + ", " + y.toString(radix) + ")";
        }
    }
}
```

Class:EllipticCurveNewFinal.java

```java
public class EllipticCurveNewFinal {

    // The three parameters of the elliptic curve equation.
    private static BigInteger a;
    private static BigInteger b;
    private static BigInteger p;

    // the base point g.
    private static ECPoint g = null;


    // some BigInteger constants that might help us in some calculations
    private static BigInteger THREE = new BigInteger("3");


    public EllipticCurveNewFinal(BigInteger a, BigInteger b, BigInteger p, ECPoint
g) {
```

```java
    this.a = a;
    this.b = b;
    this.p = p;
    this.g = g;
}


public EllipticCurveNewFinal(long a, long b, long p, ECPoint g) {
    this.a = BigInteger.valueOf(a);
    this.b = BigInteger.valueOf(b);
    this.p = BigInteger.valueOf(p);
    this.g = g;
}

public static ECPoint getBasePoint() {
    return g;
}


public static boolean isPointOnCurve(ECPoint point) {  // check if point exists on curve or not
    if (point.isPointOfInfinity()) return true;

    return point.x.multiply(point.x).mod(p).add(a).multiply(point.x).add(b)
        .mod(p).subtract(point.y.multiply(point.y)).mod(p)
        .compareTo(BigInteger.ZERO) == 0;
}


public static ECPoint doubling(ECPoint p1) { // Algo for point Doubling
    if (p1.isPointOfInfinity())
        return ECPoint.INFINITY;
    BigInteger x1 = p1.x;
    BigInteger y1 = p1.y;
    BigInteger z1 = new BigInteger("1");
```

```java
        BigInteger two = new BigInteger("2");
        BigInteger four = new BigInteger("4");
        BigInteger eight = new BigInteger("8");
        BigInteger B = y1.pow(2).multiply(x1).multiply(four).mod(p);
        BigInteger A =
x1.pow(2).multiply(THREE).add(z1.pow(4).multiply(a)).mod(p);
        BigInteger x3 = A.pow(2).subtract(B.add(B)).mod(p);
        BigInteger y3 =
B.subtract(x3).multiply(A).subtract(y1.pow(4).multiply(eight)).mod(p);
        BigInteger z3 = y1.multiply(z1).multiply(two).mod(p);
        BigInteger z3_i = z3.modInverse(p);
        x3 = z3_i.pow(2).multiply(x3).mod(p);
        y3 = z3_i.pow(3).multiply(y3).mod(p);
        return new ECPoint(x3,y3);
    }


    public static ECPoint add(ECPoint p1, ECPoint p2) {    // Algo for Point Addition
        if (p1 == null || p2 == null) return null;

        if (p1.isPointOfInfinity()) {
            return new ECPoint(p2);
        } else if (p2.isPointOfInfinity()) {
            return new ECPoint(p1);
        }

        BigInteger x1 = p1.x;
        BigInteger y1 = p1.y;
        BigInteger z1 = new BigInteger("1");
        BigInteger x2 = p2.x;
        BigInteger y2 = p2.y;
        BigInteger z2 = new BigInteger("1");
        BigInteger t1 = z1.pow(2).mod(p);
        BigInteger t2 = t1.multiply(z1).mod(p);
        t1 = t1.multiply(x2).mod(p);
```

```java
    t2 = t2.multiply(y2).mod(p);
    BigInteger t5 = t1.add(x1).mod(p);
    t1 = t1.subtract(x1).mod(p);
    t2 = t2.subtract(y1).mod(p);
    if(t1.compareTo(BigInteger.ZERO)==0){
        if(t2.compareTo(BigInteger.ZERO)==0){
            return doubling(p2);
        }
        else
            return ECPoint.INFINITY;
    }
    BigInteger z3 = z1.multiply(t1).mod(p);
    BigInteger t3 = t1.pow(2).mod(p);
    BigInteger t4 = t3.multiply(t5).mod(p);
    BigInteger t6 = t3.multiply(t1).mod(p);
    t3 = t3.multiply(x1).mod(p);
    BigInteger x3 = t2.pow(2).mod(p);
    x3 = x3.subtract(t4).mod(p);
    t3 = t3.subtract(x3).mod(p);
    BigInteger y3 = t2.multiply(t3).mod(p);
    t4 = y1.multiply(t6).mod(p);
    y3 = y3.subtract(t4).mod(p);
    BigInteger z3_i = z3.modInverse(p);
    x3 = z3_i.pow(2).multiply(x3).mod(p);
    y3 = z3_i.pow(3).multiply(y3).mod(p);
    return new ECPoint(x3,y3);
}


public static ECPoint subtract(ECPoint p1, ECPoint p2) {
    if (p1 == null || p2 == null) return null;

    return add(p1, p2.negate());
}
```

```java
public static ECPoint multiply(ECPoint p1, BigInteger n) { // Point Multiplication
    if (p1.isPointOfInfinity()) {
        return ECPoint.INFINITY;
    }

    ECPoint result = ECPoint.INFINITY;
    int bitLength = n.bitLength();
    for (int i = bitLength - 1; i >= 0; --i) {
        result = add(result, result);
        if (n.testBit(i)) {
            result = add(result, p1);
        }
    }

    return result;
}

public static ECPoint multiply(ECPoint p1, long n) {
    return multiply(p1, BigInteger.valueOf(n));
}



public BigInteger calculateRhs(BigInteger x) { // (x^3+a*x+b)%p
    return x.multiply(x).mod(p).add(a).multiply(x).add(b).mod(p);
}

public List<Object> encrypt(String str, BigInteger nA,BigInteger nB,int size){
    System.out.println("<-----------Encrypting------------>");
    long startTimer = System.currentTimeMillis();
    StringBuffer sb = new StringBuffer();
        Random rand = new Random();
    //Converting string to character array
    char ch[] = str.toCharArray();
    for(int i = 0; i < ch.length; i++)
```

```java
        {
            String hexString = Integer.toHexString(ch[i]); // string representation of
entered int in base 16
            sb.append(hexString);
        }
        String result = sb.toString();
        String initRes = result;
        System.out.println("Hexadecimal Representation of Entered String : " + result);
        sb.reverse();
        result = sb.toString();
        System.out.println("Before Encryption -> After reversing the HexString : " +
result);
        List<String> tokens = new ArrayList<>();

        for (int start = 0; start < result.length(); start += size) {
            tokens.add(result.substring(start, Math.min(result.length(), start + size)));
        }
        if(tokens.size()%2!=0)
            tokens.add("0");
        System.out.println("Tokens are : ");
        for(int i=0;i<tokens.size();i+=2){
            System.out.println("("+tokens.get(i)+") , (" + tokens.get(i+1) + ")");
        }
        int noOfPoints = tokens.size()/2;
        System.out.println("NIST_P_BIT: " + isPointOnCurve(getBasePoint()));
        ECPoint pA = multiply(getBasePoint(),nA); // public key of A
        ECPoint pB = multiply(getBasePoint(),nB); // public key of B
        List<Object> encMsgs = new ArrayList<Object>();
        int temp=0,pNo=1;
        String dHexStr = "";
        while(noOfPoints!=0){
            String xCord = tokens.get(temp);
            String yCord = tokens.get(temp+1);
            BigInteger x1 = new BigInteger(tokens.get(temp),16);
            BigInteger y1 = new BigInteger(tokens.get(temp+1),16);
```

```java
            temp+=2;
            noOfPoints-=1;
            System.out.println("<--------------------------------------------------->");
            System.out.println("Point : " + pNo);
            pNo += 1;
            ECPoint M1 = new ECPoint(x1,y1);
            System.out.println("Before Encryption : " + M1.toString(16));
            System.out.println("Encrypting.......");
            int kR = Math.abs(rand.nextInt());
            BigInteger k = BigInteger.valueOf(kR);
            System.out.println("k : "+ k);
            ECPoint c1 = multiply(getBasePoint(), k);
            ECPoint kPb = multiply(pB, k);
            ECPoint c2 = add(M1,kPb);
            encMsgs.add(c1);
            encMsgs.add(c2);
            System.out.println("C1 (k*G) = " + c1.toString(16));
            System.out.println("C2 (M + k*pB) = " + c2.toString(16));
        }
        long endTimer = System.currentTimeMillis();
        System.out.println("Total Time for Encryption : " + (endTimer-startTimer) + "
ms");
        return encMsgs;
    }

    public void decrypt(List<Object> encMsgs,BigInteger nB){
        System.out.println("<---------------Decrypting--------------->");
        long startTimer = System.currentTimeMillis();
        int noOfPoints = encMsgs.size()/2;
        String dHexStr = "";
        int itr = 0,pNo=1;
        while(noOfPoints!=0){
            ECPoint c1 = (ECPoint)encMsgs.get(itr);
            ECPoint c2 = (ECPoint)encMsgs.get(itr+1);
            itr+=2;
```

```java
            noOfPoints-=1;
            System.out.println("Point No : " + pNo);
            pNo += 1;
            ECPoint dc1 = multiply(c1,nB);
            ECPoint dM1 = subtract(c2,dc1);
            System.out.println("C2-nB*C1 (M + k*pB - nB*k*G) : " +
dM1.toString(16));
            int dxlen = dM1.x.toString(16).length();
            int dylen = dM1.y.toString(16).length();
            System.out.println("After Decryption : " + dM1.toString(16));
            if(dM1.x!=BigInteger.ZERO){
                if(dxlen%2!=0)
                    dHexStr+="0";
                dHexStr+=dM1.x.toString(16);
            }
            if(dM1.y!=BigInteger.ZERO){
                if(dylen%2!=0)
                    dHexStr+="0";
                dHexStr+=dM1.y.toString(16);
            }
        }
        System.out.println("Received Hex String : " + dHexStr);

        if(dHexStr.length()%2!=0){
         System.err.println("Invlid hex string.");
         return;
        }

        StringBuilder builder = new StringBuilder();
        builder.append(dHexStr);
        builder.reverse();
        dHexStr = builder.toString();
        builder.setLength(0);
```

```java
        System.out.println("After Decryption -> After reversing the hexString : " +
dHexStr);

        for (int i = 0; i < dHexStr.length(); i = i + 2) {
            // Step-1 Split the hex string into two character group
            String s = dHexStr.substring(i, i + 2);
            // Step-2 Convert the each character group into integer using valueOf
method
            int n = Integer.valueOf(s, 16);
            // Step-3 Cast the integer value to char
            builder.append((char)n);
        }
        System.out.println("Message after Decryption :" + builder.toString());
        long endTimer = System.currentTimeMillis();
        System.out.println("Total Time for Decryption : " + (endTimer-startTimer) + "
ms");
    }


    public static void main(String[] args) {

        Scanner sc = new Scanner(System.in);
        System.out.println("Enter Curve Parameter Bit : ");
        int cpbit = sc.nextInt();
        int size = cpbit/4;
        System.out.println("Enter value of a:");
        BigInteger a = sc.nextBigInteger();
        System.out.println("Enter value of b:");
        BigInteger b = sc.nextBigInteger();
        System.out.println("Enter value of p:");
        BigInteger p = sc.nextBigInteger();
        System.out.println("Enter x coordinate of base point :");
        BigInteger bx = sc.nextBigInteger();
        System.out.println("Enter y coordinate of base point :");
```

```java
        BigInteger by = sc.nextBigInteger();
        System.out.println("Enter nA :");
        BigInteger nA = sc.nextBigInteger();    // private key of A
        System.out.println("Enter nB :");
        BigInteger nB = sc.nextBigInteger();    // private key of B
        EllipticCurveNewFinal NIST_P_BIT = new EllipticCurveNewFinal(a,b,p,new
ECPoint(bx,by));
        System.out.print("Enter Message : ");
        sc.nextLine();
        String str = sc.nextLine();
        System.out.println("Entered Message : " + str);
        // encrypt(str,nA,nB)
        List<Object> encMsgs = NIST_P_BIT.encrypt(str,nA,nB,size);
        NIST_P_BIT.decrypt(encMsgs,nB);
    }
}
```

CHAPTER 8
RESULTS

Text Encryption and Decryption:

For the 192 bit NIST_BIT parameter these are the standard values,

a: FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFEFFFFFFFFFFFFFFFC

b: 64210519E59C80E70FA7E9AB72243049FEB8DEECC146B9B1

p: 6277101735386680763835789423207666416083908700390324961279

x: D458E7D127AE671B0C330266D246769353A012073E97ACF8

y: 325930500D851F336BDDC050CF7FB11B5673A1645086DF3B

nA: D23C756C06EAB5CC04D1D3B3EE47C64FA1935528A63425A3

d(nB): A78A236D60BAEC0C5DD41B33A542463A8255391AF64C74EE

and for user input message 1:

```
NIST Curve Parameter Bit : 192
Enter Message : Good Morning Everyone......Have a nice day!!!!
Entered Message : Good Morning Everyone......Have a nice day!!!!
<-----------Encrypting------------>
Hexadecimal Representation of Entered String : 476f6f64204d6f726e696e672045766572796f6e652e2e2e2e2e486176652061206e6963652064617921212121
Before Encryption -> After reversing the HexString : 1212121297164602563696e602160256671684e2e2e2e2e256e6f697275667540276e696e627f6d40246f6f674
Tokens are :
(1212121297164602563696e602160256671684e2e2e2e2e2) , (e256e6f697275667540276e696e627f6d40246f6f674)
NIST_P_BIT: true
<----------------------------------------------->
Point : 1
Before Encryption : (1212121297164602563696e602160256671684e2e2e2e2e2, e256e6f697275667540276e696e627f6d40246f6f674)
Encrypting.......
k : 580641724
C1 (k*G) = (809d37a2518e343ea3c6e30dbf8525993fdea3edaea374cb, 75eadaaa6a6878bbd0ec12bc050d27a77dafaf2d8e9e9cee)
C2 (M + k*pB) = (46a9ca6c00d177c58df6e2556977da9c76074c9a42042323, 44d8d95ea357bdef326e2bfc8ab4f6d3a783eff22b149085)
Total Time for Encryption : 179 ms
<--------------Decrypting-------------->
Point No : 1
C2-nB*C1 (M + k*pB - nB*k*G) : (1212121297164602563696e602160256671684e2e2e2e2e2, e256e6f697275667540276e696e627f6d40246f6f674)
After Decryption : (1212121297164602563696e602160256671684e2e2e2e2e2, e256e6f697275667540276e696e627f6d40246f6f674)
Received Hex String : 1212121297164602563696e602160256671684e2e2e2e2e256e6f697275667540276e696e627f6d40246f6f674
After Decryption -> After reversing the hexString : 476f6f64204d6f726e696e672045766572796f6e652e2e2e2e2e486176652061206e6963652064617921212121
Message after Decryption :Good Morning Everyone......Have a nice day!!!!
Total Time for Decryption : 60 ms
```

Message 2:

```
NIST Curve Parameter Bit : 192
Enter Message : Level of security offered by ECC of 160 bit is equivalent to RSA of 1024 bit.
Entered Message : Level of security offered by ECC of 160 bit is equivalent to RSA of 1024 bit.
<-----------Encrypting------------>
Hexadecimal Representation of Entered String : 4c6576656c206f662073656375726974792064206279204543206f6620313630206269742069732065717569766616c656e7420746f20525341206f662031303234206269742e
Before Encryption -> After reversing the HexString : e24796260243230313026606214352502f6470247e656c6166796571756023796024796260203631302660602343454029726024656275666666029747962757365637026606602c6566756c4
Tokens are :
(e24796260243230313026606214352502f6470247e656c6) , (16679657175602379602479626020363130266f602343454)
(0297260246562756666606029747962757365637026606602) , (c6566756c4)
NIST_P_BIT: true
<------------------------------------------------>
Point : 1
Before Encryption : (e24796260243230313026606214352502f6470247e656c6, 16679657175602379602479626020363130266f602343454)
Encrypting.......
k : 719378099
C1 (k*G) = (2e7fabb426b6852448fc2508cde237e243bb12f60f9a6529, ccc08005868c1a699d6e24c1f30ea14707583f2a0148a95)
C2 (M + k*pB) = (cf3211e47639321c67f6424bd53bc86b794be2892c7bb851, 31c7539738f6b89dee681ff72f722886945834acf540228a)
<------------------------------------------------>
Point : 2
Before Encryption : (297260246562756666606029747962757365637026606602, c6566756c4)
Encrypting.......
k : 1506863609
C1 (k*G) = (f25fce7a36f40965fb7e228f37c6f7cf16f61985ff3b61ea, eab898eff1b171b1faa59220625f3f6d43441af39300d8f4)
C2 (M + k*pB) = (60d730a06f9a5b971178072e2b29c38f0a80a8df37411c69, ba066892d4264d0f5b38992358ca97bec1160a6c3c2ea30b)
Total Time for Encryption : 217 ms
<--------------Decrypting-------------->
Point No : 1
C2-nB*C1 (M + k*pB - nB*k*G) : (e24796260243230313026606214352502f6470247e656c6, 16679657175602379602479626020363130266f602343454)
After Decryption : (e24796260243230313026606214352502f6470247e656c6, 16679657175602379602479626020363130266f602343454)
Point No : 2
C2-nB*C1 (M + k*pB - nB*k*G) : (297260246562756666606029747962757365637026606602, c6566756c4)
After Decryption : (297260246562756666606029747962757365637026606602, c6566756c4)
Received Hex String : e24796260243230313026606214352502f6470247e656c6166796571756023796024796260203631302660602343454029726024656275666666029747962757365637026606602c6566756c4
After Decryption -> After reversing the hexString : 4c6576656c206f662073656375726974792064206279204543206f6620313630206269742069732065717569766616c656e7420746f20525341206f662031303234206269742e
Message after Decryption :Level of security offered by ECC of 160 bit is equivalent to RSA of 1024 bit.
Total Time for Decryption : 112 ms
```

For 192 bit curve parameter:

a : 6277101735386680763835789423207666416083908700390324961276

b : 2455155546008943817740293915197451784769108058161191238065

p : 6277101735386680763835789423207666416083908700390324961279

bx : 5206740333133064750202129362262409028415794571159000296696

by : 1234539015068213699179346148240981644175632721097521553211

Enter Curve Parameter Bit :
192
Enter value of a:
6277101735386680763835789423207666416083908700390324961276
Enter value of b:
2455155546008943817740293915197451784769108058161191238065
Enter value of p:
6277101735386680763835789423207666416083908700390324961279
Enter x coordinate of base point :
5206740333133064750202129362262409028415794571159000296696
Enter y coordinate of base point :
1234539015068213699179346148240981644175632721097521553211
Enter nA :
37214613
Enter nB :
79213020
Enter Message : Elliptic Curve cryptography is a public key cryptographic system where the message is encrypted using private key of sender and decryption is done using senders public key and the receiver's private key.
Entered Message : Elliptic Curve cryptography is a public key cryptographic system where the message is encrypted using private key of sender and decryption is done using senders public key and the receiver's private key.
<-----------Encrypting------------>
Hexadecimal Representation of Entered String :
456c6c6970746963204375727665206372797970746f67726170687920697320612077075626c6963206b6579206372797970746f6772616c7068696326073797374656d2077686572652074686520656d6573736167652069732065616572796576206573672073656e6465657206572733207075626c6963206b6579206f662073656e646572206162066072797973740637296761756573657532073207072656776675772206370764652206572792373696573772065676b6579206265792073656e64657236206f662073656e646572206573064656e646572732070756b6c6563206b657920616e6420746865207265636569766572206573206572796576617465206b65792e
Before Encryption -> After reversing the HexString :
e29756b60256471667962707023772275667965636563562702, 5686470246e616029756b6023696c6265707023772756466e6)
...
Tokens are :
(e29756b60256471667962707023772275667965636563562702) , (5686470246e616029756b6023696c6265707023772756466e6)
(56370276e69637570256e6f64602379602e6f69647079727) , (3656460246e61602275646e656370266f6029756b6025647)
(16679627070276e69637570246564707972736e656023796) , (02567616373756d6025686470256275686702d656473797)
(370236968607162776f647079727360297560756b6023696c626) , (570702160237960297860716276f647079727360256667277)
(57340236964707096c6c654) , (0)
NIST_P_BIT: true
<--->
Point : 1
Before Encryption : (e29756b60256471667962707023772275667965636563562702, 5686470246e616029756b6023696c6265707023772756466e6)
Encrypting......
k : 525857266
C1 (k*G) = (64f583e21f1016f28ec5b4be60896262980884f38b4b09bd0, 2afe71287a002c776e12c09c849e665c5ef2344f3d7eccf)
C2 (M + k*pB) = (8490883445cbcadc6cf01d8b8cfaf984cb03839c76c882f5, 5f2333f163e3feac52ab193909e5b445c37f762f45fb10db)
<--->
Point : 2
Before Encryption : (56370276e69637570256e6f64602379602e6f69647079727, 3656460246e61602275646e656370266f6029756b6025647)
Encrypting......
k : 1999719120
C1 (k*G) = (b67b2707b3e3d3e715d36cbcc0a2cbfe448daf2bdc79b372, 13b40b2393815b7c6d8cc8bced3b047f28412d3d8960babe)
C2 (M + k*pB) = (b736566d3c52e66f3d219bc1ecde9a8af0f8ea5ff29ef0f8, f55799704130e7c06673b40ea1b08ea8154853164c01e553)
<--->
Point : 3
Before Encryption : (16679627070276e69637570246564707972736e656023796, 2567616373756d6025686470256275686702d656473797)
Encrypting......
k : 1464810371
C1 (k*G) = (9505ae709e7f0c9e4a6edb2fc285578691320cfe453e7801, db1ee3a8a93499f4e27221dd571ff49924ff99b7ca642199)

C2 (M + k*pB) = (3c6239ce8d2210f767ea38bfd18fc792191f5dd501f501a5, 821abc4e193181a6d499bf1322d9b3961fa2787d86bf0489)
<--->
Point : 4
Before Encryption : (370236968607162776f647079727360297560756b6023696c626, 570702160237960297860716276f647079727360256667277)
Encrypting......
k : 1644136156
C1 (k*G) = (93c6013e916fb0c0dbef2f886cca75db90c4369b517f3ee3, cd0391412929c6b880d87f0c0b21e4aaf8c37933eaa67e96)
C2 (M + k*pB) = (b22ea90287a1b064ff7be778047a7b599406edd74c0bd198, fea6507927bb20197d6b6997595671470822bb80dbafa55b)
<--->
Point : 5
Before Encryption : (57340236964707096c6c654, 0)
Encrypting......
k : 1035359624
C1 (k*G) = (e671f39fdf074aabb7b2b46b0902533bb772aafae1f45293, 8e4ac495381bf92af1dd8f671eb132824d1c202428799964c)
C2 (M + k*pB) = (529f74e08e387a0d10a9611bc02004df34f86794af42beda, f89f179acc77f2a9e226262d1580178c77c899191473ad5c)
Total Time for Encryption : 122 ms
<---------------Decrypting---------------->
Point No : 1
C2-nB*C1 (M + k*pB - nB*k*G) = (e29756b60256471667962707023772275667965636563562702, 5686470246e616029756b6023696c62657070237727546e6)
After Decryption : (e29756b60256471667962707023772275667965636563562702, 5686470246e616029756b6023696c62657070237727546e6)
Point No : 2
C2-nB*C1 (M + k*pB - nB*k*G) = (56370276e69637570256e6f64602379602e6f69647079727, 3656460246e61602275646e656370266f6029756b6025647)
After Decryption : (56370276e69637570256e6f64602379602e6f69647079727, 3656460246e61602275646e656370266f6029756b6025647)
Point No : 3
C2-nB*C1 (M + k*pB - nB*k*G) = (16679627070276e69637570246564707972736e656023796, 2567616373756d6025686470256275686702d656473797)
After Decryption : (16679627070276e69637570246564707972736e656023796, 2567616373756d6025686470256275686702d656473797)
Point No : 4
C2-nB*C1 (M + k*pB - nB*k*G) = (370236968607162776f647079727360297560756b6023696c626, 570702160237960297860716276f647079727360256667277)
After Decryption : (370236968607162776f647079727360297560756b6023696c626, 570702160237960297860716276f647079727360256667277)
Point No : 5
C2-nB*C1 (M + k*pB - nB*k*G) = (57340236964707096c6c654, 0)
After Decryption : (57340236964707096c6c654, 0)
Received Hex String :
e29756b60256471667962707023772275667965636563562702568647024 6e616029756b6023696c62657070237727546e669637570256e6f64602379602e6f69647079727 3656460246e61602275646e656370266f6029756b602564716679627070276e69637570246564707972736e656023796
After Decryption -> After reversing the hexString :
456c6c6970746963204375727665206372797970746f67726170687920697320612077075626c6963206b6579206372797970746f6772616c7068696326073797374656d2077686572652074686520656d6573736167652069732065616572796576206573672073656e6465657206572733207075626c6963206b6579206f662073656e646572206162066072797973740637296761756573657532073207072656776675772206370764652206572792373696573772065676b6579206265792e
Message after Decryption :Elliptic Curve cryptography is a public key cryptographic system where the message is encrypted using private key of sender and decryption is done using senders public key and the receiver's private key.
Total Time for Decryption : 25 ms

For 224 bit curve parameter:

a:26959946667150639794667015087019630673557916260026308143510066298878

b:18958286285566608000408668544493926415504680968679321075787234672564

p:26959946667150639794667015087019630673557916260026308143510066298881

bx:19277929113566293071110308034699488026831934219452440156649784352033

By:19926808758034470970197974370888749184205991990603949537637343198772

Enter Curve Parameter Bit :
224
Enter value of a:
26959946667150639794667015087019630673557916260026308143510066298878
Enter value of b:
18958286285566608000408668544493926415504680968679321075787234672564
Enter value of p:
26959946667150639794667015087019630673557916260026308143510066298881
Enter x coordinate of base point :
19277929113566293071110308034699488026831934219452440156649784352033
Enter y coordinate of base point :
19926808758034470970197974370888749184205991990603949537637343198772
Enter nA :
37214613
Enter nB :
79213020
Enter Message : Elliptic Curve cryptography is a public key cryptographic system where the message is encrypted using private key of sender and decryption is done using senders public key and the receiver's private key.
Entered Message : Elliptic Curve cryptography is a public key cryptographic system where the message is encrypted using private key of sender and decryption is done using senders public key and the receiver's private key.
<-----------Encrypting------------>
Hexadecimal Representation of Entered String :
456c6c6970746963204375726652063727970746f6772617068792069732061207075626c6963206b65792063727970746f6772617068792073797374656d2077686572652074686520656d6573736167652069732074696572656420286337372073696e6720656273657473696e6720727265636569662e72623307075626c6963206b65792063727970746f6772617068792063206573207865656e6572656573656963756e62727256073207072697973b3617465206b6579a7e
Before Encryption -> After reversing the HexString :
e29756b602564716679627070237722756679656365627025686470246e616029756b6023696c62657070237727564e656370276e6963757026f6f64602379602e6f69647079727365646024e6e61602275646e656576e656370266f6029756b6023696c626576616679627070276e696375702461656476972736e65602379602567616373756d602586670162776f647079727360297566023696c62657070216023796029786071622776f647079727360256672757340236964707
Tokens are :
(e29756b602564716679627070237722756679656365627025686470246e616029756b6023696c62657070237727564e656370276e6963757) , (46e616029756b6023696c62657070237727564e656370276e6963757)
(0256e6f64602379602e6f69647079727365646024e6e61602275646e6) , (56370266f6029756b602564716679627070276e696375702461656476e7)
(972736e65602379602567616373756d602586670162776f647079727365602d6) , (5647379737023696860716277f647079727360297566023696c62657070216e)
(57070216023796029786071622776f647079727360256672757340236) , (96470796c6c654)
NIST_P_BIT: true
<--->
Point : 1
Before Encryption : (e29756b602564716679627070237722756679656365627025686470246, 46e616029756b6023696c62657070237727564e656370276e6963757)
Encrypting.......
k : 1190984501
C1 (k*G) = (d23e5d13686de42b4eeb2dabeb1904ea5f6dcdf7eb2a051b39a81534, f1e58475fd14d273b13e15e952f17f592ebe1969a3bebc26c9d58502)
C2 (M + k*pB) = (e1c927982b5b576eabbd9211c61594cdc08fd9653cf8aa9f5140bdea, b5e10ab829c2db5bda50514495259ec653e0a684d9303099a818d75)
<--->
Point : 2
Before Encryption : (256e6f64602379602e6f69647079727365646024e6e61602275646e6, 56370266f6029756b602564716679627070276e696375702461656476e7)
Encrypting.......
k : 1986504680
C1 (k*G) = (6b73da4002dbdaf09fba856e67736199facc97c8f535128da3264b0f, df5d12a0c06a51a348067b2630549c9f9f03b676aafbd92763c1e138)
C2 (M + k*pB) = (116d2daaec7af162df13e408b79e09e932569718b98b550bde6d6a19, 94e7e57b617556f6bfe05ccc6929e9c2eb0a71297921e3e72190eef)
<--->
Point : 3
Before Encryption : (972736e65602379602567616373756d602586670162776f647079727365602d6, 5647379737023696860716277f647079727360297566023696c62657070216e)
Encrypting.......
k : 1779658135
C1 (k*G) = (d6455773ec2e7c89e37162bdee1c24437cccd02ae6f4496baa8efb0d, d9b472f5e5e360574f8e52c36676baa4704bc54326c22af63c8c98bf)
C2 (M + k*pB) = (90f2949907621a43364aba2a3e34e803597aed20686c4a5a506bb5f4, 595815a59289f93998807aefcb2bef09ad81f42938b5ae697cea2d9f)
<--->
Point : 4
Before Encryption : (57070216023796029786071622776f647079727360256672757340236, 96470796c6c654)
Encrypting.......
k : 1450774874
C1 (k*G) = (bb67ac26b9eabcca031cf1cd8c01be78b087c972f8d3369f2e5b7c39, a27615840b345908579c48d614c467c2c2838397cd9180c07c365ef1)
C2 (M + k*pB) = (87eef26948868a732c78dcf6708a56dd9646f2c997ad517e52c0973d, a2e3f8effe718eb32de5f35fdd21f2192728db1ea45e1650a42a4d2a)
Total Time for Encryption : 123 ms
<---------------Decrypting--------------->
Point No : 1
C2-nB*C1 (M + k*pB - nB*k*G) = (e29756b602564716679627070237722756679656365627025686470246, 46e616029756b6023696c62657070237727564e656370276e6963757)
After Decryption : (e29756b602564716679627070237722756679656365627025686470246, 46e616029756b6023696c62657070237727564e656370276e6963757)
Point No : 2
C2-nB*C1 (M + k*pB - nB*k*G) = (256e6f64602379602e6f69647079727365646024e6e61602275646e6, 56370266f6029756b602564716679627070276e696375702461656476e7)
After Decryption : (256e6f64602379602e6f69647079727365646024e6e61602275646n6, 56370266f6029756b602564716679627070276e696375702461656476e7)
Point No : 3
C2-nB*C1 (M + k*pB - nB*k*G) = (972736e65602379602567616373756d602586670162776f647079727365602d6, 5647379737023696860716277f647079727360297566023696c62657070216n)
After Decryption : (972736e65602379602567616373756d602586670162776f647079727365602d6, 5647379737023696860716277f647079727360297566023696c62657070216n)
Point No : 4
C2-nB*C1 (M + k*pB - nB*k*G) = (57070216023796029786071622776f647079727360256672757340236, 96470796c6c654)
After Decryption : (57070216023796029786071622776f647079727360256672757340236, 96470796c6c654)
Received Hex String :
e29756b602564716679627070237722756679656365627025686470246e616029756b6023696c62657070237727564e656370276e6963757026f6f64602379602e6f69647079727365646024e6e61602275646n656e656576e656370266f6029756b602564716679627070276e696375702461656476972736e65602379602567616373756d602586670162776f647079727365602d65647379737023696860716277f647079727360297566023696c62657070216e57070216023796029786071622776f647079727360256672757340236964707
After Decryption -> After reversing the hexString :
456c6c6970746963204375726652063727970746f6772617068792069732061207075626c6963206b65792063727970746f6772617068792073797374656d2077686572652074686520656d6573736167652069732074696572656420286337372073696e6720656273657473696e6720727265636569662e72623307075626c6963206b65792063727970746f6772617068792063206573207865656e6572656573656963756e62727256073207072697973b3617465206b6579a7e
Message after Decryption :Elliptic Curve cryptography is a public key cryptographic system where the message is encrypted using private key of sender and decryption is done using senders public key and the receiver's private key.
Total Time for Decryption : 24 ms

For 256 bit curve parameter:

a :
1157920892103562487626974469494075735300861434152903141955336313088867097853948

b :
41058363725152142129326129780047268409114441015993725554835256314039467401291

p :
1157920892103562487626974469494075735300861434152903141955336313088867097853951

bx :
48439561293906451759052585252797914202762949526041747995844080717082404635286

by :
36134250956749795798585127919587881956611106672985015071877198253568414405109

Enter Curve Parameter Bit :
256
Enter value of a:
1157920892103562487626974469494075735300861434152903141955336313088867097853948
Enter value of b:
41058363725152142129326129780047268409114441015993725554835256314039467401291
Enter value of p:
1157920892103562487626974469494075735300861434152903141955336313088867097853951
Enter x coordinate of base point :
48439561293906451759052585252797914202762949526041747995844080717082404635286
Enter y coordinate of base point :
36134250956749795798585127919587881956611106672985015071877198253568414405109
Enter nA :
37214613
Enter nB :
79213020
Enter Message : Elliptic Curve cryptography is a public key cryptographic system where the message is encrypted using private key of sender and decryption is done using senders public key and the receiver's private key.
Entered Message : Elliptic Curve cryptography is a public key cryptographic system where the message is encrypted using private key of sender and decryption is done using senders public key and the receiver's private key.
<----------Encrypting------------>
Hexadecimal Representation of Entered String :
456c6c69707469636320437572766520637279707046f677261706879206973206120707026c6963206b65792063727970746f6772617073747346656d20776865725207486865726520746186520646573736165206d65737361676520637279707046f677261706869632073797374656d656d20776865725207378374656d20776186520646573736165206d65737361676520637279707046f67726168646573736165206d65737361676520637572766520637279707046f6765791c6f672061206720707269766174656d657373616765206b65792e
Before Encryption -> After reversing the HexString :
e29756b602564716679627070237722756679656365627025686470246e61602756b6023696c62657070237275646e656370276e69637570256e6f64602379602e6f69647079727365646024 6e61602275646e656370266f6029756b602564716679627070276e69637570246564707972736e65602 379602567616373756d656 6026564702562756867702d6564373973702369686607162776f6470797273602d9756b6023696c62657070216023796029786071627776f6470797273602566727573402369647079c6c654
Tokens are :
(e29756b602564716679627070237722756679656365627025686470246e61602) , (9756b6023696c62657070237275646e656370276e69637570256e6f64602379602)
(02e6f69647079727365646024 6e61602275646e656370266f6029756b6025647) , (16679627070276e69637570246564707972736e65602379602567616373756d6)
(025686470256275686770 2d6564373973702369686607162776f6470797273602) , (9756b6023696c62657070216023796029786071627716f6470797273602566727)
(5734023696470796c6c654) , (0)
NIST_P_BIT: true
<-->
Point : 1
Before Encryption : (e29756b602564716679627070237722756679656365627025686470246e61602, 9756b6023696c62657070237275646e656370276e69637570256e6f64602379602)
Encrypting.......
k : 1179353364
C1 (k*G) = (37cb4b4ea4347830ceea90a2e2686d43e1c3a6e4b7161267a5b9d2cd508891ed, c17a5aa3dcd10caeb28634f86cdf23877bc715a6e8fa1182d21a64ea1474e3d1)
C2 (M + k*pB) = (77ec92d20602b5b9a841bea17e88d9620ab4d42cef43757984267d7173ac2f08, 30151b2509cf91ee9a87fc3fe6b985e65b2e6ed3dd2a427bac2528882d1b93a2)
<-->
Point : 2
Before Encryption : (2e6f69647079727365646024 6e61602275646e656370266f6029756b6025647, 16679627070276e69637570246564707972736e65602379602567616373756d6)
Encrypting.......
k : 1011550413
C1 (k*G) = (78909a92e8f263f2c22511000e40f999f3a71e2b3327974e4bd77796611dc092, 86e5f8c90ade309ced50687fd519b7c40c02e8011b80f749acbf75306522ccb6)
C2 (M + k*pB) = (92fea6aeb39f15f4897e8bf0078b332ef8fb5b55c307609dca23312f95ec839d, 6c2ead5b170e8abc82d1b069da1f15e0b4d912e6b482db035d8eed8e941571b1)
<-->
Point : 3
Before Encryption : (025686470256275686770 2d6564373973702369686607162776f6470797273602, 9756b6023696c62657070216023796029786071627716f6470797273602566727)
Encrypting.......
k : 56935075
C1 (k*G) = (c715d55d1dd08a1d30be2352c3b99a06a390e5ce49d39e5dea50edf5e0317c7b, 4159a93b40b2ddadbf41516a6aebe057be1e9e8cff768863d96a4a16e2960334)
C2 (M + k*pB) = (3aab0b421aee8218679f1747c6d796244ad3985798a1bc9d05963e6721588aa8, aeb4fc4e5a4df02826b6c0f55291dbe93d7b69c70930fc56792f58cc1e2940bc)
<-->

C1 (k*G) = (c715d55d1dd08a1d30be2352c3b99a06a390e5ce49d39e5dea50edf5e0317c7b, 4159a93b40b2ddadbf41516a6aebe057be1e9e8cff768863d96a4a16e2960334)
C2 (M + k*pB) = (3aab0b421aee8218679f1747c6d796244ad3985798a1bc9d05963e6721588aa8, aeb4fc4e5a4df02826b6c0f55291dbe93d7b69c70930fc56792f58cc1e2940bc)
<-->
Point : 4
Before Encryption : (5734023696470796c6c654, 0)
Encrypting.......
k : 865292875
C1 (k*G) = (5e7e966cdafd7da018d163cd6ad73831a57302f6e94a316699f2f8cccd751c55, 3de881c84ae70e515af76d206f591ede12a6dfc87afb86f9cb21869f794ea450)
C2 (M + k*pB) = (dc22f0c70aee0dbd123b6fb876e130eff835990200f0f507e7ad2431da44fcdf9, c508ea1ed2442bf51015036e4a0fd958bf724ca1318ab9fd519f0464000269e6)
Total Time for Encryption : 129 ms
<--------------Decrypting-------------->
Point No : 1
C2-nB*C1 (M + k*pB - nB*k*G) : (e29756b60256471667962707023772275667965636562702568470246e61602, 9756b6023696c62657070237275646e656370276e69637570256e6f646023796)
After Decryption : (e29756b60256471667962707023772275667965636562702568470246e61602, 9756b6023696c62657070237275646e656370276e69637570256e6f646023796)
Point No : 2
C2-nB*C1 (M + k*pB - nB*k*G) : (2e6f6964707972736564602466e61602275646e656370266f6029756b6025647, 16679627070276e69637570246564707972736e6560237960256761637a756d6)
After Decryption : (2e6f6964707972736564602466e61602275646e656370266f6029756b6025647, 16679627070276e69637570246564707972736e6560237960256761637a756d6)
Point No : 3
C2-nB*C1 (M + k*pB - nB*k*G) : (25686470256275686770d56473797370236968607162776f6470797273602, 9756b6023696c62657070216023796029786071627762776f6470797273602566727)
After Decryption : (25686470256275686770d56473797370236968607162776f6470797273602, 9756b6023696c62657070216023796029786071627762776f6470797273602566727)
Point No : 4
C2-nB*C1 (M + k*pB - nB*k*G) : (5734023696470796c6c654, 0)
After Decryption : (5734023696470796c6c654, 0)
Received Hex String :
e29756b60256471667962707023772275667965636562702568470246e61602e61602275646e656370276e69637570256e6f646023796
37960256761637375756d6025686470256275686770d56473797370236968607162776f6470797273602975b6023696c62657070216023796029786071627762776f6470797273602566727574023696470796c6c654
After Decryption -> After reversing the hexString :
456c6c69707469636930324375276652063727970746f6772617736837920619732061207075626c6963206b657920637279707468667726170868906320737973734656dd2077686572626520074686520636373361637651076520697320656e6372797074465641207573696e672072796774656461701746564207573696e62070726976617465206b6579206f662073
656e64657220616e64206a656563637279797904769 f6e206973320646f6e652065207573736e6e6420736960646720656a6572720370075626c6963206b6579206e6e6e206e6420746865726563656976657273727732070726976617465206b6579792e
Message after Decryption :Elliptic Curve cryptography is a public key cryptographic system where the message is encrypted using private key of sender and decryption is done using senders public key and the receivers private key.
Total Time for Decryption : 25 ms

For 384 bit curve parameter:

a :
3940200619639447921227904010014361380507973927046544666794829340424572177149687032904726608825893800186160697311 2316

b :
2758019355995970587784901184038904809305690585636156852142870730198868924130986086513626076488374510776543976123 0575

p :
3940200619639447921227904010014361380507973927046544666794829340424572177149687032904726608825893800186160697311 2319

bx :
2624703509579968926862315674456698189185292349110921338781561590092551885473805008902238805397571978665087247673 2087

by :
8325710961489029985546751289520108179287853048861315594709205902480503199884419224438643760392947333078086511627871

```
Enter Curve Parameter Bit :
384
Enter value of a:
39402006196394479212279040100143613805079739270465446667948293404245721771496870329047266088258938001861606973112316
Enter value of b:
27580193559959705877849011840389048093056905856361568521428707301988689241309860865136260764883745107765439761230575
Enter value of p:
39402006196394479212279040100143613805079739270465446667948293404245721771496870329047266088258938001861606973112319
Enter x coordinate of base point :
26247035095799689268623156744566981891852923491109213387815615900925518854738050089022388053975719786650872476732087
Enter y coordinate of base point :
8325710961489029985546751289520108179287853048861315594709205902480503199884419224438643760392947333078086511627871
Enter nA :
37214613
Enter nB :
79213020
Enter Message : Elliptic Curve cryptography is a public key cryptographic system where the message is encrypted using private key of sender and decryption is done using senders public key and the receiver's private key.
Entered Message : Elliptic Curve cryptography is a public key cryptographic system where the message is encrypted using private key of sender and decryption is done using senders public key and the receiver's private key.
<-----------Encrypting------------->
Hexadecimal Representation of Entered String :
456c6c69707469636320437572766520437979704667726170687920697320612070075626c6963206b65792063727970746f6772617068696320737973746d656420726768657726524074686572065206d657373616e6765207320656372797074696e67206b657920696620736e64657274065326c6963206b65792063727970746f6772617068696320737973746d65420726768
Before Encryption -> After reversing the HexString :
e29756b602564716679627070237227566796563656270256864702460602073696c6023696c62657070237275646e6563765070256e6f646023796020e6f696470397273656460246e61602275646e6563765270266f6029756b6025647166796270702763727275663656270256f616373375e65602379602563676137b13756d6025686470256275686770206256473977373660237960256027056023696c62657070216023796029786071627766470797273602566727573403696470796c6c654
Tokens are :
(e29756b602564716679627070237227566796563656270256864702460602073696c6023696c62657070237275646e6e) , (56370276e69637570256e6f646023796020e6f69647079727365460246e61602275646e6563765270266f6029756b6025647)
(16679627070276e69637570246564704707972736e656023796025676163773756d6025686470256275686770206256473797) , (37023696860716277646470797273602975606023696c6026570702160237960297860716277646470797273602566727)
(57340236964707962c6c654) , (0)
NIST_P_BIT: true
<-------------------------------------->
Point : 1
Before Encryption : (e29756b602564716679627070237227566796563656270256864702460602073696c6023696c626570702372756e6e, 56370276e69637570256e6f646023796020e6f69647079727365460246e61602275646e6563765270266f6029756b6025647)
Encrypting.......
k : 897637113
C1 (k*G) = (e37f4f585e383580d7a5ea5684b9a25265965ed87f55589c6ebb737bd84918d572262c93cec93469da75a01f510952a2, 531f0f8e6cbc0f40c99624814b0b561544c1f36f841e0d33aae9f4f105f81595e93496e0d72a3d519f5bb6654c1241d)
C2 (M + k*pB) = (61eab619bc71517ffc6a7ec2d19b8a6fbb95c2f21908254aafcefda154ca52f8b114152db30f5942d9277255605c9594, 4027a9a488df86442b3a6e915e096e998c648a04b715ee29d2b087ae8ef29b3d171975e505122334dd4961592929813)
<-------------------------------------->
Point : 2
Before Encryption : (16679627070276e69637570246564704707972736e656023796025676163773756d6025686470256275686770206256473797, 37023696860716277646470797273602975606023696c6026570702160237960297860716277646470797273602566727)
Encrypting.......
k : 1302456916
C1 (k*G) = (ede8c0132ffa2b1a4da5cd2e975710fbd9521e0dfd2f077276fb6edf4e54987d0c964d870f55ebf3e51769c2be93e950, 37732dcd63af17a3469ba1c6557fc3f3fe1195cebaa3e9f9e1ee1e651d1d50c6fc1a38b964be058aa289d22c5f329eab)
C2 (M + k*pB) = (9acb438fc8ab6f25dea8a4af404b5d544505b88804679e19d7d2591fe9c17149c762cd212a3990fd481ced0080a4db57, ca8d87902a86261d9c0c4cf41af9c14f8d678dcf989c3dc5bdf9b667914214fc64919e7d9165834604b7ef07f0bd55c5)
<-------------------------------------->
Point : 3
Before Encryption : (57340236964707962c6c654, 0)
Encrypting.......
k : 159564400
C1 (k*G) = (ca57771f6cbdf244aec56f512118a0d98a5e709f55fefd7c19dd252d0a5ae5a75d3250e19de0aa68fde41affe37dbe12, 812b81bf92a10a3525a237069b0d4f55d19e09aef3523195e0cfebc88ef4ec859a4d534625b9c477f0c7d92b7fb44792)
C2 (M + k*pB) = (f3516a856e4cce2e518dbeeada03ae1b954025b071dd8c49cc1c721406ef310a449f028ca7685b74b295a962a4ed6d5c, 1b576fb29c3077ef5f27316c1cdc617ad486f7e2477172109575a1b7541739540d5b3d410e13257c4f666363a141ccd0)
Total Time for Encryption : 149 ms

<---------------Decrypting--------------->
Point No : 1
C2-nB*C1 (M + k*pB - nB*k*G) : (e29756b602564716679627070237227566796563656270256864702460602073696c6023696c626570702372756e6e, 56370276e69637570256e6f646023796020e6f69647079727365460246e61602275646e6563765270266f6029756b6025647)
After Decryption : (e29756b602564716679627070237227566796563656270256864702460602073696c6023696c626570702372756e6e, 56370276e69637570256e6f646023796020e6f69647079727365460246e61602275646e6563765270266f6029756b6025647)
Point No : 2
C2-nB*C1 (M + k*pB - nB*k*G) : (16679627070276e69637570246564704707972736e656023796025676163773756d6025686470256275686770206256473797, 37023696860716277646470797273602975606023796c6026570702160237960297860716277646470797273602566727)
After Decryption : (16679627070276e69637570246564704707972736e656023796025676163773756d6025686470256275686770206256473797, 37023696860716277646470797273602975606023796c6026570702160237960297860716277646470797273602566727)
Point No : 3
C2-nB*C1 (M + k*pB - nB*k*G) : (57340236964707962c6c654, 0)
After Decryption : (57340236964707962c6c654, 0)
Received Hex String :
e29756b602564716679627070237227566796563656270256864702460602073696c6023696c62657070237275646e6563765070256e6f646023796020e6f696470397273656460246e61602275646e6563765270266f6029756b6025647166796270702763727275663656270256f616373375e65602379602563676137b13756d6025686470256275686770206256473977373660237960256027056023696c62657070216023796029786071627766470797273602566727573403696470796c6c654
After Decryption -> After reversing the hexString :
456c6c69707469636320437572766520437979704667726170687920697320612070075626c6963206b65792063727970746f6772617068696320737973746d656420726768657726524074686572065206d657373616e6765207320656372797074696e67206b657920696620736e64657274065326c6963206b65792063727970746f6772617068696320737973746d65420726e692e
Message after Decryption :Elliptic Curve cryptography is a public key cryptographic system where the message is encrypted using private key of sender and decryption is done using senders public key and the receiver's private key.
Total Time for Decryption : 24 ms
```

For 448 bit curve parameter:

a :
484559149530404593699549205258669689569094240458212040187660132787074885444487181790930922465784363953392589641229091574035657199637535

b :
269199527516891440944194002921483160871719022476784466770922295992819380802492878772739401369880202196329216467349495319191685664513904

p :
726838724295606890549323807888004534353641360687318060281490199180612328166730772686396383698676545930088884461843637361053498018365439

bx :
484559149530404593699549205258669689569094240458212040187660132787074885444487181790930922465784363953392589641229091574035665345629 07

by :

35529392678556817526412750206378333480897639938771427183188089843516908878696741000293267376586455091014277414726810583898559529060636 2

For 512 bit curve parameter:

a :
68647976601306097149819007990813932172694353001433054093944634591855431833976560521225596406614545549772963113914808580371219879997166438125740282911150571 48

b :
10938490380737342745111123907668055699362075989516837489945863944959531161507350160137087375737596232485921322967063133094384525315910129121423274884789859 84

p :
68647976601306097149819007990813932172694353001433054093944634591855431833976560521225596406614545549772963113914808580371219879997166438125740282911150571 51

bx :
26617408020502170632287687167233609607298591687569731477066713684188029449964278084915450806277719023520942412250655586621571135455709168141616373158959998 46

by :

375718002577002046354550722449118360359445513476976248669456777961554447744055631669123440501294553956214444453728942852258566672919658081012434427757837 6784

Enter Curve Parameter Bit :
512
Enter value of a:
6864797660130609714981900799081393217269435300143305409394463459185543183397656052122559640661454554977296311391480858037121987999716643812574028291115057148
Enter value of b:
1093849038073342745111123907668055699362075989516837489945863944959531161507350160137087375737596232485921322967061330943845253159101291214232748847898 5984
Enter value of p:
6864797660130609714981900799081393217269435300143305409394463459185543183397656052122559640661454554977296311391480858037121987999716643812574028291115057151
Enter x coordinate of base point :
2661740802050217063228768716723360960729859168756973147706671368418802944996427808491545080662777190235209424122506555866215711354557091681416163731589 5999846
Enter y coordinate of base point :
375718002577002046354550722449118360359445513476976248669456777961554447744055631669123440501294553956214444453728942852258566672919658081012434427757 8376784
Enter nA :
37214613
Enter nB :
79213020
Enter Message : Elliptic Curve cryptography is a public key cryptographic system where the message is encrypted using private key of sender and decryption is done using senders public key and the receiver's private key.
Entered Message : Elliptic Curve cryptography is a public key cryptographic system where the message is encrypted using private key of sender and decryption is done using senders public key and the receiver's private key.
<--------------Encryption------------->
Hexadecimal Representation of Entered String :
456c6c697074696332043757276652063727970746f6772617068792069732061207075626c6963206b657920637279707 46f67726170686963207374736564206720786857265207468656520643537331616576520637920656e6372797074656542075736 96e6720707269766174652036506c65792e
656e64657220616e6420646563727970746f6e4696f6e20697320646f6e65207573696e6720373656e64657273207075626c6963206b657920616e642074686520526365697665736722773207072697661746520 6b65792e
Before Encryption -> After reversing the HexString :
e29756b602564716679627070237722756679656365627025686470246e616029756b6023696c62657070237727566a656370276e6963757 02566e6f64602379602e6f696470797273656460246e61602275646e656570266f6029756b602564716679627070276e6963 757024656470797273e656027e656867162776f6470797273602975b6b6023696c62657070216023796029786071627276f6470797273602566727573402 36964707096c6c654
Tokens are :
(e29756b602564716679627070237722756679656365627025686470246e616029756b6023696c62657070237725646e656370276e6963757 02566e6f6464023796) ,
(02e6f696470797273656460246e61602275646e656570266f6029756b602564716679627070276e6963757024656470797273e65602379602567616373756d) ,
(025686470256275686f7702d65647379737023696860716277f647079727300297566b6023696c6266570702160237960297860716277f6470797273602566727) , (5734023696470796c6c654)
NIST_P_BIT: true
<--------------------------------------->
Point : 1
Before Encryption : (e29756b602564716679627070237722756679656365627025686470246e616029756b6023696c62657070276e6963757050256e6f646023796,
2e6f696470797273656460246e61602275646e656570266f6029756b602564716679627070276e6963757024656470797273e65602379602567616373756d)
Encrypting.......
k : 71412176
C1 (k*G) = (e973c43084c2d6eb670437b5889e726da99af819a62eca5ad9afd6bc4d2ef6998f3205f15e7a6793f0b3cc5555d698c7266e41d071c2bf1f006344646effc574,
bb88ce6c541a0c17d93a9ada62f63e74b8693cb0a018009fd469a1c25c2ee5de7e943f92de1f95b33b7c25e407b29b5d38d0806e184aa46bdd3eb7c59887848031)
C2 (M + k*pB) = (125ada03ea0a6dc8acec6d4f052f1fb13978269a20ff9845988d8d42105af9b32416e9845da29f91088918173ea6b6ced8869b5d5f3b1810bfd59bc5712e01ab98a,
145613d894860990daa2e1213d4299f4d3572becb3586573ef5654157a56b42767a01ba3992035b4aff482a5682c6f5e77e711c91bc1cc45b9bb0ea5d1cc7962a90)
<--------------------------------------->
Point : 2
Before Encryption : (25686470256275686f7702d65647379737023696860716277f6470797273602979756b6023696c62657070216023796029786071627f6470797273602566727, 5734023696470796c6c654)
Encrypting.......
k : 7556130
C1 (k*G) = (1cb419b58d465fbe8ea4dd77f361c05f3f6cd1249f84207fdb8e5c905342104afdfc665593d523fc86b09f05818975bda5b385d9b1e49415260699 6b69e85cb8199,
18f8f159770f71f39877cb0c9eb0fbae49c22feb9cb9c7c6b78dffda6eb1717eef7eeb8790b2227ffde035020e67bfbf9001aec6c9d183b9b628e9eb6ea37b81858)
C2 (M + k*pB) = (ec96a4986685d1fec67aa981a59468f052cf6436eb74778412e21617c90f1ee72557862223c3dd2502b943e7dfd2bf2cf5b075f8f2b83948ac9498249 45f0074aaf6,
d0295dc737dd58a85d3a8c591ab902360ace2357982d4c070d9ccd98d34d28152085a9e5f2fefbade364404fd0d08e2363451738adbe02466ebd552631fb2d7ae1)
Total Time for Encryption : 152 ms
<--------------Decrypting------------->
Point No : 1
C2-nB*C1 (M + k*pB - nB*k*G) : (e29756b602564716679627070237722756679656365627025686470246e616029756b6023696c62657070276e6963757050256e6f646023796

<--------------Decrypting------------->
Point No : 1
C2-nB*C1 (M + k*pB - nB*k*G) : (e29756b602564716679627070237722756679656365627025686470246e616029756b6023696c62657070276e6963757050256e6f646023796,
2e6f696470797273656460246e61602275646e656570266f6029756b602564716679627070276e6963757024656470797273e65602379602567616373756d)
After Decryption : (e29756b602564716679627070237722756679656365627025686470246e616029756b6023696c62657070276e6963757050256e6f646023796,
2e6f696470797273656460246e61602275646e656570266f6029756b602564716679627070276e6963757024656470797273e65602379602567616373756d)
Point No : 2
C2-nB*C1 (M + k*pB - nB*k*G) : (25686470256275686f7702d65647379737023696860716277f6470797273602979756b6023696c62657070216023796029786071627f6470797273602566727, 5734023696470796c6c654)
After Decryption : (25686470256275686f7702d65647379737023696860716277f6470797273602979756b6023696c62657070216023796029786071627f6470797273602566727, 5734023696470796c6c654)
Received Hex String :
e29756b602564716679627070237722756679656365627025686470246e616029756b6023696c62657070276e6963757050256e6f646023796 2e6f696470797273656460246e61602275646e656570266f6029756b602564716679627070276e6963757024656470797273e65602 3796025667265867162776f6470797273602979756b6023696c62657070216023796029786071627f6470797273602566727360702566727573402 36964707096c6c654
After Decryption -> After reversing the hexString :
456c6c697074696332043757276652063727970746f6772617068792069732061207075626c6963206b657920637279707 46f67726170686963207374736564206720786857265207468656520643537331616576520637920656e6372797074656542075736 96e6720707269766174652036506c65792e
656e64657220616e6420646563727970746f6e4696f6e20697320646f6e65207573696e6720373656e64657273207075626c6963206b657920616e642074686520526365697665736722773207072697661746520 6b65792e
Message after Decryption :Elliptic Curve cryptography is a public key cryptographic system where the message is encrypted using private key of sender and decryption is done using senders public key and the receiver's private key.
Total Time for Decryption : 24 ms

Performance Analysis:

We calculated the time required to encrypt and decrypt different messages using standard NIST ECC curves like 192 bit, 224 bit, 256 bit, 384 bit, 448 bit, 512 bit.

Message 1 : Welcome to JNTUK,CSE.

Message 2 : India reports under 30,000 new cases after 132 days.

Message 3 : The department of CSE,Jntuk aims to bring out talents of young engineers.

Message 4 : Rohit sharma is the vice-captain of the Indian national team in limited overs format.

Message 5 : Elliptic Curve cryptography is a public key cryptographic system where the message is encrypted using the private key of sender and decryption is done using sender's public key and the receiver's private key.

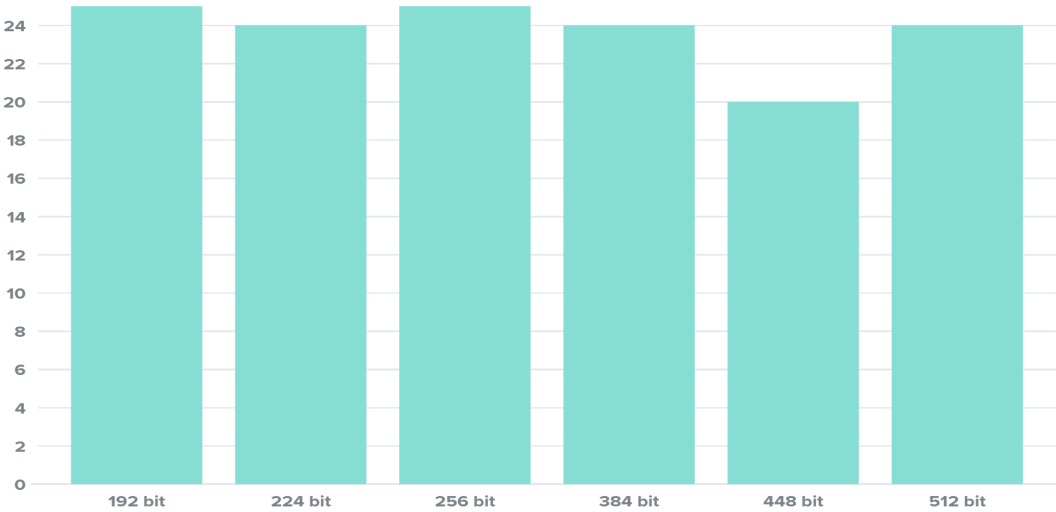**Time taken to Encrypt message 1 for different curve parameter bits**

**Time taken to Decrypt message 1 for different curve parameter bits**

Time taken to Encrypt message 5 for different curve parameter bits
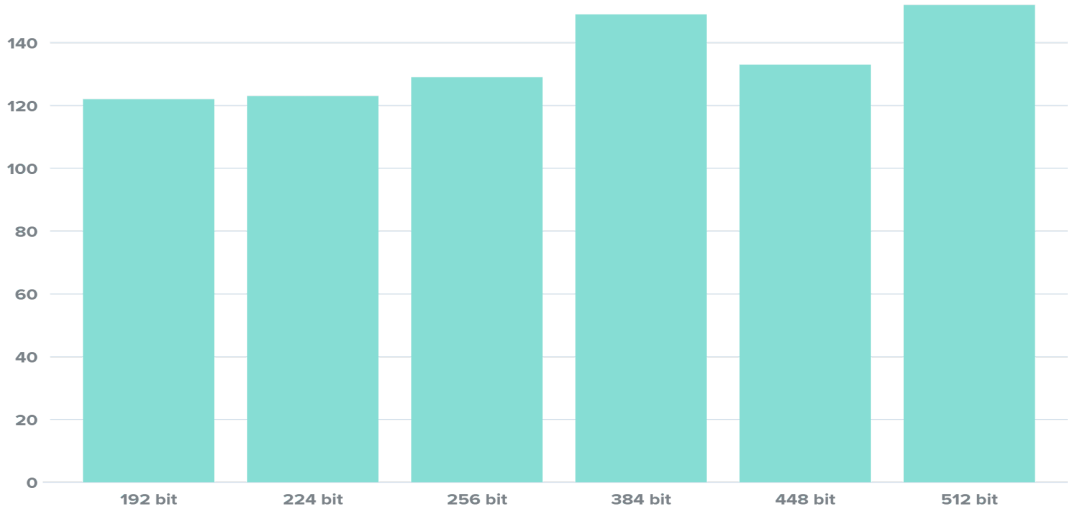
Time taken to Decrypt message 5 for different curve parameter bits

Performance Analysis on time for different messages and different curve bits parameter:

Analysis on Time to Encrypt messages of different length

Analysis on Time to Decrypt messages of different length
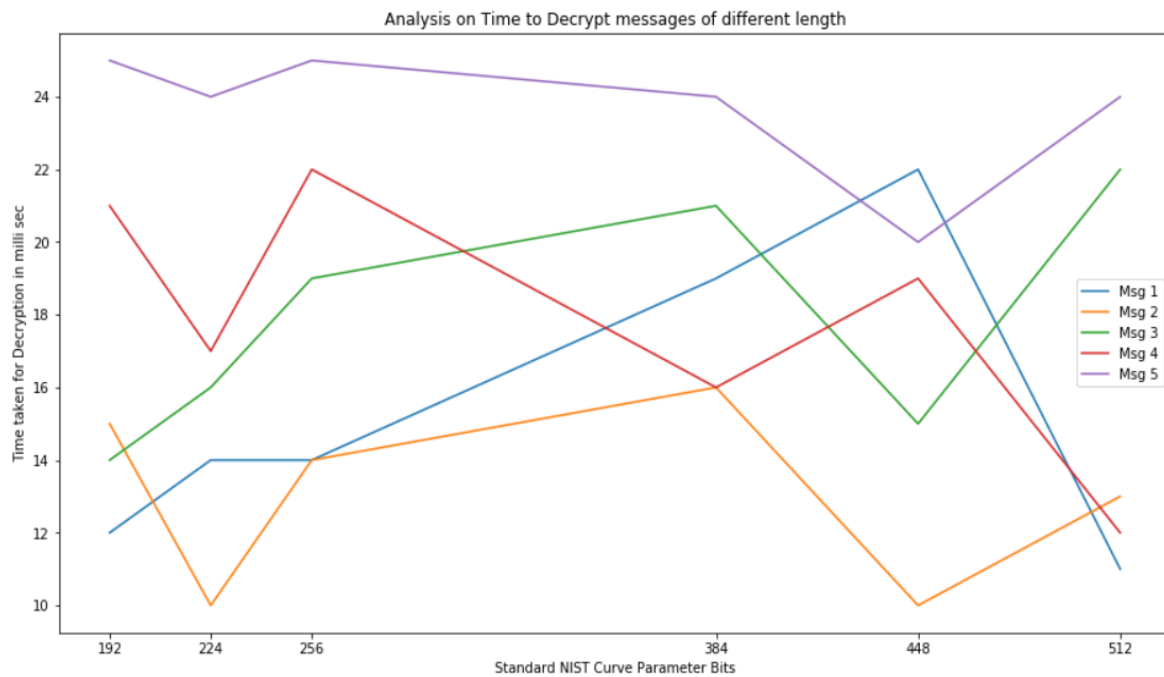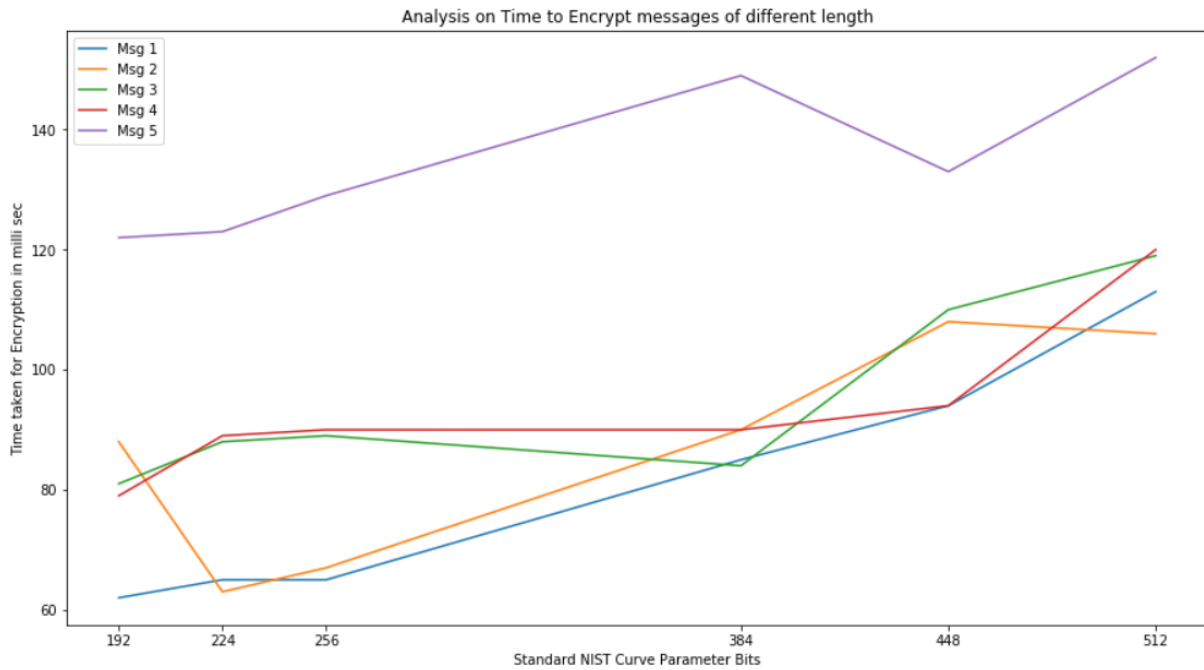
CHAPTER 9
CONCLUSION

CONCLUSION :

The previous works considered the Text encryption using the RSA algorithm in which it is based on the factoring problem.All these models use keys with the large key-size for the security due to which it is relatively slow.The main drawback of these works is low scalability power and computing speed of the algorithm.

Elliptic Curve Cryptography is a public key cryptographic system .ECC provides more security than RSA with lesser key size. The security of ECC is more since it has discrete logarithmic problem, which is difficult to solve.

Before performing text encryption we need to map the text into points on the curve. In this proposed method, we have implemented a new mapping technique that maps the plaintext into affine points on the chosen elliptic curve. In the proposed method, the characters in the plaintext are converted into ASCII values and the next step is to convert it into HEXADECIMAL. The entire HEXADECIMAL values are grouped based on the input size. The encryption is done in the reverse order of the HEXADECIMAL result in-order to provide security.

ECC implementation is more effective compared to RSA for key size and also security. It provides more security with lesser key size. So this can be utilized in electronic devices with lesser memory and lower power consumption. The security in the mapping technique will provide double security for the text encryption. Here we have implemented a secure mapping technique along with less overhead in mapping.ie, our implementation will help to reduce the common look-up table between the sender and the receiver and hence reduce the overhead. So the encryption procedure works faster. One of the major advantage of this method is that we don't have to pad extra bit when the grouped hexadecimal is odd in number. Because the length zero group is taken as NULL.

The **ECC** has been developed for the appointment of a contractor for engineering and construction project work, including any level of design

responsibility. It provides a modern method for clients, designers, contractors and project managers to work collaboratively to consistently achieve their objectives.

From the above analysis, we conclude that time required to encrypt any message increases gradually with increase in NIST curve parameter bit.Time required to encrypt a message of small length will be less than time required to encrypt a message of large length for a fixed curve parameter bit.

Similarly Time required to decrypt any message increases gradually with increase in NIST curve parameter bit.Time required to decrypt a message of small length will be less than time required to decrypt a large message for a fixed curve parameter bit.

The results show that encryption takes more time than decryption, since it contains more number of scalar multiplications.

CHAPTER 10
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REFERENCES:

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FLOOD PREDICTION SYSTEM USING MACHINE LEARNING

A Project Report submitted in partial fulfillment of the requirements for the award of the Degree of

MASTERS OF TECHNOLOGY

IN

COMPUTER SCIENCE AND ENGINEERING

Submitted by

P. NEERAJA   **19U41D5806**

Under the Esteemed Guidance of
Mrs. K. SUJATHA
Assoc. Professor, Department of CSE

DADI INSTITUTE OF ENGINEERING & TECHNOLOGY

(Approved by A.I.C.T.E, New Delhi &Affiliated to JNTU, Kakinada)

NAAC ACCREDITED INSTITUTE

ISO 9001:2008; ISO 14001:2004 & OHSAS 18001:2007 Certified Institution

NH-5, Anakapalle-531002, Visakhapatnam, A.P.

2021

<u>CERTIFICATE</u>

This is to certify that the Project work entitled " FLOOD PREDICTION SYSTEM USING MACHINE LEARNING " is being submitted by P NEERAJA (19U41D5806) in partial fulfillment of the Requirement for the award of the degree of MASTERS OF TECHNOLOGY for COMPUTER SCIENCE & ENGINEERING during the academic year 2020-2021.

Mrs. K. SUJATHA   **Dr. L. PRASANNA KUMAR**

(Assoc. PROFESSOR)   **(PROFESSOR)**

(PROJECT GUIDE)   (HEAD OF THEDEPARTMENT)

EXTERNAL EXAMINER

II

DECLARATION

I hereby declare that this project work entitled "FLOOD PREDICTION SYSTEM USING MACHINE LEARNING" has been carried out by me and contents have been presented in the form are for the award of the degree of MASTERS OF TECHNOLOGY   IN   COMPUTER   SCIENCE   AND ENGINEERING. We further declare that this dissertation has not been submitted elsewhere for any Diploma or Degree of University.

.

BY

P NEERAJA   *(19U41D5806)*

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P NEERAJA   (19U41D5806)

ABSTRACT

The flood prediction system using machine learning uses the help of IOT to predict the chances of occurrence of floods. This system uses various sensors to calculate the threshold limits and alerts the people and the government similar to the seismometer, which predicts and calculates the severity of Flood. This system gathers input from all the sensors and merges them into one output, which results in passing information whether the chances of occurrence of flood are either high or low.

 Keywords : Internet of Things(IOT), Sensors, Warning Signal, Buzzer Notification, Blynk app.

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ABBREVIATIONS

IoT	Internet of Things
IoE	Internet of Everything
M2M	machine-to-machine
AVR	Automatic Voltage Regulator
USB	Universal Serial Bus
SMS	Short Message Service
ISP	Internet Service Provider
IDE	Integrated Development Environment
GSM	Global System for Mobile
IIC	Internal Investigation Command
TTL	Transistor-Transistor Logic
PWM	Power with modulation
AREF	Analog reference
MCU	Marval Cinematic Universe
MHZ	Megahertz
PWM	Pulse Width Modulation
SS	Slave Select
DIN	Data In
MOSI	Master Out, Slave In
CS	Chip Select
SCK	Serial Clock
CLK	Clock
SPI	Serial Peripheral Interface
GND	Ground
AC	Alternating Current
DC	Direct Current
SRAM	Static random access memory
IP	Internet Protocol

CHAPTER 1
INTRODUCTION

INTRODUCTION

Floods are one of the most damaging natural disasters in this world. In the circumstances of heavy flood, it can destroy the community and take away many lives. The government will have to spend billions and billions of money to recover the affected area. It is crucial to develop a flood mitigation system as a mechanism to reduce the flood risk by alerting even before the occurrence of the flood. Scientists estimate by 2030, if 4- inch sea level rise, it could potentially caused the severe flooding in many parts of the world. This proposes a flood warning system that can detect the water level and measure the speed of the rise of water level. To give the society an earlier notification to evacuate before the water rises to the dangerous level, the measurement result is sent as the alert to a mobile phone through Short Message Service (SMS). This project is designed on the IoT based platform, where data from the sensor is collected at the mini-processor and alert is generated and transmitted as SMS to a smart phone.

CHAPTER 2
LITERATURE REVIEW

2.1 About IoT

The Internet of Things (IoT), also sometimes referred to as the Internet of Everything (IoE), consists of all the web-enabled devices that collect, send and act on data they acquire from their surrounding environments using embedded sensors, processors and communication hardware. These devices, often called "connected" or "smart" devices, can sometimes talk to other related devices, a process called machine-to-machine(M2M) communication, and act on the information they get from one another. Humans can interact with the gadgets to set them up, give them instructions or access the data, but the devices do most of the work on their own without human intervention. Their existence has been made possible by all the tiny mobile components that are available these days, as well as the always-online nature of our home and business networks. Connected devices also generate massive amounts of Internet track, including loads of data that can be used to make the devices useful, but can also be mined for other purposes. All this new data, and the Internet- accessible nature of the devices, raises both privacy and security concerns. But this technology allows for a level of real-time information that we have never had before. We can monitor our homesand families remotely to keep them safe. Businesses can improve processes to increase productivity and reduce material waste and unforeseen downtime. Sensors in city infrastructure can help reduce road congestion and warn us when infrastructure is in danger of crumbling. Gadgets out in the open can monitor for changing environmental conditions and warn us of impending disaster.

1.2 Advantages and Disadvantages of IoT

Advantages

- **Communication:** IoT encourages the communication between devices, also famously known as Machine-to-Machine (M2M) communication. Because of this, the physical devices can stay connected and hence the total transparency is available with lesser inefficiencies and greater quality.

- **Automation and Control:** Due to physical objects getting connected and controlled digitally and centrally with wireless infrastructure, there is a large amount of automation and control in the workings. Without human intervention, the machines are able to communicate with each other leading to faster and timely output.

- **Information:** It is obvious that having more information helps making better decisions. Whether it is mundane decisions as needing to know what to buy at the grocery store or if your company has enough widgets and supplies, knowledge is power, and more knowledge is better.

- **Monitor:** The second most obvious advantage of IoT is monitoring. Knowing the exact quantity of supplies or the air quality in your home, can further provide more information that could not have previously been collected easily. For instance, knowing that you are low on milk or printer ink could save you another trip to the store in the near future. Furthermore, monitoring the expiration of products can and will improve safety.

- **Time:** As hinted in the previous examples, the amount of time saved because of IoT could be quite large. And in today's modern life, we all could use more time.

- **Money:** The biggest advantage of IoT is saving money. If the price of the tagging and monitoring equipment is less than the amount of money saved, then the Internet of Things will be very widely adopted IoT fundamentally proves to be very helpful to people in their daily routines by making the appliances communicate to each other in an effective manner thereby saving and conserving energy and cost. Allowing the data to be communicated and shared between devices and then translating it into our required way, it makes our systems efficient.

- **Efficient and Saves Time:** The machine-to-machine interaction provides better efficiency, hence; accurate results can be obtained fast. This results in saving valuable time. Instead of repeating the same tasks every day, it enables people to do other creative jobs.

- **Better Quality of Life:** All the applications of this technology culminate in increased comfort, convenience, and better management, thereby improving the quality of life.

Disadvantages

- **Compatibility:** Currently, there is no international standard of compatibility for the tagging and monitoring equipment. I believe this disadvantage is the easiest to overcome. The manufacturing companies of this equipment just need to agree to a standard, such as Bluetooth, USB, etc. This is nothing new or innovative needed.

- **Complexity:** As with all complex systems, there are more opportunities of failure. With the Internet of Things, failures could skyrocket. For instance, let's say that both you and your spouse each get a message saying that your milk has expired, and both of you stop at a store on your way home, and you both purchase milk. As a result, you and your spouse have purchased twice the amount that you both needs. Or maybe a bug in the software ends up automatically ordering a new ink cartridge for your printer each and every hour for a few days, or at least after each power failure, when you only need a single replacement.

- **Privacy/ Security:** With all of this IoT data being transmitted, the risk of losing privacy increases. For instance, how well encrypted will the data be kept and transmitted with? Do you want your neighbors or employers to know what medications that you are taking or your financial situation? Safety: As all the household appliances, industrial machinery, public sector services like water supply and transport, and many other devices all are connected to the Internet, a lot of information is available on it. This information is prone to attack by hackers. It would be very disastrous if private and congenital information is accessed by unauthorized intruders.

- **Lesser Employment of Manpower:** The unskilled workers and helpers may end up losing their jobs in the eject of automation of daily activities. This can lead to unemployment issues in the society. This is a problem with the advent of any technology and can be overcome with education. With daily activities getting automated, naturally, there will be fewer requirements of human resources, primarily, workers and less educated sta. This may create Unemployment issue in the society

CHAPTER 3
EXISTING SYSTEM

EXISTING SYSTEM

In Early Flood Detection System their objective is to monitor the flood situation and send text message.

It is observed that previous system have some drawbacks like – delay in sending alert to common man regarding the upcoming disaster.

Disadvantages of Existing system

- Most of these devices are very high in costly to be used and maintained
- These devices are usually used only for monitoring purposes between the flood prone location and the monitoring station.

CHAPTER 4
PROPOSED SYSTEM

PROPOSED SYSTEM

Floods are natural disasters that cause excessive loss of life and property. A situation of flood arises when the water level across above the needed. The main objective of the proposed system is to provide early alert to the people of that particular surroundings right in the early stage.

Inspired by the literature, this work aimed to detect flood with water sensor with different level of measurement with SMS alert. SMS is considered as the most effective way to the scenario.

The notification sent can be read globally through IoT. Here ESP8266 NodeMCU which is the wireless network which has the main use in the system. In this system Sensor will pass the information to the microcontroller and based on the information we can alert the people. Early alerting of people using this project can help them to vacate the place before the occurrence of flood and save many lives.

Advantages of Proposed System

- The project is enabled with IOT technology and hence the sensor data can be monitored from anywhere in the world.

- The project is constructed with easily available and reasonably priced components and hence provides a cost effective solution for flood detection and avoidance.

- Saves more time.

- Timely detection of possible flood risks and floods.

- Helpful in emergency situations.

CHAPTER 5
REQUIREMENTS

Hardware Requirements:

The **NodeMCU ESP8266 development board** comes with the ESP- 12E module containing ESP8266 chip having Tensilica Xtensa 32-bit LX106 RISC microprocessor. This microprocessor supports RTOS and operates at 80MHz to 160 MHz adjustable clock frequency. NodeMCU has 128 KB RAM and 4MB of Flash memory to store data and programs. Its high processing power with in-built Wi-Fi / Bluetooth and Deep Sleep Operating features make it ideal for IoT projects.
NodeMCU can be powered using Micro USB jack and VIN pin (External Supply Pin). It supports UART, SPI, and I2C interface.

The NodeMCU Development Board can be easily programmed with Arduino IDE since it is easy to use. All you need is the Arduino IDE, a USB cable and the NodeMCU board.
It is having Multiple GPIO pins on the board allow us to connect the board with other peripherals and are capable of generating PWM, I2C, SPI, and UART serial communications.

In order to use digital pins, you should select GPIO numbers. For example, the D7 pin is defined as GPIO13. So you should set up the pin number 13 whenever you want to use D7 in your program. Also, you can use pin D2(GPIO4) as SDA and pin D1(GPIO5) as SCL.
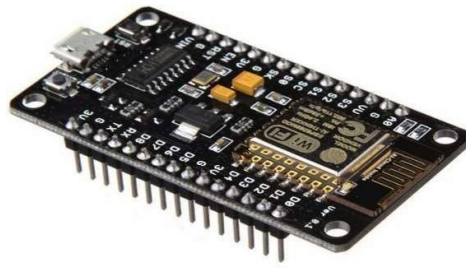
Fig.No.5.1: Node MCU Board

Pin Description:
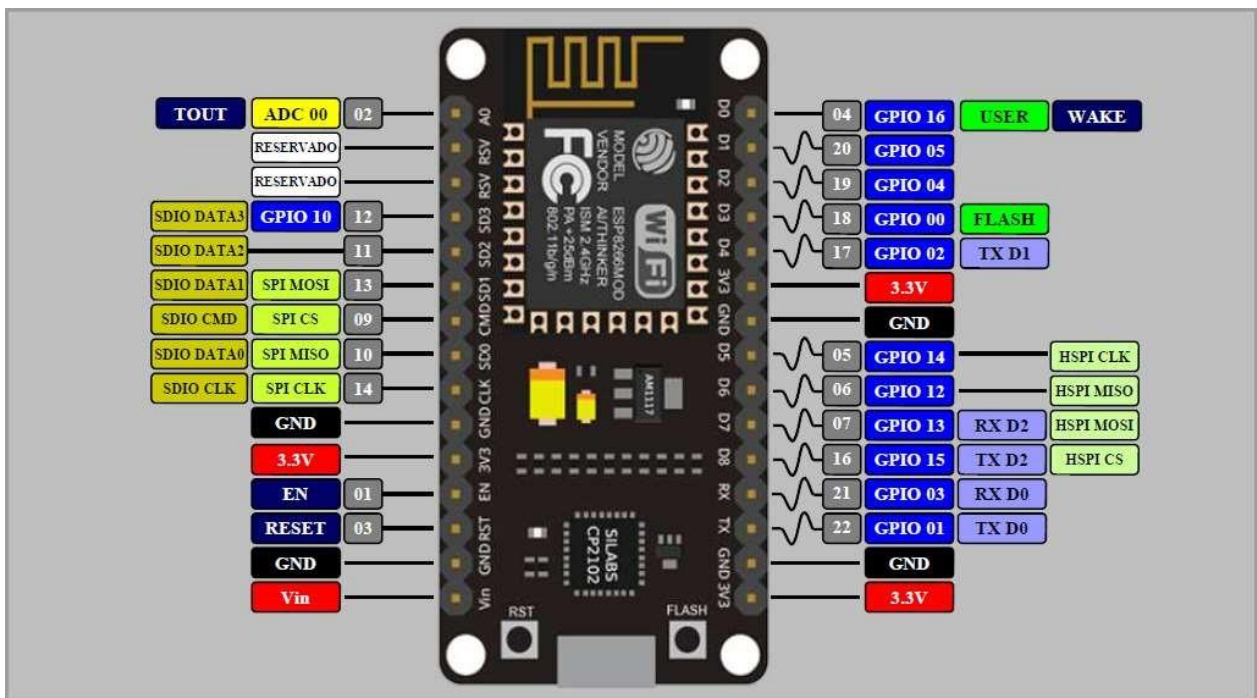
Fig.No.5.2: NodeMCU Board representing all Components

ESP-12E Module:

The development board equips the ESP-12E module containing ESP8266 chip having Tensilica Xtensa® 32-bit LX106 RISC microprocessor which operates at 80 to 160 MHz adjustable clock frequency and supports RTOS. There's also 128 KB RAM and 4MB of Flash memory (for program and data storage).

Power Requirement:

As the operating voltage range of ESP8266 is 3V to 3.6V, the board comes with a LDO voltage regulator to keep the voltage steady at 3.3V. It can reliably supply up to 600mA, which should be more than enough when ESP8266 pulls as much as 80mA during RF transmissions. The output of the regulator is also broken out to one of the sides of the board and labeled as 3V3. This pin can be used to supply power to external components.

Power to the ESP8266 NodeMCU is supplied via the on-board MicroB USB connector. Alternatively, if you have a regulated 5V voltage source, the VIN pin can be used to directly supply the ESP8266 and its peripherals.

Peripherals and I/O:

The ESP8266 NodeMCU has total 17 GPIO pins broken out to the pin headers on both sides of the development board. These pins can be assigned to all sorts of peripheral duties, including:

ADC channel:

> A 10-bit ADC channel.

 UART interface:

> UART interface is used to load code serially.

 PWM outputs:

> PWM pins for dimming LEDs or controlling motors.

 SPI, I2C & I2S interface:

> SPI and I2C interface to hook up all sorts of sensors and peripherals.

❖ I2S interface:

> I2S interface if you want to add sound to your project.

On-Board Switches and LED Indicator:

The ESP8266 NodeMCU features two buttons. One marked as RST located on the top left corner is the Reset button, used of course to reset the ESP8266 chip. The other FLASH button on the bottom left corner is the download button used while upgrading firmware.

The board also has a LED indicator which is user programmable and is connected to the D0 pin of the board.

Serial Communication:

The board includes CP2102 USB-to-UART Bridge Controller from , which converts USB signal to serial and allows your computer to program and communicate with the ESP8266 chip.

ESP8266 NodeMcu PinOut:

 Power Pin:

There are four power pins viz. one VIN pin & three 3.3V pins. The VIN pin can be used to directly supply the ESP8266 and its peripherals, if you have a regulated 5V voltage source. The 3.3V pins are the output of an on-board voltage regulator. These pins can be used to supply power to external components.

Micro-USB: NodeMCU can be powered through the USB port.

3.3V: Regulated 3.3V can be supplied to this pin to power the board.

Vin: External Power Supply.

 GND Pin:

It is a ground pin of ESP8266 NodeMCU development board.

 12C Pin:

These are used to hook up all sorts of I2C sensors and peripherals in your project. Both I2C Master and I2C Slave are supported. I2C interface functionality can be realized programmatically, and the clock frequency is 100 kHz at a maximum. It should be noted that I2C clock frequency should be higher than the slowest clock frequency of the slave device.

- **GPI0 Pins:**

    ESP8266 NodeMCU has 17 GPIO pins which can be assigned to various functions such as I2C, I2S, UART, PWM, IR Remote Control, LED Light and Button programmatically. Each digital enabled GPIO can be configured to internal pull-up or pull-down, or set to high impedance. When configured as an input, it can also be set to edge-trigger or level-trigger to generate CPU interrupts

- **ADC Channel:**

    The NodeMCU is embedded with a 10-bit precision SAR ADC. The two functions can be implemented using ADC viz. Testing power supply voltage of VDD3P3 pin and testing input voltage of TOUT pin. However, they cannot be implemented at the same time.

- **UART Pins:**

    ESP8266 NodeMCU has 2 UART interfaces, i.e. UART0 and UART1, which provide asynchronous communication (RS232 and RS485), and can communicate at up to 4.5 Mbps. UART0 (TXD0, RXD0, RST0 & CTS0 pins) can be used for communication. It supports fluid control. However, UART1 (TXD1 pin) features only data transmit signal so, it is usually used for printing log.

- **SPI Pins:**

    ESP8266 features two SPIs (SPI and HSPI) in slave and master modes.

- **SDIO Pins:**

    ESP8266 features Secure Digital Input/Output Interface (SDIO) which is used to directly interface SD cards. 4-bit 25 MHz SDIO v1.1 and 4-bit 50 MHz SDIO v2.0 are supported.

- **Analog Pin:**

    (A0) - Used to measure analog voltage in the range of 0-3.3V.

- **PWM Pins:**

    The board has 4 channels of Pulse Width Modulation (PWM). The PWM output can be implemented programmatically and used for driving digital motors and LEDs. PWM frequency range is adjustable from 1000 μs to 10000 μs, i.e., between 100 Hz and 1 kHz.

- **Control Pins:**

    They are used to control ESP8266. These pins include Chip Enable pin (EN), Reset pin (RST) and WAKE pin.

    EN pin – The ESP8266 chip is enabled when EN pin is pulled HIGH. When pulled LOW the chip works at minimum power.

    RST pin – RST pin is used to reset the ESP8266 chip.

    WAKE pin – Wake pin is used to wake the chip from deep-sleep.

- **Memory:**

    NodeMCU has 128 KB **RAM** and 4MB of Flash memory to store data and programs.

Features:

Microcontroller	Tensilica 32-bit RISC CPU Xtensa LX106
Operating Voltage	3.3V
Input Voltage	7-12V
Digital I/O Pins (DIO	16
Analog Input Pins (ADC)	1
UARTs	1
SPIs: 1	1
I2Cs: 1	1
Flash Memory	4MB
SRAM	64KB
Clock Speed	80 MHz

Table:5.1

Components:

Ultrasonic Sensor (HC-SRO4)

The ultrasonic sensor (or transducer) works on the same principles as a radar system. An ultrasonic sensor can convert electrical energy into acoustic waves and vice versa. The acoustic wave signal is an ultrasonic wave traveling at a frequency above 18kHz. The famous HC SR04 ultrasonic sensor generates ultrasonic waves at 40kHz frequency.
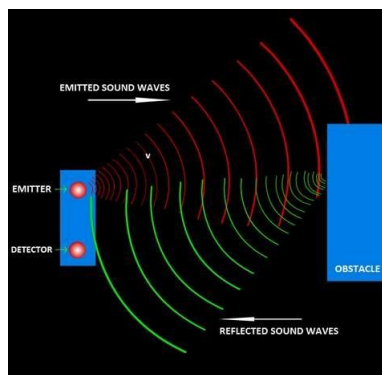
Typically, a microcontroller is used for communication with an ultrasonic sensor. To begin measuring the distance, the microcontroller sends a trigger signal to the ultrasonic sensor. The duty cycle of this trigger signal is 10μS for the HC-SR04 ultrasonic sensor. When triggered, the ultrasonic sensor generates eight acoustic (ultrasonic) wave bursts and initiates a time counter. As soon as the reflected (echo) signal is received, the timer stops. The output of the ultrasonic sensor is a high pulse with the same duration as the time difference between transmitted ultrasonic bursts and the received echo signal.

Fig.No.5.3: Ultrasonic Sensor (HC-SRO4)

❖ Ultrasonic Sensor Pin Configuration

Pin Name	Description
Vcc	The Vcc pin powers the sensor, typically with +5V
Trigger	Trigger pin is an Input pin. This pin has to be kept high for 10us to initialize measurement by sending US wave.
Echo	Echo pin is an Output pin. This pin goes high for a period of time which will be equal to the time taken for the US wave to return back to the sensor.
Ground	This pin is connected to the Ground of the system.

⬜ Water flow sensors (YF-S201):

Water flow sensors are installed at the water source or pipes to measure the rate of flow of water and calculate the amount of water flowed through the pipe. Rate of flow of water is measured as liters per hour or cubic meters.

Fig.No.5.4 Water flow sensors (YF-S201)

WorkingPrinciple: Water flow sensor consists of a plastic valve from which water can pass. A water rotor along with a hall effect sensor is present the sense and measure the water flow.

When water flows through the valve it rotates the rotor. By this, the change can be observed in the speed of the motor. This change is calculated as output as a pulse signal by the <u>hall effect sensor</u>. Thus, the rate of flow of water can be measured.
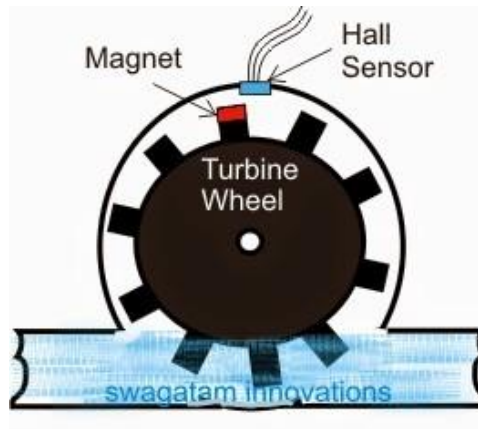
The main working principle behind the working of this sensor is the Hall effect. According to this principle, in this sensor, a voltage difference is induced in the conductor due to the rotation of the rotor. This induced voltage difference is transverse to the electric current. When the moving fan is rotated due to the flow of water, it rotates the rotor which induces the voltage. This induced voltage is measured by the hall effect sensor.

 Water sensor

It is widely used in sensing rainfall, water level, and even liquid leakage. It can be used to detect the presence, the level, the volume It consists of 3 pins. VCC, GND and Data pin.
We can see the indication LED turn ON when the sensor detects water.
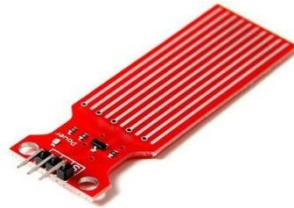
Fig.No.5.5 Water sensor

 Temperature and Humidity (DHT11)

A temperature and humidity (DHT11) sensor senses, measures and reports both moisture and temperature.It uses a capacitive humidity sensor and a thermistor to measure the surrounding .It consists of 3 pins. VCC, GND and Data pin.
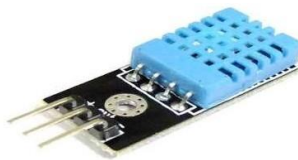
Fig.No.5.6 Temperature and Humidity (DHT11)

GSM

GSM (Global System for Mobile) / GPRS (General Packet Radio Service) TTL -Modem is SIM900A Dual-band GSM / GPRS device, works on frequencies 900 MHZ and 1800 MHZ. It is very compact in size and easy to use as plug in GSM Modem. The Modem is designed with 3V3 and 5V DC TTL interfacing circuitry, which allows User to directly interface with 5V Microcontrollers (PIC, AVR, Arduino, 8051 etc.) as well as 3V3 Microcontrollers (ARM, ARM Cortex XX, etc.). The baud rate can be configurable from 9600-115200 bps through AT (Attention) commands. This GSM/GPRS TTL Modem has internal TCP/IP stack to enable User to connect with internet through GPRS feature. It is suitable for SMS as well as DATA transfer application in mobile phone to mobile phone interface. The modem can be interfaced with a Microcontroller using USART (Universal Synchronous Asynchronous Receiver and Transmitter) feature (serial communication).

Fig.No.5.7 GSM

 Jumper wires

It is used to connect the components to each other.

Fig.No.5.8 Jumper Wires

25

communication:

The Arduino Uno has a number of facilities for communicating with a computer, another Arduino, or other microcontrollers. The ATmega328 provides UART TTL 5V serial communication, which is available on digital pins 0 for RX and 1 for TX. An ATmega8U2 on the board channels this serial communication over USB and appears as a virtual com port to software on the computer. The '8U2 firmware usesthe standard USB COM drivers, and no external driver is needed. However, on Windows, an *.inf file is required. The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the Arduino board. The RX and TX LEDs on the board willflash when data is being transmitted via the USB-to serial chip and USB connection to the computer but not for serial communication on pins 0 and 1. A Software Serial library allows for serial communication on any of the Uno's digital pins.

Software Requirements:

- **Arduino IDE**:

    The Arduino integrated development environment (IDE) is a cross-platform application (for Windows, MacOS, Linux) that is written in the programming language Java. It is used to write and upload programs to Arduino board.

- **Proteus Design Suite**:

    The Proteus Design Suite is a proprietary software tool suite used primarily for electronic design automation. The software is used mainly by electronic design engineers and technicians to create schematics and electronic prints for manufacturing printed circuit boards.

BLYNK APP

- **Introduction**

    This guide will help you understand how to get started using Blynk and give a comprehensive overview of all the features.

    If you want to jump straight into playing with Blynk, check out Getting Started.

Fig.No.5.10: Blynk

- **How Blynk Works**

    Blynk was designed for the Internet of Things. It can control hardware remotely, it can display sensor data, it can store data, visualize it and do many other cool things.

- **What do I need to Blynk?**

    At this point you might be thinking: "**Ok, I want it. What do I need to get started**?" – Just a couple of things, really:

    - **Hardware**.
    - **A Smartphone**.
    - **Why do I need to create an account?**

    An account is needed to save your projects and have access to them from multiple devices from anywhere. It's also a security measure. You can always set up your own Private Blynk Server and have full control.

CHAPTER 6
TECHNOLOGY ADOPTED

6.1 IOT (Internet of Things):

The Internet of Things, or IoT, refers to the billions of physical devices around the world that are now connected to the internet, all collecting and sharing data. Thanks to the arrival of super-cheap computer chips and the ubiquity of wireless networks, it's possible to turn anything, from something as small a pill to something as bigas an airplane, into a part of the IoT. Connecting up all these different objects and adding sensors to them adds a level of digital intelligence to devices that would be otherwise dumb, enabling them to communicate real-time data without involving a human being. The Internet of Things is making the fabric of the world around us smarter and more responsive, merging the digital and physical universes.

The term IoT is mainly used for devices that wouldn't usually begenerally expected to have an internet connection, and that can communicate with the network independently of human action. For this reason, a PC isn't generally considered an IoT device and neither is a Smartphone -- even though the latter is crammed with sensors. A smart watch or a fitness band or other wearable device might be counted as an IoT device, however.

CHAPTER 7 SYSTEM DESIGN

ESP8266NodeMCU Wi-Fi Devkit
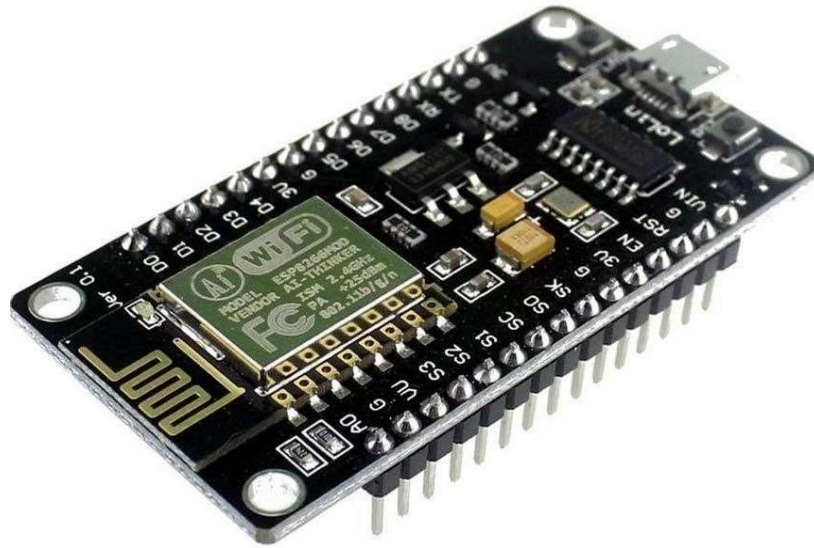
Fig.No.7.1: ESP8266 NodeMCU Wi-Fi Devkit

The ESP8266 is the name of a micro controller designed by Espress if Systems. The ESP8266 itself is a self-contained Wi-Fi networking solution offering as a bridge from existing micro controller to Wi-Fi and is also capable of running self-contained applications.

This module comes with a built in USB connector and a rich assortment of pin-outs. With a micro USB cable, you can connect Node MCU devkit to your laptop and flash it without any trouble, just like Arduino. It is also immediately breadboard friendly.

Specification:

- Voltage:3.3V.

- Wi-Fi Direct (P2P), soft-AP.

- Current consumption: 10uA~170mA.

- Flash memory attachable: 16MB max (512K normal).

- Integrated TCP/IP protocol stack.

- Processor: Tensilica L106 32-bit.

- Processor speed: 80~160MHz.

- RAM: 32K + 80K.

- GPIOs: 17 (multiplexed with other functions).

- Analog to Digital: 1 input with 1024 step resolution. •+19.5dBm output power in 802.11b mode

- 802.11 support: b/g/n.

- Maximum concurrent TCP connections: 5.

Pin Definition:
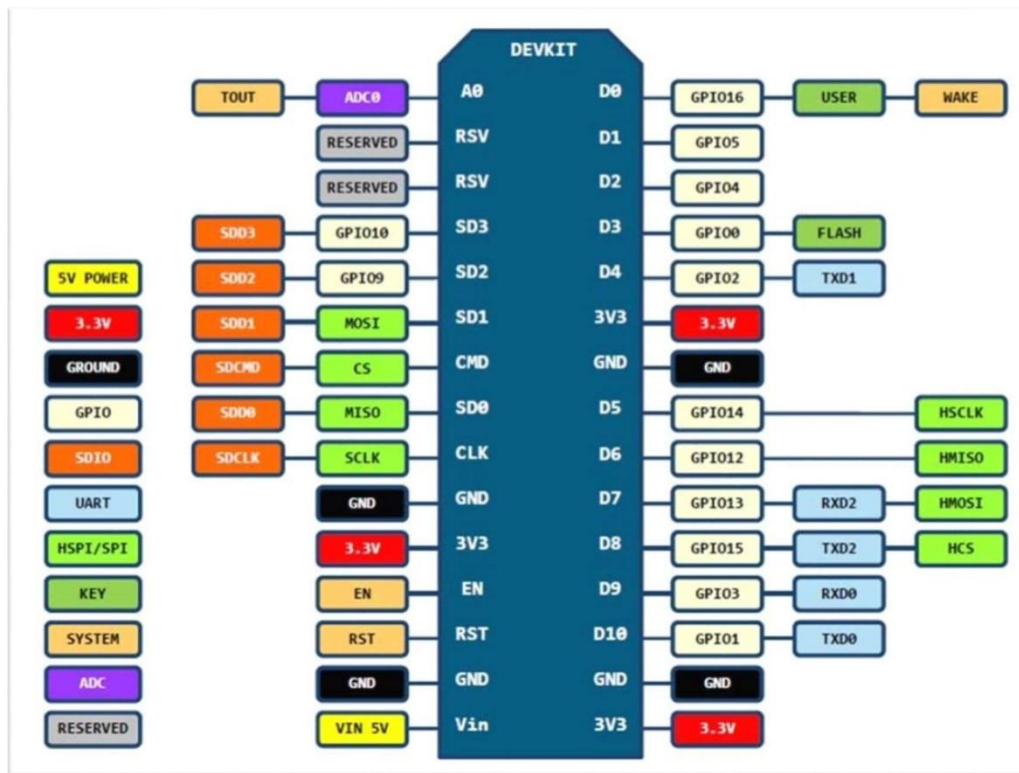
Fig.No.7.2: Pin Definition

Using ArduinoIDE:

The most basic way to use the ESP8266 module is to use serial commands, as the chip is basically a Wi-Fi/Serial transceiver. However, this is not convenient. What we recommend is using the very cool Arduino ESP8266 project, which is a modified version of the Arduino IDE that you need to install on your computer. This makes it very convenient to use the ESP8266 chip as we will be using the well- known Arduino IDE. Following the below step to install ESP8266 library to work in Arduino IDE environment.

Install the Arduino IDE 1.6.4 or greater

Download the Arduino IDE 1.6.4 or greater but don't download 1.6.2because feature updates will not be updated by proxy server.

Install the ESP8266 Board Package

Enter *http://arduino.esp8266.com/stable/package_esp8266com_index.j son* into *Additional Board Manager URLs* field in the Arduino v1.6.4+preferences.
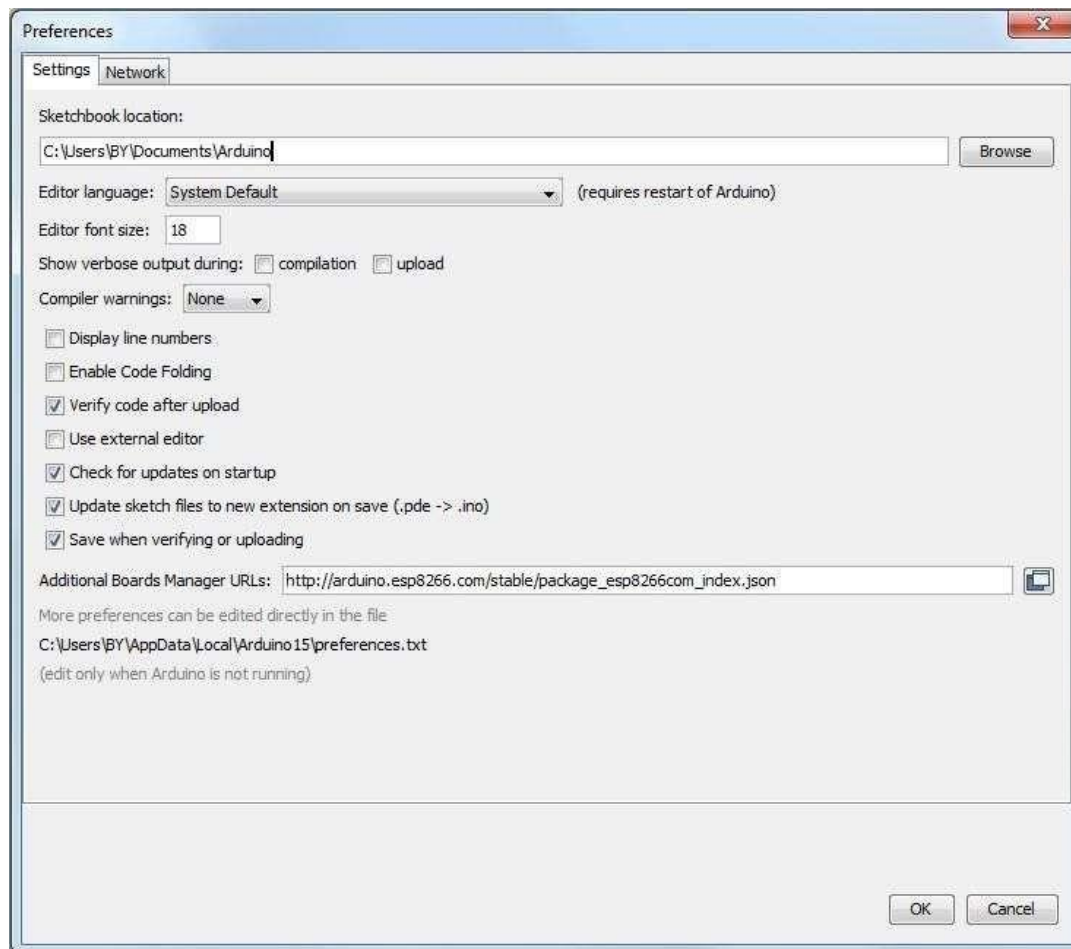
Fig.No.7.3: InstallingESP8266 boardpackage

'File' -> 'Preferences' to access this panel. Next, use the Board manager to install the ESP8266 package. Click 'Tools' -> 'Board:' -> 'Board Manager...' to access this panel.

Setup ESP8266 Support

When you've restarted Arduino IDE, select 'Generic ESP8266 Modulefrom the drop-down menu
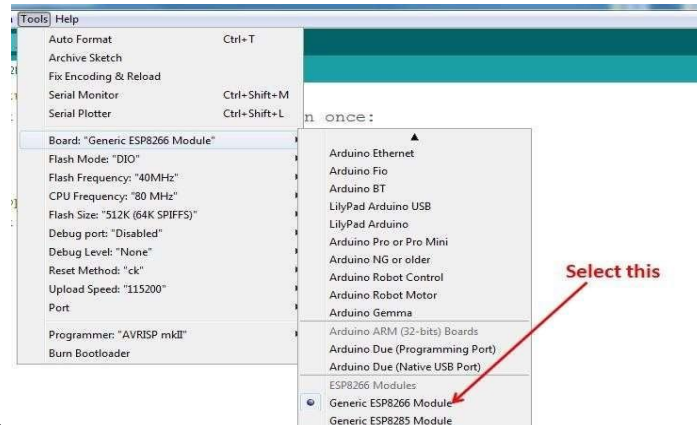
Fig.No.7.4: Setting up ESP8266 support

Select 80 MHz as the CPU frequency (you can try 160 MHz overclock
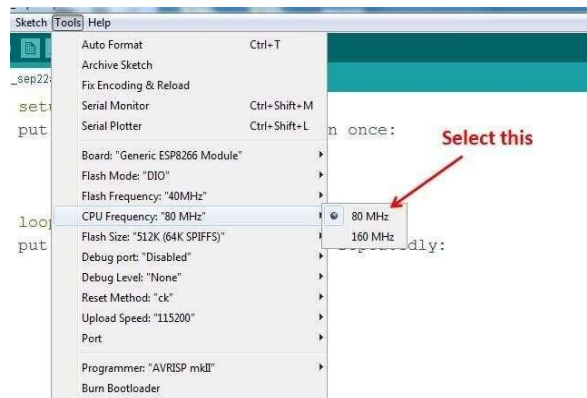
Fig.No.7.5: Selecting CPU frequency

Select '115200' baud upload speed is a good place to start - later onyou can try higher speeds but 115200 is a good safe place to set Select the correct Com Port as indicated on 'Device'.

Blink Test
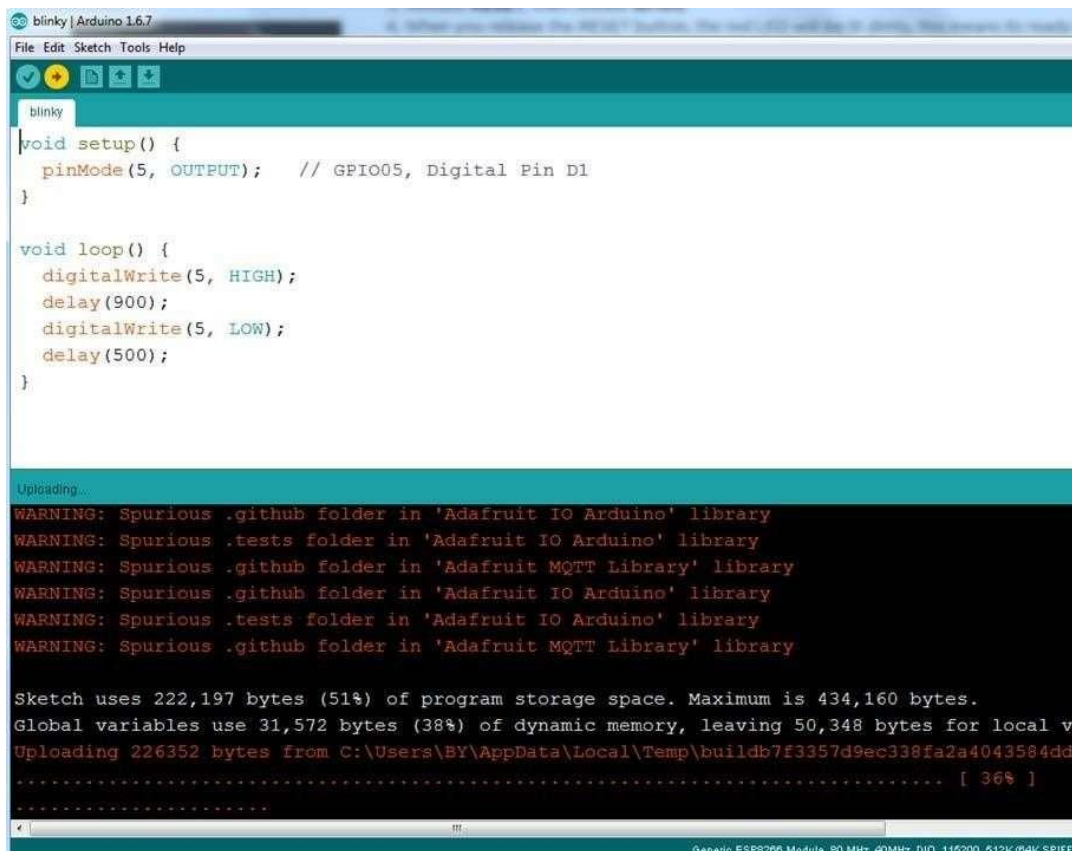
We'll begin with the simple blink test.

Enter this into the sketch window (and save since you'll have to).
Connect a LED

Now you'll need to put the board into bootload mode. You'll have to
do this before each upload. There is no timeout for bootload mode,
so youdon't have to rush!

 Hold down the 'Flash' button.

 While holding down 'Flash', press the 'RST'
button.

 Release 'RST', and then release 'Flash'.

  Fig.No.7.6: **Uploading the sketch to ESP8266 NodeMCU module**.

The sketch will start immediately - you'll see the LED blinking.
Hooray!

Connecting via Wi-Fi

OK once you've got the LED blinking, let's go straight to the fun part,connecting to a webserver.
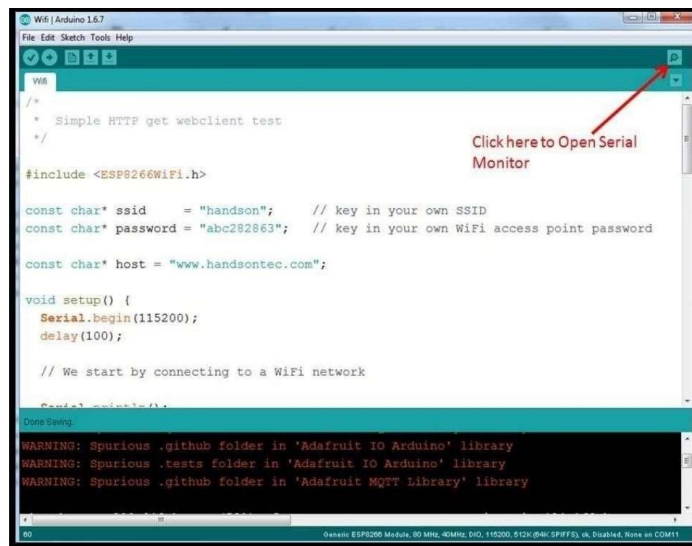
Don't forget to update:

const char* ssid   = "yourssid";

const char* password = "yourpassword";

To your Wi-Fi access point and password, then upload the same way:get into bootload mode, and then upload code via IDE.

Open the IDE serial console at 115200 baud to see the connection and webpage printout!

Fig.No.7.7: Checking the connection

CHAPTER 8
SYSTEM
IMPLEMENTATION

BLYNK APP

Introduction

This guide will help you understand how to get started using Blynk and give a comprehensive overview of all the features.

How Blynk works

Blynk were designed for the internet of things. It can control hardware. It can display sensor data, it can store data, visualize it an do many cool things.

There are two major components in the platform

- **Blynk App-**allows you to create amazing interfaces for your projectsusing various widgets provided
- **Blynkserver-**responsible for the communication between the smart phone and hardware
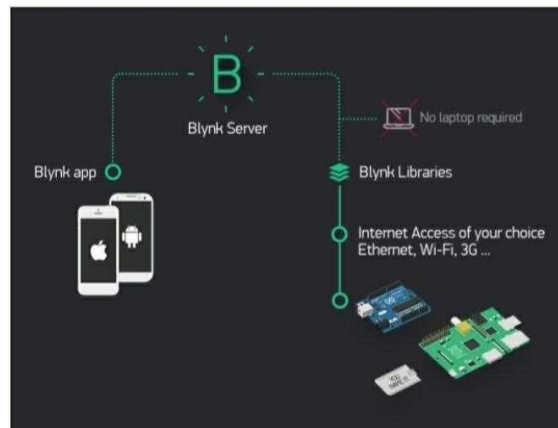

Fig.No.8.1:BLYNK architecture

Features

- Similar API & UI for all supported hardware & devices
- Connection to the cloud using:
- Wi-Fi
- Bluetooth and BLE
- Ethernet
- USB (Serial)
- GSM
- Set of easy-to-use Widgets
- 21/01/2019   https://docs.blynk.cc/#getting-started
- https://docs.blynk.cc/#getting-started   3/20
- Direct pin manipulation with no code writing
- Easy to integrate and add new functionality using virtual pins
- History data monitoring via Super Chart widget
- Device-to-Device communication using Bridge Widget
- Sending emails, tweets, push notifications, etc.
- ... new features are constantly added!

You can find example sketches covering basic Blynk Features. They are included in the library. All the sketches are designed to be easily combined with each other.

 Hardware:

An Arduino, Raspberry Pi, or a similar development kit.

 Blynk works over the Internet:
This means that the hardware you choose should be able to connect to the internet. Some of the boards, like Arduino Uno will need an Ethernet or Wi-Fi Shield to communicate, others are already Internet-enabled: like the ESP8266, Raspberry Pi with Wi-Fi dongle, Particle Photon or Spark Fun Blynk Board. But even if you don't have a Shield, you can connect it over USB to your laptop or desktop (it's a bit more complicated for newbie's, but we got

you covered). What's cool, is that the list of hardware that workswith Blynk is huge and will keep on growing.

▢ **A Smartphone**: The Blynk App is a well-designed interface builder. It works on both iOS and Android, so no holy wars here, ok?

Downloads

Blynk Apps for iOS orAndroid

21/01/2019 https://docs.blynk.cc/#getting-started

▢ **Blynk Library**

DOWNLOAD THE BLYNK LIBRARY

In case you forgot, or don't know how to install Arduino libraries.

▢ **Getting Started**

Let's get you started in 5 minutes (reading doesn't count!). We will switch on an LED connected to your Arduino using the Blynk App on your Smartphone.
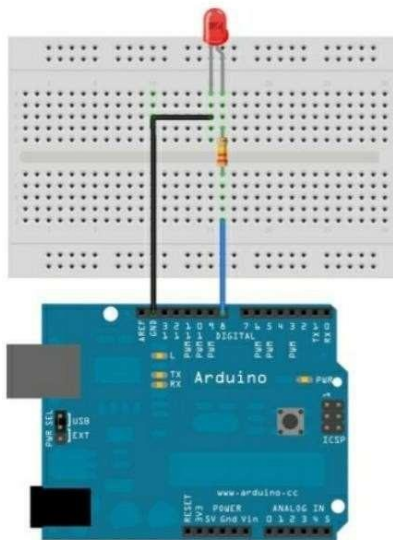

Fig.No.8.2: Connecting authentication token

Getting Started with The Blynk App

- **Create a Blynk Account**

After you download the Blynk App, you'll need to create a New Blynk account. This account is separate from the accounts used for the Blynk Forums; in case you already have one.

We recommend using a real email address because it will simplify things later.

- **Why do I need to create an account?**

An account is needed to save your projects and have access to them from multiple devices from anywhere. It's also a security measure.

You can always set up your own Private Blynk Server and have full control.

- **Create a New Project:** After you've successfully logged into your account, start by creating a new project.
- **Choose Your Hardware**

Select the hardware model you will use. Check out the list of supported hardware.

Auth Token

Auth Token is a unique identifier which is needed to connect your hardware to your smartphone. Every new project you create will hav Auth Token. You'll get Authentication token automatically on your email after project creation. You can also copy it manually. Click on devices section and selected required device: and you'll see token. Its very convenient to send it over e-mail token will be sent tothe email for verification which is used for registration.

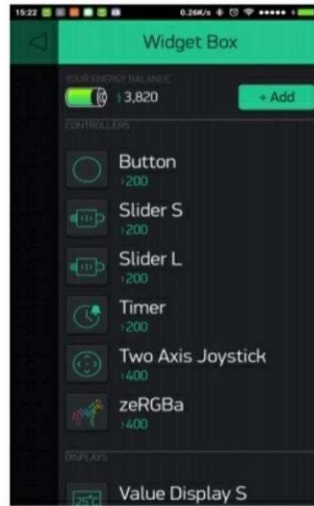- **Add a Widget** Your project canvas is empty, let's add a button to control our LED

Fig.No.8.3:Operating widget box

☐ **Drag-n-Drop** - Tap and hold the Widget to drag it to the new position.

☐ **Widget Settings** - Each Widget has its own settings. Tap on the widget
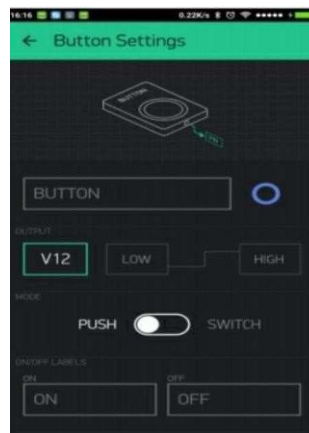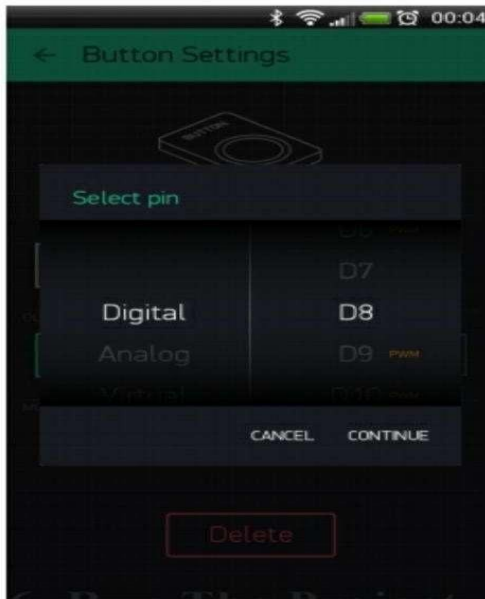

Fig.No.8.4: Widget settings

Three most important parameter to set is PIN. The list of pins reflects physical pins defined by your hardware. If your LED is connected to Digital Pin 8 - then select D8 (D - stands for Digital).

☐ **Fig.No.8.5: PIN configuration**

Run the Project

When you are done with the Settings - press the **PLAY** button. This will switch you from **EDIT** mode to **PLAY** mode where you can interact with the hardware. While in **PLAY** mode, you won't be able to drag or set up new widgets, press **STOP** and get back to EDIT mode.

You will get a message saying, "Arduino UNO is offline". We'll deal with that in the next section.
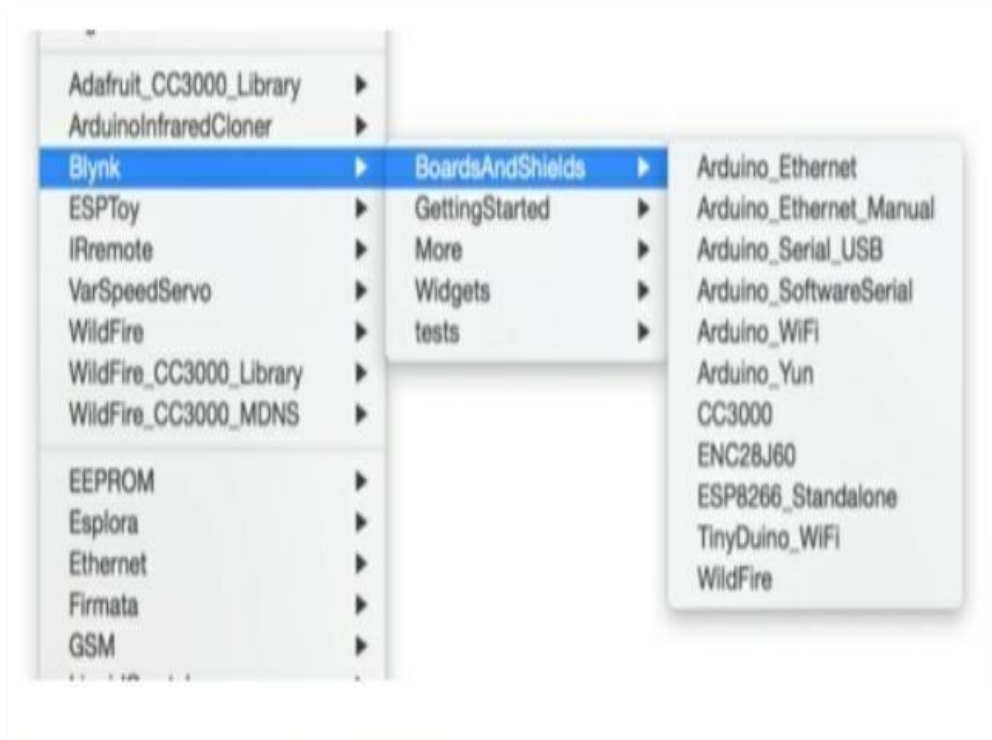
Fig.No.8.6: Running project

Getting Started with Hardware

You should by now have the Blynk Library installed on your computer. If not click here

Example sketches will help you get your hardware online quickly and major Blynk features.

Open the example sketch according to the hardware model or shield you are using.

Let's look at the example sketch for an Node MCU + Ethernet shield.

#define BLYNK_PRINT Serial

#include <SPI.h>

#include <Ethernet.h>

```
#include <BlynkSimpleEthernet.h>

char auth[] = "YourAuthToken";

void setup()

{

Serial.begin(9600); // See the connection status in Serial Monitor

Blynk.begin(auth); // Here your Arduino connects to the Blynk Cloud.

}

void loop()

{

Blynk.run(); // All the Blynk Magic happens here...

}
```

Auth Token

In this example sketch, find this line:

```
char auth[] = "YourAuthToken";
```

This is the Auth Token that you emailed yourself. Please check your email and copy it, then paste it inside the quotation marks.

It should look similar to this:

```
char auth[] = "f45626c103a94983b469637978b0c78a";
```

Upload the sketch to the board and open Serial Terminal. Wait until you see something like this:

Blynkv.X.X.X

Your IP is 192.168.0.11

Connecting...

Blynk connected!

Congrats! You are all set! Now your hardware is connected to the Blynk Cloud!

 BLYNKING
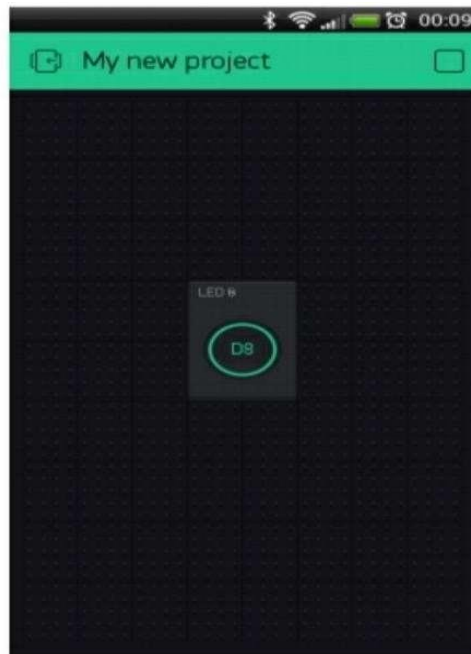
Fig.No.8.7: Running new project

Go back to the Blynk App, push the button and turn the LED on and off! It should be Blynking.

Check out other example sketches.

Feel free to experiment and combine different examples together to create your own amazing projects.

For example, to attach an LED to a PWM-enabled Pin on your Arduino, set the slider widget to control the brightness of an LED. Just use the same steps described above.

 Hardware set-ups
 Arduino over USB (noshield)

If you don't have any shield and your hardware doesn't have any connectivity, you can still use Blynk – directly over USB:

Open Arduino Serial USB example and change Auth Token

```
// you could use a spare Hardware Serial on boards that have it (like Mega)

#include <SoftwareSerial.h>

SoftwareSerialDebugSerial(2, 3); // RX, TX

#define BLYNK_PRINT DebugSerial

#include <BlynkSimpleStream.h>

// You should get Auth Token in the Blynk App.

// Go to the Project Settings (nut icon).

char auth[] = "YourAuthToken";

void setup()

{

// Debug console

DebugSerial.begin(9600);

// Blynk will work through Serial

Serial.begin(9600);

Blynk.begin(auth, Serial);

}void loop()

{
```

CHAPTER 9 SOURCE CODE

9.1 SOURCE CODE

```
#define BLYNK_PRINT Serial
#include <ESP8266WiFi.h>
#include <BlynkSimpleEsp8266.h>
#include <SimpleTimer.h>
#include <SPI.h>
#include <DHT.h>

int X;
int Y;
float TIME = 0;
float FREQUENCY = 0;
float WATER = 0;
float TOTAL = 0;
float LS = 0;
int Flowsensor = D5;

int resval = 0;  //  holds the value
int respin = A0; // sensor pin used

#define TRIGGER 4
#define ECHO    5

#define DHTPIN 2
#define DHTTYPE DHT11

DHT dht(DHTPIN, DHTTYPE);

SimpleTimer timer;

int lastState1 = 0;
```

```cpp
char auth[] = "hFt3Us0ohmwftc526UC8YYRxQqUolg6n";
char ssid[] = "Itsmeee";
char pass[] = "123@Nivas";

WidgetLCD lcd(V0);
WidgetLED LED1Blynk(V1);

void setup()
{
  Serial.begin(9600);
  pinMode(Flowsensor,INPUT_PULLUP);
  Blynk.begin(auth, ssid, pass);

  pinMode(TRIGGER, OUTPUT);
  pinMode(D5, OUTPUT);
  pinMode(ECHO, INPUT);

}

void loop()
{
  Blynk.run();
  flow();
  waterlevel();
  HumiditySensor();
  ultraonic();
}

void flow()
{
X =  pulseIn(Flowsensor,  HIGH);
Y = pulseIn(Flowsensor, LOW);
TIME = X + Y;
```

```
FREQUENCY = 1000000/TIME;
WATER = FREQUENCY/7.5;
LS = WATER/60;

 if (lastState1 == 1)
 {
  if(FREQUENCY >= 100)
  {
   if(isinf(FREQUENCY))
   {
     Blynk.virtualWrite(V7, 0);
   }
   else
   {
     Blynk.virtualWrite(V7, 255);
     Blynk.virtualWrite(V6, FREQUENCY);
     sendsms1();
   }
  }
 }
}
void waterlevel()
{
  resval = analogRead(respin);

  if (resval<=100)
  {
    Serial.println("Water Level: Empty");
    Blynk.virtualWrite(V10, 0);
  }
    if (resval>100 && resval<=350)
    {
      Serial.println("Water Level: Low");
      Blynk.virtualWrite(V10, 25);
```

```
      }
      if (resval>350 && resval<=450)
      {
        Serial.println("Water Level: Medium");
        Blynk.virtualWrite(V10, 50);
      }
        if (resval>450)
        {
          Serial.println("Water Level: High");
          Blynk.virtualWrite(V10, 75);
          lastState1 = 1;
        }
  delay(1000);
}

void HumiditySensor()

{
  float h = dht.readHumidity();
  float t = dht.readTemperature();

  if (isnan(h) || isnan(t))
  {
    Serial.println("Failed to read from DHT sensor!");
    return;
  }
  Blynk.virtualWrite(V5, h); //V5 is for Humidity
  Blynk.virtualWrite(V6, t); //V6 is for Temperature
}

void ultraonic()
{
  long duration, distance;
  digitalWrite(TRIGGER, LOW);
```

```
  delayMicroseconds(2);

  digitalWrite(TRIGGER, HIGH);
  delayMicroseconds(10);

  digitalWrite(TRIGGER, LOW);
  duration = pulseIn(ECHO, HIGH);
  distance = (duration/2) / 29.1;

  Blynk.virtualWrite(V5, distance);

  if (distance <= 80) {
    Blynk.virtualWrite(V2, 255);
}
  else   {
    Blynk.virtualWrite(V2, 0);
  }

  if (distance <= 40) {
    Blynk.virtualWrite(V3, 255);
}
  else   {
    Blynk.virtualWrite(V3, 0);
  }

  if (distance <= 20) {
    Blynk.virtualWrite(V4, 255);
}
  else   {
    Blynk.virtualWrite(V4, 0);

  }
}
```

```
void sendsms1()
{
  Serial.println("AT+CMGF=1");    //To send SMS in Text Mode
  delay(1000);
  Serial.println("AT+CMGS=\"919701939790\"\r"); //Change to
destination phone number
  delay(1000);
  Serial.println("Flood detectet take action");//the content of the
message
  delay(200);
  Serial.println((char)26); //the stopping character Ctrl+Z
  delay(1000);
}
```

CHAPTER 10
RESULTS ANALY

RESULTS AND ANALYSIS

The main objective we have gained from this system is able to spread the news quickly during flood disaster to the general public by using SMS and social buzzer. The proposed system is better in the performance and execution of the given task very quickly. It is used for saving the human life.

CHALLENGES

- □ **.BUDGET**:As a graduate student the budget will be the main problem for implementing the project.
- □ **LACKOFTIME**: To implement the project we should have more time but as lack of time we implemented it by using with the help of blynk app**.**

CHAPTER 11
CONCLUSION

CONCLUSION

Disasters, as the name suggests, brings about great havoc on lives and property indiscriminately across the globe. Developing countries, however, experience much worse destruction than the developed ones and are as well as less equipped to deal with the aftereffects of these calamities. Foreknowledge of the disaster could thus help all, especially the developing countries by providing time to secure property and evacuate. Developing early warning systems may be complicated, with many facets to the system requirements and many additional intricacies, when within a developing country. This paper has tried to propose a potential and economic solution to the problem of floods. Floods cannot be predicted easily, but we are trying to develop a system which tries to detect flood and give early intimation to nearby people. The IoT based flood detection and alert system may prove to save the lives of people by reducing the human quick out during emergency situations. Development of a wireless sensor network has been successfully carried out, with considerations on area of deployment and efficiency. So far, we have built a micro-model through a prototype; the sensors utilized were fundamental in obtaining the required data necessary for monitoring and detecting flood events, and a live feed has also been actualized for end users. The proposed system can later be used to provide solutions to real-life challenges, thereby bringing relief to people in communities ravaged by persistent flood occurrences.

CHAPTER 12 FUTURE SCOPE

FUTURE SCOPE

In the future advancements of this FLOOD MITIGATION SYSTEM, To give the society an earlier notification to evacuate before the water rises to the dangerous level through Short Message Service (SMS).

In future it can be extended with so many multiple features by so many experts and efficient persons. So here when we take an initial step to start a project then the government will give support to that project by adding budget and it will try to execute that project in a efficient manner.

The main concept of future scope is to use that project in a way such that it can be extended and it can be updated anyplace, anywhere and by anybody and it should be easily understand by every human because we may should handle any situation where our project should be extended and it should be executed by someone.

When governments are seeking to extend a project then they will give most preference to these projects where it deals with most dangerous problem.

CHAPTER 13
REFERENCES

REFERENCES

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IOT BASED DRUNK DRIVER DETECTION

A Project Report submitted in partial fulfilment of the requirements for the award of the Degree of

MASTER OF TECHNOLOGY

IN

COMPUTER SCIENCE AND ENGINEERING

Submitted by

P. KUMUDINIDEVI   19U41D5807

Under the Esteemed Guidance of
Dr. K. SUJATHA
Professor, Department of CSE

DADI INSTITUTE OF ENGINEERING & TECHNOLOGY
(Approved by A.I.C.T.E, New Delhi &Affiliated to JNTU, Kakinada)

NAAC ACCREDITED INSTITUTE

ISO 9001:2008; ISO 14001:2004 & OHSAS 18001:2007 Certified Institution

NH-5, Anakapalle-531002, Visakhapatnam, A.P.

2021

CERTIFICATE

This is to certify that the Project work entitled "IOT BASED DRUNK DRIVER DETECTION" is a being submitted by P KUMUDINIDEVI (19U41D5807), in partial fulfilment of the Requirement for the award of the degree of MASTER OF TECHNOLOGY for COMPUTER SCIENCE & ENGINEERING during the academic year 2020-21.

Dr. K. SUJATHA   **Dr. L. PRASANNA KUMAR**

PROFESSOR   **ASSOCIATE PROFESSOR**

(PROJECT GUIDE)   (HEAD OF THE DEPARTMENT)

EXTERNAL EXAMINER

2

DECLARATION

We hereby declare that this project work entitled "IOT BASED DRUNK DRIVER DETECTION" has been carried out by us and contents have been presented in the form are for the award of the degree of MASTER OF TECHNOLOGY IN COMPUTER SCIENCE AND ENGINEERING. We further declare that this dissertation has not been submitted elsewhere for any Diploma or Degree of University.

BY

P KUMUDINIDEVI   (19U41D5807)

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P KUMUDINIDEVI   (19U41D5807)

ABSTRACT

Now a days drunk driving is a growing problem in our country and accounts for one-third of traffic related accidents and deaths. Driving under influence of alcohol has affected and killed countless of people's lives. If you drink and drive, not only you put yourself at risk, but your passengers and pedestrians, and other people who were on the roads will be at risk. For every thirty minutes someone's life is cut short and families are devastated. Due to this drunk driving many innocent families are accused and losing their lives.

To overcome this problem, we propose an efficient system on Drunk Driver Detection using Internet of Things. The MQ3 alcohol sensor is used in this system to detect the alcohol levels of the driver. If the sensor detects drunken driver, a notification alert is passed to the vehicle's owner as well as to the nearby police station. Then the owner or police may take severe action on the driver. Hence the proposed live project IOT based Drunk Driver Detection is the need of the day and can save many lives on Road.

Keywords: Drunk Driving, Drunk Driver Detection, Internet of Things, MQ3 alcohol sensor, IOT based Drunk Driver Detection

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NOMENCLATURE

Symbol	Definition	Unit
V_C	Loop Voltage	V
V_H	Heater Voltage	V
R_L	Load Resistance	Ω
R_H	Heater Resistance	Ω
P_H	Heater Consumption	Ω
R_S	Sensing Resistance	Ω

ABBREVATIONS

IOT   Internet of Things

BAC   Blood Alcohol Content

GPS   Global Positioning System

SPP   Serial Port Protocol

MCU   Micro Controller Unit

DC   Direct Current

WI-FI   Wireless Fidility

API   Application Programming Interface

GND   Ground

VCC   Voltage Common Collector

ADC   Analog to Digital Conversion

GPIO   General Purpose Input/output

IDE   Integrated Development Environment

1.INTRODUCTION

Accidents caused by impairment of alertness in vehicle drivers pose a serious danger to people, not only to drivers themselves but also often to the general public. According to latest data compiled by the National Crime Records Bureau (NCRB), drunk driving was responsible for 7,061 – a mere 1.5% of the road accidents in India. The concern related to drunk driving is not only the high accident rate, but also the type of crashes that are most likely to happen. Road safety has become a major public health concern. Over 1, 37,000 people were died in road accidents in 2013.

The report of Road Accidents in India 2015 puts the number of accidents caused by drivers under the influence of alcohol as well as the fatalities much higher — 3.3 per cent of all road accidents and 4.6 per cent of all fatalities from road accidents. During these crashes, ten thousandsof people were killed, and much more people injured. Besides being a great threat to public safety and health, drunk driving also imposes a heavy financial burden on the whole society, especially on the healthcare sector.

Now-a-days, many road accidents are occurring due to the alcohol consumption of the person who is driving the vehicle. Despite the fact that drunk driving is a serious problem, its detection has been so far relying. Drivers under the influence of alcohol show a marked decline of perception, recognition, and vehicle control, so they tend to make certain types of dangerous manoeuvres. Thus drunken driving is most common reason of accidents in almost all countries all over the world. Most of the accidents occur outside the cities are due to drunken driving and no testing methodology is adopted to avoid these fatalities in highways.

Andhra Pradesh has been placed third on the list of states with the highest accident rates in 2017.A.P. witnessed 30,045 road accidents with 8,210 deaths which makes 7.52% of the country's total.The below table shows the accident

rate and cause for the accidents in A.P. Out of these 30,045 accidents, 20% are only due to drunken driving.

PERCENTAGE OF ACCIDENTS (30,045)	CAUSE FOR ACCIDENTS
40%	Over Speeding
20%	Drunken Driving
18%	Negligent Driving
12%	Driving without rest
5%	Technical Failures

Table No. 1.1: Accident rate and cause for the accidents in A.P.

Another latest report of National Crime Records Bureau or NCRB says that 40 people under the age of 25 die in road accidents all around the world. It states that the drunken driving is a major factor for rising of death on roads.

Driving a vehicle requires complete concentration, reflexive action and quick decision-making abilities for the drivers to avoid any untoward incidences. The consumption of alcohol beyond safety limits can obstruct functioning of the brain and impact "presence-of-mind" capability of the driver resulting in accidents that can prove fatal not only for the driver but also for the fellow-passenger. In turn, it can result in endless trauma to the members of the family back-home. The technology-enabled device if fitted in the car will test the multiple-conditions that will trigger the alarm indicating that the current state of mind of the driver is not apt to behind the wheels.

1.1. The Alarming Statistics

❖ Over 1, 37,000 people were killed in road accidents in 2013 alone, that is more than the number of people killed in all our wars put together.

- There is one death every four minutes due to road accidents in India.
- Drunken driving is one of the leading causes of road facilities.
- 1214 road crashes occur every day in India.
- Two wheelers account for 25% of total road crash deaths.
- 20 children under the age of 14 die every day due to road crashes in the country.

As stated earlier, the alcohol in the blood seizes the working of human brain to such an extent that it can result in lack of concentration, drowsiness and can make the drivers go overboard, increase the speed, skip the lane, jumpthe signal and hit the stationary object damaging the vehicle to unimaginable. The manual detection device that cops use, do analyze the breath and detect the alcohol consumption and penalize the defaulting drivers but then it becomes increasingly impossible for the traffic-cops to control, measure and monitor the vehicle movement given the size of modern-day traffic. It therefore becomes imperative for government-authorities to take advantage of the growing-technology to prevent such accidents and possibly prevent drunken-driving.

1.2.KEYWORDS

1.2.1.Automobile

- Motorized vehicle consisting of 4 wheels and powered by an internal engine.
- Automobiles are used to transport people and items from one location to another location.
- The benefits include on-demand transportation, mobility, independence and convenience.

1.2.2.Embedded system

- An embedded system is some combination of computer hardware and software.
- These are computing systems but can range from having no user interface.

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❖ These can be Micro-Processor or Micro Controller based.

1.2.3. Drunk and drive

❖ Driving under the influence of alcohol is drunk and driving.

❖ It is currently the crime or offense of driving or operating a motor vehicle while impaired by alcohol or other drugs.

❖ Drunk driving, or officially Driving Under the Influence (DUl) of alcohol, is a major cause of traffic accidents throughout the world.

1.2.4. IOT

❖ The Internet of Things is the network of physical devices, vehicles, home appliances and other items embedded with electronics, software, sensors, and connectivity which enable these things to connect and exchange data.

❖ The IoT involves extending Internet connectivity beyond standard devices, such as desktops, laptops, smartphones and tablets, to any range of traditionally dumb or non-internet-enabled physical devices and everyday objects.

1.3. OBJECTIVES

❖ This system can be used in the various vehicles for detecting the drunken driver. As the project is based on IOT an alcohol sensor is to detect.

❖ It can immensely decrease the rate of drunken driving cases which often leads to accidental deaths.

❖ An android application is used by both police and the owner of the vehicle in order to get notified when the driver was drunk.

❖ Through GPS, the vehicle can be tracked by the police as well as the owner.

❖ Severe punishment will be given to the drunk driver by the police so the driver may not repeat drunk driving in the future.

❖ Repetition of this activity may leads to permanent seize of driver's license.

2. LITERATURE REVIEW

2.1. MOBILE PHONE BASED DRUNK DRIVING DETECTION

Drunk driving, or officially Driving Under the Influence (DUl) of alcohol, is a major cause of traffic accidents throughout the world. In this paper, we propose a highly efficient system aimed at early detection and alert of dangerous vehicles manoeuvres typically related to drunk driving. The entire solution requires only a mobile phone placed in vehicle and with accelerometer and orientation sensor. A program installed on the mobile phone computes accelerations based on sensor readings, and compares them with typical drunk driving patterns extracted from real driving tests.

2.2. DRUNKEN DRIVING DETECTION AND PREVENTION MODELS USING INTERNET OF THINGS

The Internet of Things comprises of a number of uniquely identifiable devices capable of communicating over a network. An individual device in IoT can be used in a wide range of applications. In this paper a model based on IoTis proposed with the aim to safeguard drunk and drowsy drivers especially at night. It also discusses several models which have already been proposed and attempts to assimilate the best ideas which are proposed there. It includes analysis of alcohol concentration, eye-blinking rate and the rate at which the car is made to turn to detect a drunken or drowsy state and hence undertake protective measures. Such measures include speed reduction, triggering an alarm, informing the traffic control, activation of auto-pilot.

2.3. DRUNKEN DRIVING DETECTION AND DROWSINESS DETECTION

Driving when drowsy can lead to higher crash risk than being in alert state. Therefore, by using assistive systems to monitor driver's level of alertness can be of significant help in prevention of accidents. This paper aims towards the detection of driver's drowsiness is based on real-time detection of the driver's head, face and mouth, where-in HAAR-Cascade classifier for face and eye detection and template matching in the mouth region for yawning detection.

The system will also have an alcohol detection sensor which will determine whether the driver is drunk or not, thus covering the major reasons behind road accidents.

2.4. SMARTPHONE AND SENSOR BASED DRUNK DRIVING PREVENTION SYSTEM

By statistics, at least 3 people are killed every 2 hours due to drunk driving cases, thus leading to thousands of deaths each year. Drunk driving, or Driving under Influence (DUI) of alcohol, has been and will be a major cause of automobile accidents throughout the entire world. So by this paper, we would like to propose an exceedingly competent system. The system requires a smart mobile phone placed in vehicle, and specially designed hardware consisting of sensors which can be easily integrated in the car. A program will be installed on the hardware device as well as the smart mobile phone. Once any it is found that the driver is under influence of alcohol, an alert will be automatically generated for the owner/relative and/or call the police before even the automobile starts, thus prevent the accident before it actually happens.

3. EXISTING SYSTEM

In 1927, a Chicago chemist, William Duncan McNally, invented a breathalyser in which the breath moving through chemicals in water would change colour. One use for his invention was for housewives to test whether their husbands had been drinking.

In 1935, the first practical roadside breath-testing device was the drunkometer. It was developed by Rolla Neil Harger of the Indiana University School of Medicine. The drunkometer collects a motorist's breath sample into a balloon inside the machine. The breath sample was then pumped through an acidified potassium permanganate solution. If there was alcohol in the breath sample, the solution changes colour. The greater the colour change, the more alcohol was present in the breath.

Fig.No. 3.1:Drunkometer

The main drawback to Harger'sDrunkometer was that it required re-calibration every time it was moved. Therefore, it was not portable and was impractical for police officers.

In 1967 in Britain, Bill Ducie and Tom Parry Jones developed and marketed the first electronic breathalyser. The Road Safety Act 1967 introduced the first legally enforceable maximum blood alcohol level for drivers in the UK, above which it became an offence to be in charge of a motor vehicle and introduced the roadside breathalyser, made available to police forces across the country.

Later this Electronic Breathalyser was implemented in India to detect the drunken people. It is mainly used by the police in order to detect the people who were driving vehicles by consuming alcohol. The main limitation of this system is that the police are not able to check each and every vehicle. Also there is a chance for drunk drivers to escape from the police in the traffic. So, there is a need for an effective system to check every drunken driver.

Chemical reactions in breathalyser:

When the user exhales into a breathalyser, any ethanol present in their breath is oxidized to acetic acid at the anode:

$CH_3CH_2OH(g) + H_2O(l) \rightarrow CH_3CO_2H(l) + 4H^+(aq) + 4e^-$

At the cathode, atmospheric oxygen is reduced:

$O_2 (g) + 4H^+ (aq) + 4e^- \rightarrow 2H_2O (l)$
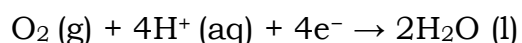
The overall reaction is the oxidation of ethanol to acetic acid and water.

$CH_3CH_2OH(l) + O_2(g) \rightarrow CH_3COOH(aq) + H_2O(l)$

The electric current produced by this reaction is measured by a microcontroller, and displayed as an approximation of overall blood alcohol content (BAC) by the Alco sensor.

Fig. No. 3.2: Breathalyzer

The main limitation of this system is that the police are not able to check each and every vehicle. Also there is a chance for drunk drivers to escape from the police in the traffic. So, there is a need for an effective system to check every drunken driver.
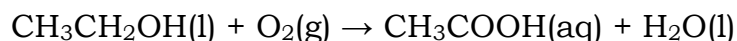
4.PROPOSED SYSTEM

The proposed system is to create an effective alcohol detector in vehicle where we detect the drunk driver when he enters the vehicle and notifies the owner and the police. As this system will be developed using IOT, we use a sensor which detects the presence of alcohol.

4.1.BLOCK DIAGRAM
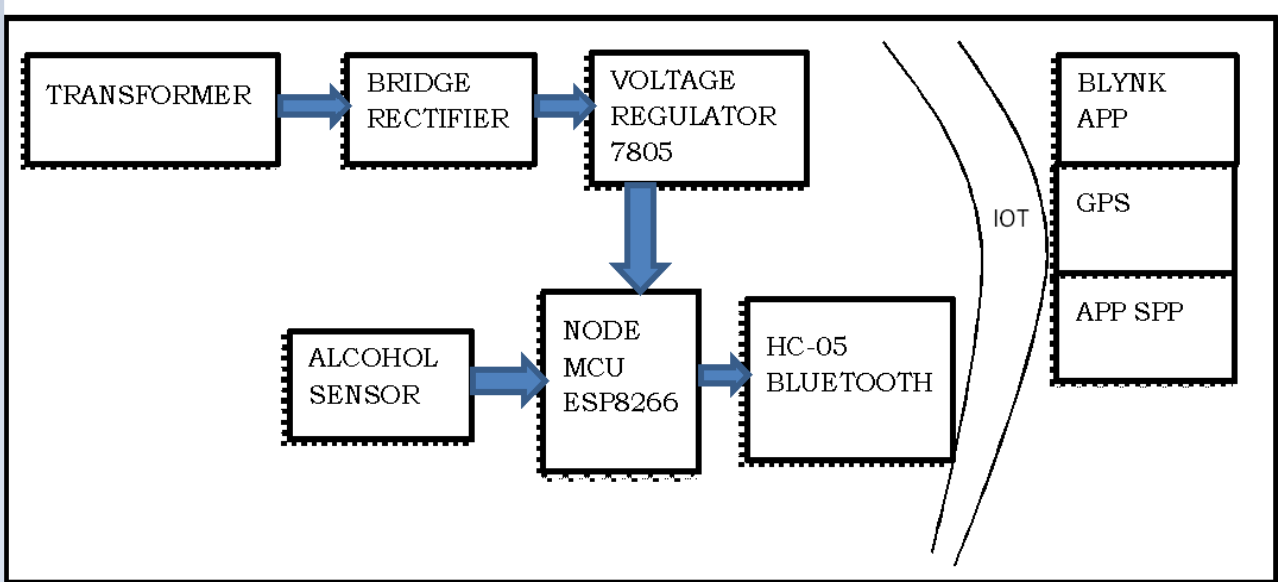
Fig. No. 4.1: Block Diagram of IOT based drunk driving detection

4.2.WORKING OF DRUNK DRIVER DETECTION SYSTEM

As soon as the driver enters the key to ignite the engine the MQ3 sensor gets activated and detect the alcohol level through exhale, and if it is measured to be beyond the excessive limit, immediately the owner and nearby police station get the notification. In case, if the driver is intoxicated before but starts consuming the alcohol while on move, the sensor keeps measuring and moment the level crosses the limit, the vehicle starts slowing down and gets stationed at the detected location. In this system, in order to notify the owner and police an app will be developed using Blynk App.

Since, the MQ-3 alcohol sensor is expected to detect alcohol level of the driver alone and not that of the fellow passengers in the motor-vehicle, it is important to embed the device at that position that is at the top of the steering wheel. This will ensure that the device work efficiently and effectively. The remaining sensors and modules such as the GPS (Global Positioning System) module can be placed anywhere inside the motor-vehicle as per the convenience and design compulsion by manufacturers. As Global Positioning System (GPS) is even accessible by the smartphones, it can be used to obtain the specific location of the driver, making it easy for the correspondents to track the vehicle.

Fig. No. 4.2: Placing of MQ3 sensor

5.SYSTEM REQUIREMENTS

5.1.HARDWARE REQUIREMENTS

- ❖ MQ3 Alcohol sensor
- ❖ NodeMCUESP8266
- ❖ HC-05 Bluetooth module
- ❖ Transformer
- ❖ Bridge rectifier
- ❖ Voltage Regulator

5.1.1.MQ3 ALCOHOL SENSOR

This module is made using Alcohol Gas Sensor MQ3. It is a low cost semiconductor sensor which can detect the presence of alcohol gases at concentrations from 0.05 mg/L to 10 mg/L. the sensitive material used for this sensor is SnO2, whose conductivity is lower in clean air. Its conductivity increases as the concentration of alcohol gases increases. It has high sensitivity to alcohol and has a good resistance to disturbances due to smoke, vapour and gasoline. This module provides both digital and analog outputs. MQ3 alcohol sensor module can be easily interfaced with Microcontrollers, Arduino Boards, and Raspberry Pi.

Sensitive material of MQ-3 gas sensor is SnO2, which with lower conductivity in clean air. When the target alcohol gas exist, the sensor's conductivity is higher along with the gas concentration rising. Please use simple electro circuit, Convert change of conductivity to correspond output signal of gas concentration. MQ-3 gas sensor has high sensitivity to Alcohol, and has good resistance to disturb of gasoline, smoke and vapour. The sensor could be used to detect alcohol with different concentration; it is with low cost and suitable for different application.
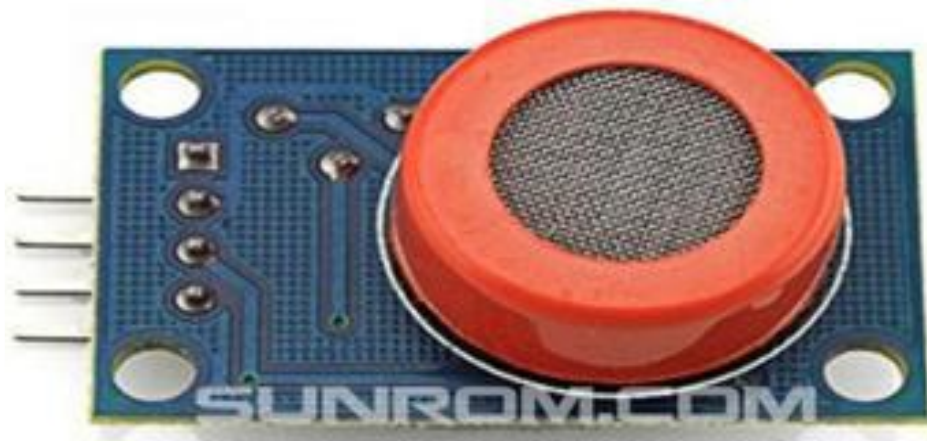
Fig. No. 5.1: MQ3 Alcohol Sensor

This alcohol sensor is suitable for detecting alcohol concentration on your breath, just like your common breathalyser. It has a high sensitivity and fast response time. Sensor provides an analog resistive output based on alcohol concentration.

❖ Character: Good sensitivity to alcohol gas, Long life and low cost, Simple drive circuit.

❖ Application:Vehicle alcohol detector, Portable alcohol detector.
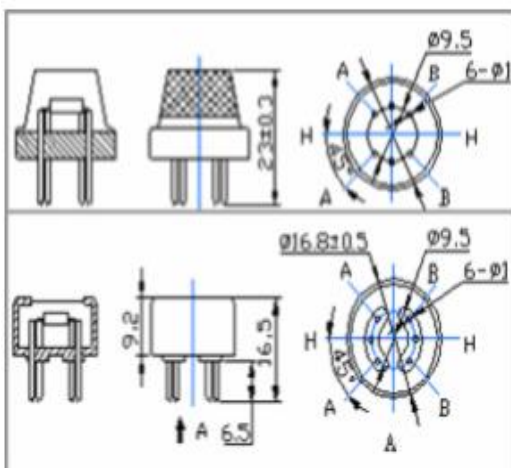
Configuration: Test circuit:
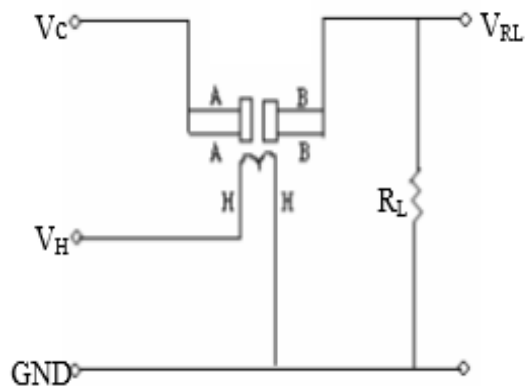
Fig. No. 5.2: Configuration and Test circuit of MQ3 sensor

❖ Technical Data:

Model No.			MQ-3
Sensor Type			Semiconductor
Standard Encapsulation			Bakelite (Black Bakelite)
Detection Gas			Alcohol gas
Concentration			0.04-4mg/1 alcohol
Circuit	Loop Voltage	V_C	≤24V DC
	Heater Voltage	V_H	5.0±0.2V AC or DC
	Load Resistance	R_L	Adjustable
character	Heater Resistance	R_H	31Ω±3Ω (Room Tem.)
	Heater consumption	P_H	≤900mW
	Sensing Resistance	R_S	2KΩ-20KΩ(in 0.4mg/1 alcohol)
	Sensitivity	S	Rs(in air)/Rs(0.4mg/L Alcohol)≥5
	Slope	A	≤0.6(R_{300ppm}/ R_{100ppm} Alcohol)

Condition	Tem. Humidity	$20^0C\pm2^0C$; $65\%\pm5\%RH$
	Standard test circuit	$V_C:5.0V\pm0.1V$; $V_H:5.0V\pm0.1V$
	Preheat time	Over 48 hours

Table No. 5.1: Basic test loop

Following conditions must be prohibited:

- ❖ Exposed to organic silicon steam: Organic silicon steam cause sensors invalid, sensors must be avoid exposing to silicon bond, fixture, silicon latex, putty or plastic contain silicon environment

- ❖ High Corrosive gas:If the sensors exposed to high concentration corrosive gas (such as H2Sz, SOX，Cl2，HCl etc.), it will not only result in corrosion of sensors structure, also it cause sincere sensitivity attenuation.

- ❖ Alkali, Alkali metals salt, halogen pollution:The sensors performance will be changed badly if sensors be sprayed polluted by alkali metals salt especially brine, or be exposed to halogen such as fluorine.

- ❖ Touch water: Sensitivity of the sensors will be reduced when spattered or dipped in water.

- ❖ Freezing:Do avoid icing on sensor' surface, otherwise sensor would lose sensitivity.

- ❖ Applied voltage higher: Applied voltage on sensor should not be higher than stipulated value, otherwise it cause down-line or heater damaged, and bring on sensors' sensitivity characteristic changed badly.

- ❖ Voltage on wrong pins:For 6 pins sensor, if apply voltage on 1,3 pins or 4,6 pins, it will make lead broken, and without signal when apply on 2,4 pins.

Following conditions must be avoided:

- ❖ Water Condensation: Indoor conditions, slight water condensation will affect sensors performance lightly. However, if water condensation on sensors surface and keep a certain period.

- ❖ Used in high gas concentration: No matter the sensor is electrified or not, if long time placed in high gas concentration, if will affect sensors characteristic.

- ❖ Long-time storage: The sensors resistance produce reversible drift if it's stored for long time without electrify, this drift is related with storage conditions. Sensors should be stored in airproof without silicon gel bag with clean air. For the sensors with long time storage but no electrify, they need long aging time for stability before using.

- ❖ Long-time exposed to adverse environment: No matter the sensors electrified or not, if exposed to adverse environment for long time, such as high humidity, high temperature, or high pollution etc, it will effect the sensors performance badly.

- ❖ Vibration: Continual vibration will result in sensors down-lead response then rapture. In transportation or assembling line, pneumatic screwdriver/ultrasonic welding machine can lead this vibration.

- ❖ Concussion: If sensors meet strong concussion, it may lead its lead wire disconnected.

- ❖ Usage: For sensor, handmade welding is optimal way.

If use wave crest welding should meet the following conditions:

- ❖ Soldering flux: Rosin soldering flux contains least chlorine
- ❖ Speed: 1-2 Meter/ Minute
- ❖ Warm-up temperature：100±20℃
- ❖ Welding temperature：250±10℃
- ❖ Time pass wave crest welding machine

If disobey the above using terms, sensors sensitivity will be reduced.

5.1.2.NodeMCU ESP8266

NodeMCU v2
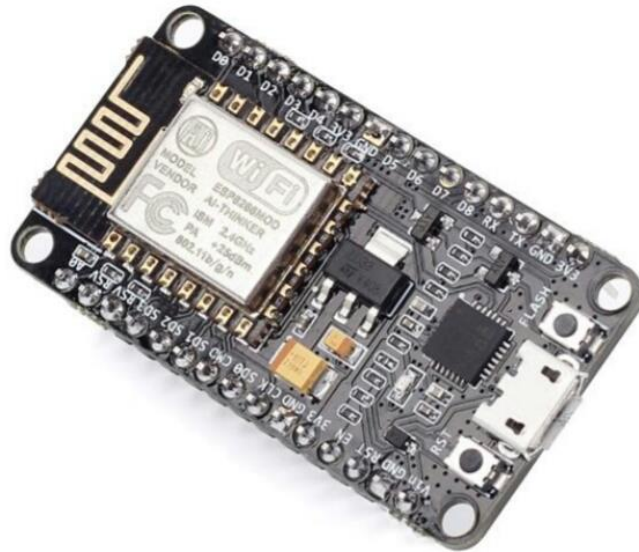
Fig.No. 5.3: NodeMCU

The NodeMcu is an open-source firmware and development kit that helps you to Prototype your IOT product within a few Lua script lines.

❖ Features: Open-source, Interactive, Programmable, Low cost, Simple and smart, WI-FI enabled

❖ Arduino like hardware IO:AdvancedAPI for hardware IO, which can dramatically reduce the redundant work for configuringand manipulating hardware. Code like arduino, but interactively in Lua script.

❖ Nodejs style network: API Event-driven API for network applications, which facilitates developers writing code running on a 5mm*5mm,sized MCU in Nodejs style. Greatly speed up your IOT application developing process.

❖ Specification: The Development Kit based on ESP8266, integrates GPIO, PWM, IIC, 1-Wire and ADC all in one board. Power your development in the fastest way combining with NodeMCU Firmware! USB-TTL included, plug & play, 10 GPIO, every GPIO can be PWM, I2C, 1-wire, FCC CERTIFIED WI-FI module (Coming soon), PCB antenna.

This is the suggested installation method for end users.

- ❖ Prerequisites:Arduino 1.6.8, we can get it from Arduino website. Internet connection

- ❖ Instructions: Start Arduino and open Preferences window. Enter http://arduino.esp8266.com/stable/package_esp8266com_index.json into the Additional Board Manager URLs field. You can add multiple URLs, separating them with commas. Open Boards Manager from Tools > Board menu and find esp8266 platform. Select the version you need from a drop-down box. Click install button.

- ❖ Don't forget to select your ESP8266 board from Tools > Board menu after installation. You may optionally use staging boards' manager package. This may contain some new features, but at the same time, some things might be broken.

- ❖ Digital IO: Pin numbers in Arduino correspond directly to the ESP8266 GPIO pin numbers. pinMode, digitalRead, and digitalWrite functions work as usual, so to read GPIO2, call digitalRead(2).

Digital pins 0—15 can be INPUT, OUTPUT, or INPUT_PULLUP. Pin 16 can be INPUT, OUTPUT or INPUT_PULLDOWN_16. At startup, pins are configured as INPUT.

Pinsmayalsoserveotherfunctions,likeSerial,I2C,SPI.Thesefunctionsarenormal lyactivatedbythecorresponding library.

Digital pins 6-11 are not shown on this diagram because they are used to connect flash memory chip on most modules. Trying to use these pins as IOs will likely cause the program to crash.

Note that some boards and modules (ESP-12ED, NodeMCU 1.0) also break out pins 9 and 11. These may be used as IO if flash chip works in DIO mode (as opposed to QIO, which is the default one).

Pin interrupts are supported through attachInterrupt, detachInterrupt functions. Interrupts may be attached to any GPIO pin, except GPIO16. Standard Arduino interrupt types are supported: CHANGE, RISING, FALLING.

The diagram below shows pin mapping for the popular ESP-12 module.
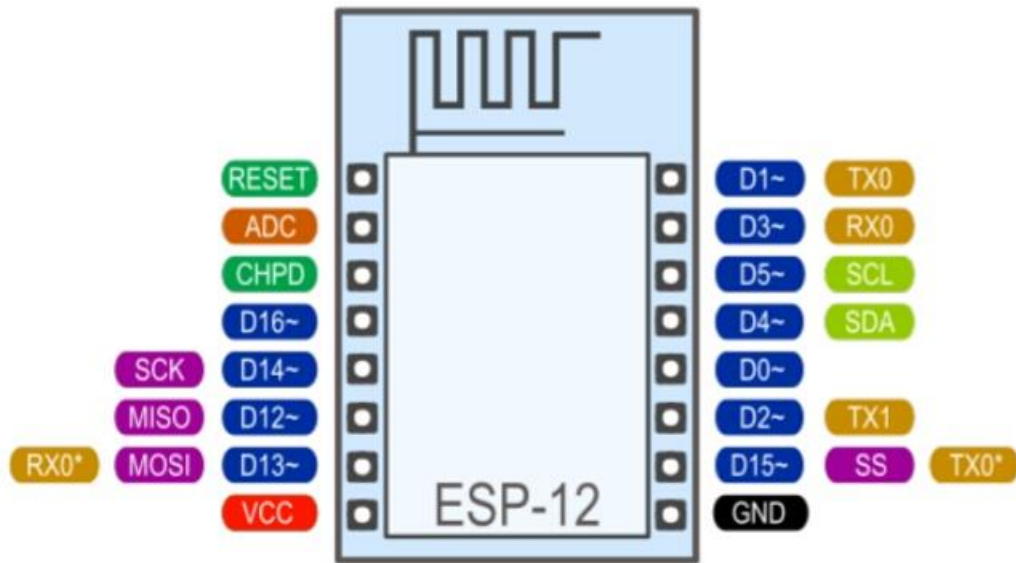
Fig. No. 5.4: Pin Functions of NodeMCU

Analog input: ESP8266 has a single ADC channel available to users. It may be used either to read voltage at ADC pin, or to read module supply voltage (VCC).

To read external voltage applied to ADC pin, use analogRead(A0). Input voltage range is 0 — 1.0V. To read VCC voltage, use ESP.getVcc() and ADC pin must be kept unconnected. Additionally, the following line has to be added to the sketch.

ADC_MODE(ADC_VCC); This line has to appear outside of any functions, for instance right after the #include lines of your sketch.

Analog output: analogWrite(pin, value) enables software PWM on the given pin. PWM may be used on pins 0 to 16. Call analogWrite(pin, 0) to disable PWM on the pin. value may be in range from 0 to PWMRANGE, which is equal to 1023 by default. PWM range may be changed by calling analogWriteRange(new_range).

PWM frequency is 1kHz by default. Call analogWriteFreq(new_frequency) to change the frequency.

Timing and delays:millis() and micros() return the number of milliseconds and microseconds elapsed after reset, respectively. delay(ms) pauses the sketch

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for a given number of milliseconds and allows WiFi and TCP/IP tasks to run. DelayMicroseconds(us) pauses for a given number of microseconds.

Remember that there is a lot of code that needs to run on the chip besides the sketch when WiFi is connected. WiFi and TCP/IP libraries get a chance to handle any pending events each time the loop() function completes, OR when delayiscalled. Ifyouhavealoop somewhere inyoursketchthattakesalotoftime(>50ms)withoutcallingdelay, you might consider adding a call to delay function to keep the WiFi stack running smoothly.

There is also a yield() function which is equivalent to delay(0). The delayMicroseconds function, on the other hand, does not yield to other tasks, so using it for delays more than 20 milliseconds is not recommended.

Serial:Serial object works much thesame way as on a regular Arduino. Apart from hardware FIFO (128 bytes for TX and RX) Hardware Serial has additional 256-byte TX and RX buffers. Both transmit and receive is interrupt-driven. Write and read functions only block the sketch execution when the respective FIFO/buffers are full/empty.

Serial uses UART0, which is mapped to pins GPIO1 (TX) and GPIO3 (RX). Serial may be remapped to GPIO15 (TX) and GPIO13 (RX) by calling Serial.swap() after Serial.begin. Calling swap again maps UART0 back to GPIO1 and GPIO3.

Serial1 uses UART1, TX pin is GPIO2. UART1 can not be used to receive data because normally it's RX pin is occupied for flash chip connection. To use Serial1, call Serial1.begin(baudrate).

If Serial1 is not used and Serial is not swapped - TX for UART0 can be mapped to GPIO2 instead by calling Serial.set_tx(2) after Serial.begin ordirectlywith Serial.begin(baud, config, mode, 2).

By default the diagnostic output from WiFi libraries is disabled when you call Serial.begin. To enable debug output again, call Serial.SetDebugOutput(true). To redirect debug output to Serial1 instead, callSerial1.SetDebugOutput(true).

You also need to use Serial.setDebugOutput(true) to enable output from printf() function.

Both Serial and Serial1 objects support 5, 6, 7, 8 data bits, odd (O), even (E), and no (N) parity, and 1 or 2 stop bits. To set the desired mode, call Serial.begin(baudrate, SERIAL_8N1), Serial. begin(baudrate, SERIAL_6E2), etc. A new method has been implemented on both Serial and Serial1 to get current baud rate setting. To get the current baud rate, call Serial.baudRate(), Serial1.baudRate(). Return aint of current speed. For example

```
// Set Baud rate to 57600
Serial.begin(57600);
```

```
// Get current baud rate
intbr = Serial.baudRate();
```

```
// Will print "Serial is 57600 bps"
Serial.printf("Serial is %d bps", br);
```

This is done also for official ESP8266 Software Serial library, see this pull request. Note that this implementation isonlyforESP8266basedboards, and will not works with other Arduino boards.

Progmem:The Program memory features work much the same way as on a regular Arduino; placing read only data and stringsin read only memory and freeing heap for your application. The important difference is that on the ESP8266 the literal strings are not pooled. This means that the same literal string defined inside a F("") and/or PSTR("") will take up space for each instance in the code. So you will need to manage the duplicate strings yourself.

There is one additional helper macro to make it easier to pass const PROGMEM strings to methods that take a __FlashStringHelper called FPSTR(). The use of this will help make it easier to pool strings. Not pooling strings...

String response1;

response1 += F("http:");

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...

String response2;

response2 += F("http:");

using FPSTR would become...

const char HTTP[] PROGMEM = "http:";

...

{

    String response1;

    response1 += FPSTR(HTTP);

    ...

    String response2;

    response2 += FPSTR(HTTP);

}

5.1.3.Wi-Fi(ESP8266Wi-Fi library)

ESP8266WiFi library has been developed basing on ESP8266SDK, using naming convention and overall functionality philosophy of the ArduinoWi-Fi Shield library. Overtime the wealth Wi-Fi features ported from ESP8266SDK to this library out grew the APIs of Wi-Fi Shield library and it became apparent that we need to provide separate documentation on what is new and extra.

Devices that connect to Wi-Fi network are called stations (STA). Connection to Wi-Fi is provided by an access point (AP) that actsasahubforoneormorestations. Theaccesspointontheotherendisconnectedtoawirednetwork. An accesspointisusuallyintegratedwitharoutertoprovideaccessfromWi-Fi networktotheinternet. Eachaccess point is recognized by a SSID (Service Set Identifier) that essentially is the name of network you select when connecting a device (station) to the Wi-Fi.

ESP8266 module can operate as a station, so we can connect it to the Wi-Fi network. It can also operate as a soft access point (soft-AP), to establish its own Wi-Fi network. Therefore we can connect other stations to such ESP module. ESP8266 is also able to operate both in station and soft access point mode.
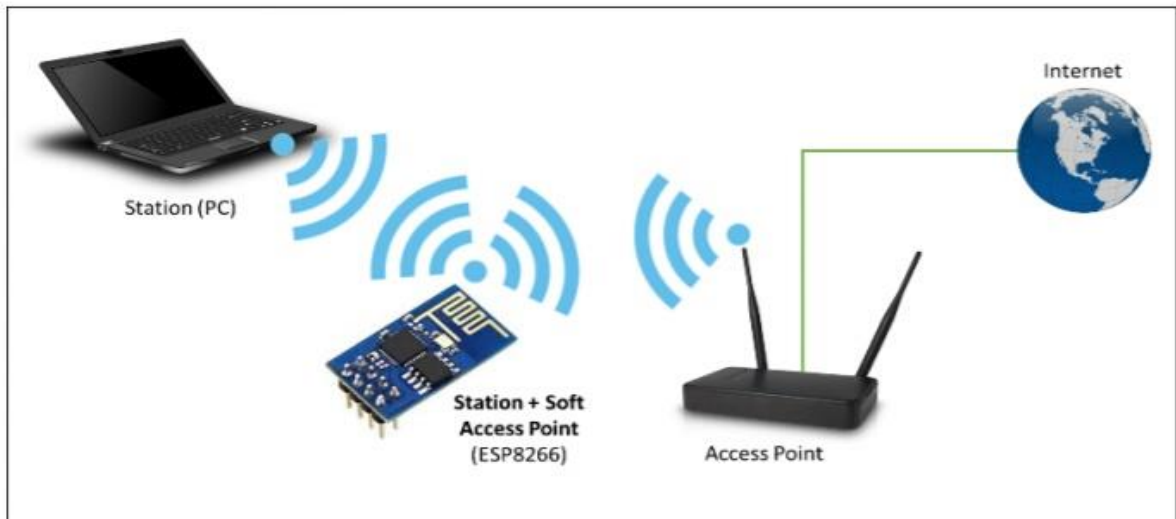
Fig. No. 5.5: ESP8266 operating in the Station + Soft Access Point mode

An ESP8266 port of Software Serial library is done by Peter Lerup (@plerup) supports baud rate up to 115200 and multiples Software Serial instances.

ESP-specific APIs:Some ESP-specific APIs related to deep sleep, RTC and flash memories are available in the ESP object.

ESP.deepSleep(microseconds, mode) will put the chip into deep sleep. mode is one of WAKE_RF_DEFAULT, WAKE_RFCAL, WAKE_NO_RFCAL, WAKE_RF_DISABLED. (GPIO16 needs to be tied to RST to wake from deepSleep.) ESP.rtcUserMemoryWrite(offset, &data, sizeof(data)) and ESP. rtcUserMemoryRead(offset, &data, sizeof(data)) allow data to be stored in and retrieved from the RTC user memory of the chip respectively. Total size of RTC user memory is 512 bytes, so offset + sizeof(data) shouldn't exceed 512. Data

should be 4-byte aligned. The stored data can be retained between deep sleep cycles. However, the data might be lost after power cycling the chip.

ESP.restart() restarts the CPU.

ESP.getResetReason() returns a String containing the last reset reason in human readable format.

ESP.getFreeHeap() returns the free heap size.

ESP.getChipId() returns the ESP8266 chip ID as a 32-bit integer. ESP.getCoreVersion() returns a String containing the core version. ESP.getSdkVersion() returns the SDK version as a char.

ESP.getCpuFreqMHz() returns the CPU frequency in MHz as an unsigned 8-bit integer.

ESP.getSketchSize() returns the size of the current sketch as an unsigned 32-bit integer.

ESP.getFreeSketchSpace() returns the free sketch space as an unsigned 32-bit integer.

ESP.getSketchMD5() returns a lowercase String containing the MD5 of the current sketch.

ESP.getFlashChipId() returns the flash chip ID as a 32-bit integer. ESP.getFlashChipSize() returns the flash chip size, in bytes, as seen by the SDK (may be less than actual size).

ESP.getFlashChipRealSize() returns the real chip size, in bytes, based on the flash chip ID.

ESP.getFlashChipSpeed(void) returns the flash chip frequency, in Hz. ESP.getCycleCount() returns the cpu instruction cycle count since start as an unsigned 32-bit. Thisisusefulfor accurate timing of very short actions like bit banging.

ESP.getVcc() may be used to measure supply voltage. ESP needs to reconfigure the ADC at startup in order for this feature to be available. Add the following line to the top of your sketch to use getVcc:

5.1.4.HC-05 BLUETOOTH MODULE

HC-05 Bluetooth Module is an easy to use Bluetooth SPP (Serial Port Protocol) module, designed for transparent wireless serial connection setup. Its communication is via serial communication which makes an easy way to interface with controller or PC. HC-05 Bluetooth module provides switching mode between master and slave mode which means it able to use neither receiving nor transmitting data.
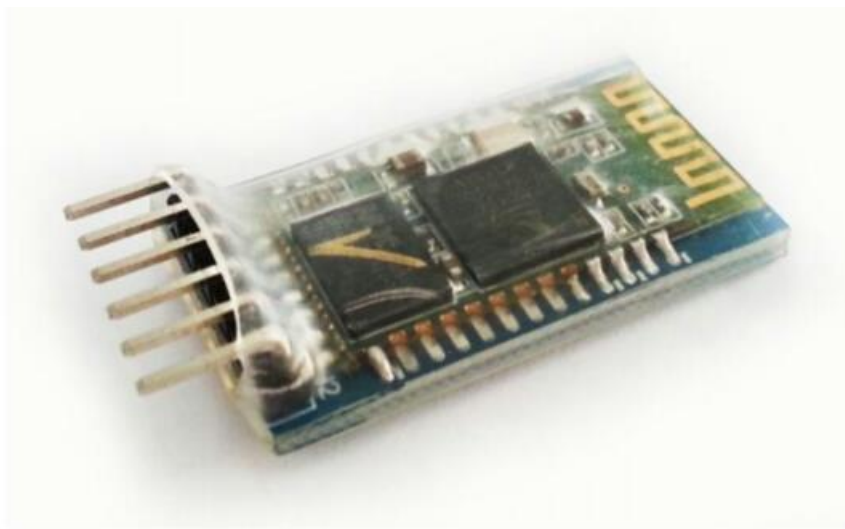

Fig. No. 5.6: HC-05 Bluetooth Module

Specification:

- ❖ Model: HC-05
- ❖ Input Voltage: DC 5V
- ❖ Communication Method: Serial Communication
- ❖ Master and slave mode can be switched
- ❖ Pin Definition:
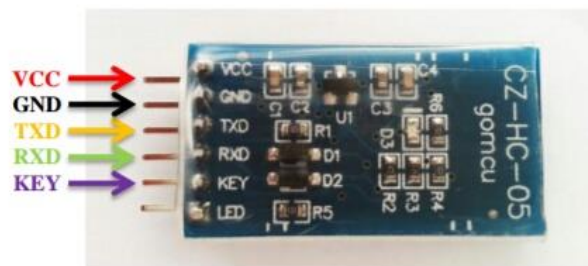
Fig. No. 5.7: Pin Diagram of HC-05

Pin	Description	Function
VCC	+5V	Connect to +5V
GND	Ground	Connect to Ground
TXD	UART_TXD, Bluetooth serial signal sending PIN	Connect with the MCU's (Microcontroller and etc.) RXD PIN.
RXD	UART_RXD, Bluetooth serial signal receiving PIN	Connect with the MCU's (Microcontroller and etc.) TXD PIN.
KEY	Mode switch input	If it is input low level or connect to the air, the module is at paired or communication mode. If it's input high level, the module will enter to AT mode.

Table No. 5.2: Pin Functions of HC-05 Bluetooth module

Sample Hardware Installation and Sample Source Code:

Below is the example of interfacing between Arduino UNO and PC via HC-05 Bluetooth Module. In this example, the communication mode is used.

Diagram below shows the hardware connection between HC-05 Bluetooth Module and Arduino UNO. Besides Arduino, it may interface with any microcontroller such as PIC and etc.

VCC ->Arduino 5V

GND ->Arduino GND

TXD ->Arduino Pin RX

RXD ->Arduino Pin TX

KEY -> Connect to the air for communication mode

After completing hardware and source code installation on Arduino UNO, the next step is setting up PC site. In order to communicate with Arduino UNO, a Bluetooth device is needed as well on PC site. We recommend using USB plug in Bluetooth device in PC site.

5.1.5.TRANSFORMER

A transformer is a device that transfers electricity between two circuits by magnetic induction, according to the Nuffield Foundation. Transformers also increase or decrease the effective voltage as step-up or step-down transformers. A common use of an electric transformer is to convert the high-voltage electricity in overhead power lines into a lower-voltage connection suitable for home appliances.

A transformer consists of an iron core that is shaped like a ring, with one electrical circuit wrapped around each side but not directly connected. The magnetic flux created by the current flowing around the iron core transfers electric power to the other circuit. If the primary circuit has fewer coils wrapped around the core than the secondary circuit has, it transfers a higher voltage, stepping up the power provided. If the primary circuit has more coils than the secondary circuit, it reduces the effective voltage on that end. Transformers are important for reducing voltage, transferring high-voltage mains electricity into household current, and then transferring that current into a lower-voltage supply for electronic devices. The electricity that flows into a home computer, for instance, may flow through a large number of transformers to alter the effective voltage, ensuring that all components receive just as much power as they need.

Principle of Working of a Transformer:An electrical transformer works on the principle of Mutual Induction, which states that a uniform change in current in a coil will induce an E.M.F in the other coil which is inductively coupled to the first coil.In its basic form, a transformer consists of two coils with high mutual inductance that are electrically separated but have common

magnetic circuit. The following image shows the basic construction of a Transformer.

How Transformer Works? The first set of the coil, which is called as the Primary Coil or Primary Winding, is connected to an alternating voltage source called Primary Voltage.The other coil, which is called as Secondary Coil or Secondary Winding, is connected to the load and the load draws the resulting alternating voltage (stepped up or stepped down voltage). The alternating voltage at the input excites the Primary Winding, an alternating current circulates the winding. The alternating current will result in an alternating magnetic flux, which passes through the iron magnetic core and completes its path. Since the secondary winding is also linked to the alternating magnetic flux, according to Faraday's Law, an E.M.F is induced in the secondary winding. The strength of the voltage at the secondary winding is dependent on the number of windings through which the flux gets passed through. Thus, without making an electrical contact, the alternating voltage in the primary winding is transferred to the secondary winding.
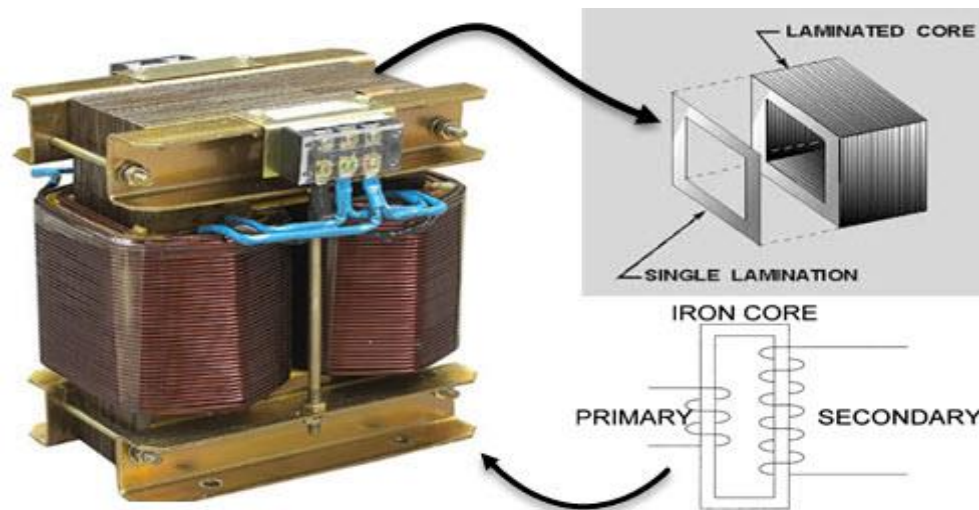

Fig. No. 5.8: Transformer

5.1.6.BRIDGE RECTIFIER

A bridge rectifier circuit is a common part of the electronic power supplies. Many electronic circuits require rectified DC power supply for powering the

various electronic basic components from available AC mains supply. We can find this rectifier in a wide variety of electronic AC power devices like home appliances, motor controllers, modulation process, welding applications, etc.

A Bridge rectifier is an Alternating Current (AC) to Direct Current (DC) converter that rectifies mains AC input to DC output. Bridge Rectifiers are widely used in power supplies that provide necessary DC voltage for the electronic components or devices. They can be constructed with four or more diodes or any other controlled solid state switches.

5.1.7.VOLTAGE REGULATOR

A Voltage Regulator is a system designed to automatically maintain a constant voltage level. It may be used to regulate one or more AC or DC voltages.Here, 12V DC received from bridge rectifier is splitted into 5V each to Node MCU, and MQ3 sensor.

5.2.SOFTWARE REQUIREMENTS

❖ Arduino IDE
❖ Blynk App
❖ Embedded C

5.2.1.ARDUINO IDE

Arduino is an open-source computer hardware and software company, project and user community that designs and manufactures single-board microcontrollers and microcontroller kits for building digital devices and interactive objects that can sense and control objects in the physical and digital world. The project's products are distributed as open-sourcehardware and software, which are licensed under the GNU Lesser General Public License (LGPL) or the GNU General Public License (GPL), permitting the manufacture of Arduino boards and software distribution by anyone. Arduino boards are available commercially in preassembled form or as do-it-yourself (DIY) kits.

Arduino board designs use a variety of microprocessors and controllers. The boards are equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards or breadboards (shields) and other circuits. The boards feature serial communications interfaces, including Universal Serial Bus (USB) on some models, which are also used for loading programs from personal computers. The microcontrollers are typically programmed using a dialect of features from the programming languages C and C++. In addition to using traditional compiler toolchains, the Arduino project provides an integrated development environment (IDE) based on the Processing language project.

A program for Arduino hardware may be written in any programming language with compilers that produce binary machine code for the target processor. Atmel provides a development environment for their 8-bit AVR and 32-bit ARM Cortex-M based microcontrollers: AVR Studio (older) and Atmel Studio (newer).

The Arduinointegrated development environment (IDE) is a cross-platform application (for Windows, macOS, Linux) that is written in the programming language Java. It originated from the IDE for the languages Processing and Wiring. It includes a code editor with features such as text cutting and pasting, searching and replacing text, automatic indenting, brace matching, and syntax highlighting, and provides simple one-click mechanisms to compile and upload programs to an Arduino board. It also contains a message area, a text console, a toolbar with buttons for common functions and a hierarchy of operation menus. The source code for the IDE is released under the GNU General Public License, version 2.

The Arduino IDE supports the languages C and C++ using special rules of code structuring. The Arduino IDE supplies a software library from the Wiringproject, which provides many common input and output procedures. User-written code only requires two basic functions, for starting the sketch and the main program loop, that are compiled and linked with a program stub main() into an executable cyclic executive program with the GNU

toolchain, also included with the IDE distribution. The Arduino IDE employs the program to convert the executable code into a text file in hexadecimal encoding that is loaded into the Arduino board by a loader program in the board's firmware.

5.2.2.EMBEDDED C

Embedded C is a set of language extensions for the C programming language by the C Standards Committee to address commonality issues that exist between C extensions for different embedded systems. Historically, embedded C programming requires nonstandard extensions to the C language in order to support exotic features such as fixed-point arithmetic, multiple distinct memory banks, and basic I/Operations.

In 2008, the C Standards Committee extended the C language to address these issues by providing a common standard for all implementations to adhere to. It includes a number of features not available in normal C, such as fixed-point arithmetic, named address spaces and basic I/O hardware addressing

Embedded C uses most of the syntax and semantics of standard C, e.g., main() function, variable definition, datatype declaration, conditional statements (if, switch case), loops (while, for), functions, arrays and strings, structures and union, bit operations, macros, etc.

Controlling Arduino board with smartphone and Blynk via internet:This is my first work concerning the use of Blynk application to control the Arduino board. Blynk allow us to create applications and then use it to control Arduino board connected to a PC with internet access, from anywhere in the world, (for instance, controlled, servos, receive data, etc.), with a smartphone. It is one of the most interesting actions! The connection can also be established by Bluetooth between smartphone and Arduino board, but this will be not presented in this work.

Blynk can be download from Google play store (for Android) & app store (for apple), providing us the dashboard as well as the connectivity to Arduino, (it is a virtual connectivity). Programming Blynk is very simple, push and drag

widgets form the tools bar and allocating them pins on Arduino board. For such project can be used an ordinary Arduino board, without internet shield, connected to a PC with internet access and a smartphone. The role of PC is to ensure the connectivity of the Arduino board to the internet and to upload the Arduino code. For this purpose it is necessarily to install Blynk library on the PC and made some settings. The Arduino codes used for Blynk have the same structure as ordinary codes, but contain specific parts to communicate with Android devices. I will present a simples example, taken from internet, and partially modified by me. You can see that creating new codes is almost similar with the coding of the ordinary Arduino.

To create project we need to follows many steps:

1. Install Blynk app on your smartphone and create your simplest application, for instance control one led.

2. Download blynk v0.3.1 library and install on your PC. Set the right port of the PC to communicate with the Arduino board, (very important), from the script of the Blynk library.

3. Upload the Arduino code, (from the examples presented in this work, or other).

4. Run the Blynk on the smartphone.Download Blynk and install on the smartphone.
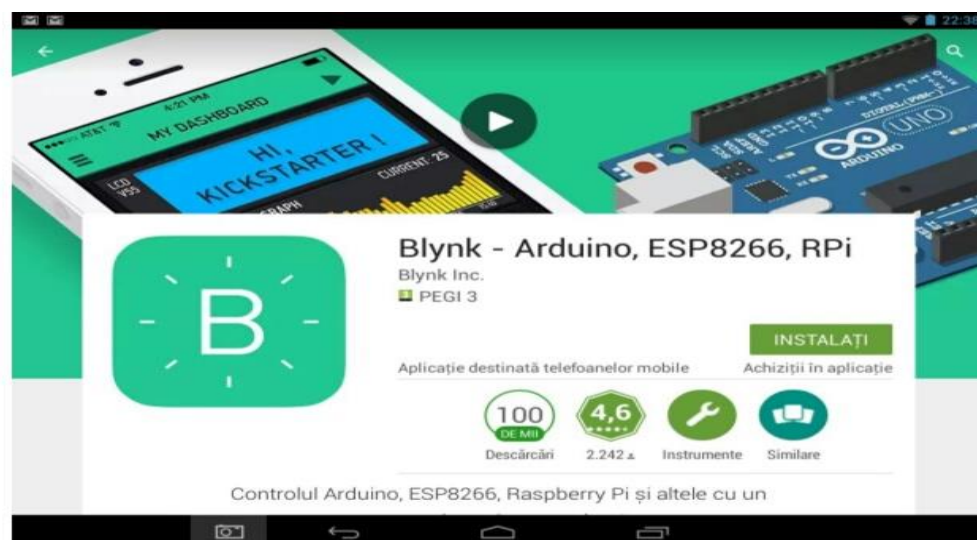
Fig. No. 5.9: Snapshot of blynk

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Create an account with your email and password. This e-mail will be used by Blynk server to send your "YourAuthToken", which allows only you to command the Arduino board.
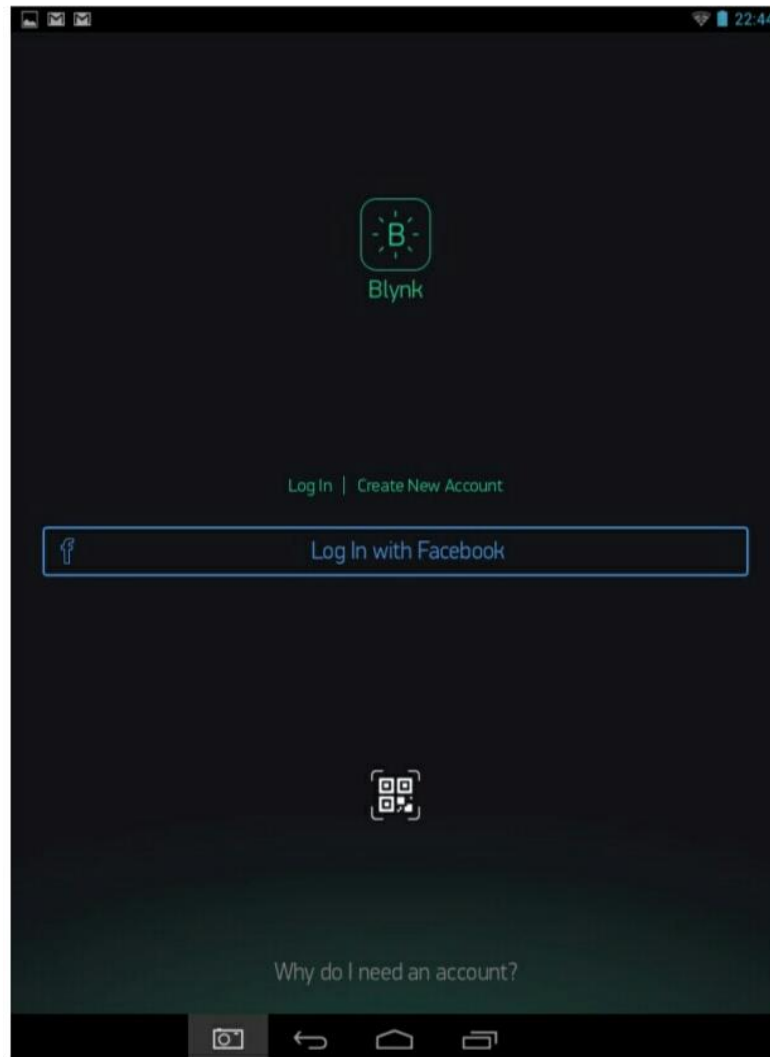
Fig. No. 5.10: Snapshot of blynk login page

Open a new project, give it a name, select your board, (for instance Arduino Uno), and Email the "YourAuthToken", (push the E-mail button), and then create. The "YourAuthToken" is a series of letters and numbers appearing above the E-mail button. This "YourAuthToken" must be introduced into your Arduino code, (see next steps).
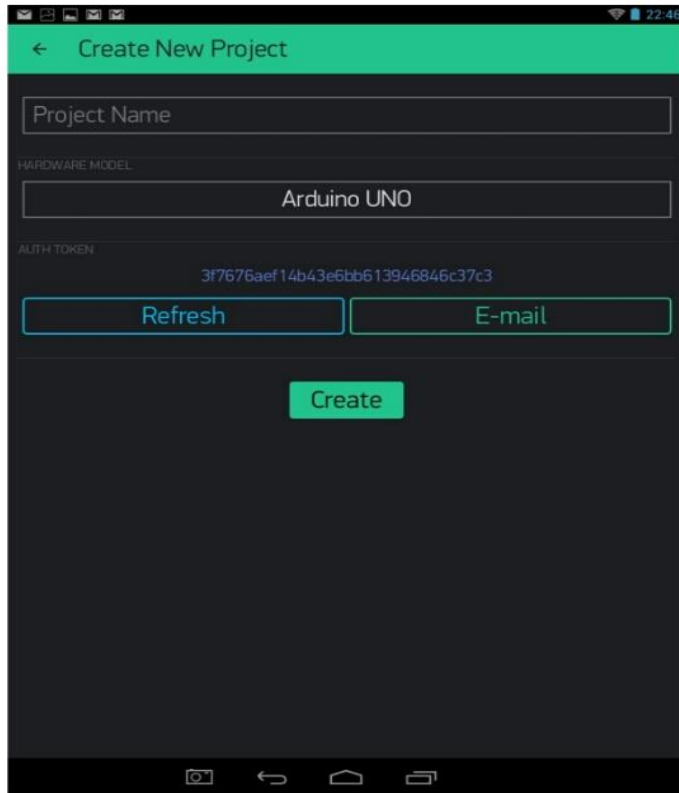
Fig. No. 5.11: Snapshot of blynk create page

Go to the Widget Box and select the desired widget, in our case Button
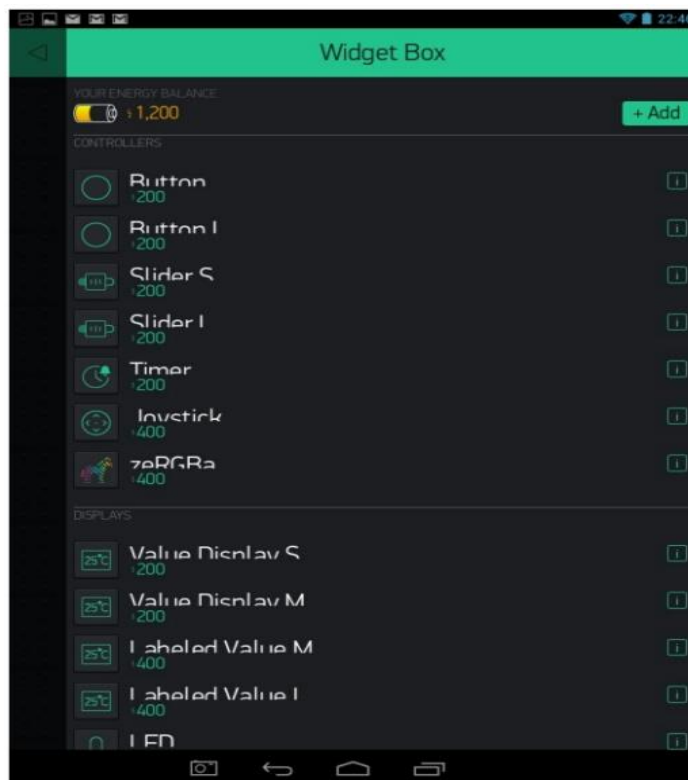
Fig. No. 5.12: Snapshot of blynk widget box

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Drag it into the dashboard, give it a name, (button led), and select the Arduinopin to which will be connected, in our case D13. Select the colour, (optional), and the mode of activation, switches for our project. After uploading the Arduino code on the board and after setting the right ports of the computer, play the application on your smartphone. Of course, the computer and the smartphone must be connected to the internet. That's all.

Fig. No. 5.13: Snapshot of collection of widgets of project in blynk app

6.TECHNOLOGY ADAPTED

In this project the Technology adapted is "INTERNET OF THINGS". The Internet of Things (IoT) is the network of devices such as vehicles, and home appliances that contain electronics, software, actuators, and connectivity which allows these things to connect, interact and exchange data.

The IoT involves extending Internet connectivity beyond standard devices, such as desktops, laptops, smartphones and tablets, to any r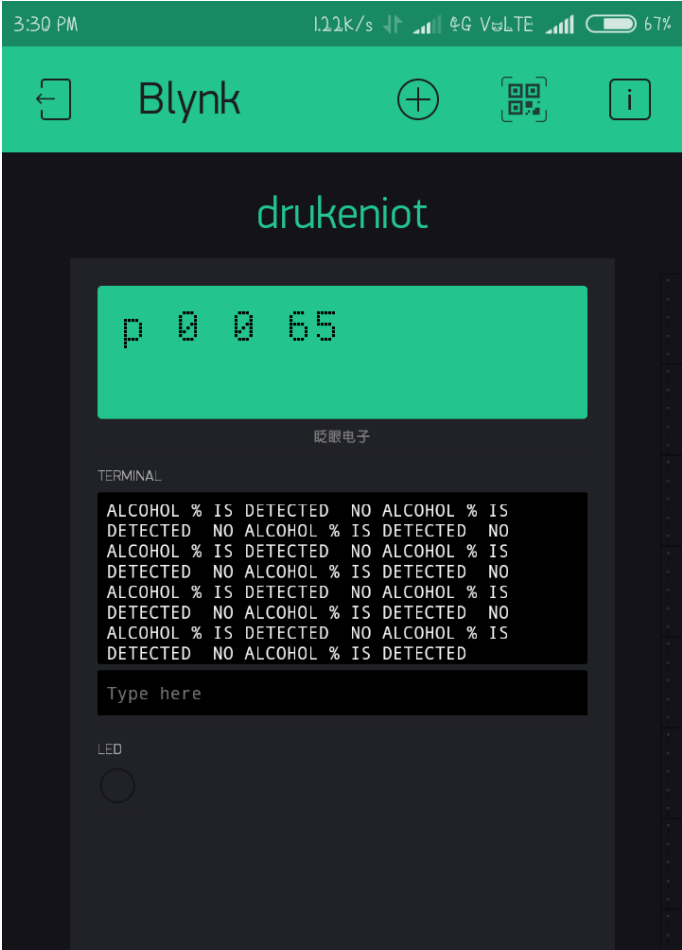ange of traditionally dumb or non-internet-enabled physical devices and everyday objects. Embedded with technology, these devices can communicate and interact over the Internet, and they can be remotely monitored and controlled.

The definition of the Internet of things has evolved due to convergence of multiple technologies, real-time analytics, machine learning, commodity sensors, and embedded systems. Traditional fields of embedded systems, wireless sensor networks, control systems, automation (including home and building automation), and others all contribute to enabling the Internet of things.

The concept of a network of smart devices was discussed as early as 1982, with a modified Coke vending machine at Carnegie Mellon University becoming the first Internet-connected appliance, able to report its inventory and whether newly loaded drinks were cold.Mark Weiser's 1991 paper on ubiquitous computing, "The Computer of the 21st Century", as well as academic venues such as UbiComp and PerCom produced the contemporary vision of the IoT.In 1994, Reza Raji described the concept in IEEE Spectrum as "[moving] small packets of data to a large set of nodes, so as to integrate and automate everything from home appliances to entire factories". Between 1993 and 1997, several companies proposed solutions like Microsoft's at Work or Novell's NEST. The field gained momentum when Bill Joy envisioned Device to Device (D2D) communication as a part of his "Six Webs" framework, presented at the World Economic Forum at Davos in 1999.

The term "Internet of things" was likely coined by Kevin Ashton of Procter &Gamble, later MIT's Auto-ID Center, in 1999, though he prefers the phrase "Internet forthings". At that point, he viewed Radio-frequency identification (RFID) as essential to the Internet of things, which would allow computers to manage all individual things.

The IoT can assist in the integration of communications, control, and information processing across various transportation systems.Application of the IoT extends to all aspects of transportation systems (i.e. the vehicle, the infrastructure, and the driver or user). Dynamic interaction between these components of a transport system enables inter and intra vehicular communication,smart traffic control, smart parking, electronic toll collection systems, logistic and fleet management, vehicle control, and safety and road assistance. In Logistics and Fleet Management for example, The IoT platform can continuously monitor the location and conditions of cargo and assets via wireless sensors and send specific alerts when management exceptions occur (delays, damages, thefts, etc.). This can only be possible with the IoT and its seamless connectivity among devices. Sensors such as GPS, Humidity, Temperature, send data to the IoT platform and then the data is analysed and send further to the users. This way, users can track the real-time status of vehicles and can make appropriate decisions. If combined with Machine Learning then it also helps in reducing traffic accidents by introducing drowsiness alerts to drivers and providing self-driven cars too.

A challenge for producers of IoT applications is to clean, process and interpret the vast amount of data which is gathered by the sensors. There is a solution proposed for the analytics of the information referred to as Wireless Sensor Networks. These networks share data among sensor nodes that are sent to a distributed system for the analytics of the sensory data.

Another challenge is the storage of this bulk data. Depending on the application, there could be high data acquisition requirements, which in turn lead to high storage requirements. Currently the Internet is already responsible

for 5% of the total energy generated, and "daunting challenge to power" IoT devices to collect and even store data still remains.

Security is the biggest concern in adopting Internet of things technology. In particular, as the Internet of things spreads widely, cyber-attacks are likely to become an increasingly physical (rather than simply virtual) threat. The current IoTspace comes with numerous security vulnerabilities. These vulnerabilities include weak authentication (IoT devices are being used with default credentials), unencrypted messages sent between devices, SQL injections and lack of verification or encryption of software updates. This allows attackers to easily intercept data to collect PII (Personally Identifiable Information), user credentials can be stolen at login or malware can be injected into newly updated firmware.

7.FEASIBILITY STUDY

The feasibility of the project is analyzed in this phase and business proposal is put forth with a very general plan for the project and some cost estimates. During system analysis the feasibility study of the proposed system is to be carried out. This is to ensure that the proposed system is not a burden to the company. For feasibility analysis, some understanding of the major requirements for the system is essential.

Three key considerations involved in the feasibility analysis are

- ❖ ECONOMICAL FEASIBILITY
- ❖ TECHNICAL FEASIBILITY
- ❖ SOCIAL FEASIBILITY

7.1.ECONOMICAL FEASIBILITY

This study is carried out to check the economic impact that the system will have on the organization. The amount of fund that the company can pour into the research and development of the system is limited. The expenditures must be justified. Thus the developed system as well within the budget and this was achieved because most of the technologies used are freely available. Only the customized products had to be purchased.

7.2.TECHNICAL FEASIBILITY

This study is carried out to check the technical feasibility, that is, the technical requirements of the system. Any system developed must not have a high demand on the available technical resources. This will lead to high demands on the available technical resources. This will lead to high demands being placed on the client. The developed system must have a modest requirement, as only minimal or null changes are required for implementing this system. Any system developed must not have a high demand on the available technical resources.

7.3.SOCIAL FEASIBILITY

The aspect of study is to check the level of acceptance of the system by the user. This includes the process of training the user to use the system efficiently. The user must not feel threatened by the system, instead must accept it as a necessity. The level of acceptance by the users solely depends on the methods that are employed to educate the user about the system and to make him familiar with it. His level of confidence must be raised so that he is also able to make some constructive criticism, which is welcomed, as he is the final user of the system.

8.SYSTEM DESIGN

8.1.CONCEPTUAL MODEL (UML)

8.1.1.USE CASE DIAGRAM

A use case diagram in the Unified Modelling Language (UML) is a type of behavioural diagram defined by and created from a Use-case analysis. Its purpose is to present a graphical overview of the functionality provide by a system in terms of actors, their goals (represented as use cases), and any dependencies between those use cases.A use case diagram shows a set of use cases and actors (a special kind of class) and their relationships. Use case diagrams address the static use case view of a system. These diagrams are especially important in organizing and modelling the behaviours of a system.Interaction among actors is not shown on the use case diagram. If this interaction is essential to a coherent description of the desired behavior, perhaps the system or use case boundaries should be re-examined. Alternatively, interaction among actors can be part of the assumptions used in the use case.
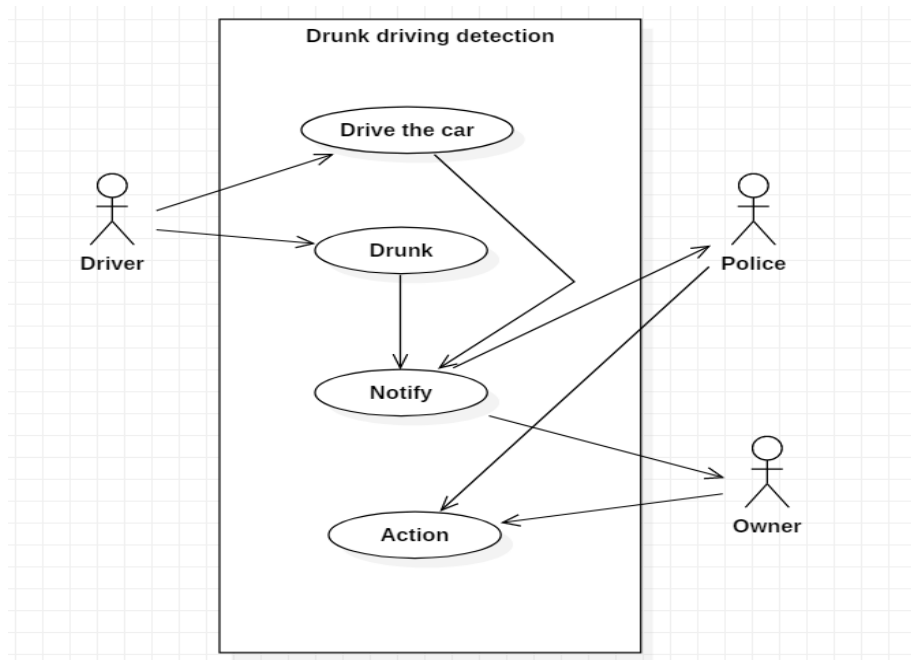

Fig. No. 8.1: Figure showing Use case diagram

8.1.2.CLASS DIAGRAM

A class diagram is a type of static structure diagram that describes the structure of a system by showing the system's classes, their attributes, operations (or methods), and the relationships among objects.

The class diagram is the main building block of object-oriented modelling. It is used for general conceptual modelling of the systematic of the application, and for detailed modelling translating the models into programming code.

Class diagrams can also be used for data modelling.[1] The classes in a class diagram represent both the main elements, interactions in the application, and the classes to be programmed. In the diagram, classes are represented with boxes that contain three compartments:

❖ The top compartment contains the name of the class. It is printed in bold and centred, and the first letter is capitalized.

❖ The middle compartment contains the attributes of the class. They are left-aligned and the first letter is lowercase.

❖ The bottom compartment contains the operations the class can execute. They are also left-aligned and the first letter is lowercase.

In the design of a system, a number of classes are identified and grouped together in a class diagram that helps to determine the static relations between them. With detailed modelling, the classes of the conceptual design are often split into a number of subclasses.

For general conceptual modelling of the systematic of the application, and for detailed modelling translating the models into programming code, class diagram is used.

The below figure represents the class diagram of drunk driver detection process:
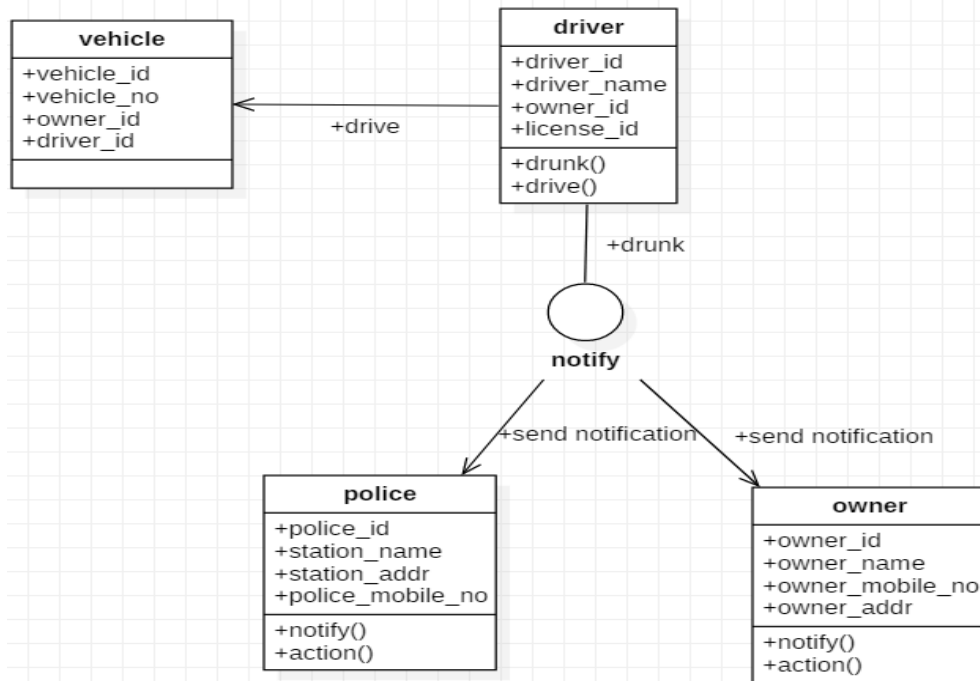
Fig. No. 8.2: Figure showing class diagram

8.1.3.SEQUENCE DIAGRAM

A sequence diagram is a kind of interaction diagram that shows how processes operate with one another and inn what order. It is a construct of a Message Sequence Chart. Sequence diagrams are sometimes called event diagrams, event scenarios, and timing diagrams.

A sequence diagram shows, as parallel vertical lines (lifelines), different processes or objects that live simultaneously, and as horizontal arrows, the messages exchanged between them, in the order in which they occur. This allows the specification of simple runtime scenarios in a graphical manner.

A sequence diagram is an interaction diagram that emphasizes the dynamic view of a system; a sequence diagram is an interaction diagram that emphasizes the time-ordering of messages.
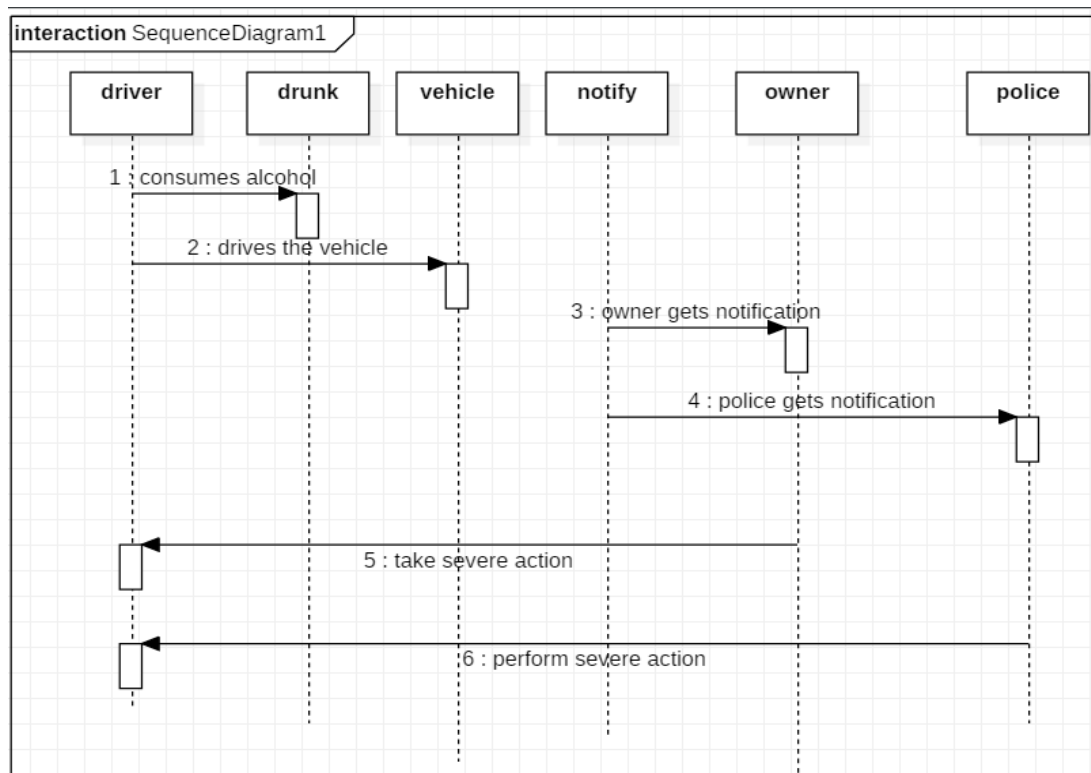
Fig. No. 8.3: Figure showing Sequence diagram

8.1.4.COMPONENT DIAGRAM

A component diagram depicts how components are wired together to form larger components or software systems. They are used to illustrate the structure of arbitrarily complex systems.

A component is something required to execute a stereo type function. Examples of stereo types in components include executable, documents, database tables, files, and library files. Components are wired together by using an assembly connector to connect the required interface of one component with the provided interface of another component. This illustrates the service consumer – service provider relationship between the two components.

An assembly connector is a "connector between two components that defines that one component provides the services that another component requires. An assembly connector is a connector that is defined from a required interface or port to a provided interface or port."
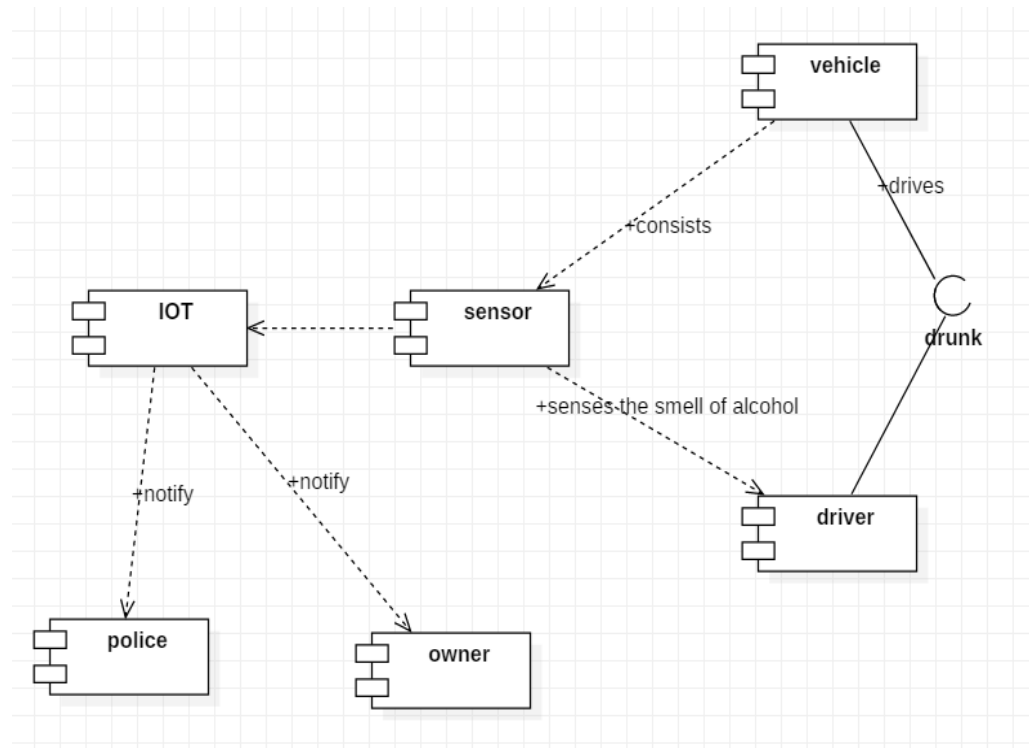
Fig. No.8.4: Component diagram

8.1.5. DEPLOYMENT DIAGRAM

A deployment diagram in the Unified Modelling Language models the physical deployment of artifacts on nodes. To describe a web site, for example, a deployment diagram would show what hardware components ("nodes") exist (e.g., a web server, an application server, and a database server), what software components ("artifacts") run on each node (e.g., web application, database), and how the different pieces are connected (e.g. JDBC, REST, RMI).

The nodes appear as boxes, and the artifacts allocated to each node appear as rectangles within the boxes. Nodes may have subnodes, which appear as nested boxes. A single node in a deployment diagram may conceptually represent multiple physical nodes, such as a cluster of database servers.

There are two types of Nodes:

❖ Device Node
❖ Execution Environment Node

Device nodes are physical computing resources with processing memory and services to execute software, such as typical computers or mobile phones.

An Execution environment node (EEN) is a software computing resource that runs within an outer node and which itself provides a service to host and execute other executable software elements.
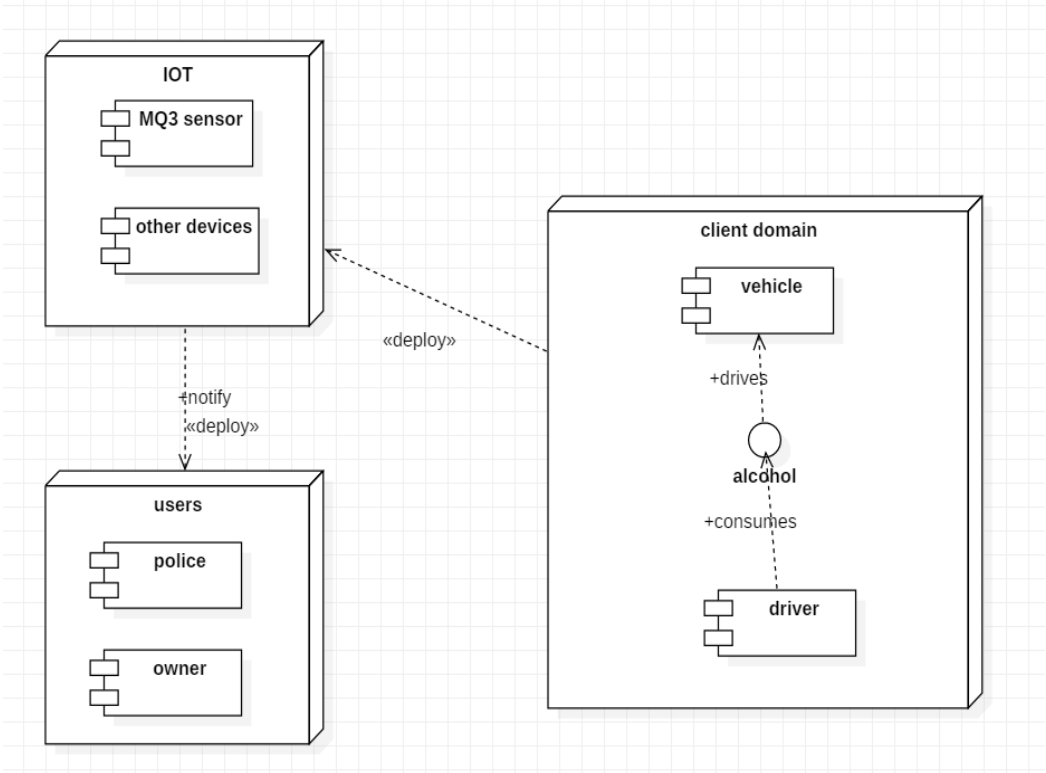
Fig. No. 8.5: Deployment diagram

9. SYSTEM IMPLEMENTATION

9.1.SAMPLE CODE

```
#define BLYNK_PRINT Serial
#define googlestaticgps
#include <ESP8266WiFi.h>
#include <BlynkSimpleEsp8266.h>
// You should get Auth Token in the Blynk App.
// Go to the Project Settings (nut icon).
charauth[] = "4b98cf3b445b483e9cd4ab0db53b6b60";
// Your WiFi credentials.
// Set password to "" for open networks.
charssid[] = "Jyo";
char pass[] = "1234567809";
WidgetLCDlcd(V1);
WidgetTerminalTE(V2);
WidgetLEDled(V3);
void setup()
{

  // Debug console
Serial.begin(9600);
pinMode(D0, OUTPUT);
Blynk.begin(auth, ssid, pass);

  //Blynk.begin(auth1, ssid, pass);

  // You can also specify server:
 //Blynk.begin(auth, ssid, pass, "blynk-cloud.com", 8442);

  //Blynk.begin(auth, ssid, pass, IPAddress(192,168,1,100), 8442);
```

```
Serial.println("Google Static gps activated");
lcd.clear(); //Use it to clear the LCD Widget
lcd.print(0, 0, "Distance in cm"); // use: (position X: 0-15, position Y: 0-1,
"Message you want to print")

  // Please use timed events when LCD printintg in void loop to avoid sending
too many commands
  // It will cause a FLOOD Error, and connection will be dropped
}
void loop()
{
intsensorValue = analogRead(A0);
  // print out the value you read:
Serial.print("Alcohol = ");
Serial.println(sensorValue);
Serial.println();
delay(1000);

lcd.clear();
lcd.print(0, 0, "Alcohol");
lcd.print(0, 0, sensorValue);
lcd.clear();
Blynk.run();
if(sensorValue>900)
 {
Blynk.virtualWrite(V2,"DRUKEN ALCOHOL 50% IS DETECTED IN YOUR CAR"
);
Serial.println("DRUKEN ALCOHOL 50% IS DETECTED IN YOUR CAR");
Serial.println("GPS ACTIVATED");
Serial.println("GOOGLE GPS CALL BY    17° 41' 9.6036'' N 83° 0' 31.6116'' E");
led.on();
 }
```

```
else
{
digitalWrite(D0,HIGH);
led.off();led.off();
Serial.println("NO ALCOHOL IS DETECTED");
Blynk.virtualWrite(V2,"  NO ALCOHOL % IS DETECTED");
  }
}


#from tkinter import *
import tkinter
from tkinter import messagebox


import csv


#Import Gaussian Naive Bayes model
from sklearn.naive_bayes import GaussianNB
  #draw gui
import PySimpleGUI as sg



def resetalgorithm():
  #window.Element('-OUTPUT-').Update("qqqqqqqqqqqqqqqqqq")
  window.Close()
  startalgorithm()



def startalgorithm():


  #reading rows
  with open('dataset1.csv', 'r') as f:
```

```python
  reader = csv.reader(f)
  your_list = list(reader)

print('total dataset drivers: = ' , len(your_list)-1)
#print(your_list[0])
#print(your_list[1])
#reading rows
with open('test1.csv', 'r') as f:
  reader = csv.reader(f)
  yourtest_list = list(reader)

print('total testdrivers: = ' , len(yourtest_list)-1)

#reading columns
#import csv

# open the file in universal line ending mode
with open('dataset1.csv', 'rU') as infile:
  # read the file as a dictionary for each row ({header : value})
  reader = csv.DictReader(infile)
  data = {}
  for row in reader:
    for header, value in row.items():
      try:
        data[header].append(value)
      except KeyError:
        data[header] = [value]

# open the file in universal line ending mode
with open('test1.csv', 'rU') as infile:
  # read the file as a dictionary for each row ({header : value})
  reader = csv.DictReader(infile)
```

```python
  test1 = {}
  for row in reader:
    for header, value in row.items():
      try:
        test1[header].append(value)
      except KeyError:
        test1[header] = [value]




# extract the variables you want

Age = data['Age']
Speed = data['Speed']
Reading1 = data['Reading1']
Reading2 = data['Reading2']
SF = data['SF']
Res = data['Res']
print(Res)


"""
# Import LabelEncoder
from sklearn import preprocessing
#creating labelEncoder
le = preprocessing.LabelEncoder()
# Converting string labels into numbers.
Age_encoded=le.fit_transform(Age)
Speed_encoded=le.fit_transform(Speed)
Reading1_encoded=le.fit_transform(Reading1)
Reading2_encoded=le.fit_transform(Reading2)
```

```python
SF_encoded=le.fit_transform(SF)
Res_encoded=le.fit_transform(Res)


print ("Age_encoded:" ,Age_encoded)
print ("Speed_encoded:" ,Speed_encoded)
print ("Reading_encoded:" ,Reading1_encoded)
print ("Reading2_encoded:" ,Reading2_encoded)
print ("SF_encoded:" ,SF_encoded)yourtest_list

print ("Res_encoded:" ,Res_encoded)
"""

#thresholds
Age_thresh = 60
Speed_thresh = 60
Reading1_thresh = 50
Reading2_thresh = 50
SF_thresh = 0

#converting to binary

Age_encoded_binarry = Age
for i,item in enumerate(Age):
    print(item)
    if int(item) >= Age_thresh:
        Age_encoded_binarry[i] = 1
    else:
        Age_encoded_binarry[i] = 0
print(Age_encoded_binarry)

Speed_encoded_binarry = Speed
```

```python
for i,item in enumerate(Speed):
    print(item)
    if int(item) >= Speed_thresh:
        Speed_encoded_binarry[i] = 1
    else:
        Speed_encoded_binarry[i] = 0
print(Speed_encoded_binarry)


Reading1_encoded_binarry = Reading1
for i,item in enumerate(Reading1):
    print(item)
    if int(item) >= Reading1_thresh:
        Reading1_encoded_binarry[i] = 1
    else:
        Reading1_encoded_binarry[i] = 0
print(Reading1_encoded_binarry)


Reading2_encoded_binarry = Reading2
for i,item in enumerate(Reading2):
    print(item)
    if int(item) >= Reading2_thresh:
        Reading2_encoded_binarry[i] = 1
    else:
        Reading2_encoded_binarry[i] = 0
print(Reading2_encoded_binarry)


SF_encoded_binarry = SF
for i,item in enumerate(SF):
    print(item)
    if int(item) > SF_thresh:
        SF_encoded_binarry[i] = 1
    else:
```

```python
        SF_encoded_binarry[i] = 0
    print(SF_encoded_binarry)




    def merge(list1, list2,list3,list4,list5):

        #merged_list = [(list1[i], list2[i]) for i in range(0, len(list1))]

        merged_list2 = [(list1[i], list2[i],list3[i],list4[i],list5[i]) for i in range(0, len(list1))]
        #merged_list3 = [(merged_list2[i], Reading2_encoded[i]) for i in range(0, len(merged_list2))]
        #merged_list4 = [(merged_list3[i], SF_encoded[i]) for i in range(0, len(merged_list3))]
        return merged_list2



    #Combining weather and temp into single listof tuples

features=merge(Age_encoded_binarry,Speed_encoded_binarry,Reading1_encoded_binarry,Reading2_encoded_binarry,SF_encoded_binarry)
    label = Res
    print (features)
    print (label)



    #prediction
```

```
#Create a Gaussian Classifier
model = GaussianNB()


# Train the model using the training sets
model.fit(features,label)




#print(sg.ListOfLookAndFeelValues())
"""
['SystemDefault', 'Reddit', 'Topanga', 'GreenTan',
'Dark', 'LightGreen', 'Dark2', 'Black', 'Tan', 'TanBlue',
'DarkTanBlue', 'DarkAmber', 'DarkBlue', 'Reds', 'Green',
'BluePurple', 'Purple', 'BlueMono', 'GreenMono', 'BrownBlue',
'BrightColors', 'NeutralBlue', 'Kayak', 'SandyBeach', 'TealMono']
"""
#sg.ChangeLookAndFeel('TealMono')
# Very basic window.  Return values as a list
dummyid = ['0']
DRIVERids = dummyid+test1['LicenseID']
layout = [[sg.Image("picture.png")],
        [sg.Text('                                DRUNK DRIVER DETECTION')],
        [sg.Text('Please Select Driver ID')],
        [sg.Combo(DRIVERids,                        enable_events=True,
key='_combo_'),sg.Button('Confirm')],
        [sg.Text('Age', size=(15, 1)), sg.InputText('100',key='Age')],
        [sg.Text('Speed', size=(15, 1)), sg.InputText('25',key='Speed')],
        [sg.Text('Reading 1', size=(15, 1)), sg.InputText('175',key='Reading 1')],
        [sg.Text('Reading 2', size=(15, 1)), sg.InputText('175',key='Reading 2')],
        [sg.Text('SF', size=(15, 1)), sg.InputText('0',key='SF')],
```

```python
        [sg.Text('                                    Waiting For Information....' , key='-
OUTPUT-')],
        [sg.Submit(),sg.Button('Reset')]
        ]
 global window
 window = sg.Window('DRUNK DRIVER DETECTION').Layout(layout)
 button, values = window.Read()


 #print(button, values[1], values[2], values[3],values[4],values[5])
 print(button, values)



 #CONFIRM
 while True:
  event, values = window.Read()

  if event == '_combo_':
      combo = values['_combo_']  # use the combo key

      if combo == '0':
        print('xxxxxxxxxxxxx combo' ,combo)
        messagebox.showerror("Error", "Please Select ID")
      else:
        print('xxxxxxxxxxxxx combo' ,combo)
        #get index of selected element
        print(STUDENTids.index(combo))

        #fetch row by index
        print(yourtest_list[DRIVERids.index(combo)])
        studentinfo = yourtest_list[DRIVERids.index(combo)]
        print("studentinfo" , studentinfo)
        #update studentinfo
```
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```python
            window.Element('Age').Update(studentinfo[3])
            window.Element('Speed').Update(studentinfo[4])
            window.Element('Reading 1').Update(studentinfo[5])
            window.Element('Reading 2').Update(studentinfo[6])
            window.Element('SF').Update(studentinfo[7])


  if event == 'Confirm':
     combo = values['_combo_']  # use the combo key
     if combo == '0':
         print('xxxxxxxxxxxxx combo' ,combo)
         messagebox.showerror("Error", "Please Select ID")
     else:
       break



print("id checking over")

while True:
 event, values = window.Read()

 if event == 'Submit':
    #gui
    Age_input = int(values['Age'])
    Speed_input = int(values['Speed'])
    Reading1_input = int(values['Reading 1'])
    Reading2_input = int(values['Reading 2'])
    SF_input = int(values['SF'])

    if Age_input >= Age_thresh :
      Age_input = 1
    else :
      Age_input = 0
```

```python
        if Speed_input >= Speed_thresh :
            Speed_input = 1
        else :
            Speed_input = 0

        if Reading1_input >= Reading1_thresh :
            Reading1_input = 1
        else :
            Reading1_input = 0

        if Reading2_input >= Reading2_thresh :
            Reading2_input = 1
        else :
            Reading2_input = 0

        if SF_input > SF_thresh :
            SF_input = 1
        else :
            SF_input = 0

        break



    #Predict Output
    inputvalues                                                    =
[Age_input,Speed_input,Reading1_input,Reading2_input,SF_input]
    predicted= model.predict([inputvalues]) # 0:Overcast, 2:Mild

    print ("input Value:", inputvalues)
```

```python
        print ("Predicted Value:", predicted[0])
        result = ''
        if predicted[0] == "1":
            print("Continued")
            result = "Continued"
        else:
            print("Terminated")
            result = "Terminated"

        finalresult = 'According to Prediction the driver is '+result
        print(finalresult)
        window.Element('-OUTPUT-').Update(finalresult)


startalgorithm()

while True:
    event, values = window.Read()

    if event == 'Reset':
        resetalgorithm()
        #break
```
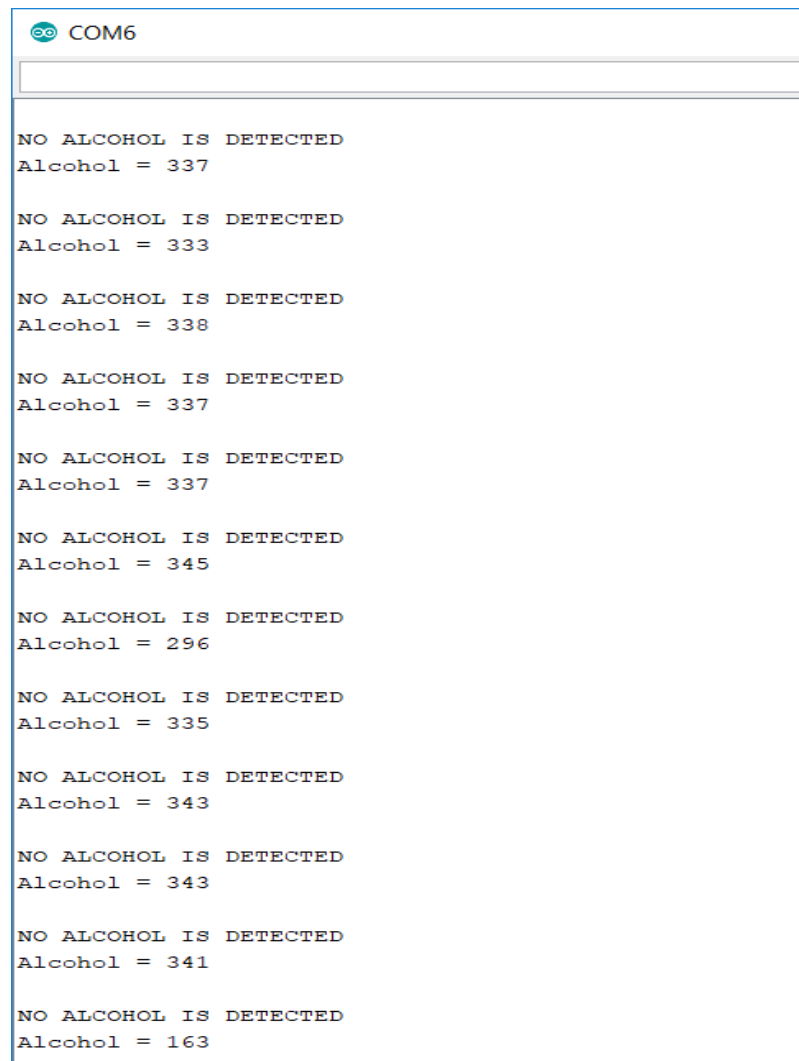
9.2.OUTPUT SCREENS

In serial monitor the following output is appeared

Fig. No. 9.1(a): Snapshot showing the output in serial monitor

The Arduino IDE has a feature that can be a great help in debugging sketches or controlling Arduino from your computer's keyboard.

The Serial Monitor is a separate pop-up window that acts as a separate terminal that communicates by receiving and sending Serial Data. See the icon on the far right of the image above.

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You will use the Serial Monitor to debug Arduino Software Sketches or to view data sent by a working Sketch. You must have an Arduino connected by USB to your computer to be able to activate the Serial Monitor.

```
COM6

NO ALCOHOL IS DETECTED
Alcohol = 337

NO ALCOHOL IS DETECTED
Alcohol = 333

NO ALCOHOL IS DETECTED
Alcohol = 338

NO ALCOHOL IS DETECTED
Alcohol = 337

NO ALCOHOL IS DETECTED
Alcohol = 337

NO ALCOHOL IS DETECTED
Alcohol = 345

NO ALCOHOL IS DETECTED
Alcohol = 296

NO ALCOHOL IS DETECTED
Alcohol = 335

NO ALCOHOL IS DETECTED
Alcohol = 343

NO ALCOHOL IS DETECTED
Alcohol = 343

NO ALCOHOL IS DETECTED
Alcohol = 341

NO ALCOHOL IS DETECTED
Alcohol = 163
```

Fig. No.9.1(b): Snapshot showing the output in serial monitor

Drag it into the dashboard, give it a name, (button led), and select the Arduinopin to which will be connected, in our case D13. Select the colour, (optional), and the mode of activation, switches for our project. After uploading the Arduino code on the board and after setting the right ports of the computer, play the application on your smartphone. Of course, the computer and the smartphone must be connected to the internet.

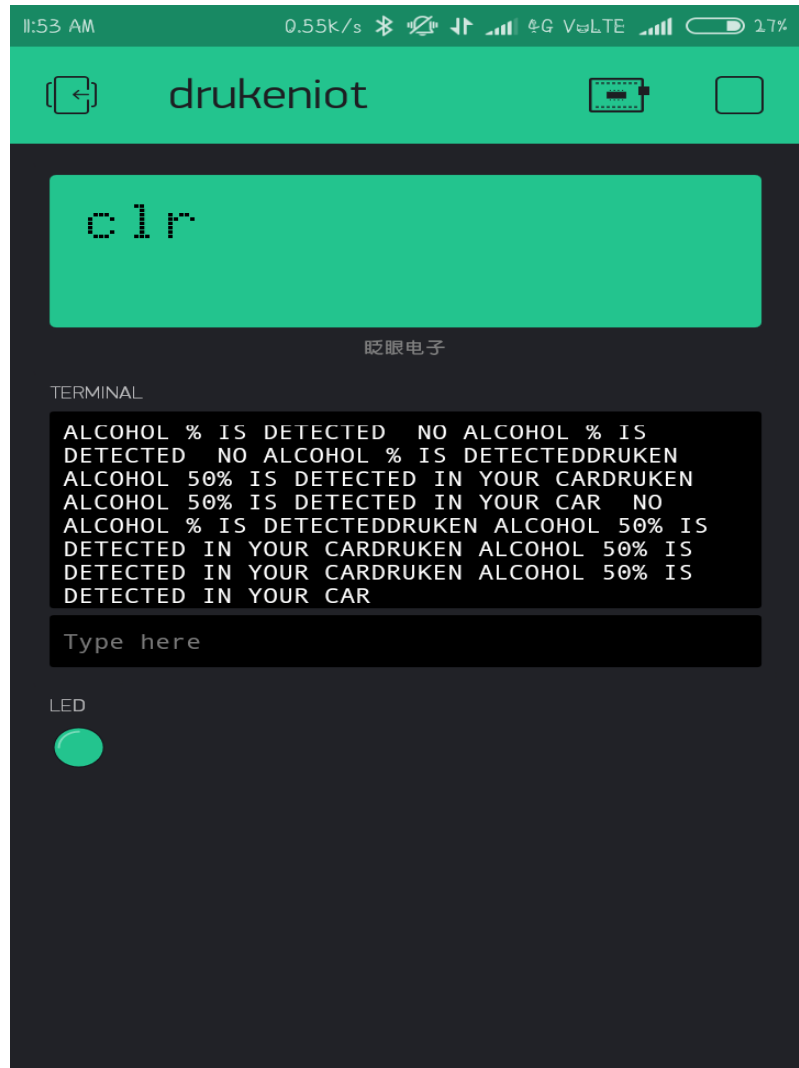In blynk app the following output is appeared.

Fig. No.9.2: Snapshot showing the output in blynk app when alcohol is detected.
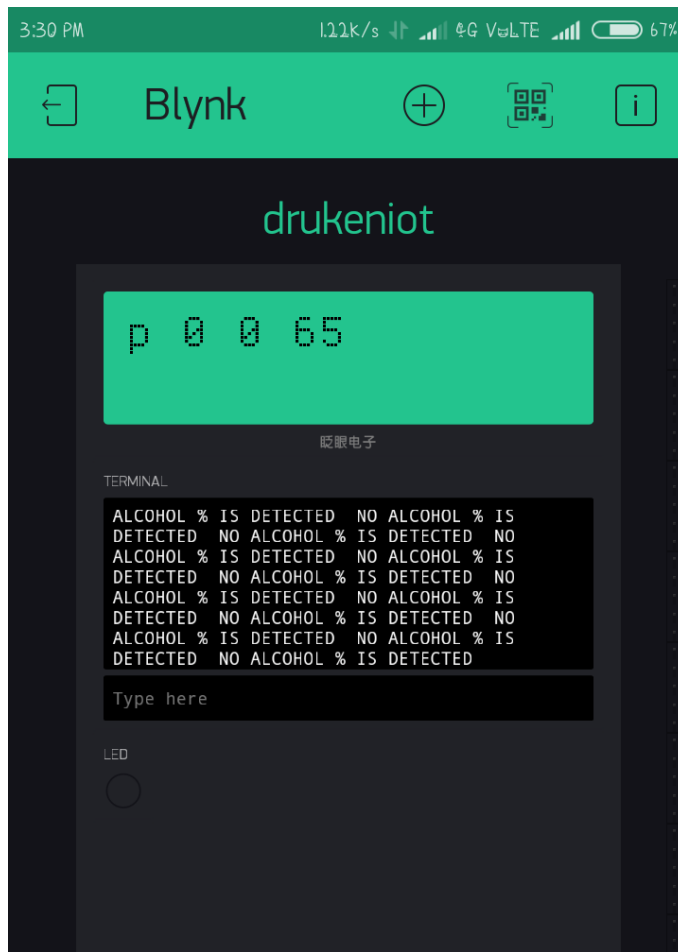
Fig. No.9.3: Snapshot showing the output in blynk app when alcohol not detected.

Bluetooth terminal is one of a kind App that gives you compatibility with all microcontrollers. All you need is a HC-05 serial adapter connection with serial ports of the controllers.Control any Micro-controller that uses a Bluetooth Module HC 05 or HC 06 through your smart phone.This app can send and receive commands via Bluetooth so you can debug your hardware problems easily.

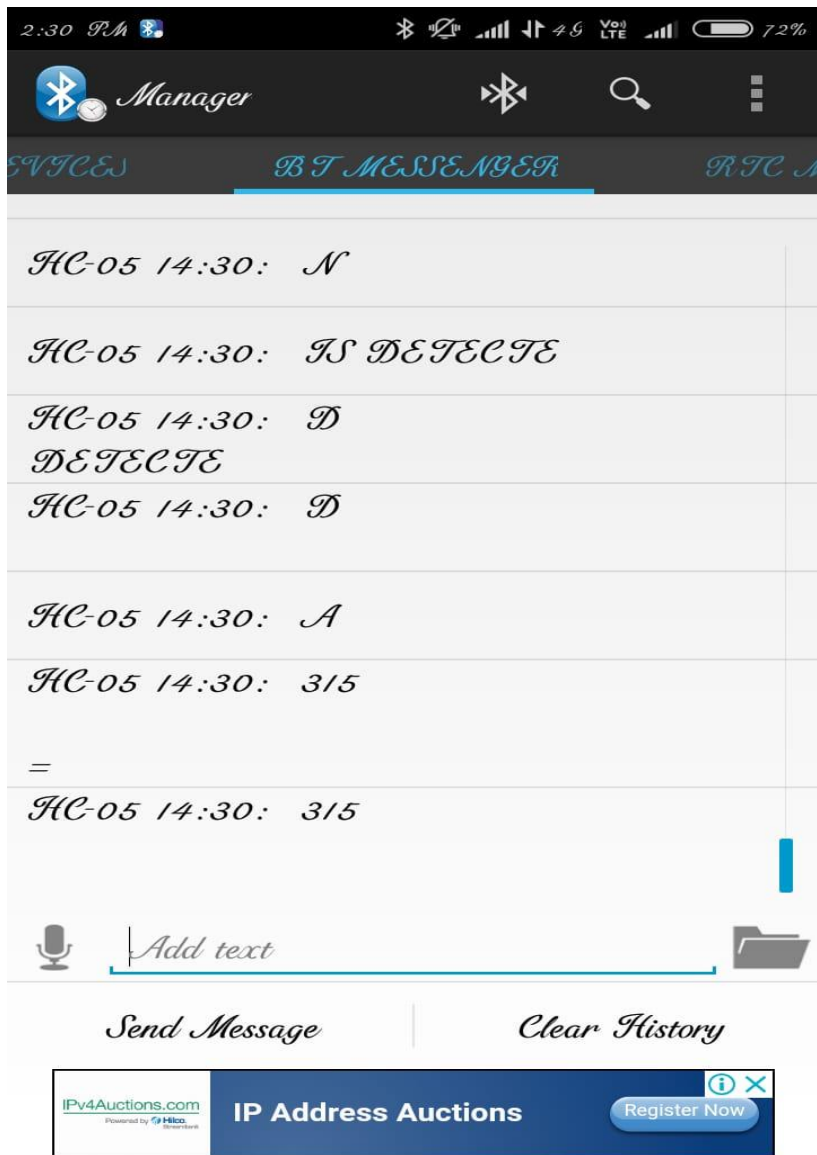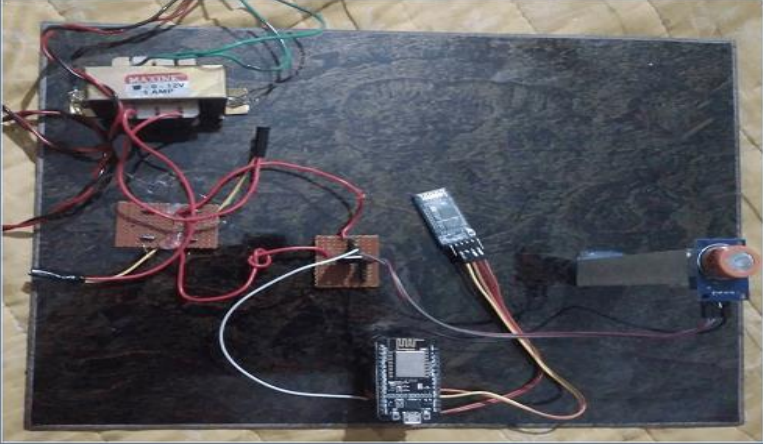In the Bluetooth terminal the following output is produced.

Fig. No.9.4: Snapshot showing the output in SPP manager

DRUNK DRIVER DETECTION
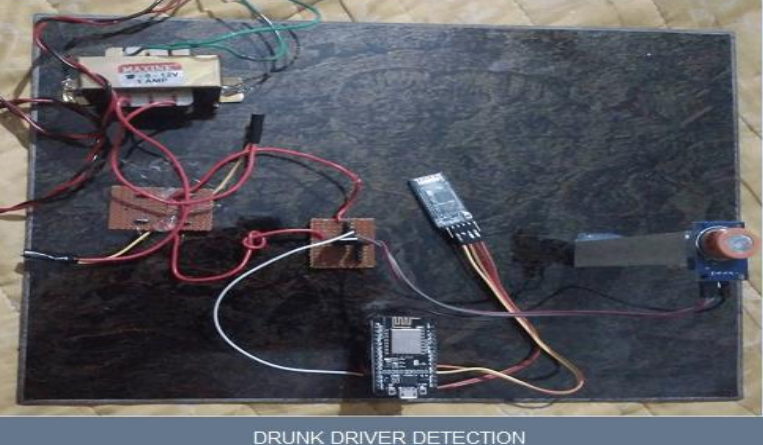
Please Select Driver ID

| 0 |
| 885553 |
| 423873 |
| 225485 |
| 225492 |
| 221495 |

Confirm

100

25

175

175

SF   0

Waiting For Information....

Submit   Reset

DRUNK DRIVER DETECTION

Please Select Driver ID

Confirm

Age	100
Speed	25
Reading 1	175
Reading 2	175
SF	0

Waiting For Information....

Submit   Reset

Terminal output:

```
35
[1, 0, 1, 1, 0]
25
15
28
23
10
[0, 0, 0, 0, 0]
165
90
175
147
54
[1, 1, 1, 1, 1]
170
80
0
158
75
[1, 1, 0, 1, 1]
0
4
0
0
5
[0, 1, 0, 0, 1]
[(1, 0, 1, 1, 0), (0, 0, 1, 1, 1), (1, 0, 1, 0, 0), (1, 0, 1, 1, 0), (0, 0, 1, 1, 1)]
['1', '0', '1', '1', '0']
_combo_ {'_combo_': '225485', 'Age': '100', 'Speed': '25', 'Reading 1': '175', 'Reading 2': '175', 'SF' :
id checking over
input Value: [0, 0, 0, 0, 0]
Predicted Value: 1
Continued
According to Prediction the driver is Continued
```

DRUNK DRIVER DETECTION

DRUNK DRIVER DETECTION

Please Select Driver ID

225485   Confirm

Age   50
Speed   25
Reading 1 17
Reading 2 20
SF   0

According to Prediction the driver is Continued

Submit   Reset

Activate Windows
Go to Settings to activate Windows.

10. CONCLUSION

❖ Drunken driving prevention system proposed here is anIoTapplication which will prevent drunk and drive cases to larger extent as well as protect the "innocent" pedestrians from getting harmed due to this unwarranted menace on roads.

❖ The proposed design ideated in this paper has many limitations and can further be improved by usage of more and more new versions of technology based applications.

❖ This model has the potential to become more successful as safety provider system.

❖ This system can be used by the automobile manufacturers and integrate it in the manufacturing design process ofvehicles.

❖ It should be made compulsory by the regulatory authorities or government to make this system integrated into every possible automobile.

❖ As this system can be implemented only if the windows of the car are shut and air currents would disturb the detection level of the MQ-3 alcohol sensor.

❖ This situation can be considered as a future scope for upgraded sensor technology.

❖ In case of motorbikes or heavy vehicles there are no window closing options, in such a case the proposed system needs a few changes for its effective working.

❖ The system illustrated in this paper is tested in many scenarios and results were found to be effective in order to reduce the number of accidents gradually.

❖ By implementing this proposed system we can have a much safer world free of drunk and drive accidental cases.

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