Intelligent Power Quality Event Recognition Through MRA-DWT in Combination with AdaBoost Classifier

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Abstract:
The reliable and efficient operation of electrical power systems is paramount in modern society, necessitating the continuous monitoring and timely recognition of power quality disturbances. This paper presents an intelligent approach for Power Quality Event Recognition (PQER) by combining Multiresolution Analysis with Discrete Wavelet Transform (MRA-DWT) and the AdaBoost classifier. The MRA-DWT technique allows for the decomposition of power signals into multiple scales, enabling the extraction of informative features from both time and frequency domains. Subsequently, the AdaBoost classifier is employed to enhance the classification accuracy by training an ensemble of weak learners, thereby creating a robust and adaptive PQER system. The proposed methodology is evaluated on a real-world dataset of power quality disturbances, showcasing its effectiveness in distinguishing and classifying various types of disturbances, including voltage sags, swells, interruptions, harmonics, and transients. Experimental results demonstrate the superiority of the MRA-DWT-AdaBoost combination over traditional methods, achieving higher accuracy and faster recognition of power quality events. This research contributes to the advancement of intelligent power quality monitoring systems, offering a promising solution for enhancing the reliability and stability of electrical grids through the timely identification and classification of power quality disturbances.

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Contents

I. Introduction

In our increasingly electrified world, the availability of a stable and high-quality electrical supply is a fundamental requirement for the proper functioning of all modern devices and systems. However, the reality is that electrical power systems are susceptible to a wide range of disturbances and anomalies that can compromise the quality of the delivered electricity [1]. These disturbances, collectively referred to as “power quality events,” represent a significant concern for utilities, industries, and consumers alike. Power quality events encompass a broad spectrum of irregularities in the electrical supply, which can manifest as voltage sags, swells, interruptions, harmonics, transients, and flicker, among others. These events can have detrimental effects on sensitive electronic equipment, industrial processes, and even our daily lives. For example, voltage sags can cause disruptions in manufacturing processes, while harmonic distortion can lead to premature equipment failure. In a residential setting, flicker caused by power quality events can affect the performance of household appliances and lead to discomfort [2]. Understanding and effectively managing power quality events is crucial not only for ensuring the proper functioning of electrical systems but also for maintaining the integrity of the interconnected electrical grid. Power quality issues can propagate through the grid, leading to cascading failures and, in some cases, large-scale blackouts. Power quality events encompass a wide range of irregularities and disturbances in the electrical supply that can affect the quality and reliability of electrical power [3]. These events can be categorized into several main types, each with its unique characteristics and implications. Voltage sags, also known as voltage dips, are short-term reductions in voltage levels below the normal or rated value. They are typically caused by faults on the distribution network or the sudden starting of large loads, such as motors. Voltage sags can lead to equipment malfunctions or shutdowns. Voltage swells, or surges, are transient increases in voltage levels above the normal or rated value. They can result from events like capacitor bank switching or lightning strikes. Voltage swells can damage sensitive electronic equipment and cause insulation breakdown. Voltage interruptions occur when the electrical supply is completely lost for a short duration [4]. These events can have severe consequences, especially in critical applications like data centres or healthcare facilities. Harmonics are unwanted frequency components in the electrical waveform that are integer multiples of the fundamental frequency (typically 60 Hz or 50 Hz). Harmonic distortion can result from nonlinear loads, such as variablespeed drives, and can lead to overheating of transformers and interference with electronic equipment. Voltage fluctuations and flicker refer to rapid and random variations in voltage levels [5]. They can be caused by large industrial loads or power system imbalances. Flicker can be visually disturbing and affect the performance of lighting systems. Transients are short-duration, high-energy voltage spikes or noise on the electrical waveform. They can be caused by lightning strikes, switching events, or capacitor bank discharges. Transients can damage sensitive electronic equipment. Variations in the system frequency can occur due to imbalances in generation and demand. Large frequency deviations can disrupt the operation of synchronous equipment and certain types of electronic devices [6]. Voltage unbalance refers to unequal distribution of voltage among the phases in a three-phase power system. Unbalance can lead to increased current and heating in motors and can cause erratic behaviour in threephase loads. Voltage notching involves the presence of shortduration, repetitive notches or notching on the voltage waveform. Notching can affect the performance of power supplies and electronic equipment. Poor power factor, often caused by reactive power consumption in industrial processes, can lead to increased losses in electrical distribution systems and result in higher utility charges [7], [8]. Understanding and mitigating these power quality events is essential to ensure the reliable and efficient operation of electrical systems and the protection of sensitive equipment and processes. Detection and analysis techniques, as well as appropriate mitigation strategies, are employed to address these various power quality challenges. Power quality disturbances are a critical concern in modern electrical power systems due to their potential to disrupt the operation of sensitive electronic equipment, industrial processes, and even compromise the reliability of the entire power grid. Detection and classification of these disturbances are essential for maintaining a high level of power quality and ensuring the uninterrupted operation of critical infrastructure. This literature review provides an overview of key research and developments in the field of power quality disturbance detection and classification [9]–[11]. Historically, power quality disturbances were identified and analysed primarily through manual inspection of voltage and current waveforms. This labour-intensive approach was limited in its ability to capture transient events and often relied on visual inspection. Researchers and engineers soon recognized the need for automated methods to handle the increasing complexity of power systems and the proliferation of sensitive electronic devices. In recent decades, signal processing techniques have played a significant role in the detection and classification of power quality disturbances. Time-domain and frequency-domain analyses have been used to extract features from voltage and current waveforms, enabling the development of algorithms for identifying voltage sags, swells, interruptions, harmonics, and transients. Techniques such as Fourier analysis, wavelet transforms, and empirical mode decomposition have been applied to improve detection accuracy. Machine learning, particularly supervised learning algorithms, has gained prominence in power quality disturbance detection and classification. Support Vector Machines (SVM), Artificial Neural Networks (ANN), Decision Trees, and Random Forests have been employed to build classification models [12]–[14]. These approaches have demonstrated high accuracy and the ability to adapt to different disturbance patterns. Researchers have explored hybrid approaches that combine signal processing and machine learning techniques to enhance detection and classification performance. For instance, Multiresolution Analysis (MRA) and Discrete Wavelet Transform (DWT) have been integrated with machine learning classifiers like AdaBoost to improve accuracy and speed. The availability of large datasets, both simulated and real-world, has driven advancements in power quality disturbance detection and classification. These datasets, often including labelled examples of different disturbance types, have facilitated the development and evaluation of machine learning models. Despite significant progress, challenges persist in this field. These include the need for robust models capable of handling diverse disturbance scenarios, real-time detection and response, and the integration of distributed energy resources (DERs) into power quality management. Future research may focus on the development of adaptive algorithms that can continuously learn and adapt to evolving power system conditions, as well as the integration of advanced data analytics techniques, such as deep learning, to further improve detection and classification accuracy. The mathematical formulas of Power Quality Events are shown in Table I [15]. Table I Mathematical representation PF power quality events.

PQES	MATHEMATICAL FORMULATIONRANGE
Normal	
Sag	
Swell	
Interruption	
Harmonic	
Sag-Harmonic	
Swell-Harmonic	
Flicker	
Transients	

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