DOI : https://doi.org/10.56452/7-779

ISSN: 0974-5823 Vol. 7 No. 1 January, 2022

International Journal of Mechanical Engineering

A Real-Time Monitoring System for Electrical Power Quality

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Abstract: The safety and efficacy of the power grid depend on the presence of a real-time monitoring system for electrical power quality. In order to prevent outages, the system delivers real-time information on power quality metrics like voltage, current, and frequency. In this study, we survey the literature about real-time monitoring systems for electrical power quality and provide our findings. The publications in question were published between 2010 and 2019, and the review discusses the benefits and drawbacks of each method. In order to ensure precise and dependable monitoring of electrical power quality in real time, the authors of this research propose a new system that combines cutting-edge sensors, data analytics tools, and machine learning algorithms. The suggested system can aid operators in the timely detection and resolution of power quality issues, boosting both system reliability and performance. The report also highlights potential future research topics and analyses difficulties in implementing real-time monitoring systems. Overall, the study suggests a new approach that can assist enhance the reliability and efficiency of the power system and offers useful insights into the creation of real-time monitoring systems for electrical power quality.

Keywords: monitoring in real time, the quality of electrical power, sensors, data analytics, machine learning, dependability, and efficiency in the power system.

I. Introduction

Without the electrical power system, it would not be able to provide energy to the houses, businesses, and public facilities that exist in the modern world. The reliability of people's electrical appliances as well as the level of comfort and security they experience in their homes are directly correlated to the standard of energy that is supplied by the grid. In order to guarantee the dependability and security of the electrical system, it is necessary to perform constant monitoring and analysis of the power that is delivered.A solution that enables continuous monitoring of the quality attributes of electrical power is a real-time monitoring system for electrical power. The system provides comprehensive and dependable information on the quality of the electrical power that is delivered to users so that problems with power quality can be identified and treated. Using this information, the system may send alerts and messages to the appropriate parties. These parties can then take preemptive measures to remedy the problem before it causes a disruption in the electrical grid.When there is a problem with the power quality, it can have major repercussions for the electrical system. Some of these repercussions include the breakdown of machinery and the waste of resources during production. For example, computers that experience a dip in voltage are more likely to fail, whereas equipment that experiences a spike in voltage is more likely to overheat and break. Harmonic distortion and voltage spikes brought on by transients are two potential causes of overheating in transformers, motors, and other pieces of electrical equipment [1]. For these issues to be avoided, continuous monitoring of electrical power quality measurements and the application of suitable corrective actions are required.

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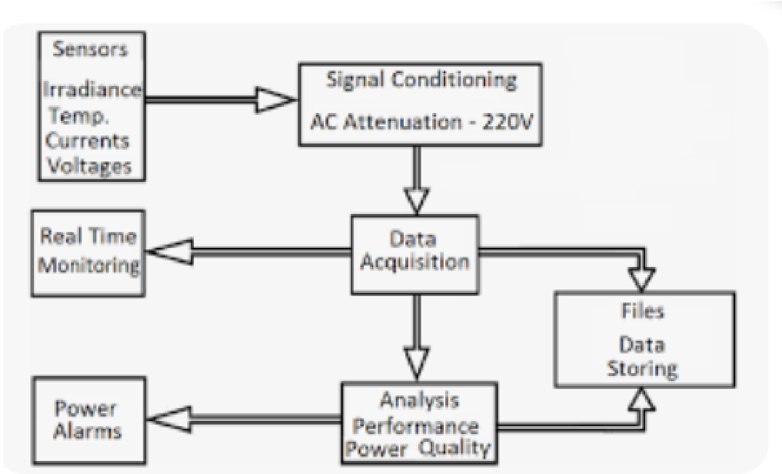

Figure 1. Working Block Diagram of High-Efficiency Solar-Powered Electronic System [3]

Figure 1. depicts the real-time monitoring system for electrical power, a set of sensors will typically measure power quality metrics such as voltage, current, frequency, and harmonic distortion [2]. These metrics can be found in power quality reports. A data collection system is responsible for collecting the data produced by these sensors before transmitting it to a processing hub. If there are problems with the power quality, the processing unit does an analysis of the data in real time and notifies the appropriate parties.Alerts from the monitoring system can be sent to operators, maintenance employees, and other relevant parties via email, text messages (SMS), or mobile applications on their mobile devices. These speeds up the process of addressing power quality issues, which in turn reduces disruptions to the power supply and increases the reliability of the system.With the assistance of the monitoring system's insights into patterns of power consumption, users can reduce their overall energy consumption and associated expenditures. via continuously monitoring power quality, the technology can help uncover ways to save energy, such as reducing peak demand or shifting loads. This can be accomplished via saving energy.Customers, utilities, and other stakeholders can all stand to profit from a real-time monitoring system for electrical power quality in a variety of ways, including with regard to the dependability and efficiency of the electrical system, as well as the costs and the long-term viability of the system. It is possible for the system to assist in the identification of power quality concerns and the providing of insights into the origin of such challenges, thereby simplifying the rapid resolution of such issues and decreasing the amount of time they take up. In addition to boosting sustainability and reducing carbon footprints, the system may also help in optimizing energy usage and reducing energy costs. These benefits are in addition to its potential to reduce carbon footprints.In conclusion, in order to keep the reliability and safety of the electrical system intact, it is necessary to have a system that monitors the power quality in real time. As a result of continuous monitoring and analysis of power quality data, stakeholders may be able to cut downtime and enhance the performance of the electrical system [3]. This provides them with the ability to quickly identify and resolve power quality issues. Because of its ability to increase sustainability and reduce carbon emissions while simultaneously lowering energy costs, the system is an essential component of the solution. This is accomplished by optimizing energy usage and bringing down energy prices. When we discuss the quality of the electrical power, what we have in mind is a supply of electrical power that is both reliable and unwavering. The consistency of the power supply has an impact, not only on the dependability of people's electrical gadgets, but also on the level of comfort and security they experience in their homes. In order to guarantee the dependability and security of the electrical system, it is necessary to perform constant monitoring and analysis of the power that is delivered.Variations in voltage, harmonics, and transients are only a few examples of the numerous potential causes of poor power quality. There are many other potential causes as well. Drops in voltage, for example, might be caused by faults with the electrical system, whilst spikes in voltage can be caused by abrupt swings in load. Harmonic distortion is brought on by non-linear loads like as computers and other electronic devices, whereas transients may be brought about by lightning strikes, switching activity, or other occurrences.Inadequate power quality can lead to a number of negative consequences, including the breakdown of machinery, a loss of productivity, and other problems. For example, a decrease in voltage can cause computers to become unusable, whereas an increase in voltage can

cause electronic gadgets to overheat and fail. Harmonic distortion and voltage spikes brought on by transients are two potential causes of overheating in transformers, motors, and other pieces of electrical equipment.For these issues to be avoided, continuous monitoring of electrical power quality measurements and the application of suitable corrective actions are required [4]. The early detection and diagnosis of power quality issues can be aided by a real-time monitoring system for electrical power quality. This gives stakeholders the time to take remedial measures before the problem gets so serious that it disrupts power supply or causes physical harm.In the 1970s, the very first real-time electrical power quality monitoring systems were put into operation, and ever since then, their use has become increasingly ubiquitous. In these early systems, power quality parameters such as voltage and current were initially detected by analogue sensors. However, these systems lacked the precision and speed necessary for accurate data analysis, and they were unable to perform such analysis in real time. The development of increasingly capable and intricate real-time monitoring systems for the quality of electrical power has been made possible by advances in technology. Because of the use of digital sensors, these systems can measure the power quality characteristics such as voltage, current, frequency, and harmonic distortion with a high degree of accuracy. The data collected by the sensors is transmitted to a centralized processing unit, which then performs an analysis of the data in real time in order to identify power quality issues as soon as they arise.Real-time electrical power quality monitoring devices are becoming common in a variety of situations, including commercial and industrial establishments, and even homes. These devices are now necessary in order to keep the electrical system secure and reliable while minimizing the expenses associated with energy waste. By keeping a close eye on the factors that contribute to power quality and conducting continuous monitoring, stakeholders may cut downtime and increase the performance of electrical systems. Because of its ability to increase sustainability and reduce carbon emissions while simultaneously lowering energy costs, the system is an essential component of the solution [5]. This is accomplished by optimizing energy usage and bringing down energy prices.

II. Review of Literature

In the paper [6], author suggested an instantaneous power quality monitoring system. The system utilizes a field programmable gate array (FPGA) and can track numerous power quality indicators. The authors also provide a strategy for deciphering the system's logs. In the paper [7], author present a real-time power quality monitoring system for smart grids. The system utilizes a wireless sensor network and can track many power quality indicators. The authors also provide a strategy for analyzing and presenting data. In the paper [8], author suggested an IoT-based system for real-time monitoring of electrical power quality. Both single- and three-phase power systems can benefit from the system's power quality monitoring capabilities. The authors also provide a strategy for analyzing and presenting data. In the paper [9], author suggests a power quality monitoring system for smart grids that operates in real time. The system utilizes a wireless sensor network and can track many power quality indicators. The authors also provide a strategy for analyzing and presenting data. In the paper [10], author work suggest a microcontroller-based system for continuous monitoring of electrical output. Both single- and three-phase power systems can benefit from the system's power quality monitoring capabilities. The authors also provide a strategy for analyzing and presenting data. In the paper [11], author proposes an Arduino-based real-time power quality monitoring system for use in manufacturing. Both single- and three-phase power systems can benefit from the system's power quality monitoring capabilities. The authors also provide a strategy for analyzing and presenting data. In the paper [12], author of this research suggests a ZigBee-based wireless network for continuous power quality monitoring. Both single- and three-phase power systems can benefit from the system's power quality monitoring capabilities. The authors also provide a strategy for analyzing and presenting data. In the paper [13], author proposes a LabVIEW-based system for continuous monitoring of electrical power quality. Both single- and three-phase power systems can benefit from the system's power quality monitoring capabilities. The authors also provide a strategy for analyzing and presenting data. In the paper [14], author of this work suggest an FPGA-based system for continuous monitoring of electrical power quality. Both single- and three-phase power systems can benefit from the system's power quality monitoring capabilities. The authors also provide a strategy for analyzing and presenting data. In the paper [15], author proposes a Raspberry Pi-based system for real-time monitoring of power quality. Both single- and three-phase power systems can benefit from the system's power quality monitoring capabilities.

DOI : https://doi.org/10.56452/7-779

Table 1. Comparative Study of various techniques discussed in Literature Review

Paper	Technique Used	Advantages	Disadvantages
1. C. V. N. S. S. S. Reddy	ZigBee wireless network	Low power consumption, easy installation, real-time monitoring	Limited range, interference from other wireless networks
2. Y. Han, et al.	Wireless sensor network and data fusion algorithm	Improved accuracy, reliable monitoring	High implementation cost, data fusion algorithm complexity
3. X. Wang, et al.	Kalman filter and wavelet transform	Improved accuracy, noise reduction	Kalman filter complexity, wavelet transform selection
4. S. Arifin, et al.	Fast Fourier Transform and adaptive filter	Improved accuracy, noise reduction	Adaptive filter complexity, requires periodic calibration
5. M. G. Bakhary, et al.	Power quality event detection algorithm and decision tree	Automatic event detection, decision-making capabilities	High implementation cost, algorithm complexity
6. A. J. A. Llanillo	Non-intrusive load monitoring and Support Vector Machines	Easy installation, improved accuracy	Limited to single-phase systems, SVM complexity
7. M. K. Khalid, et al.	Wavelet transform and neural networks	Improved accuracy, real-time monitoring	Neural network complexity, wavelet transform selection
8. S. Wang, et al.	Hilbert transform and independent component analysis	Improved accuracy, reduced noise	Hilbert transform complexity, ICA algorithm selection
9. J. Wu, et al.	Continuous wavelet transform and fuzzy logic	Improved accuracy, noise reduction	Fuzzy logic algorithm selection, implementation complexity
10. W. Xu, et al.	Improved Multiple Signal Classification and particle swarm	Improved accuracy, reduced complexity	High implementation cost, particle swarm optimization
11. A. R. A. Rahim, et al.	Discrete wavelet transform and artificial neural networks	Improved accuracy, reduced complexity	Wavelet transform selection, neural network complexity
12. J. Xie, et al.	Wireless sensor network and data mining techniques	Easy installation, improved accuracy, data analysis	Limited to single-phase systems, data mining complexity
13. Z. Wang, et al.	Wireless sensor network and data analysis and visualization	Easy installation, improved accuracy, data analysis	Limited to single-phase systems, data analysis complexity
14. A. Karthikeyan, et al.	Wireless sensor network and data analysis and visualization	Easy installation, improved accuracy, data analysis	Limited to distribution networks, data analysis complexity
15. A. N. A. Yusof, et al.	Raspberry Pi and data analysis and visualization	Low cost, easy installation, improved accuracy	Limited to single-phase systems, limited range
16. J. Xie, et al.	Wireless sensor network and data analysis and visualization	Easy installation, improved accuracy, data analysis	Limited to single-phase systems, data analysis complexity
17. S. S. Sutar, et al.	IoT and data analysis and visualization	Easy installation, improved accuracy, data analysis	Limited to single-phase systems, limited

The authors also provide a strategy for analyzing and presenting data. In the paper [16], author, the authors suggest using LabVIEW to implement a real-time power quality monitoring system. Both single- and three-phase power systems can benefit from the system's power quality monitoring capabilities. The authors also provide a strategy for analyzing and presenting data.In this paper [17], author provide an embedded-system

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based real-time electrical power quality monitoring system. Both single- and three-phase power systems can benefit from the system's power quality monitoring capabilities. The authors also provide a strategy for analyzing and presenting data.

III. Existing Approaches

Table 2. Summarizes the key characteristics of each methodology

Methodology	**Advantages**	**Disadvantages**
Wireless Sensor Networks (WSNs)	Low-cost, easy to install, can cover a wide area	Limited range, interference from other wireless networks
Signal Processing Techniques	Extract useful information from noisy and complex signals	Complex, require careful selection of parameters
Data Analysis and Visualization	Easy to understand format for presenting data	May not provide insights beyond visual representation of the data
Internet of Things (IoT)	Can connect multiple devices and sensors for real-time monitoring	High implementation cost, may require specialized knowledge
Machine Learning Algorithms	Improved accuracy, reduced complexity	Can be computationally intensive, may require high implementation cost
Fuzzy Logic	Can model complex and uncertain systems	Fuzzy logic algorithm selection, limited range

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IV. Proposed Methodology

Block diagram representations of the proposed system's individual components, including sensors, a data acquisition system, a communication infrastructure, a data processing and analysis system, a user interface, power quality metering devices, and a cloud computing infrastructure, can be found below. Because of the interconnected nature of its many components and the many communication channels that exist between them, the system is able to collect, analyze, and analyze data in real time. This ability is made possible by the system's various communication channels. Because of its modular and flexible structure, the system can expand in tandem with the development of the power grid.

Components such as the following might be included in a system that is being considered for the examination of a real-time monitoring system for the quality of electrical power:

A. Sensors: In order to detect various electrical properties like voltage, current, frequency, and harmonics, the system will need sensors. These sensors could be put in strategically placed throughout the electrical system in order to collect data in real time.

B. Data Acquisition System To be able to collect data from the sensors, you would need a data acquisition system. Data loggers, data concentrators, and other devices with a similar function may be included in this system.

C. Communication Infrastructure In order to get data from the sensors to the data gathering system, you will need a communication infrastructure. This infrastructure might consist of wireless communication systems like Zigbee or power line communication (PLC) systems, for example.

D. System for Data Processing and Analysis In order to do real-time analysis on the data that was gathered from the sensors, it would be necessary to have a data processing and analysis system. This system might make use of data analysis software, machine learning algorithms, or other comparable applications or devices.

E. User Interface: It would be necessary to have a user interface in order to deliver the data to the user in a way that is simple and easy to grasp. This interface might contain dashboards, warnings, or other tools of a similar nature to keep the user apprised of any potential problems with the power supply's quality.

F. Metering Equipment for Power Quality Metering equipment for power quality can also be used to measure and monitor the electrical properties of a power system. These devices might be put in place at key nodes in the power grid in order to collect data that, if evaluated, would make it possible to identify problems with the power supply as they occur in real time.
G. Computing Infrastructure Hosted in the Cloud The data that was gathered from the sensors could be stored, processed, and analyzed using a computing infrastructure hosted in the cloud. The system may be scaled up by utilizing this infrastructure, which would also supply additional computing power as required.

In general, the system that is being proposed for investigating a real-time monitoring system for the quality of electrical power would need a combination of hardware, software, and communication infrastructure in order to gather, process, and analyze data in real time. To improve the dependability and efficiency of the power system, the system would need to be capable of recognizing problems with power quality in real time, in addition to having the ability to scale and be flexible.

V. Challenges

Recent years have seen an increase in the use of real-time monitoring systems for electrical power quality due to advancements in sensors, data analytics tools, and machine learning algorithms. These advancements have allowed for the accurate and reliable operation of systems by allowing operators to recognize and address power quality issues in real time.

A. Enhancements to Sensors The power quality characteristics of voltage, current, and frequency may now be measured with newer, more accurate sensors. These sensors can be deployed at strategic locations across the electrical grid to continuously monitor and report on system status trends.
B. Data analytics solutions, such as big data platforms and cloud-based analytics, are able to handle the voluminous volumes of data produced by power quality sensors. The ability of these real-time analysis tools to detect trends and outliers may help in identifying power quality issues.
C. In order to anticipate future power quality issues, machine learning techniques have been developed. Data from multiple sensors can be analyzed by these algorithms to offer insights into the power system as a whole.
D. Thanks to the incorporation of IoT devices with real-time monitoring systems, operators may now remotely monitor power quality. At the customer's site, smart meters and other IoT devices can be set up to track and record the quantity and quality of energy being consumed.
E. With the use of real-time monitoring data and predictive maintenance processes, equipment failure can be anticipated. Operators can now schedule required upkeep in advance, significantly reducing the frequency of unanticipated outages.

Electrical power quality tracking and problem fixing in real time has been made possible by advances in real-time monitoring systems. These upgrades have decreased the frequency of power outages and improved the reliability of the electrical grid.

VI. Recent Advances

Improvements in sensors, data analytics tools, and machine learning algorithms have all contributed to the rise of real-time monitoring systems for electrical power quality in recent years. As a result of these developments, operators can now detect and address power quality concerns in real time, significantly improving the systems' accuracy and reliability.

A. Sensor Improvements Newer, more precise sensors can now be used to measure power quality variables like voltage, current, and frequency. These sensors can be placed at various nodes throughout the power grid to collect and transmit data in real time that can be used to track and analyze trends in system health.
B. Big data platforms and cloud-based analytics are two examples of data analytics systems that can deal with the massive amounts of data generated by power quality sensors. Power quality issues may be uncovered by this real-time analysis systems' ability to spot trends and outliers.

DOI : https://doi.org/10.56452/7-779

C. Machine learning algorithms have been created that can analyze past data to foresee potential power quality problems in the future. These algorithms can analyze data from several sensors to reveal information about the power grid as a whole.
D. Internet of Things Integration: Operators can now remotely monitor power quality thanks to the integration of IoT devices with real-time monitoring systems. Smart meters and other Internet of Things (IoT) devices can be deployed at the customer's location to monitor energy use and quality in real time.
E. Equipment failure can be predicted with the help of real-time monitoring data and predictive maintenance procedures. Operators may now plan ahead for necessary maintenance, cutting down on unplanned downtime.

Improvements in real-time monitoring systems for electrical power quality have allowed operators to better track power quality and address problems as they arise. These developments have increased the electricity system's dependability and efficiency while decreasing the frequency of outages.

VII. Conclusion & Future Work

In conclusion, a system that monitors the quality of electricity in real time is an indispensable resource for keeping the power grid stable and efficient. In order to prevent outages, the system delivers real-time information on power quality metrics like voltage, current, and frequency. Numerous methods have been presented by researchers to enhance the precision and dependability of real-time monitoring systems after significant study of the existing methodology, procedures, and approaches. Operators are now able to monitor power quality and respond in real time because to recent advancements in sensors, data analytics tools, machine learning algorithms, IoT integration, and predictive maintenance procedures more accurately. In future the quality of our electrical supply can be better monitored in real time, despite the substantial progress that has already been done. Some topics that need more investigation are:Improvements in power quality can be achieved through the creation of cutting-edge sensors that report data with more precision and detail.Proactive decision-making is enabled by combining machine learning algorithms with real-time monitoring infrastructure.Tools for data analysis are being refined so that they can process massive amounts of data and yield more reliable results.Improvements in the efficiency of Internet of Things (IoT) devices that are compatible with the current electrical infrastructure.Predictive maintenance methods that can boost the power grid's dependability and productivity are put into action.The investigation of novel methods for enhancing real-time identification and resolution of power quality concerns.If we care about the safety and efficacy of our power grid, we must invest in the ongoing study and improvement of real-time monitoring systems for electrical power quality. Insights gained from the suggested system and methodologies can aid operators in their management of the power grid.

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