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MONITORING OF POWER SYSTEM EVENTS AT TRANSMISSION AND DISTRIBUTION LEVEL USING IOT

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Abstract:

Real-time monitoring of power system events has become a fundamental requirement for ensuring grid stability, operational reliability, and power quality in modern electrical networks. This paper presents a comprehensive IoT-based framework for monitoring electrical parameters such as voltage and current across transmission and distribution systems. The proposed system employs an ESP8266 microcontroller integrated with voltage and current sensors to continuously acquire and transmit data. Fault simulation techniques are incorporated to emulate disturbances such as short circuits, overloads, and voltage fluctuations under controlled conditions. The acquired data is transmitted to the ThingSpeak cloud platform for real-time visualization, storage, and analysis. Furthermore, MATLAB is used for advanced signal processing, including filtering, classification, and disturbance identification. The proposed system is cost-effective, scalable, and suitable for smart grid applications, academic laboratories, and power quality research, offering improved situational awareness and faster fault diagnosis.

1. Introduction:

The modern power system is undergoing rapid transformation due to the integration of renewable energy sources, distributed generation, electric vehicles, and intelligent loads. These advancements, while beneficial, introduce complexity in maintaining system stability and reliability. Traditional monitoring systems are often inadequate because they rely on periodic inspection and offline analysis, which cannot capture transient disturbances or provide immediate feedback during faults.

Power quality issues such as voltage sags, swells, harmonics, transients, and interruptions can significantly impact the performance of electrical equipment and lead to system failures. These disturbances often occur unexpectedly and propagate quickly across the network, making real-time monitoring essential. Early detection of such events enables faster corrective actions, reducing downtime and preventing damage to critical infrastructure.

The emergence of Internet of Things (IoT) technology has revolutionized the way power systems are monitored. IoT enables continuous data acquisition, remote accessibility, and cloud-based analytics. With low-cost microcontrollers such as ESP8266, it is now possible to deploy distributed monitoring systems capable of collecting and transmitting data in real time. This shift from conventional systems to IoT-based frameworks enhances visibility, improves decision-making, and supports predictive maintenance strategies.

2. System Overview:

The proposed IoT-based monitoring system is designed to provide continuous and real-time observation of electrical parameters in power systems. The architecture is divided into three main layers: data acquisition, communication, and cloud analytics. Each layer plays a crucial role in ensuring accurate monitoring and efficient data handling.

In the data acquisition layer, voltage and current sensors measure real-time electrical parameters. These sensors convert physical electrical quantities into analog signals that can be processed by the microcontroller. The ESP8266 acts as the central processing unit, converting analog signals into digital data and preparing them for transmission.

The communication layer ensures seamless data transfer between the hardware and the cloud platform. Using built-in Wi-Fi capabilities, the ESP8266 sends data to the ThingSpeak server through HTTP protocols. This eliminates the need for complex wired communication systems and enables remote monitoring from any location.

The cloud and analytics layer is responsible for data storage, visualization, and advanced processing. ThingSpeak provides graphical representations of voltage and current waveforms, allowing users to observe system behavior in real time. MATLAB integration further enhances the system by enabling advanced signal processing, disturbance classification, and trend analysis.

3. Literature Review:

Recent developments in power system monitoring have focused on improving fault detection accuracy, response time, and system reliability. Various approaches have been proposed, including observer-based techniques, machine learning models, and signal processing methods. These techniques aim to identify faults quickly and accurately, even under complex operating conditions.

Observer-based methods, such as sliding mode observers and Kalman filters, have been widely used for detecting faults in power electronic systems. These techniques offer high accuracy but often require precise system models and are sensitive to parameter variations. Machine learning approaches, including artificial neural networks and support vector machines, have gained popularity due to their ability to learn patterns and classify disturbances automatically. However, these methods require large datasets and high computational power.

Signal processing techniques, such as Fast Fourier Transform (FFT) and Short-Time Fourier Transform (STFT), are commonly used for analyzing power quality disturbances. These methods provide valuable insights into frequency components and transient behavior but may struggle with non-stationary signals.

Despite these advancements, challenges remain in implementing real-time, cost-effective, and scalable monitoring systems. Many existing solutions are expensive, complex, and not suitable for academic or small-scale applications. The proposed IoT-based system addresses these limitations by providing an affordable and efficient monitoring solution.

4. Methodology:

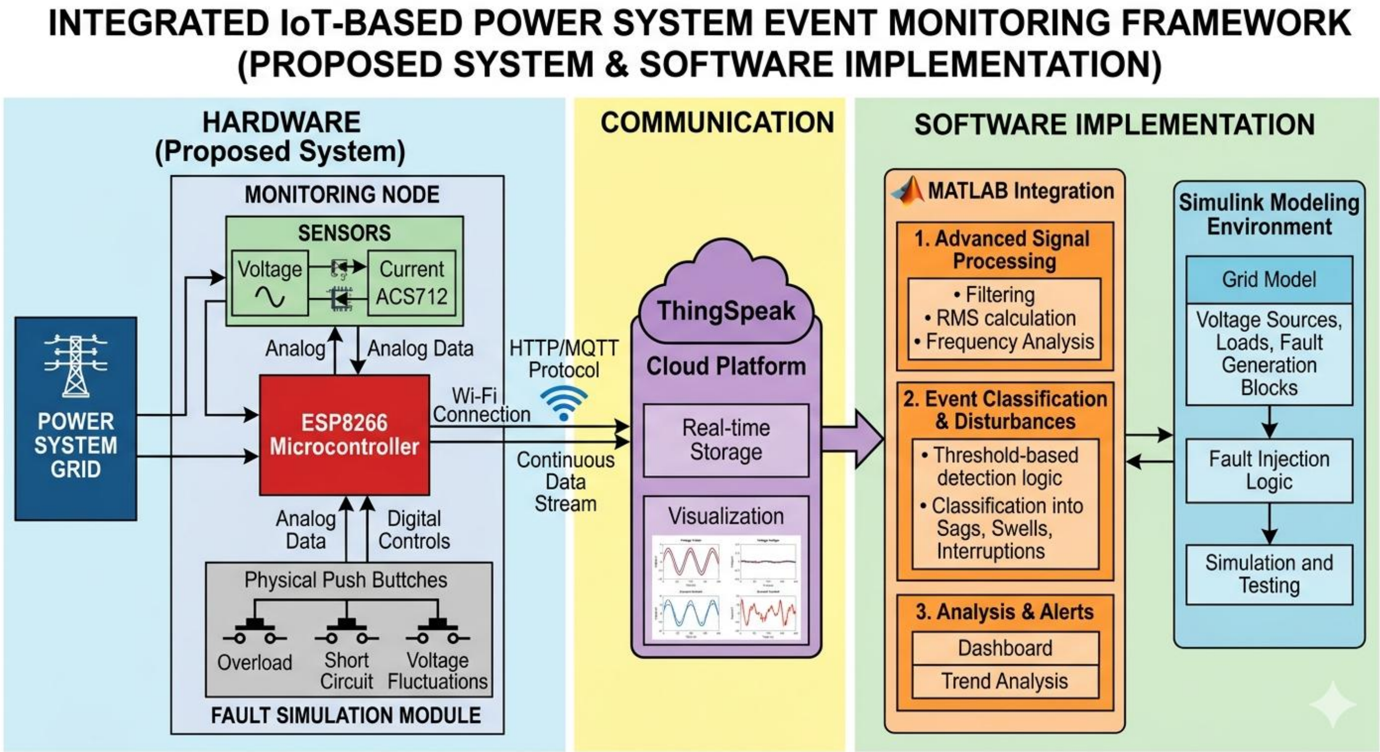
4.1 Existing System:

Conventional power system monitoring relies heavily on SCADA systems, digital meters, and manual inspection techniques. While these systems are effective for large-scale industrial applications, they suffer from several limitations when applied to real-time monitoring. One of the major drawbacks is the lack of continuous data acquisition, which makes it difficult to detect transient events.

Another limitation is the high cost associated with installation and maintenance. SCADA systems require complex infrastructure, including communication networks, control centers, and specialized personnel. This makes them unsuitable for small-scale applications and academic institutions.

Additionally, traditional systems lack fault simulation capabilities, which limits their usefulness in research and training environments. Engineers and students cannot safely study fault conditions in real systems, leading to a gap between theoretical knowledge and practical understanding.

4.2 Proposed System:



The proposed system introduces a modern approach to power system monitoring by integrating IoT technology, cloud computing, and advanced analytics. The system continuously monitors voltage and current parameters and provides real-time feedback through cloud visualization.

A key feature of the system is its ability to simulate faults using push-button switches. These switches create controlled disturbances, allowing users to study system behavior under abnormal conditions. This feature is particularly useful for educational and research purposes.

The use of ESP8266 microcontroller ensures low-cost implementation while providing reliable performance. Its built-in Wi-Fi capability simplifies communication and enables seamless integration with cloud platforms. The system is designed to be modular, allowing easy expansion and customization.

4.3 Sensor Integration:

Sensor integration plays a critical role in the accuracy and reliability of the monitoring system. Voltage sensors operate on the principle of voltage division, reducing high voltage levels to safe values suitable for microcontroller input. Current sensors, such as ACS712, use Hall-effect technology to measure current without direct electrical contact.

To ensure accurate measurements, sensors are calibrated before deployment. Calibration involves adjusting scaling factors to match actual electrical values. Noise reduction techniques, such as filtering and averaging, are applied to eliminate unwanted disturbances in the signal.

The microcontroller samples sensor data at regular intervals, ensuring continuous monitoring. High sampling rates allow the system to capture transient events effectively, improving fault detection capability.

4.4 Cloud Integration:

Cloud integration is a key component of the proposed system, enabling remote monitoring and data analysis. ThingSpeak acts as the central platform for storing and visualizing data. Each data point is time stamped, allowing users to track system performance over time.

The platform provides graphical dashboards that display voltage and current variations. These visualizations help users quickly identify abnormal conditions and analyze trends. In addition, ThingSpeak supports automated alerts, which notify users when predefined thresholds are exceeded.

MATLAB integration enhances the analytical capabilities of the system. Users can write custom scripts to perform advanced operations such as harmonic analysis, event classification, and predictive modeling.

5. Software Implementation:

The software implementation of the system is carried out using MATLAB and Simulink, which provide a powerful environment for modeling and analysis. Simulink is used to simulate power system behavior under various conditions, including faults and disturbances.

The simulation model includes voltage sources, loads, and fault generation blocks. These components replicate real-world conditions and allow testing of system performance before hardware implementation. Event detection logic is implemented using threshold-based conditions, enabling automatic identification of disturbances.

MATLAB is used to process real-time data obtained from the cloud. It performs operations such as RMS calculation, filtering, and frequency analysis. The integration of MATLAB with ThingSpeak allows seamless data exchange and real-time processing.

7. Results and Analysis:

The proposed system was tested under various conditions to evaluate its performance. The results demonstrate that the system can accurately detect and classify different types of faults. Voltage sags, swells, interruptions, and current spikes were successfully identified and visualized on the cloud platform.

The system showed high accuracy in capturing real-time data, with minimal delay in transmission. The integration of MATLAB enabled detailed analysis of disturbances, providing insights into system behavior. The results also highlight the effectiveness of the fault simulation module in generating controlled disturbances.

Overall, the system performed reliably under different operating conditions, demonstrating its suitability for real-time monitoring applications.

8. Conclusion:

This paper presents a comprehensive IoT-based solution for monitoring power system events in real time. The integration of sensors, microcontrollers, cloud platforms, and analytical tools provides a powerful framework for detecting and analyzing electrical disturbances.

The proposed system offers several advantages, including low cost, scalability, and ease of implementation. It enhances system visibility, improves fault detection speed, and supports advanced data analysis. These features make it suitable for academic, industrial, and smart grid applications.

9. Future Scope:

Future improvements can focus on integrating machine learning algorithms for predictive maintenance and intelligent fault classification. The system can be expanded to include multiple nodes for large-scale monitoring, enabling deployment in smart grid environments.

Additional enhancements may include mobile applications for real-time alerts, integration with renewable energy systems, and incorporation of advanced sensors for monitoring temperature, vibration, and other parameters.

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