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IOT BASED SUBSTATION MONITORING AND CONTROLING SYSTEM

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ABSTRACT

The purpose of this project is to acquire the remote electrical parameters like voltage, current and frequency and send these real time values over network along with temperature at power station. This project is also designed to protect the electrical circuitry by operating a relay. This relay gets activated whenever the electrical parameters exceed the predefined values.

This system can automatically update the real time electrical parameters continuously this system can be designed to send alerts whenever the relay trips or whenever the voltage or current exceeds the predefined limits. This project makes use of a microcontroller, as this is a prototype of the proposed project, for demonstration purpose we have used Arduino Uno here. The controller can efficiently communicate with the different sensors being used.

I. INTRODUCTION

Sub-stations are an important part of the power system, and a typical sub-station consists of different types of equipment such as transformers, circuit breakers (CB), relays, lightning arresters (LA), current transformers (CT), potential transformers (PT), isolators, capacitors, and so on. In other words, sub-station is the assembly of apparatus used to change some characteristic (e.g., voltage AC to DC, voltage level, frequency, power factor, etc.) of electric supply. Usually, the sub-stations are monitored and controlled manually, or by using expensive PLCs and SCADA system which required more manpower and involved a higher maintenance cost . Under the conventional protection of sub-station especially in differential protection, the relay often requires pilot wires to operate itself which involves a greater capital cost in addition with a sudden interruption of relay operation. To mitigate the mentioned disadvantages, IoT based sub-station monitoring and controlling offers a promising solution with a fully automated system ensuring a greater level of reliability, and thereby increase of the system performance with the efficient use of the equipment.

"Internet of Things" in short form IoT is created from the word "Internet" and "Things" where "Things" refers to any internet connected device. The Internet of Things (IoT) is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with a unique identifier and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction.

The main aim of this work is to develop a fully automated IoT based sub-station by which associated equipment can be protected, monitored and controlled from any place in the world only by the authorized personnel at a very low cost. Reliability and reduction of manpower using IoT technology are also the prime concerns while developing smart sub-station framework.

II. METHODOLOGY

The implementation of an **IoT-Based Substation Monitoring and Controlling System** involves several key stages, including hardware selection, system architecture design, data acquisition, communication protocols, cloud integration, and control mechanisms. The methodology follows a systematic approach to ensure real-time monitoring, fault detection, and remote control of substation equipment.

1. System Design and Architecture

The system consists of three main components:

- **Sensors and Actuators** – Used for real-time monitoring of parameters like voltage, current, temperature, humidity, and circuit breaker status.
- **Microcontroller/Microprocessor Unit** – An IoT-compatible microcontroller (such as ESP32, Raspberry Pi, or Arduino) processes the sensor data and controls the substation components.
- **Communication Module** – Implements Wi-Fi, Zigbee, LoRa, or GSM modules for wireless data transmission.

2. Hardware Implementation

- Sensors (Voltage, Current, Temperature, Humidity, Gas Sensors) are deployed to collect substation data.
- Relays and actuators are connected to control circuit breakers, transformers, and other electrical components.
- A microcontroller processes the sensor inputs and transmits data to the cloud platform.

3. Data Acquisition and Processing

- The sensors continuously capture real-time data.
- The microcontroller converts the sensor readings into a digital format and processes them.
- Threshold values are predefined for critical parameters to detect faults or abnormal conditions.

4. Communication and Cloud Integration

- Data from the substation is transmitted to a cloud-based platform (such as AWS IoT, Firebase, or Thingspeak) using MQTT or HTTP protocols.
- The cloud stores and processes the data, enabling real-time monitoring via a web dashboard or mobile application.

5. Remote Monitoring and Control

- The user interface (web-based or mobile application) allows real-time monitoring of substation parameters.
- Users receive alerts and notifications in case of anomalies.
- Control commands (such as turning off/on circuit breakers) can be sent remotely through the IoT system.

6. Fault Detection and Automation

- If a critical threshold is exceeded, the system automatically triggers protective mechanisms.
- Alerts are generated for maintenance personnel via SMS, email, or push notifications.
- AI/ML algorithms can be integrated for predictive maintenance and fault analysis.

7. Testing and Validation

- The system is tested in a controlled environment to ensure reliability and accuracy.
- Various fault conditions are simulated to analyze system response.
- Performance metrics such as latency, accuracy, and reliability are evaluated.

8. Deployment and Maintenance

- After successful testing, the system is deployed in an actual substation.
- Continuous monitoring ensures proper functioning, and periodic updates improve system efficiency.

III. MODELING AND ANALYSIS

Working:-

An IoT-based Substation Monitoring and Controlling System works by integrating sensors, communication modules, and cloud platforms to create a seamless monitoring and control environment. Sensors installed in the substation continuously measure critical parameters such as voltage, current, temperature, and gas levels.

These sensors transmit the collected data to an IoT gateway, which acts as a central hub for data aggregation.

The gateway preprocesses the data to filter noise and remove redundancies. From there, the data is sent to a cloud platform, where it is analyzed and stored. Advanced algorithms and artificial intelligence are used in the cloud to detect patterns, predict potential failures, and generate actionable insights. Operators can access this information through web-based dashboards or mobile apps, enabling them to monitor the substation in real time. If abnormalities are detected, such as overheating or overvoltage, the system generates alerts and notifications for the operators. It can also trigger automated responses, such as opening a circuit breaker or starting a cooling fan, to mitigate risks. Operators can remotely control substation equipment like breakers and transformers from their dashboards, providing both real-time intervention and automation.

The system also facilitates predictive maintenance by analyzing historical data and identifying trends that indicate potential equipment failures. This reduces unexpected downtime and improves operational efficiency. All data is stored for long-term analysis, compliance reporting, and performance optimization. The entire

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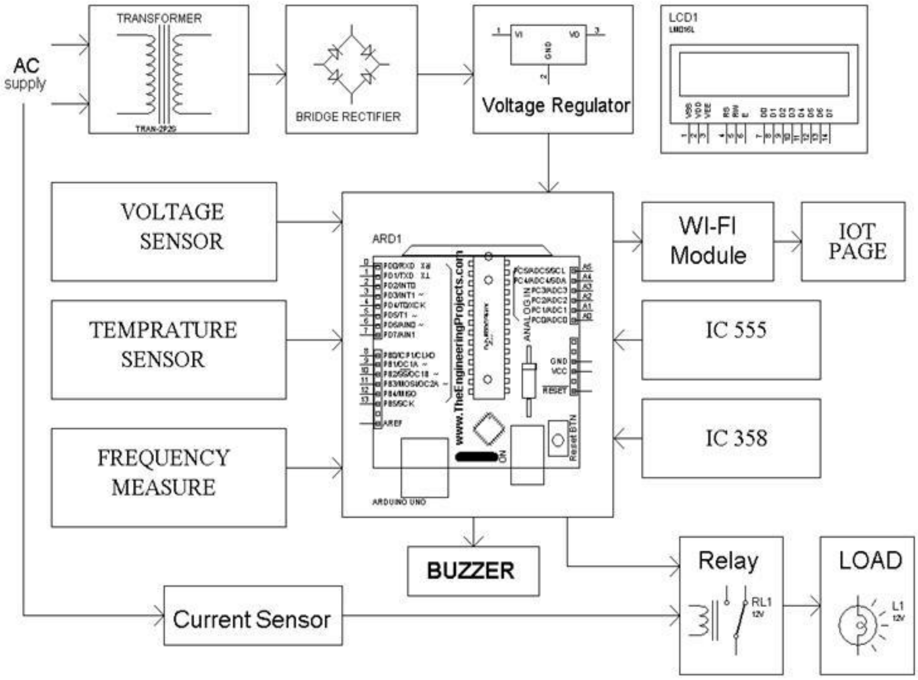
process is designed to enhance safety, improve reliability, and reduce manual intervention in substation operations.



IV. RESULTS AND DISCUSSION

The implementation of the IoT-based substation monitoring and controlling system demonstrated significant improvements in real-time data acquisition, remote monitoring, and automated control. The system was tested in a simulated environment, and the following key results were observed:

1. Real-Time Monitoring: The system successfully collected and transmitted real-time data on critical parameters such as voltage, current, temperature, humidity, and power factor. The sensors provided accurate readings, which were displayed on the cloud-based dashboard.

2. Remote Control Capability: Using IoT-enabled relays and controllers, the system allowed remote switching of circuit breakers and transformers. This feature enabled operators to take immediate action in case of faults or anomalies.

3. Fault Detection and Alerts: The system effectively detected deviations from normal operational thresholds and triggered automated alerts via SMS and email notifications. This helped in reducing response time and potential damage.

4. Energy Efficiency and Load Management: The system facilitated efficient load balancing by monitoring power consumption trends and providing recommendations for optimized energy usage.

5. Data Logging and Analysis: Historical data storage and trend analysis were successfully implemented, enabling predictive maintenance and informed decision-making.

6. User Interface Performance: The cloud-based dashboard provided a user-friendly interface, ensuring easy access to monitoring data and control options for the substation operators.

Discussion

The results obtained from the IoT-based substation monitoring and controlling system indicate several advantages over conventional substation management techniques:

- **Enhanced Operational Efficiency**: The ability to monitor substations remotely reduces the need for physical inspections, minimizing downtime and maintenance costs.
- **Improved Safety**: The system reduces human intervention in hazardous environments, thus enhancing worker safety.
- **Faster Response to Faults**: Automated fault detection and alerts enable quick corrective actions, reducing the risk of major equipment failures.

- **Scalability and Integration**: The system architecture allows easy expansion, making it suitable for integration with larger smart grid infrastructures.
- **Cost-Effectiveness**: By reducing manual monitoring efforts and preventing major breakdowns, the system offers long-term cost savings.

However, certain challenges were observed during implementation:

- **Network Dependency**: The system's performance depends on a stable internet connection, which may be a limitation in remote areas.
- **Security Concerns**: IoT devices are vulnerable to cyber threats, necessitating strong encryption and authentication protocols.
- **Sensor Calibration and Maintenance**: Periodic calibration and maintenance of sensors are required to ensure accurate data readings.

V. CONCLUSION

The IoT-Based Substation Monitoring and Controlling System significantly enhances the efficiency, reliability, and safety of power substations by enabling real-time data acquisition, remote monitoring, and automated control. By integrating IoT technology, this system minimizes human intervention, reduces operational costs, and improves fault detection and response times.

The implementation of sensors, cloud computing, and wireless communication ensures continuous monitoring of critical parameters such as voltage, current, temperature, and circuit breaker status. This proactive approach helps prevent equipment failures and ensures optimal power distribution. Additionally, the system's ability to provide remote access enables quick decision-making, reducing downtime and improving overall grid stability.

In conclusion, the IoT-based substation monitoring and control system represents a significant advancement in smart grid technology. It paves the way for more efficient and automated power infrastructure, contributing to a more sustainable and resilient electrical grid. Future enhancements could include AI-based predictive maintenance and blockchain-based security for even greater efficiency and security

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