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TriVolt Tracker: The Monitoring and Fluctuation Detection

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Abstract: This paper presents the design and implementation of an IoT-based three-phase power monitoring system with voltage fluctuation detection and LED indicators. The system is developed to provide real-time monitoring and fault detection for three-phase electrical networks commonly used in industrial and commercial applications. Utilizing voltage and current sensors, the system continuously measures power parameters for each phase. A micro-controller processes the acquired data to detect abnormalities such as voltage fluctuations, imbalances, over voltage, and under voltage conditions. The integrated LED indicators offer immediate visual feedback, while IoT connectivity enables remote monitoring and data analysis via a cloud platform or mobile application. By identifying anomalies early, the system enhances energy efficiency, reducing downtime and preventing equipment damage through real-time alerts and notifications. This solution enables users to manage power quality effectively, optimize energy consumption, and achieve cost savings while improving overall system reliability.

Index Terms - IoT-based power monitoring, three-phase electrical system, voltage fluctuation detection, real-time fault detection, energy efficiency, micro-controller-based monitoring, industrial power management, remote monitoring, power quality optimization, cloud-integrated monitoring.

I. INTRODUCTION

This paper presents an advanced IoT-enabled three-phase current monitoring system designed to enhance the reliability, safety, and efficiency of electrical distribution systems. Traditional Miniature Circuit Breakers (MCBs) offer basic circuit protection but lack real-time monitoring and predictive capabilities. To address these limitations, the proposed system integrates smart sensors, microcontrollers, and IoT connectivity to monitor critical electrical parameters, such as voltage and current, in real- time. By detecting circuit faults, voltage fluctuations, and phase imbalances, the system enables proactive maintenance, reducing equipment damage, downtime, and fire risks. A three-LED visual indication mechanism provides immediate fault diagnosis, while remote monitoring and data analysis enhance predictive maintenance and energy optimization. This paper details the system architecture, hardware, software, and experimental results, demonstrating its effectiveness in real-world applications.

II. RELATED WORK

TITLE: IOT-BASED 3 PHASE INDUCTION MOTOR PARAMETER MONITORING AND CONTROLLING
AUTHORS: CHANCHAL PANDE, SHIVENDRA SINGH THAKUR, C.S. SHARMA
PUBLICATION: JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR), 2021

DESCRIPTION:
This paper presents an IoT-based system for real-time monitoring and control of three-phase induction motors. It utilizes sensors to measure key parameters such as voltage, current, and temperature, sending data to a cloud platform for remote access. The system enhances motor efficiency and reduces downtime by enabling predictive maintenance.

TITLE: THINGSPEAK BASED SENSING AND MONITORING SYSTEM FOR IOT WITH MATLAB ANALYSIS

AUTHORS: SHARMAD PASHA
PUBLICATION: INTERNATIONAL JOURNAL OF NEW TECHNOLOGY AND RESEARCH (IJNTR), 2016

DESCRIPTION:
This research focuses on using ThingSpeak for IoT-based sensing and monitoring applications. The study highlights real-time data acquisition, cloud storage, and analysis using MATLAB, showcasing the potential for integrating IoT in industrial and electrical systems for fault detection and efficiency improvement.

TITLE: IOT INNOVATIONS IN POWER SYSTEM MONITORING: REVIEWING TRANSMISSION LINE MULTIPLE FAULT DETECTION SYSTEMS
AUTHORS: SIDDESH BONDRE, YASH WALKUNDE, ROHIT SALUNKHE, N.G. BHOSKAR
PUBLICATION: JOURNAL OF CONTROL & INSTRUMENTATION, 2024

DESCRIPTION:

This paper reviews advancements in IoT-based power system monitoring, focusing on transmission line fault detection systems. It discusses the integration of Arduino-based fault detection, voltage sensors, current sensors, and ESP8266 modules to enhance the reliability and efficiency of power transmission networks through real-time monitoring and fault detection.

TITLE: DESIGN AND IMPLEMENTATION OF AN IOT-BASED SMART GRID MONITORING SYSTEM FOR REAL-TIME ENERGY MANAGEMENT

AUTHORS: DESIGN AND IMPLEMENTATION OF AN IOT-BASED SMART GRID MONITORING SYSTEM FOR REAL-TIME ENERGY MANAGEMENT

PUBLICATION: INTERNATIONAL JOURNAL OF COMPUTATIONAL AND EXPERIMENTAL SCIENCE AND ENGINEERING, 2025

DESCRIPTION:

This research presents an IoT-based smart grid monitoring system aimed at enhancing energy efficiency. It employs an Arduino Uno microcontroller, ZMPT101B voltage sensor, ACS712 current sensor, and a NodeMCU Wi-Fi module to monitor and manage energy consumption in real-time. The system displays data on an LCD and sends MQTT messages to users' smartphones when thresholds are exceeded, facilitating proactive energy management.

II. EXISTING SYSTEM

Traditional three-phase power monitoring and protection systems primarily rely on Miniature Circuit Breakers (MCBs) and manual monitoring methods. These systems provide basic protection against overcurrent, short circuits, and electrical faults, but they have several limitations:

1. Manual Monitoring:
   - Conventional systems require periodic human intervention to check voltage and current levels using voltmeters and ammeters.
   - Lack of real-time monitoring increases the risk of undetected fluctuations and faults.
2. Delayed Fault Detection:
   - Standard MCBs and circuit breakers only trip when a severe fault occurs, such as overcurrent or short circuits.
   - They do not detect voltage fluctuations, phase imbalances, or minor faults that could lead to long-term equipment damage.
3. No Remote Monitoring:
   - Traditional systems do not support remote access or IoT integration.
   - Faults can go unnoticed for extended periods, leading to costly repairs and downtime.
4. Lack of Predictive Maintenance:
   - Conventional monitoring does not provide early warnings or predictive analytics.
   - Equipment failures occur suddenly without prior alerts, increasing maintenance costs.
5. Increased Energy Loss & Inefficiency:
   - Voltage fluctuations and imbalances lead to unnecessary energy consumption.
   - Without continuous monitoring, inefficiencies remain undetected, resulting in higher operational costs.

Limitations of the Existing System

- No real-time monitoring of voltage, current, and phase imbalances.
- No IoT-based remote access, making monitoring inconvenient.
- Lack of early fault detection, leading to equipment damage.
- Higher maintenance costs due to reactive rather than proactive maintenance.

III. PROPOSED SYSTEM

To address the limitations of traditional power monitoring methods, this paper proposes an IoT-enabled three-phase current monitoring system that integrates smart sensors, microcontrollers, wireless communication, and a visual indication mechanism for real-time monitoring and fault detection.

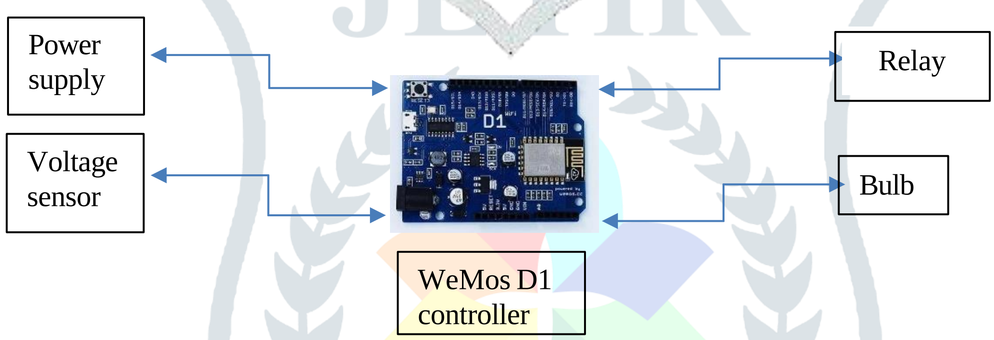
Key Features of the Proposed System:

1. Real-Time Monitoring
   - The system continuously measures voltage and current for each phase using smart sensors (ZMPT101B voltage sensor & ACS712 current sensor).
   - A Wemos D1 microcontroller processes the data and detects anomalies such as voltage fluctuations, phase imbalances, and circuit breaks.

2. IoT-Based Remote Monitoring
    - The system is equipped with Wi-Fi (NodeMCU ESP8266) and GSM modules for wireless data transmission.
    - Users can monitor power parameters remotely via a cloud platform or mobile application.
3. Fault Detection and Alerts
    - The system identifies abnormalities such as overvoltage, undervoltage, short circuits, and phase imbalance.
    - SMS/email alerts are sent to users whenever a fault is detected, enabling proactive maintenance.
4. Three-LED Visual Indication Mechanism
    - Green LED: Normal operation
    - Yellow LED: Minor fluctuation detected
    - Red LED: Critical fault detected, requiring immediate attention
5. Energy Optimization & Predictive Maintenance
    - The system collects real-time data, logs historical trends, and provides predictive analytics for efficient power usage.
    - Helps reduce maintenance costs and optimize energy consumption by detecting faults early.
6. Enhanced Safety & System Reliability
    - The system prevents equipment damage by detecting issues before they escalate.
    - Reduces the risk of fire hazards and system failures caused by unstable voltage conditions.

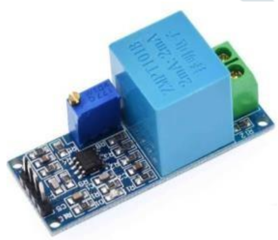
Module Description: A module is a Hardware and software component or part of a program that contain one or more routines.

IV. BLOCK DIAGRAM:



ZMPT101B

The ZMPT101B is a popular voltage sensor module used to detect AC voltage, primarily designed for low-voltage AC measurements, including household or industrial applications. It is often utilized in Arduino and other microcontroller-based systems for voltage measurement and fluctuation detection. While the ZMPT101B is mainly designed for single-phase voltage detection, its principles can also be adapted for use in three-phase fluctuation detection systems, particularly in cases where monitoring of each individual phase voltage is required.



WEMOS D1 CONTROLLER

The Wemos D1 Controller is a popular development board based on the ESP8266 microchip, which is widely used for building IoT (Internet of Things) applications. It is favored due to its built-in Wi-Fi capabilities, small form factor, and ease of use with Arduino IDE. The board has digital I/O pins for controlling external devices, such as relays or sensors, and can be integrated into a system to monitor and manage three-phase voltage fluctuations. In the context of three-phase fluctuation detection, the Wemos D1 controller can be used as the central processing unit that gathers real-time data from voltage sensors, processes the information, and triggers appropriate actions (such as disconnecting a faulty phase, sending alerts, or activating backup systems).
This detailed content explores how the WeMos D1 controller can be employed to detect and manage voltage fluctuations in three-phase systems, focusing on its integration with voltage sensors, relay control, real-time monitoring, and potential use cases.

RELAY

The JQC-3FF-S-Z relay is a widely used electromechanical relay known for its reliability in switching applications in various electrical systems. This relay can be employed for detecting and controlling various electrical parameters such as voltage fluctuations in a three- phase system. A relay like the JQC-3FF-S-Z is often used in industrial automation, motor control, and protection systems where fast and reliable switching is essential.

In the context of three-phase fluctuation detection, the JQC-3FF-S-Z relay can act as a protective switching device, providing essential protection against conditions like voltage imbalances, over-voltage, under-voltage, and other fluctuations. The relay will typically be interfaced with a control system, which monitors the voltage levels in each phase. If the system detects an abnormal voltage condition, the relay can be used to disconnect the faulty phase, activate an alarm, or switch to a backup system to prevent damage to the connected equipment.

LED DISPLAY

In modern electrical systems, three-phase power is commonly used for efficient transmission of electricity. This system is prevalent in industrial applications, large motors, power distribution, and renewable energy sources. A three-phase electrical system involves three distinct voltage waveforms, each offset by 120 degrees, which helps deliver a more consistent power supply. However, fluctuations in these voltage phases—such as voltage imbalances, over-voltage, under-voltage, or transient spikes—can lead to damage, inefficiency, or failure of electrical equipment.

To ensure smooth operation and early detection of such fluctuations, the use of LED displays has become a standard method for three- phase fluctuation detection. The integration of LED technology in monitoring systems provides a visual representation that is easy to understand and provides real-time feedback. This article explores the role of LED displays in three-phase fluctuation detection in depth.

Web-Based Monitoring and Cloud Integration

The IoT-enabled three-phase current monitoring system utilizes web-based monitoring and cloud integration to provide real-time data access, remote fault detection, and predictive analytics. The system transmits voltage, current, and fault status to a cloud platform (e.g., AWS, Google Cloud, or ThingSpeak) via Wi-Fi or GSM modules, allowing users to monitor power parameters remotely through a web dashboard or mobile app.

It features automated alerts via SMS/email, historical data analysis for predictive maintenance, and visualized reports for better decision-making. Additionally, the system supports integration with smart grids and renewable energy sources, enhancing power reliability, energy efficiency, and fault prevention. This cloud-based approach ensures 24/7 accessibility, improved diagnostics, and optimized power management for industrial and commercial applications.

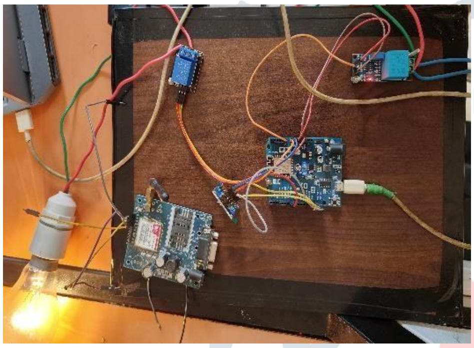
Data Visualization and Control

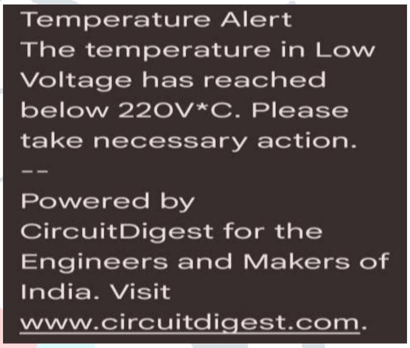
The IoT-enabled three-phase current monitoring system features real-time data visualization through interactive dashboards and mobile apps, displaying voltage, current, and fault conditions in graphs and charts. Automated alerts via SMS/email notify users of power fluctuations and system faults. The system also supports remote control, allowing users to turn electrical loads ON/OFF and manage load balancing. Additionally, historical data analysis helps in predictive maintenance and energy optimization, ensuring better power management, enhanced safety, and reduced downtime.

V.RESULT

The implementation of the IoT-enabled three-phase current monitoring system demonstrated accurate real-time monitoring of voltage and current using smart sensors and microcontrollers. The system effectively detected electrical faults such as overvoltage, undervoltage, phase imbalance, and circuit breaks, providing immediate feedback through a three-LED visual indication mechanism. IoT integration enabled remote monitoring via a cloud platform and real-time alerts through SMS/email, ensuring rapid response to faults. The system also logged historical data, facilitating predictive maintenance and optimizing energy consumption. Overall, the results validate the system's efficiency in enhancing power reliability, minimizing downtime, reducing maintenance costs, and improving the safety and longevity of three-phase electrical systems.

VI. OUTPUT





VII. CONCLUSION:

The proposed IoT-enabled three-phase current monitoring system successfully addresses the limitations of traditional power monitoring methods by providing real-time voltage and current measurement, fault detection, and remote accessibility. By integrating smart sensors, microcontrollers, and IoT connectivity, the system enhances power reliability, safety, and efficiency. It effectively detects faults such as overvoltage, undervoltage, phase imbalance, and circuit breaks, ensuring proactive maintenance and minimizing equipment damage. The three-LED visual indication mechanism and instant SMS/email alerts allow for quick fault identification and resolution. Additionally, the system supports remote monitoring via cloud platforms, enabling users to optimize energy consumption and reduce operational costs.

Future enhancements, such as AI-based predictive maintenance, smart grid integration, and renewable energy compatibility, can further improve the system’s capabilities. Overall, this project demonstrates a cost-effective, scalable, and reliable solution for modern industrial and commercial power management, contributing to the advancement of smart energy monitoring and automation.

VIII. FUTURE WORK

- AI-Based Predictive Maintenance – Implement machine learning to predict failures and classify faults accurately.
- Integration with Smart Grid Systems – Enable automatic load balancing and demand-side management.
- Enhanced IoT Connectivity – Upgrade to 5G for better real-time data transmission.
- Mobile Application for Remote Control – Develop a mobile app for real-time monitoring and control.
- Advanced Fault Detection and Isolation – Improve fault location accuracy and introduce self-healing mechanisms.
- Energy Consumption Analytics & Cost Optimization – Provide reports on power usage and suggest ways to reduce energy waste.
- Integration with Renewable Energy Sources – Adapt the system to monitor solar and wind power integration.
- Hardware Miniaturization & Cost Reduction – Develop a compact and cost-effective version for wider adoption.
- Security Enhancements – Implement blockchain and cybersecurity features for secure data transmission.
- Scalability for Large-Scale Deployment – Design a centralized dashboard to monitor multiple industrial sites.

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