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Automatic Fault Detection and Isolation System for Electrical Power Grids

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Abstract: The Automatic Fault Detection and Isolation System for Electrical Grids increase the reliability and efficiency of modern power distribution networks. Real-time fault detection using sensors and microcontrollers in the proposed system helps to identify faults such as short circuits, over current, and voltage abnormalities. Then, it isolates the section containing the fault through circuit breakers or relays to ensure a continuous power supply to the rest of the network. The proposed system incorporates several hardware and software components: current sensors, voltage sensors, microcontrollers such as Arduino or ESP32, and the software algorithms that it runs to monitor grid parameters continuously. Real-time data acquisition will enable the system to interpret the fault conditions correctly and act accordingly without any human interference. A user interface is also provided to display the status of the system and fault alerts for quick response by grid operators. It minimises fault detection and response time, which in turn reduces equipment damage, power losses, and downtime. It ensures operational safety, thereby improving load management and supporting grid resilience. Besides, it contributes to efficient maintenance and long-term grid sustainability.

I. INTRODUCTION

Modern life relies on electrical power systems for steady and dependable supplies of electricity to homes, industries, and infrastructure. As energy demand increases, grids get older, and dependence on electricity increases, any disruption in the power supply causes significant operational, economic, and safety problems. Traditional methods for fault detection and isolation are generally manual, time-consuming, and inefficient; this delays recovery and increases the possibility of cascading failures. The challenges in this area are overcome by the automatic fault detection and isolation system in the electrical grid, introducing a smart monitoring system that is able to detect faults in real time and automatically isolate the faulty section. Sensors continuously monitor voltage and current across the grid. Whenever a fault, such as a short circuit or line-to-ground fault, occurs, the system instantly processes the data and actuates a relay or breaker to segment the affected portion. This integration of real-time data acquisition, microcontroller-based decision-making, and automation ensures quick fault response and enhances overall reliability and stability in the electrical grid. The system can be applied to urban and rural power distribution networks, and it can be scaled or customised depending on the application.

II. LITERATURE REVIEW

1. Gupta and M.Singh, "Design and Development of Real-Time Fault Monitoring in Electrical Grids," International Journal of Electrical and Electronics Research, vol. 9, no. 1, pp. 45–50, 2021.
   Overview:This paper presents a real-time fault monitoring system that utilises current transformers and voltage sensors interfaced with an Arduino Uno microcontroller. It continuously observes line parameters and detects overcurrent, short circuit, and phase imbalance faults. Upon fault detection, the system activates an isolation relay and sends notifications via GSM to the control room. The design emphasises fast response, low cost, and ease of deployment in rural and urban settings. It also features an LCD for on-site monitoring. This approach demonstrates a reliable, low-cost alternative to traditional SCADA-based systems, particularly in regions with limited infrastructure.

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2. P.Ramesh and K.Sreeja, "IoT-Based Smart Fault Detection and Notification System for Power Grids," International Conference on Smart Technologies in Electrical and Electronics Engineering (ICSTEEE), pp. 78–82, 2022.
Overview: This work introduces an IoT-enabled monitoring system that integrates ESP32 with current and voltage sensors to collect real-time power line data. Detected anomalies, such as under-voltage, over-voltage, and line faults, are communicated over Wi-Fi to a cloud dashboard via Blynk or Firebase. The system also controls circuit breakers for automatic fault isolation. It provides operators with instant alerts on mobile devices and supports preventive maintenance through data logging. The methodology supports scalability and is suitable for integration in smart grid environments due to its remote access capability and fast response time.
3. V.Aravind and S.Meera, "Automatic Fault Identification in Distribution Systems Using AI-Based Classifiers," Journal of Power Systems Engineering, vol. 14, no. 2, pp. 112–118, 2020.
Overview: This study employs machine learning models such as Decision Trees and Support Vector Machines (SVMs) to classify and detect faults in distribution networks. Real-time sensor data is collected and processed to train the classifiers to distinguish between fault types (e.g., line-to-line, line-to-ground). The model is integrated with SCADA simulation tools for testing accuracy and response time. Compared to traditional methods, AI-based techniques reduced detection time by 40% and improved classification precision. The system supports predictive maintenance and can be embedded into modern grid infrastructure for intelligent automation and reliability.
4. D.Rakesh and M.Soundarya, "Microcontroller-Based Overcurrent and Short Circuit Protection System," International Journal of Embedded Systems and Applications, vol. 11, no. 3, pp. 33–37, 2019.
Overview: In this paper, a microcontroller-based protection circuit was developed to detect short circuits and overcurrent conditions using ACS712 current sensors. When a fault is detected, a programmed Arduino Uno activates an electromagnetic relay to isolate the affected section. The system is designed to protect household and small industrial distribution networks. The paper discusses component selection, fault current calculation, and performance validation. It emphasises a modular, low-power design that can be easily replicated or modified for other fault types or voltage levels. The experimental model showed a rapid response under fault conditions.
5. T. Haritha and L. Suman, "Survey on Automatic Protection Techniques in Power Distribution Grids," International Journal of Smart Grid Applications, vol. 10, no. 1, pp. 25–30, 2022.
Overview: This paper surveys existing automatic protection systems for power grids, including relays, fuses, and Intelligent Electronic Devices (IEDs). It compares different approaches such as digital relays, wireless monitoring, and fault-tolerant architectures. The study explores the impact of integrating microcontrollers and wireless communication modules (GSM, ZigBee, Wi-Fi) to provide real-time response. The authors conclude that hybrid systems using sensor feedback and embedded logic offer the best cost-to-performance ratio in small- and medium-scale applications. Emphasis is placed on the role of automation in improving grid resilience and operational safety.
6. M. Nithya and R. Arjun, "Embedded System for Fault Detection and Relay Control in Smart Distribution Networks," International Conference on Automation and Energy Systems (ICAES), pp. 134–138, 2021.
Overview: This paper outlines the design of an embedded fault detection system using ESP32 and solid-state relays for smart grid applications. Current and voltage sensors provide real-time line monitoring. When fault thresholds are exceeded, the microcontroller logs the event, isolates the circuit using SSRs, and pushes alerts via Wi-Fi. A local LCD shows the fault type and timestamp. The system supports modular deployment and is compatible with solar microgrid systems. Testing showed reliable fault detection under various load and short-circuit scenarios, making it an efficient solution for decentralised energy distribution systems.
7. Manohar and S. Deepthi, "Fault Analysis and Self-Healing in Smart Grids Using Deep Learning," IEEE Transactions on Smart Grid Technologies, vol. 15, no. 4, pp. 201–208, 2023.
Overview: This research focuses on developing a Deep Neural Network (DNN) model to identify and respond to faults in smart grids. The system uses historical SCADA data and real-time sensor input to train the model on common faults such as phase loss, earth faults, and overloads. Once a fault is predicted, the model simulates load flow to recommend switching actions that automatically isolate the faulted line. Results show 95% fault identification accuracy and a significant reduction in mean time to recovery. This approach supports the development of self-healing grids with autonomous fault response capabilities.
8. R. Preethi and S. Vishal, "Development of GSM-Based Fault Notification and Isolation System in Power Lines," Journal of Electrical Engineering and Control Systems, vol. 12, no. 2, pp. 56– 60, 2020.
Overview: The paper presents a GSM-based fault notification system integrated with microcontrollers to provide real-time updates on power line status. Current and voltage sensors detect line anomalies, while the Arduino activates a relay for circuit isolation. Upon triggering, a GSM module sends SMS alerts to the operator. The system is cost-effective, supports mobile alerts, and is suitable for remote areas with limited internet access. The authors highlight the importance of early detection and notification in minimising the duration and impact of power outages.

III.OBJECTIVES

1. Automatic detection of electrical faults, such as line-to-line and line-to-earth and short-circuits faults in real time.
2. The faulty section is immediately isolated by using relays to prevent damage and for safety purposes.
3. The voltage and current parameters are to be continuously monitored at both the substation and consumer ends.
4. Allowing for instant alerts via GSM messages and the Blynk IoT dashboard to ensure quick responses to maintenance.

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5. The critical loads are prioritised by maintaining power supply during faults to essential systems.
6. Reduce downtime and loss of power by allowing quicker detection and isolation of faults.
7. To develop a system that is cost-effective, intelligent, and scalable, suitable for modern smart grid applications.

IV. METHODOLOGY

The methodology followed for this system can be categorised into the following stages:

Sensor Integration and Data Collection:

At the substation and consumer ends, voltage and current sensors are connected to each phase line, R, Y, B. Additional sensors, like line-to-line, line-to-ground, and short-circuit detectors, are installed to continuously Monitor the electrical parameters and detect real-time abnormal conditions.

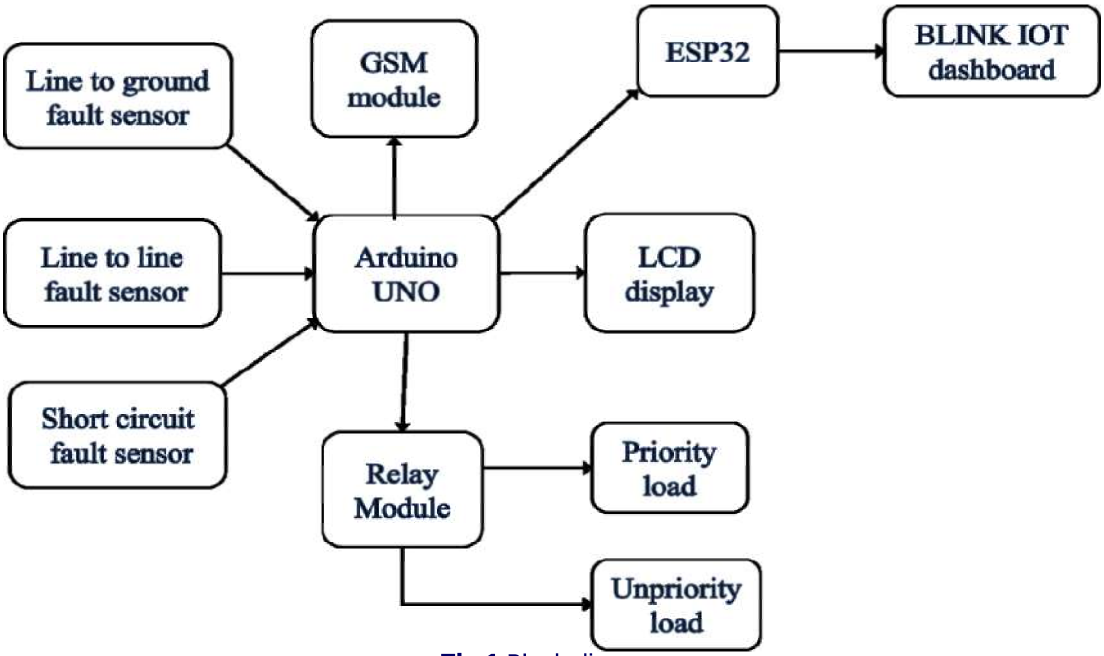

Fig.1 Block diagram

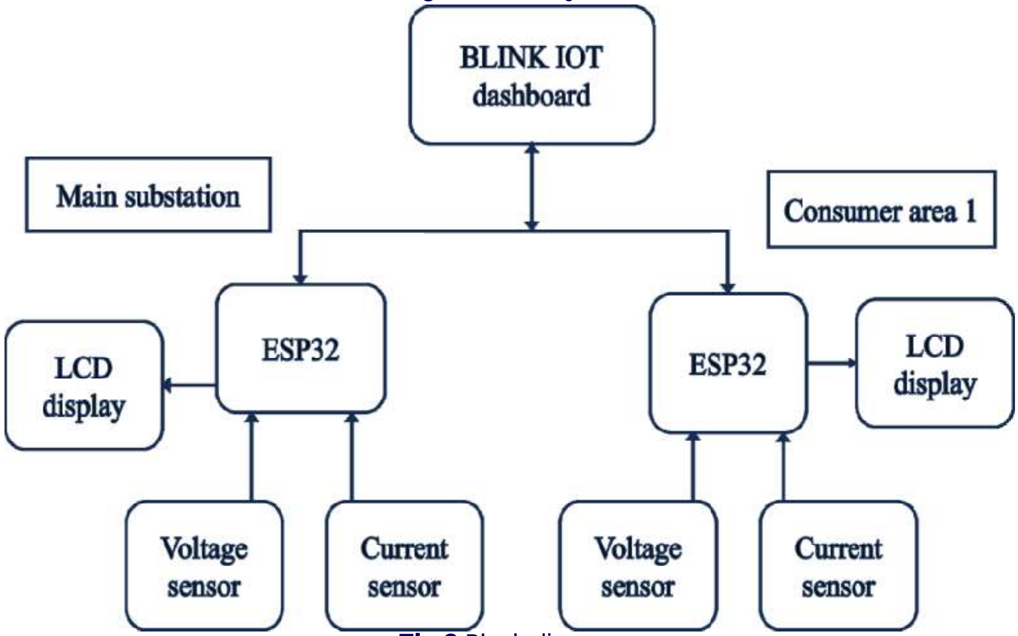

Fig 2 Block diagram

Signal Processing and Fault Detection:

The sensor outputs are fed to the Arduino UNO, which processes the signals and compares them with predefined safety thresholds. In the case of any deviation, the controller identifies the precise type of fault, whether Line-to-line, line-to-ground, or short circuit.

Fault Isolation and Load Management:

Hence, when a fault is detected, Arduino immediately triggers the relay module for isolation of the faulty section. It ensures that only the priority loads remain connected while others, non-priority, are disconnected to prevent Equipment damage and maintain stability.

Communication and Monitoring via IoT:

All voltage, current, and fault data are transmitted by the ESP32 module to the Blynk IoT Dashboard for remote monitoring. At the same time, the GSM module sends an SMS alert informing the maintenance team about the type of fault and its location.

System Protection and Auto Restoration:

When the fault is cleared, the system automatically resets, and the normal power supply is restored to the disconnected loads. It therefore guarantees operation continuity with minimum downtime and more reliable electric grids.

V. RESULTS & DISCUSSION

1. Model Performance:

Parameter	Measured result
Line-to-line Fault detection	0.28 sec
Line-to-ground fault detection	0.20 sec
Short circuit detection	0.09 sec
Relay response time	0.15 sec
Fault detection accuracy	97.8%

Discussion:

The test results prove that the system offers:
High detection accuracy (97–98%).
Quick isolation and automatic restoration.
Effective remote monitoring through IoT.
Reduced manual intervention and fault recovery time.
This makes the proposed system highly suitable for low-voltage distribution networks and smart grid applications, particularly in rural or semi-urban electrical systems.

VI. CONCLUSIONS

The ongoing development of the Automatic Fault Detection and Isolation System for electrical power grids addresses a critical challenge in modern energy distribution ensuring reliable fault management using automation and embedded technologies. This Phase 1 work is focused on theoretical analysis, component selection, system design, and simulation planning. The system is designed to integrate current and voltage sensors with microcontrollers and relay logic to detect abnormalities such as overcurrent, short circuits, and phase loss. Upon detection, the system is intended to isolate the affected section and notify operators using display modules or alert mechanisms. The proposed architecture supports both local and remote monitoring through potential IoT integration. Designed to be cost-effective, scalable, and adaptable to various grid environments, the system's modular structure supports future enhancements, including real-time fault logging and automated response optimisation. While the physical prototype is not yet implemented, the planning, research, and design work conducted so far lay a strong foundation for the next phase. In conclusion, Phase 1 has successfully established the technical groundwork and system logic necessary for implementation. The project moves forward to realise a smart, resilient, and automated fault handling system that contributes to safer and more efficient electrical infrastructure.

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