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Ai-Based Smart Grid Fault Detection System

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Abstract- - Electrical power systems are an important part of our daily lives, and their reliable operation is essential for domestic, commercial, and industrial applications. However, electrical faults such as short circuits, overloads, overcurrent, and voltage fluctuations can affect the performance of the power system and may cause equipment damage or power interruptions. Traditional protection methods are useful, but there is a need for improved monitoring and faster identification of different fault conditions. This paper presents an AI-Based Smart Grid Fault Detection System that uses voltage and current sensors to monitor electrical parameters. The collected readings are processed using a Raspberry Pi 4 with support from an ESP32 microcontroller. A machine learning model is used to analyse the measurements and identify selected abnormal operating conditions. Whenever a fault is detected, the system provides an alert through an LCD display and buzzer. A relay module is used to demonstrate automatic disconnection of the load during selected fault conditions. The main aim of this project is to show how artificial intelligence can be combined with electrical monitoring to make fault detection more intelligent, reliable, and efficient.

Keywords— Artificial Intelligence, Smart Grid, Fault Detection, Machine Learning,

Raspberry Pi 4,ESP32, Voltage Sensor, Current Sensor.
Keyword - Raspberry Pi, IoT, Energy Monitoring, ZMPT101B, ACS712, ADS1115, Relay Protection, Flask, SQLite, Smart Energy Management.

I INTRODUCTION

Electricity plays an important role in almost every field, including homes, industries, businesses, and public services. As the demand for electrical energy continues to increase, maintaining a reliable power supply has become more important. During the operation of an electrical network, different types of faults may occur. Common examples include short circuits, overloads, overcurrent, and abnormal voltage conditions. If these faults are not identified in time, they can damage electrical equipment and interrupt the power supply[1]. Normally, electrical systems use protective devices such as fuses, circuit breakers, and protective relays to detect and isolate faults. These devices provide basic protection, but additional intelligent monitoring can help identify and understand different fault conditions. Smart grid technology combines electrical systems with digital monitoring, communication, and automation. Artificial Intelligence (AI) and Machine Learning (ML) can make this technology more effective by analysing electrical readings and recognising abnormal patterns. In this project, an AI-based fault[2].

detection system is developed to monitor voltage and current parameters, identify selected electrical faults, and provide alerts. The system also demonstrates automatic load disconnection using a relay module.

II RELATED WORK

Several researchers have studied different methods to improve fault detection and protection in electrical power systems. Their work shows how conventional protection techniques can be supported by modern monitoring systems and artificial intelligence.

Vaish et al. [3] presented a detailed study on the use of machine learning for power system fault diagnosis. Their work discussed different techniques used for fault detection, classification and location. The study also explained how machine learning can help overcome some limitations of conventional methods, particularly when power systems become more complex.

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Porawagamage et al. [4] reviewed the applications of machine learning in power system protection and emergency control. They explained that machine learning can help analyse electrical system data and support faster decisions during abnormal operating conditions. At the same time, they highlighted challenges such as reliability, false detection, model complexity and the need for proper testing before practical implementation.

Another study on incipient fault detection in power distribution networks [5] examined both conventional and advanced approaches. It highlighted the importance of identifying faults at an early stage to reduce equipment damage and avoid unnecessary power interruptions. The study also discussed the growing role of artificial intelligence and data-based monitoring in modern distribution systems.

From the above studies, it is clear that intelligent fault detection has the potential to improve the monitoring and reliability of electrical networks. However, practical implementation also requires suitable sensors, reliable data collection, proper processing and timely fault indication.

The present project, AI-Based Smart Grid Fault Detection System, focuses on developing a prototype that combines voltage and current sensing with Arduino/ESP32 and Raspberry Pi 4. The system is intended to monitor electrical parameters, identify abnormal conditions and provide alerts, with relay-based isolation demonstrated in the prototype. This work brings together sensor-based monitoring and intelligent processing in a compact setup suitable for an educational smart-grid application.

III PROPOSED METHOD

The proposed system is designed to monitor electrical parameters and identify abnormal operating conditions. It consists of voltage and current sensors, an ESP32 microcontroller, Raspberry Pi 4, relay module, LCD display, buzzer, power supply, and test load. The voltage and current sensors continuously measure the electrical parameters of the circuit. The ESP32 collects these readings and sends them to the Raspberry Pi 4. The Raspberry Pi 4 processes the collected data and runs the selected machine learning model. The model analyses the measurements and identifies the operating condition based on the data used during training. If an abnormal condition is detected, the system displays the corresponding message on the LCD and activates the buzzer. The relay module then demonstrates load disconnection when the programmed fault conditions are satisfied.

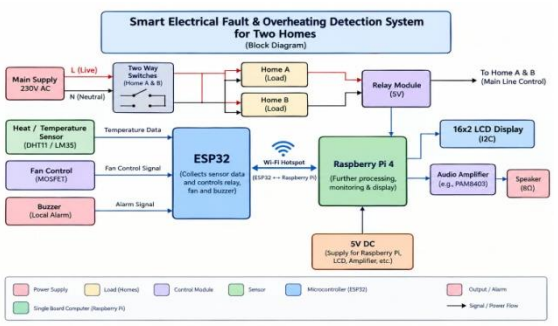


Fig.A Block diagram

The project is developed through a series of steps, starting from hardware connections and ending with testing and result analysis.

A. Hardware Setup: The voltage sensor, voltage and current sensor, ESP32, Raspberry Pi 4, relay module, LCD, and buzzer are connected according to the circuit design. Each component is checked to ensure proper operation.

B. Fault Detection: During operation, new voltage and current readings are supplied to the trained model. The model analyses these values and predicts the corresponding operating condition.

C. Fault Indication: When an abnormal condition is identified, the system displays the fault information on the LCD. At the same time, the buzzer produces an audible warning[6].

D. Automatic Isolation: If the detected condition satisfies the programmed control logic, the relay module disconnects the test load[7]. This demonstrates the basic working principle of automatic fault isolation.

E.Testing: The complete prototype is tested under different operating conditions. Sensor readings, fault identification, buzzer operation, relay response, and detection time are observed and recorded[8].

IV. RESULTS AND DISCUSSION

The developed prototype was tested to observe its performance under different electrical operating conditions. Voltage and current readings were collected using the connected sensors and processed through the proposed hardware arrangement. The Raspberry Pi4[9] is used to analyse the collected measurements using the selected machine learning model. The system response is observed through the LCD display, buzzer, and relay module. When a selected abnormal condition is identified, the system provides an alert and demonstrates load disconnection according to the programmed control logic. The results should be analysed using the actual experimental readings. The machine learning model can be evaluated using accuracy, precision, recall, and a confusion matrix. The time taken to identify a fault and the number of false detections should also be considered.

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Overall, the prototype demonstrates how electrical sensors and machine learning can work together to monitor selected fault conditions and provide an automatic response.

4.1 BYNK IOT DISPLAY

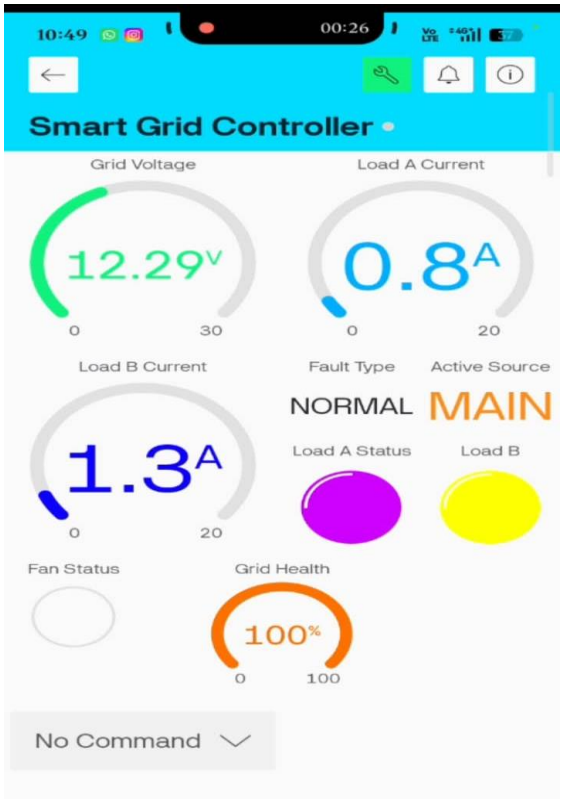


Fig.B Blynk Iot Display (no fault)

The Blynk IoT application was used to display the electrical parameters and operating status of the system. It provides a simple visual representation of grid voltage, individual load currents, fault type, active power source, fan status and overall grid health[10].

During normal operation, the application displayed a grid voltage of 12.29 V, Load A current of 0.8 A and Load B current of 1.3 A. The fault status was shown as NORMAL, the active source was MAIN and grid health was displayed as 100%.

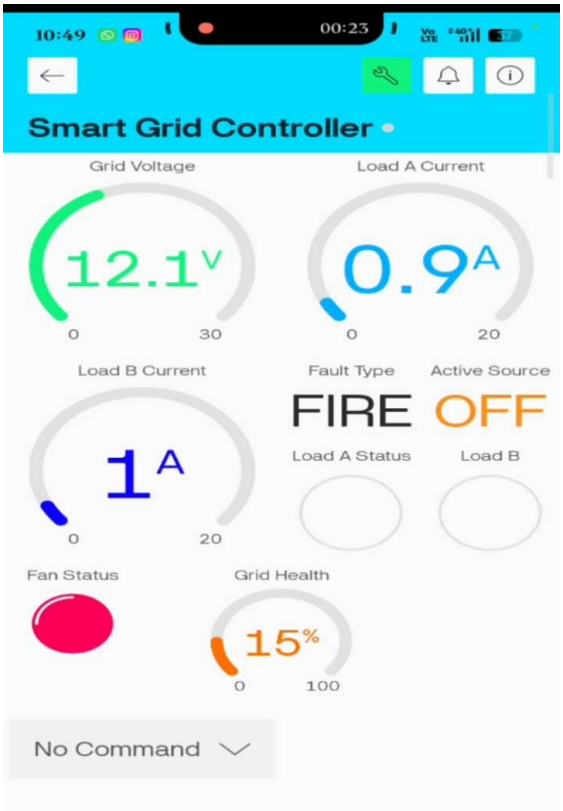


Fig.C Blynk Iot Display (Fault detected)

When a fire condition was introduced during testing, the application showed the fault type as FIRE. The voltage reading changed to 12.1 V, while Load A and Load B currents were 0.9 A and 1.0 A, respectively. The active source changed to OFF, the load indicators changed to their isolated state, the fan indicator became active and grid health dropped to 15%.

The difference between the normal and fault conditions shows that the application can help the user understand the condition of the system at a glance. It also provides a convenient way to observe the response of the prototype without being physically present near the panel.

4.2 WEB DASHBOARD

A web-based dashboard was also developed to provide a central view of the smart grid operation. It displays important information such as grid health, voltage, total current, active source, power flow, fault intelligence and system status.

During normal operation, the dashboard displayed a grid voltage of 12.1 V and a total current of 1.4 A. The main source was shown as active, and grid health was displayed as 100%. The AI fault intelligence panel showed a confidence score of 98.7% and indicated that no fire, overload or short-circuit condition was detected at that time.

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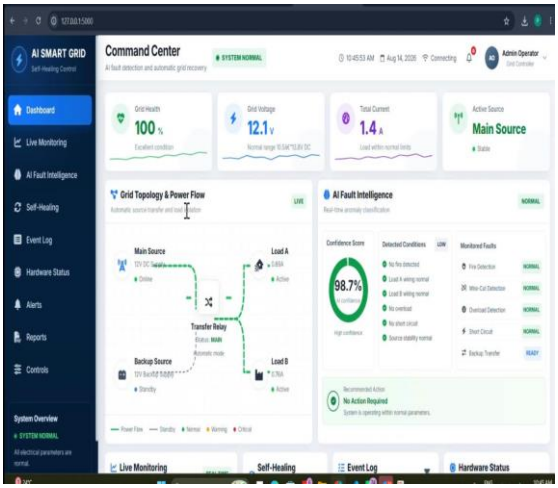


Fig.D.Website data display

The dashboard also displayed the power flow between the main source, backup source, transfer relay and two loads. The live monitoring section provided voltage and current trends, while the event log recorded system activity. These features help the operator understand the present condition of the grid and review its previous events.

E. Overall Discussion

The results indicate that the developed prototype can monitor electrical parameters, display system conditions and provide notifications when a fault is detected. The combination of Telegram, Blynk IoT and the web dashboard makes the monitoring process more convenient and gives the operator information through different platforms.

The fault response demonstrated during testing includes switching OFF the source, isolating the loads, activating the fan and generating a buzzer alert. The recovery notification further shows that the system can communicate when the detected condition has cleared.

Overall, the prototype demonstrates the basic concept of an intelligent and self-healing smart grid monitoring system. Further testing with more fault conditions, repeated measurements and verified machine-learning performance can help improve its reliability and suitability for larger electrical applications

4.3 TELEGRAM

The Telegram notification system was used to provide information about important events in the grid. During testing, a fire or dangerous temperature condition was detected in the grid panel. The system immediately generated a notification showing the detected condition, voltage and current readings, and the actions taken by the protection system.

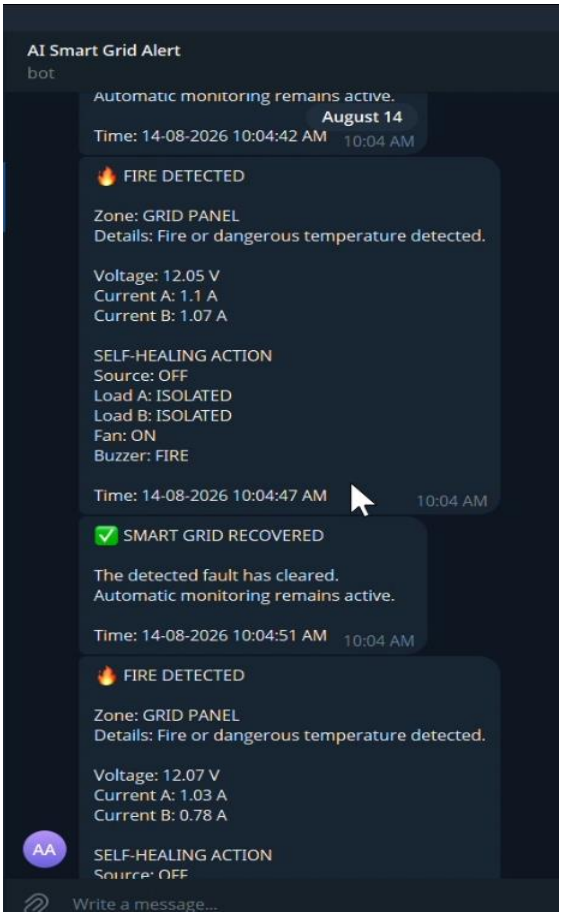


Fig E.Telegram Notifications

In the recorded alert, the voltage was 12.05 V, while Load A and Load B currents were 1.1 A and 1.07 A, respectively. After detecting the condition, the source was switched OFF, both loads were isolated, the fan was turned ON and the buzzer was activated. These actions demonstrate how the system responds to a dangerous condition and informs the user remotely.

A subsequent Telegram message indicated that the detected fault had cleared and automatic monitoring was still active. This makes it possible for the user to know both when a fault occurs and when the system returns to its normal monitoring condition.

V. CONCLUSION

The AI-Based Smart Grid Fault Detection System demonstrates how artificial intelligence can be used in electrical power system monitoring. The project combines voltage and current sensors with ESP32 and Raspberry Pi 4 to collect and analyse electrical measurements. The system identifies selected abnormal operating conditions using a machine learning model and provides alerts through an LCD display and buzzer. It also demonstrates automatic load disconnection using a relay module. This project provides a

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practical understanding of how AI and electrical engineering can be combined to develop intelligent monitoring systems. In the future, the system can be improved by using additional sensors, larger datasets, better classification algorithms, and remote

monitoring facilities. Further testing and validation are required before applying the system to actual power distribution networks.

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