



# AI-ENABLED EDGE DEVICE FOR GRID FAULT ANALYSIS

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**Abstract:** This paper presents an AI-enabled edge-based system for real-time grid fault detection and analysis. Electrical parameters such as voltage, current, frequency, and phase angle are continuously monitored using sensors. The data is processed locally on an edge device such as Raspberry Pi or ESP32 integrated with a lightweight AI model. The trained machine learning model identifies abnormal patterns and classifies fault types including single line-to-ground, line-to-line, and three-phase faults. Immediate alerts are generated and transmitted to the control center through IoT communication. By performing analytics at the edge, the system minimizes latency, reduces bandwidth usage, and ensures rapid fault isolation. This approach enhances grid reliability and supports smart grid automation. The increasing complexity of modern power systems demands fast and reliable fault detection mechanisms to ensure system stability and safety.

**KEYWORDS :** Artificial Intelligence, Edge Computing, Fault Detection, Smart Grid, IoT, Power System protection

## ● Introduction

This Electrical power systems form the backbone of modern infrastructure, requiring continuous monitoring and protection to ensure stability and reliability. Faults such as short circuits, overcurrent conditions, and voltage fluctuations can disrupt power supply and cause severe damage to equipment. Traditional fault detection methods rely on centralized control systems, which involve transmitting large volumes of data to a central processing unit. This approach introduces communication delays and limits real-time responsiveness. With the advent of smart grids and distributed energy resources, the need for intelligent and decentralized fault detection systems has become critical. Edge computing enables data processing at or near the source of data generation, reducing latency and improving response time. When combined with Artificial Intelligence (AI), edge devices can analyze data in real time and make autonomous decisions. This complexity increases the probability of faults such as line to-ground faults, line-to-line faults, overloads, and

voltage instability. Traditional grid fault detection methods rely on centralized monitoring and manual inspection, which often leads to delayed fault identification and longer restoration times. Recent advancements in [1] Artificial Intelligence (AI) and Edge Computing have enabled real-time fault analysis directly at the network edge. An AI-enabled edge device processes sensor data locally, reducing latency and dependence on cloud infrastructure. Machine learning models deployed on edge devices can quickly detect anomalies, classify fault types, and initiate protective actions. This paper proposes an AI-enabled edge device for grid fault analysis, designed to provide rapid detection and isolation of faults, thereby enhancing the reliability and efficiency of power system.

### *Literature Survey*

The rapid evolution of modern power systems, particularly with the integration of renewable energy sources and distributed generation, has significantly increased the complexity of grid operation and fault management. Traditional fault detection methods, which rely on threshold-based protection schemes and centralized monitoring, are often insufficient in handling dynamic and large-scale grid environments. Consequently, recent research has focused on the integration of [2] Artificial Intelligence (AI), Internet of Things (IoT), and edge computing for efficient and real-time fault analysis.

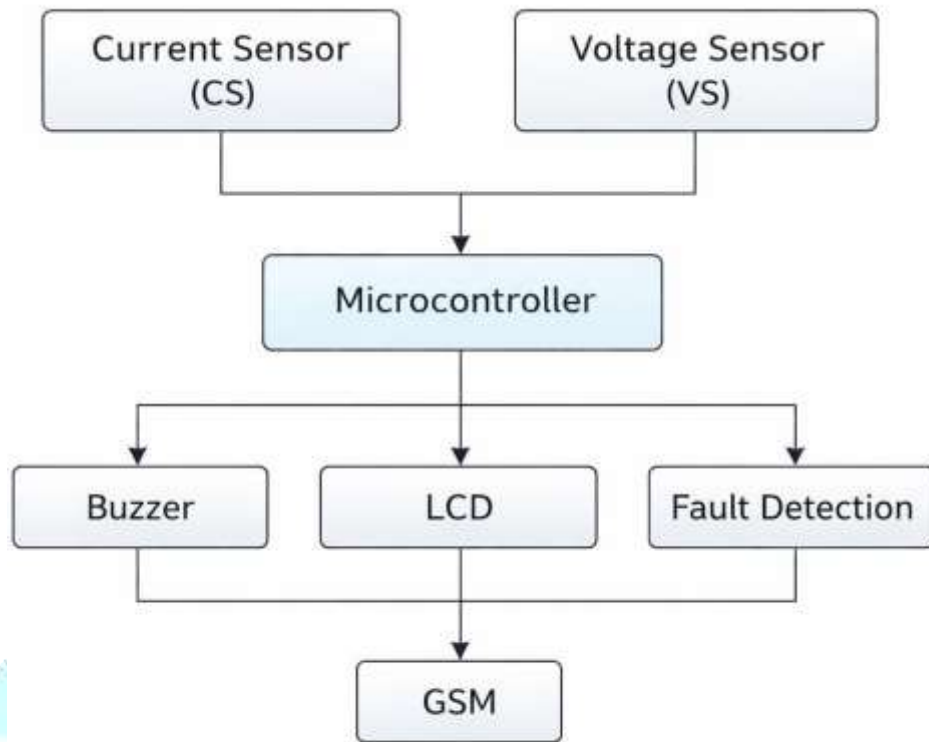
### *Proposed Method*

This paper proposes an intelligent fault detection and isolation system based on an AI-enabled edge device architecture. The objective of the proposed method is to achieve real-time fault analysis with minimal latency by performing data processing locally at the grid edge rather than relying on centralized cloud systems.

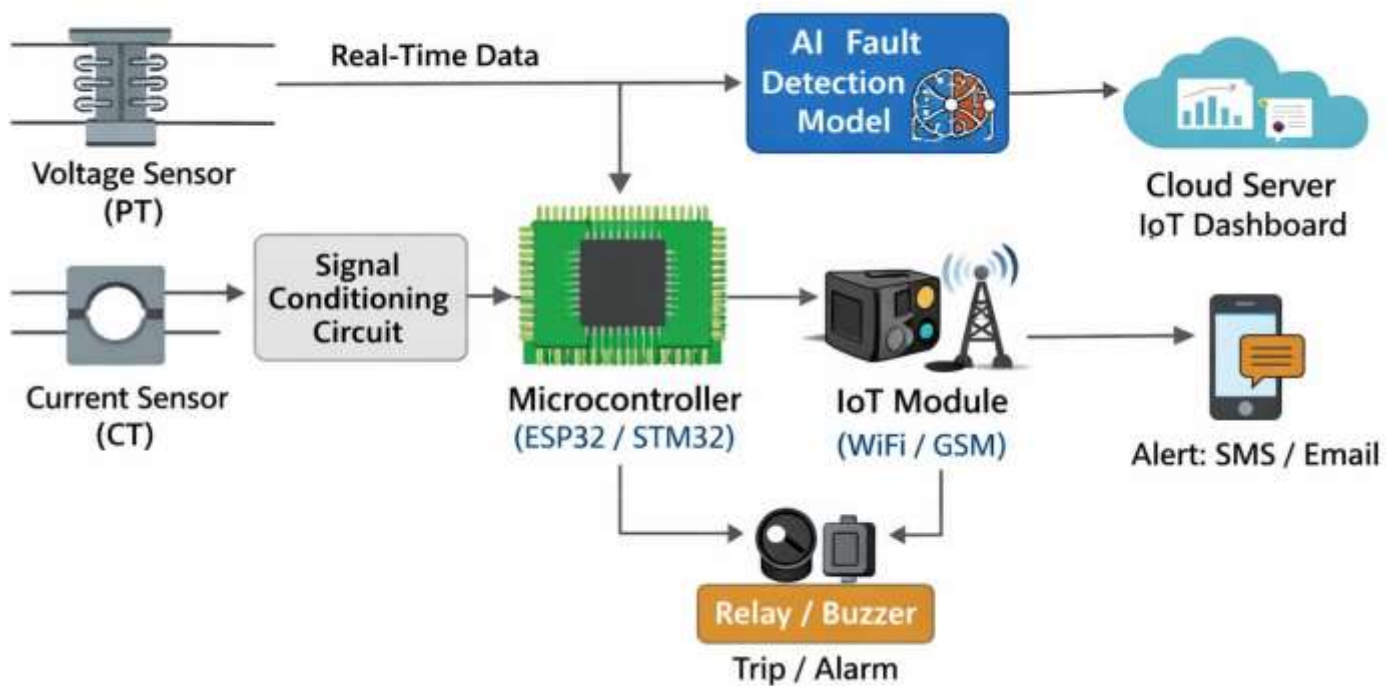
### *Components*

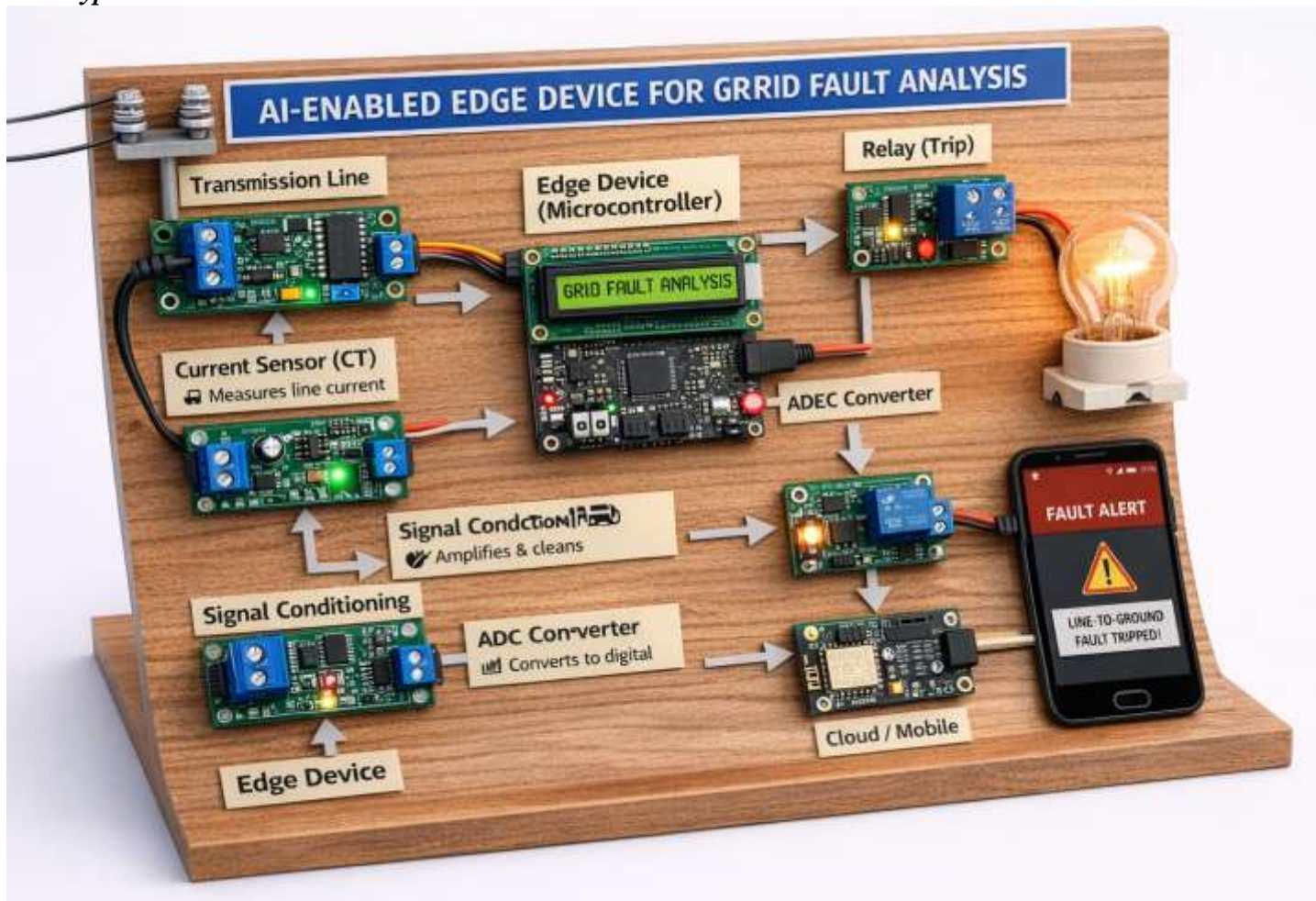
Components	Software Components
<b>Hardware Components</b> <ul style="list-style-type: none"> <li>• Sensors (CT &amp; PT)</li> <li>• Signal Conditioning Circuit</li> <li>• ADC</li> <li>• Microcontroller</li> <li>• Relay</li> <li>• IoT Module</li> <li>• Power Supply</li> <li>• Display</li> </ul>	<b>Software Components</b> <ul style="list-style-type: none"> <li>• Embedded C</li> <li>• Machine Learning (ANN)</li> <li>• Signal Processing</li> <li>• IoT Platforms</li> <li>• Simulation Tools</li> </ul>

*Block Diagram*



*Circuit diagram*



*Prototype model*

The prototype model of the AI-Enabled Edge Device for Grid Fault Analysis demonstrates a real-time system for detecting and isolating electrical faults in a power network. In this setup, voltage and current sensors continuously monitor the electrical parameters and send the signals to a signal conditioning unit, where noise is filtered and the data is prepared for processing. The conditioned signals are then analyzed by a microcontroller acting as an edge device, which performs local computation using Edge Computing. An AI-based module, such as an Artificial Neural Network, is used to identify abnormal conditions and classify different types of faults. Once a fault is detected, a relay is activated to disconnect the faulty section and protect the system.

*Equations*

$$\frac{I_p}{I_s} = \frac{N_s}{N_p}$$

Equation:1

$$V_{out} = I_s \times R_b$$

Equation:2

$$V_{out} = V_{offset} + (S \times I)$$

Equation:3

$$V_{out} = V_{in} \times \frac{R_2}{R_1 + R_2}$$

Equation:4

$$V_{out} = 10 \text{ mV} \times T$$

Equation:5

Equation:6

$$T = \frac{V_{out}}{10 \text{ mV}}$$

Equation:7

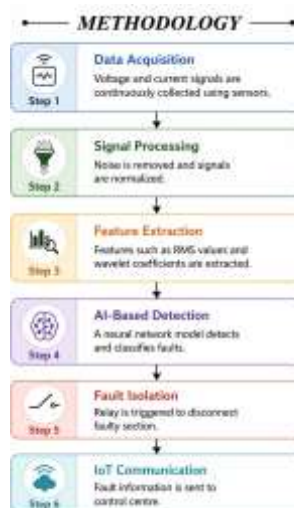
$$f = \frac{1}{T}$$

$$f = \frac{N}{t}$$

IJCRT

Equation:8

## Methodology

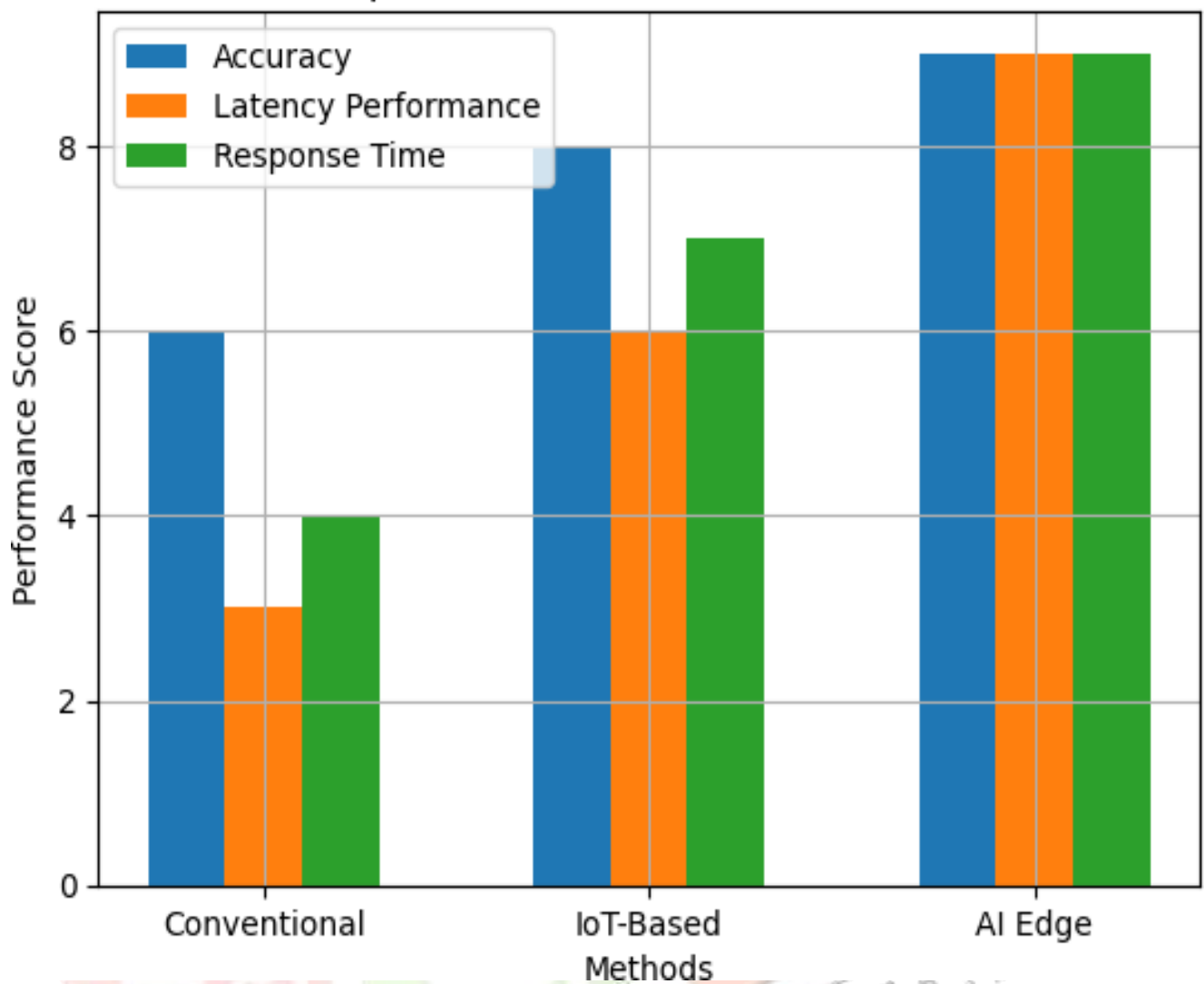


## Results and Discussion

The proposed AI-enabled edge device was implemented and tested under different grid fault conditions such as voltage sag, swell, overcurrent, and short circuit faults. The system performance was evaluated based on fault detection accuracy, response time, and reliability. The edge device successfully processed real-time data from voltage and current sensors and identified abnormal conditions using the trained machine learning model. The results indicate that edge computing significantly reduces latency compared to cloud-based systems and ensures faster fault isolation.

Fault Type	Voltage (V)	Current (A)	Detected Condition	Response Time (ms)	Accuracy (%)
Normal Condition	230	5	No Fault	5	100
Voltage Sag	180	6	Fault Detected	8	97
Voltage Swell	260	5.5	Fault Detected	7	96
Overcurrent	230	10	Fault Detected	6	98
Short Circuit	50	20	Fault Detected	4	99

Overall, the proposed AI-enabled edge device presents a robust and efficient solution for modern smart grid applications. It offers a balance between speed, intelligence, and reliability, making it highly suitable for real-time fault detection and isolation in power transmission and distribution networks.

*Comparison chart***Comparison of Fault Detection Methods****References**

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