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ELECTROSENTRIX: AN IOT-BASED INTELLIGENT ELECTRICAL POLE FAULT DETECTION AND ACCIDENT PREVENTION FRAMEWORK

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Abstract: Electrical poles are critical components of power distribution networks, yet faults such as current leakage, conductor breakage, and pole electrification can pose serious risks to public safety and infrastructure reliability. This paper presents ElectroSentrix, an IoT-based intelligent electrical pole fault detection and accident prevention framework designed to monitor pole conditions continuously and respond to hazardous situations in real time. The proposed system integrates voltage sensors, current sensors, an ATmega328 microcontroller, a NodeMCU communication module, an LCD display, and a voice alert unit to detect abnormal electrical conditions and issue timely warnings. Upon fault identification, the framework generates local audio notifications, displays fault information, and transmits alerts to authorized personnel through an IoT platform for rapid maintenance action. Automated monitoring minimizes manual inspection efforts and enhances operational efficiency while reducing the likelihood of electrocution incidents. Experimental implementation demonstrates reliable fault detection, prompt alert generation, and effective communication capabilities. The developed framework offers a cost-effective, scalable, and practical solution for improving electrical pole safety, ensuring public protection, and supporting smarter power distribution infrastructure.

Index Terms – Electrical Pole Safety, Internet of Things (IoT), Fault Detection, Accident Prevention, Smart Monitoring, NodeMCU, ATmega328, Voltage Sensor, Current Sensor, Public Safety.

I. INTRODUCTION

Electricity has become an indispensable part of modern life, supporting residential, commercial, industrial, and public utility applications. The effectiveness of any power distribution system depends not only on its ability to deliver uninterrupted electricity but also on maintaining a high level of operational safety. With the rapid growth of urban infrastructure and increasing dependence on electrical energy, ensuring the reliability and protection of distribution networks has become a significant challenge. Failures within electrical systems can result in power outages, equipment damage, economic losses, and serious threats to human life. Therefore, continuous monitoring and timely fault detection are essential for improving the safety and efficiency of electrical infrastructure.Among the various components of the power distribution network, electrical poles play a crucial role in supporting overhead transmission and distribution lines. These poles are exposed to diverse environmental conditions such as rainfall, storms, humidity, corrosion, and accidental physical damage. Over time, such conditions may lead to insulation failures, current leakage, conductor breakage, or the presence of hazardous voltages on pole structures. When an electrical pole becomes energized due to a fault condition, it can pose a severe risk to pedestrians, animals, and maintenance personnel. In many cases, delayed fault identification increases the possibility of electrical accidents and complicates maintenance operations.Traditional inspection and maintenance practices primarily rely on manual observation and periodic checking, which may not provide immediate information regarding developing fault conditions. As a result, dangerous situations can remain unnoticed until significant damage or accidents occur. The growing availability of smart sensing technologies and wireless communication systems has created opportunities for developing intelligent monitoring solutions capable of addressing these limitations effectively.Recent advancements in the Internet of Things (IoT), embedded systems, and wireless communication technologies have enabled the development of intelligent monitoring solutions for electrical infrastructure. By integrating sensors, microcontrollers, communication modules, and alert mechanisms, electrical faults can be detected and reported in real time with minimal human intervention. Such systems provide continuous monitoring of voltage and current conditions, allowing rapid identification of abnormal situations that may threaten public safety. The generated alerts can be transmitted instantly to responsible authorities, enabling timely maintenance and corrective actions. Furthermore, the inclusion of local warning mechanisms helps prevent accidental contact with hazardous electrical poles and damaged conductors.

II. Related Works

Article [1] "IoT Based Smart Fault Identification and Monitoring System for Electric Poles" by Mohammed Mushraf M and Krishnapriya C in 2024: This paper presents an IoT-enabled monitoring framework for electric poles to improve fault detection and public safety. The system continuously monitors electrical parameters using smart sensors. Real-time data transmission is achieved through wireless communication technology. Fault conditions such as line breakage and abnormal voltage levels are detected automatically. The proposed approach reduces maintenance delays and improves fault localization. Remote monitoring capabilities help utility authorities respond quickly to hazardous situations. Experimental results demonstrate improved reliability and safety in power distribution networks.

Article [2] "IoT Based Smart Street Light Fault Detection and Control System" by S. Choudhary and D. Bisen in 2020: This study focuses on the implementation of an IoT-based street lighting system with integrated fault detection capabilities. Sensors continuously monitor the operational status of street lights. Fault information is transmitted to a centralized monitoring platform. The system reduces manual inspection requirements and maintenance costs. Automatic detection improves service reliability and operational efficiency. The proposed architecture supports remote control and fault management. Results indicate enhanced safety and better energy utilization in urban environments.

Article [3] "Smart Street Light System Using IoT and GSM" by Z. Hussain and I. Hussain in 2021: This paper introduces a smart street lighting infrastructure based on IoT and GSM communication technologies. The system automatically detects lighting failures and transmits notifications to maintenance personnel. Real-time monitoring enables rapid fault diagnosis and corrective action. GSM communication provides reliable long-distance alert transmission. The approach minimizes power wastage and operational downtime. Intelligent control mechanisms improve system efficiency and reliability. The proposed model demonstrates significant improvements in public infrastructure management.

Article [4] "GSM-GPRS Based Smart Street Light" by Imran Kabir and Shihab Uddin Ahamad in 2021: This research proposes a GSM-GPRS-based street light monitoring framework for automated operation and fault reporting. The system supports manual, semi-automatic, and fully automatic control modes. Faulty street lights are identified and reported to responsible authorities. Remote monitoring improves maintenance effectiveness and service continuity. The communication network enables efficient information exchange. The solution reduces unnecessary energy consumption and maintenance costs. Experimental analysis confirms the effectiveness of the proposed architecture.

Article [5] "Autonomous Smart Grid Fault Detection" by Qiyue Li and Yuxing Deng in 2022: This paper discusses autonomous fault detection methods for modern smart grid systems. Advanced monitoring techniques are utilized to identify electrical disturbances in real time. The study highlights challenges associated with grid reliability and fault management. Intelligent algorithms support accurate detection and classification of faults. Automated monitoring reduces dependency on human intervention. The proposed framework improves operational awareness and grid stability. Future directions for autonomous power system monitoring are also discussed.

Article [6] "IoT Anomaly Detection Methods and Applications: A Survey" by Ayan Chatterjee and Bestoun S. Ahmed in 2022: This survey reviews recent developments in IoT-based anomaly detection systems. Various sensor monitoring and fault detection techniques are analyzed. The paper discusses applications in smart infrastructure and industrial systems. Different machine learning approaches for anomaly identification are compared. Challenges related to sensor integration and data quality are examined. The study highlights opportunities for enhancing fault diagnosis accuracy. The findings support the development of intelligent monitoring solutions.

Article [7] "Design of Wireless Electric Pole Fault Detection System" by S. Karthikeyan and R. Prakash in 2023: This paper proposes a wireless electric pole fault detection system for transmission line monitoring. Voltage and current variations are continuously analyzed to identify faults. IoT and GSM technologies are used for communication and reporting. The system estimates fault locations and transmits alerts to maintenance personnel. Automated monitoring improves response time during emergencies. The framework enhances reliability and reduces labor-intensive inspections. Results indicate improved safety and operational performance.

Article [8] "IoT-Based Intelligent Streetlights System with Fault-Tolerant Mechanism" by Saw Wei Chin and Kok Siong Tan in 2023: This research investigates an intelligent street lighting system with integrated fault tolerance. IoT devices continuously monitor streetlight conditions and operational performance. Fault-tolerant mechanisms improve service availability and reliability. The system supports automated fault detection and corrective actions. Real-time monitoring helps reduce maintenance delays. Smart control strategies improve energy efficiency and infrastructure management. Experimental evaluation validates the effectiveness of the proposed approach.

Article [9] "IoT Based Smart Street Light Fault Detection Management System" by R. P. Sharan Kumar and R. Vadivel in 2024: This paper presents an IoT-enabled fault detection system for smart street lighting networks. A NodeMCU controller and LDR sensor are used for monitoring and control. Fault conditions are detected automatically and reported through cloud platforms. Remote access enables efficient maintenance planning. The system improves energy conservation through adaptive lighting control. Continuous monitoring enhances operational reliability. Results demonstrate effective fault management and reduced maintenance costs.

Article [10] "Centralized Monitoring System for Street Light Fault Detection" by M. A. Rahman and F. Zafar in 2024: This study explores centralized monitoring techniques for smart street lighting systems. Fault information from distributed nodes is collected and processed centrally. The proposed architecture enables real-time monitoring and analysis. Automated alerts improve maintenance efficiency and reduce downtime. IoT connectivity supports scalable deployment across large urban areas. The framework enhances system reliability and safety. Performance evaluation confirms improved operational management.

Article [11] "Real-Time Fault Detection in Power Distribution Systems Using IoT and Machine Learning for Smart Grid Reliability" by Nitesh K. Anand and Priya Rai Menon in 2025: This paper combines IoT technologies with machine learning algorithms for fault detection in power distribution networks. Sensor data is analyzed continuously to identify abnormal operating conditions. Predictive analytics improve fault diagnosis accuracy and response speed. The framework supports proactive maintenance strategies. Cloud-based monitoring enhances accessibility and scalability. The proposed system improves reliability and reduces outage durations. Experimental findings demonstrate the effectiveness of intelligent fault management.

Article [12] "A New Approach to Electrical Fault Detection in Urban Distribution Networks" by R. Villarreal and J. Martinez in 2025: This research proposes an advanced fault detection methodology for urban electrical distribution systems. The approach combines intelligent algorithms with real-time monitoring infrastructure. Electrical abnormalities are identified accurately using data-driven techniques. Rapid fault localization supports faster restoration of services. The system enhances network reliability and operational safety. Advanced analytical methods improve detection performance under varying conditions. The study demonstrates the potential of intelligent monitoring for future smart grid applications.

III. Problem Statement

Electrical poles and overhead distribution lines are frequently exposed to environmental conditions, aging infrastructure, insulation degradation, conductor breakage, and accidental damage. These factors can result in current leakage, pole electrification, and undetected electrical faults that pose serious threats to public safety. Conventional monitoring methods rely heavily on manual inspection and periodic maintenance, making fault identification slow and inefficient. Delayed detection of hazardous conditions can lead to electric shocks, injuries, fatalities, equipment damage, and prolonged power interruptions. The absence of real-time fault monitoring and instant alert mechanisms increases the risk of accidents and delays maintenance response, creating significant safety and reliability challenges in power distribution networks.

IV. Objectives

The primary objective of this study is to enhance the safety and reliability of electrical distribution systems through continuous monitoring of electrical pole conditions. The study aims to detect faults such as current leakage, abnormal voltage levels, conductor breakage, and pole electrification at an early stage to prevent accidents and electrical hazards. Another objective is to provide real-time fault identification and rapid alert generation for timely maintenance actions. The study also focuses on reducing dependence on manual inspection by utilizing IoT-based monitoring techniques. Furthermore, it aims to improve public safety through warning mechanisms, minimize power distribution interruptions, support efficient fault management, and contribute to the development of intelligent and secure electrical infrastructure systems.

V. Methodology

1) Data Acquisition and Sensing : The methodology begins with continuous acquisition of electrical parameters from the distribution pole using voltage and current sensors. These sensors monitor the electrical condition of the pole and power line in real time. The collected data helps identify abnormal operating conditions such as voltage leakage, overcurrent, or conductor faults. Accurate sensing ensures reliable monitoring and forms the foundation of the fault detection process.

2) Signal Processing and Monitoring : The acquired sensor data is continuously processed by the microcontroller to evaluate the operating condition of the electrical pole. Measured values are compared with predefined threshold levels to determine whether the system is functioning normally. This process enables rapid identification of unusual electrical behavior. Continuous monitoring improves fault detection accuracy and enhances overall system reliability.

3) Fault Detection and Analysis : The processed voltage and current values are analyzed to detect faults such as pole electrification, conductor breakage, current leakage, and abnormal voltage conditions. The fault detection mechanism operates automatically without requiring human intervention. Early identification of hazardous situations helps prevent accidents and equipment damage. The analysis stage plays a crucial role in ensuring electrical safety.

4) Local Warning and Alert Generation : When a fault is detected, the system activates local warning mechanisms to alert nearby individuals about potential danger. A voice module generates emergency announcements while the LCD display presents fault information. These alerts provide immediate awareness of hazardous conditions. The warning mechanism helps reduce the risk of accidental contact with energized poles.

5) IoT-Based Fault Communication : The system employs an IoT communication module to transmit fault information to authorized personnel. Fault data is sent wirelessly through the internet for remote monitoring and supervision. Real-time communication ensures that maintenance teams receive instant notifications regarding abnormal conditions. This feature significantly improves response time during emergency situations.

6) Remote Monitoring and Maintenance Support : The transmitted fault information can be accessed remotely by utility operators and maintenance personnel. This capability eliminates the need for frequent manual inspection of electrical poles. Remote monitoring helps in efficient fault localization and maintenance planning. It also reduces operational costs and improves maintenance effectiveness.

7) Safety Enhancement and Response Management : The final stage focuses on improving public safety and protecting electrical infrastructure through rapid fault reporting and warning generation. Timely detection and communication reduce the likelihood of electric shocks, injuries, and power distribution failures. The integrated monitoring framework supports continuous protection of electrical poles. This approach enhances system reliability and promotes safer power distribution networks.

VI. SYSTEM ARCHITECTURE

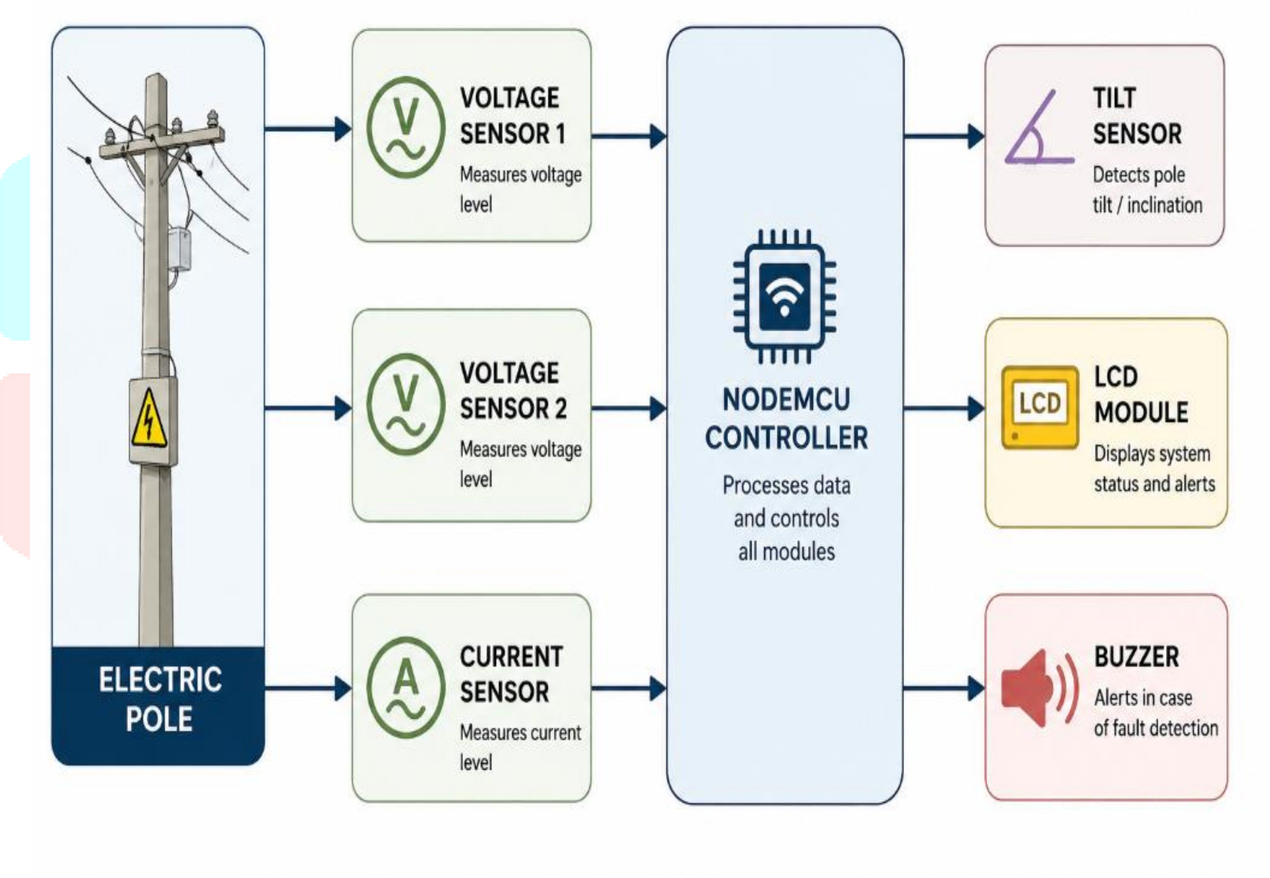

Fig 1: System Architecture of ElectroSentrix: IoT-Based Intelligent Electrical Pole Fault Detection and Accident Prevention Framework

The proposed system architecture is designed to continuously monitor the safety condition of an electrical pole and detect hazardous situations in real time. Voltage Sensor 1 and Voltage Sensor 2 are used to measure voltage conditions at different points of the electrical pole and distribution line, while the Current Sensor monitors current flow to identify abnormalities such as leakage, overcurrent, or line faults. All sensor data is transmitted to the NodeMCU ESP8266 controller, which acts as the central processing unit of the system. The controller analyzes the received values and determines whether the operating conditions are normal or faulty. A Tilt Sensor is incorporated to detect pole inclination or structural instability caused by environmental conditions or physical damage. When a fault is detected, the NodeMCU activates a buzzer to provide an immediate local warning and displays fault information on the LCD module. Simultaneously, fault notifications and status updates are transmitted through the

Wi-Fi-enabled ESP8266 module to the Blynk application, enabling real-time remote monitoring, rapid maintenance response, enhanced safety management, and effective fault reporting.

VII. EXPERIMENTAL SETUP

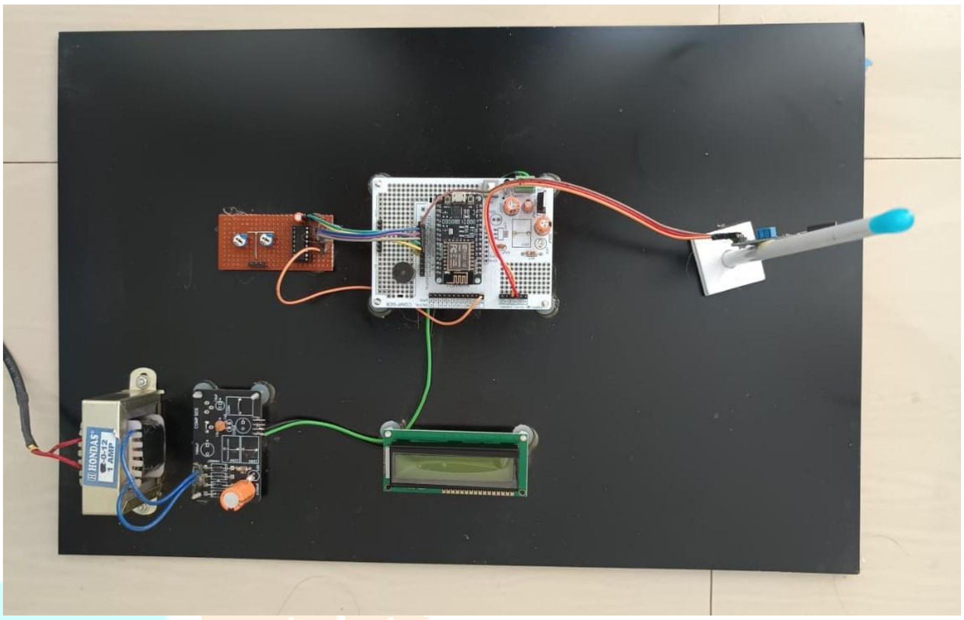

Fig. 2: Hardware Prototype of ElectroSentrix: IoT-Based Intelligent Electrical Pole Fault Detection and Accident Prevention Framework

The developed hardware prototype consists of a NodeMCU ESP8266 controller, voltage sensing circuit, tilt sensor, LCD display, power supply unit, and buzzer integrated on a compact platform.

VIII. CONCLUSION AND FUTURE WORKS

In this research, an IoT-based intelligent electrical pole fault detection and accident prevention framework was developed to enhance public safety and improve the reliability of power distribution infrastructure. The system successfully monitors voltage, current, and pole inclination conditions while providing real-time fault identification and alert generation. Integration of wireless communication enables rapid fault reporting and maintenance support. Future work can focus on cloud-based analytics, machine learning for predictive fault detection, GPS-enabled location tracking, solar-powered operation, enhanced cybersecurity, mobile application integration, automated power isolation, advanced sensor networks, scalable deployment across smart cities, improved energy management, faster emergency response, greater operational efficiency.

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