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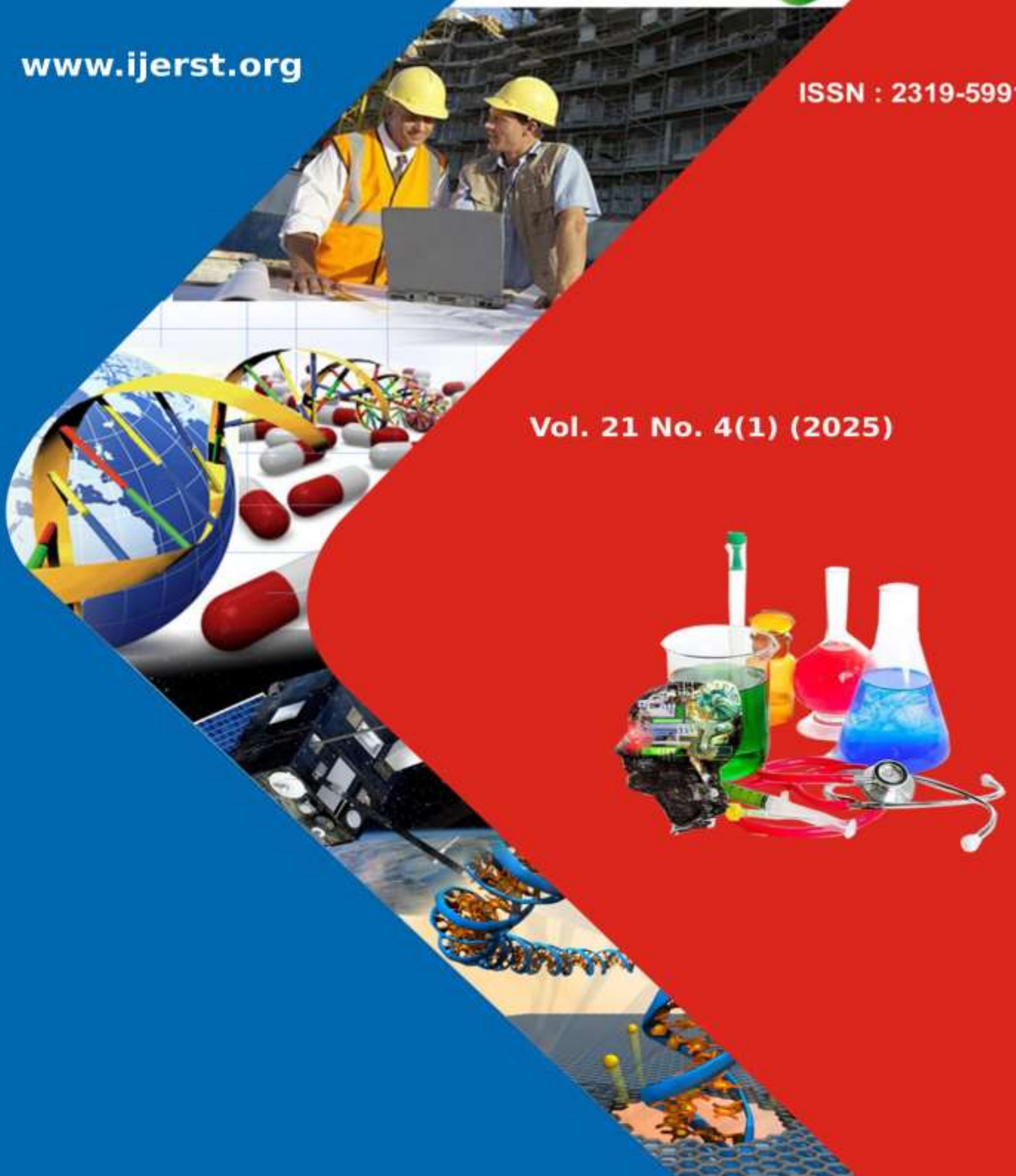

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UNDERGROUND CABLE FAULT DETECTION USING NODE MCU IN AN IOT FRAMEWORK

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ABSTRACT

Because underground cables are long-lasting and less susceptible to environmental influences, they are frequently utilized for power distribution. But finding flaws in these cables is still very difficult and frequently involves expensive and time-consuming physical labor. The goal of this project is to create an Internet of Things (IOT)-based fault detection system that uses the NodeMCU module to locate and detect faults in subterranean cables in real time. Utilizing cutting-edge parts like LEDs, relays, & a buzzer, the equipment guarantees prompt notifications and effective fault state monitoring. This initiative aims to improve subterranean power networks' dependability, decrease downtime, and save maintenance expenses. By automating the procedure and facilitating quick reaction, the system also removes the shortcomings of conventional fault detection techniques. This initiative helps to create more intelligent and dependable power systems by providing problem detection and real-time data transmission.

Keywords: automatic detection, real-time monitoring, fault localization, IOT, subterranean cables, and fault detection.

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I. INTRODUCTION

Industries that rely heavily on telecommunications and electrical power distribution networks face significant challenges in detecting faults in underground cables. Traditional fault detection techniques generally require manual inspection, excavation, or the use of expensive testing equipment, making them time-consuming, labor-intensive, and inefficient [1], [2], [4]. In many cases, faults remain undetected for extended periods, leading to prolonged downtime, costly repairs, and severe service disruptions [5], [6]. Moreover, conventional approaches often fail to provide real-time fault identification and precise fault localization, especially in complex underground cable networks [3], [9].

The rapid expansion of the Internet of Things (IoT) has enabled the development of more cost-effective, automated, and reliable solutions for underground cable fault detection [8]. Several studies have demonstrated that IoT-based systems can significantly improve fault detection accuracy by integrating sensors, microcontrollers, and cloud platforms for continuous monitoring [1], [5]. In this project, an IoT-based fault detection system utilizing the NodeMCU module is proposed to automate fault identification and localization in underground cables. The system employs voltage-sensing mechanisms across resistors to detect abnormal variations and accurately determine fault locations along the cable length [2], [6].

The NodeMCU module transmits real-time sensor data to a remote server, enabling continuous monitoring and rapid fault response [5]. Fault locations are displayed locally on an LCD screen, while switches placed at predefined intervals simulate cable faults for testing and validation purposes [3]. Additionally, buzzer alerts and LED indicators provide immediate on-site notifications, ensuring quick awareness of fault conditions. Integration with cloud platforms such as Google Database allows fault data to be stored, analyzed, and retrieved for future maintenance planning and performance evaluation [1], [8]. Advanced studies further suggest that combining IoT with intelligent analytics and predictive maintenance techniques can significantly enhance fault diagnosis and operational reliability [7].

Overall, by leveraging IoT technology, the proposed system aims to improve the efficiency, reliability, and responsiveness of underground cable fault detection. It provides a modern and scalable solution to long-standing challenges in cable maintenance, reduces downtime, and enhances the operational effectiveness of critical infrastructure networks [1], [6], [7].

II. LITERATURE SURVEY

1. Identification of Underground Cable Fault Location and Development,M. R. Hans, S. C. Kor, and A. S. Patil, 2017

India's rapid urbanization and infrastructural expansion have increased the adoption of underground power cables due to their advantages, such as reduced transmission losses, lower maintenance requirements, and improved resistance to harsh weather conditions [1], [5], [6]. However, underground cables also present significant challenges, including high installation costs and difficulty in fault detection and localization because faults are not visually observable [2], [4]. To address this issue, the authors propose two effective techniques for identifying the exact distance of a fault from the base station. One technique is based on Ohm's Law, while the other utilizes the Murray loop method, which applies a Wheatstone bridge principle to determine fault distance accurately [2], [9]. The Murray loop method transmits fault location data to user devices, whereas the Ohm's law-based approach estimates fault distance through voltage drop variations caused by current changes along the cable length. Both methods employ a microcontroller, potentiometer, and voltage converter to detect LG, LL, and LLL faults, aligning with modern IoT-based fault localization strategies discussed in recent studies [1], [3], [6].

2. Fault in Transmission Cables and Current Fault Location Methods,C. F. Jensen, 2014

This work forms a foundational study for understanding fault location methodologies in cross-bonded and high-voltage underground transmission cables. The author emphasizes the importance of reviewing existing fault detection techniques to assess their suitability for practical deployment. The study first discusses the physical and electrical mechanisms responsible for underground cable faults, which include insulation degradation, thermal stress, and environmental influences [4], [9]. Such insights are essential for evaluating modern fault detection frameworks and have influenced later research integrating IoT and sensor-based monitoring for improved fault diagnosis and localization [1], [7], [8]. The analysis presented in this work provides a theoretical basis that supports the transition from conventional fault location methods to automated, real-time IoT-based solutions [5], [6].

3. Finding Emerging Problems in Distribution Underground Wires, T. S. Sidhu and Z. Xu, 2010

This study focuses on the early detection of incipient faults in underground distribution cables, which commonly originate from insulation gaps, joint defects, or accessory failures. Such faults may initially appear intermittently but gradually evolve into permanent failures if left undetected [3], [7]. The authors propose two algorithms for identifying and classifying underground cable faults at distribution voltage levels. The first method employs wavelet-based analysis to detect fault-induced transients, while the second uses time-domain analysis of overlaid fault current and negative sequence current to identify single-line-to-ground (SLG) faults, which are prevalent in underground cable systems [9]. These techniques are validated under varied fault conditions, system configurations, and real-world scenarios, demonstrating their robustness and practicality. The study also examines other transient events such as load changes and capacitor switching, reinforcing the need for intelligent, automated monitoring systems—a requirement that is increasingly addressed by IoT-based fault detection and predictive maintenance approaches [7], [8], [10].

III. EXISTING SYSTEM

Existing systems for underground cable fault detection primarily depend on manual inspection techniques or conventional fault detection devices that require direct physical access to the cables. Such traditional approaches are often labor-intensive, time-consuming, and expensive, particularly in densely populated or urban areas where excavation is difficult and disruptive [1], [2], [4]. Moreover, these methods generally lack real-time monitoring capabilities, leading to delayed fault identification and prolonged service interruptions [5], [6]. Some earlier systems employ basic sensors with wired connections to detect faults; however, these setups suffer from limited flexibility, lack of remote accessibility, and absence of automated fault reporting mechanisms [2], [3].

Recent advancements have introduced microcontroller-based fault detection solutions that improve measurement accuracy and reduce human intervention to some extent. Nevertheless, many of these systems still face challenges related to scalability, continuous monitoring, and real-time data transmission, especially when deployed across large underground cable networks [6], [9]. Additionally, conventional systems often fail to support predictive maintenance or intelligent fault analysis, which are increasingly required for modern power distribution infrastructures [7]. Integrating Internet of Things (IoT) technology with wireless microcontroller platforms such as NodeMCU provides a promising alternative by enabling real-time fault detection, remote monitoring, and cloud-based data analysis [1], [5], [8]. This IoT-enabled approach significantly enhances the speed, accuracy, and reliability of underground cable fault identification compared to existing systems, while also supporting scalable and efficient maintenance strategies [6], [7].

IV. PROPOSED SYSTEM

The proposed system leverages the Node MCU module integrated with IoT technology to enable efficient and real-time underground cable fault detection. By using sensors connected to the Node MCU, the system continuously monitors cable parameters such as current, voltage, and resistance to detect anomalies indicating faults. When a fault is identified, the Node MCU processes the data and wirelessly transmits alerts to a centralized monitoring platform via the internet. This allows for remote fault detection and immediate notification to maintenance teams, reducing downtime and repair costs. The system aims to provide a more scalable, automated, and cost-effective solution compared to traditional methods, with enhanced accuracy, continuous monitoring, and easy integration into existing infrastructure.

V. SYSTEM ARCHITECTURE

1. Sensor Nodes (Edge Devices)

The system uses Node MCU modules with connected sensors such as current sensors, voltage sensors, and resistance measurement circuits deployed along underground cables. These edge devices continuously monitor electrical parameters to detect anomalies indicating faults. Each Node MCU runs local firmware for real-time data acquisition, initial fault pattern recognition, and immediate fault alert generation. The modules support wireless communication via Wi-Fi to transmit processed data to the gateway.

2. Edge Processing & Security

At the Node MCU level, signal preprocessing filters noise from sensor readings, and basic fault detection algorithms (e.g., threshold checks, pattern matching) identify potential cable faults locally. Only summarized and encrypted fault indicators or alerts are sent to the cloud, while raw sensor data is temporarily stored with optional AES-128 encryption for security and privacy compliance.

3. Network & IoT Gateway

Data from multiple Node MCU sensor nodes is securely transmitted over a TLS 1.3 encrypted Wi-Fi network to the IoT gateway. The gateway acts as a centralized controller that aggregates sensor data via MQTT protocol and sends it to the cloud backend. It also supports offline mode, where local thresholds trigger alarms directly from the gateway to maintenance personnel when internet connectivity is unavailable.

4. Cloud Backend

The cloud platform hosts advanced fault diagnosis models using machine learning algorithms to analyze incoming data. It maintains an encrypted database of cable health status, historical fault

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records, and system logs. The platform provides predictive alerting through SMS or email notifications to field engineers and presents an admin dashboard with visualization of cable integrity and fault locations. Role-based access control ensures only authorized users view sensitive data.

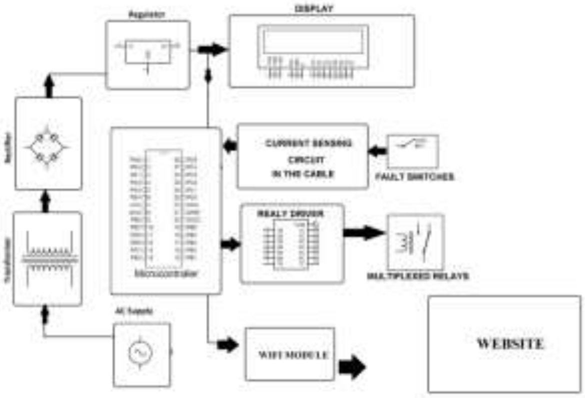

Fig. 5.1: Structure of the Proposed System

Node MCU Module:

The Node MCU is a low-cost microcontroller with built-in Wi-Fi, based on the ESP8266 chip, ideal for IoT applications in fault detection. It features a 32-bit processor running at 80 MHz, integrated ADC for analog sensor inputs (such as voltage or current sensing), and supports multiple GPIO pins for interfacing sensors and communication modules. Programmed in Arduino IDE or Lua, the Node MCU runs firmware that supports secure boot, data encryption, and low power consumption for continuous monitoring.

Key pins include:

Analog Input Pin A0: Single 10-bit ADC channel (0–3.3V) for sensor signals

Digital GPIO Pins: Used for sensor interfacing, status LEDs, and communication control (PWM, I2C, SPI)

Wi-Fi Antenna: Internal antenna supporting IEEE 802.11 b/g/n, enabling real-time data transmission

Power Pins (3.3V, GND): Power the microcontroller and sensors

VI. IMPLEMENTATION

The underground cable failure detection system's entire hardware configuration is seen in the picture below. The Node MCU component, relays, indicator LEDs, cable segments that represent them, and a buzzer make up this device.

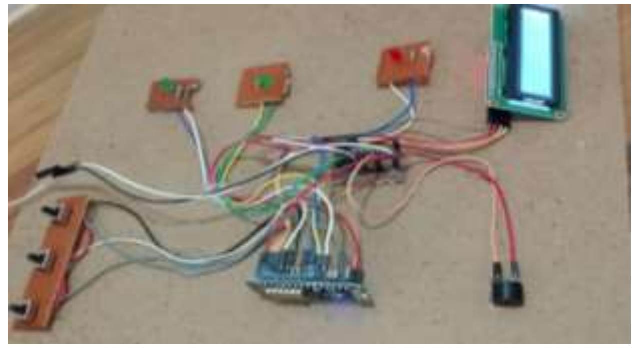

Fig. 6.1: Hardware Prototype of IoT-Based Smart Monitoring System with Sensors and LCD Module

For testing, every part is organized neatly on a breadboard. The system is operational and prepared to monitor subterranean cable line issues.

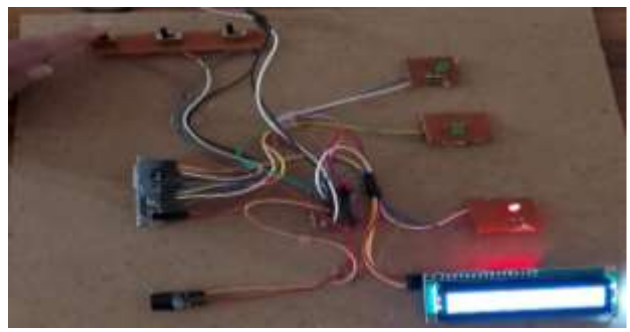

Fig. 6.2: Prototype Hardware Setup of Smart Authentication System Using RFID and Microcontroller

In order to create a open circuit or low in one of the line segments, a switch is pressed to simulate a malfunction. This mimics actual circumstances, like an underground cable breaking. The system starts checking for voltage variations that could be a sign of a malfunction right away.

VII. CONCLUSION

An IOT-Based Fault Identification System to subterranean cables is a creative fix for a persistent issue in telecommunications and electricity networks. The sluggish, costly, and ineffective nature of traditional defect detection techniques frequently results in extended downtime and higher operating expenses. With the use of Node MCU technology, the above system provides real-time alerts and precise problem locations by automating the identification of errors and localization procedure. The combination of buzzers, LCD screens, sensors, and Google Database guarantees that the framework is not only incredibly effective but also simple to remotely monitor and control.

By drastically cutting down on the time needed for issue identification and repair, this initiative increases operational effectiveness, minimizes downtime, and lowers maintenance expenses. IOT connectivity makes it possible for the system to be remotely updated and monitored continually, facilitating proactive maintenance and quick fault-resolution. An essential tool for industries that depend on subterranean cables for communication networks and power distribution, this Internet of Things (IOT)-based solution provides a scalable, economical, and dependable method of finding faults and localization in response to the increasing demand for dependable, real-time monitoring in subterranean cable systems.

VIII. FUTURE SCOPE

The proposed IoT-based underground cable fault detection system using NodeMCU can be significantly enhanced in the future by integrating machine learning models to predict faults before they occur through analysis of historical electrical and environmental data. The system can be connected to GIS platforms to provide real-time map-based visualization of fault locations, enabling faster repair responses. Additional sensors—such as temperature, moisture, vibration, and partial discharge detectors—may be incorporated to improve accuracy and reliability. Communication can be upgraded from Wi-Fi to long-range technologies like LTE-M or 5G for city-wide deployment. The solution can further evolve into a smart self-healing grid that automatically isolates faulted sections and restores power. A dedicated mobile application may also be developed to deliver instant alerts, GPS navigation to the fault point, and on-site diagnostics for field engineers. Enhancing data security using blockchain and powering remote sensor nodes through energy-harvesting techniques will also contribute to long-term scalability. Ultimately, this system can be integrated into utility dashboards and SCADA systems to support large-scale smart grid infrastructure across urban environments.

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