UNDERGROUND CABLE FAULT DETECTION USING IOT

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***Abstract*—Underground cable faults cause long outages and expensive, time consuming excavation and repairs in urban distribution networks. This project develops an IoT enabled fault detection and location system for medium voltage underground cables that combines edge sensing (voltage/current / impedance sampling and partial discharge indicators), distance estimation algorithms (time domain reflectometry / impedance based pre location) and real time cloud reporting. A compact sensor/injector node (ESP32/MCU + measurement front end) continuously monitors electrical parameters and uploads processed fault alerts and estimated distances to a cloud dashboard via MQTT. When the system detects an anomaly (e.g., sudden earth fault, large PD signature, open or short), it pre locates the fault to a segment length using TDR/impedance calculations and timestamps the event for crew dispatch. A proof-of-concept lab setup and field trial on a short-buried cable demonstrator validate detection sensitivity and location error (target ¡1% of cable length). The solution aims to reduce time to pinpoint, excavation scope, and outage duration through automated alarms, GPS tagged fault locations, and historical analytics that support predictive maintenance. This work demonstrates feasibility of low cost IoT augmentation for existing cable networks and outlines pathways to integrate AI-assisted PD classification and optical-fiber sensing for future scalability**

***Index Terms*—Underground cable fault, GPS, IOT ,Distribution network**.

I. INTRODUCTION

The modern urban power infrastructure relies heavily on underground cables for electricity distribution due to their superior reliability, safety, and resistance to environmental influences such as wind, rain, and pollution. However, the detection and repair of underground cable faults remain challenging due to their hidden nature. Traditional fault detection methods—based on manual testing or time-domain reflectometry—are often expensive, slow, and technically demanding. With the increasing deployment of smart technologies, integrating the Internet of Things (IoT) into electrical monitoring systems has become a transformative step. IoT allows distributed sensors and communication modules to exchange data in real time, enabling faster detection and localization of faults in underground cables. By combining IoT, embedded systems, and microcontroller-based architectures, this project aims to develop a cost-effective and automated method for identifying the exact location and type of cable faults. The project proposes an Arduino-based system interfaced with a Node MCU (ESP8266) Wi-Fi module and current-sensing circuitry. Faults such as short circuits, open circuits, or earth faults are simulated through switches, and their status is displayed both locally on an LCD and remotely through an IoT dashboard. The proposed system thus reduces the downtime, maintenance effort, and financial losses associated with traditional underground cable maintenance.

Urbanization has significantly increased the density of underground power networks. As a result, any fault can cause serious interruptions to public services and industries. Detecting the exact fault location quickly helps minimize repair time and operational costs. Furthermore, IoT-based systems provide remote visibility to operators, enabling preventive maintenance and efficient fault management. Locating faults in underground power cables is often complex, time-consuming, and costly. Conventional systems require manual testing, which involves disconnecting power and physically inspecting cable sections. This work aims to address these limitations by implementing an IoT-enabled fault detection system capable of identifying fault type and location automatically

The primary goal of this paper is to design and implement an IoT-enabled underground cable fault detection system. Main objectives are to integrate Arduino Nano and Node MCU for automated sensing, processing, and cloud reporting. And analyze the performance of fault sensing circuits for accuracy and reliability. This proposed system is also used to display fault distance and type on an LCD and IoT dashboard in real time. This paper is arranged as follows. Section II illustrates literature survey. The circuit diagram and block diagram are described in depth in Section III, and the control strategies for EV integration in power grid is established in Section IV.

II. LITERATURE REVIEW

Md. Fakhrul Islam and other authors presented a comprehensive study of various fault detection techniques, including Bridge methods (Murray and Varley loop tests), Time Domain Reflectometry (TDR), impedance-based analysis, and power factor or voltage drop methods. Each method was compared in terms of accuracy, cost, fault type sensitivity, and applicability under different network topologies. The study also classified these techniques based on their signal domain time, frequency, and traveling-wave based approaches [1].

Himanshu Katara and authors designed a prototype system capable of detecting and locating underground cable faults using microcontroller-based measurement and IoT integration. The system utilizes a microcontroller interfaced with voltage and current sensors to measure potential drops along the cable. The fault distance is determined using Ohm's law by correlating the measured voltage with predefined resistance per unit length. The setup includes an IoT module for data transmission and display of fault distance in real time [2].

Dr. Kanta Prasad Sharma and authors developed a real time IoT based underground cable fault detection system using a Node MCU microcontroller integrated with cloud-based monitoring The system employs a Node MCU (ESP8266) microcontroller that monitors voltage variations along the cable to detect open, short, or earth faults. The detected data is uploaded to a Google Firebase cloud server for visualization and remote monitoring. Ohm's law principles are applied to calculate the distance to the fault. An LCD display and Wi-Fi interface provide both local and remote system feedback [3].

Nikhil Kumar Sain and authors suggested a scheme to design a cost-effective microcontroller-based system that automatically detects and locates underground cable faults and communicates the fault distance via GSM technology. The system uses an AT mega microcontroller interfaced with voltage sensors and a GSM module (SIM900). Voltage drops across resistive cable segments are used to determine the fault distance using Ohm's law. The calculated distance is then transmitted to a registered mobile number through SMS. A local LCD display is also used for immediate fault indication.[4].

C. Bharati raja and authors proposed a timing correction algorithm for the Space Vector Modulation (SVM) technique applied to three level Neutral Point Clamped (NPC) multilevel inverters, ensuring improved voltage waveform linearity and harmonic performance in the over modulation zone. Methodology: The authors proposed an extended SVM method with timing correction logic for precise pulse generation under nonlinear conditions. MATLAB/Simulink simulations were performed to evaluate output voltage, harmonic distortion, and switching performance. Comparative analysis with conventional SVM schemes was also presented [5].

S. K. Satyanarayana and other authors suggested a design with IoT based system for real time detection and localization of underground cable faults, improving maintenance response and reducing downtime [6].

Minal Yadav Rao Barhate and other authors proposed a scheme to enhance the reliability of underground power distribution systems using an advanced IoT based cable fault monitoring framework that ensures early detection and predictive maintenance. The proposed system integrates voltage, current, and leakage sensors with a microcontroller to monitor cable health parameters. When anomalies are detected, the system triggers an IoT based alert through GSM/Wi-Fi connectivity. Real time monitoring dashboards are designed to visualize and log data, providing continuous condition tracking. The paper also discusses fault identification logic and potential integration with existing distribution systems [7].

III. METHODOLOGY OF THE PROPOSED WORK

The proposed system is designed to detect and locate faults in underground cables efficiently using IoT enabled embedded technology. It integrates both hardware and software modules to form a complete fault monitoring and reporting mechanism. The core of the system consists of an Arduino Nano microcontroller and a Node MCU (ESP8266) Wi-Fi module that together perform sensing, processing, and data transmission. The detection principle is based on Ohm's Law, where changes in voltage or current across cable sections indicate fault occurrences such as short circuits, open circuits, or earth faults. The underground cable is conceptually divided into multiple segments, each represented by switches or relays in the prototype. When a fault occurs, the corresponding switch changes state, leading to a detectable voltage drop or current variation. The Arduino Nano receives these analog inputs through its ADC pins, processes the signals, and calculates the fault distance based on pre calibrated resistance values. The detected fault type and distance are displayed locally on a 16x2 LCD display and simultaneously transmitted to the cloud through the Node MCU module via Wi-Fi. A buzzer and LED indicators provide immediate local alerts, ensuring quick recognition and response to faults. In advanced configurations, manual switches are replaced by sensors such as ACS712 current sensors, voltage dividers, and earth leakage detectors to achieve real time and precise fault monitoring.
The Node MCU then uploads the processed data to an IoT platform like Thing Speak or Things Board, where operators can remotely monitor the cable's condition and analyze fault histories. The software implementation involves programming in Arduino IDE for fault detection logic, communication routines, and threshold settings. The overall methodology ensures seamless interaction between hardware sensing and cloud-based supervision, allowing continuous fault detection, location estimation, and remote visualization. This IoT-enabled approach significantly reduces manual inspection, improves reliability, and enables predictive maintenance in underground power distribution networks. As in block diagram Fig1,

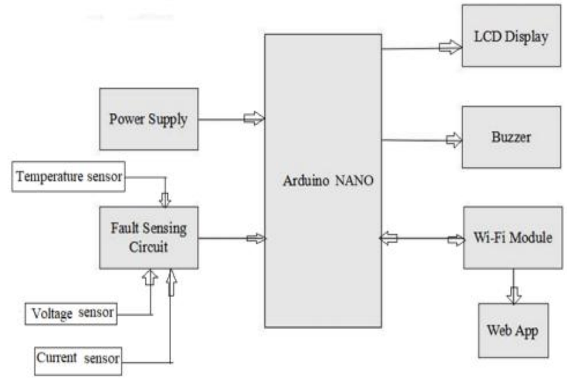

FIG 1: BLOCK DIAGRAM OF THE PROPOSED IOT-BASED FAULT DETECTION SYSTEM

The power supply circuit provides regulated 5V DC to all components. The fault sensing circuit detects current variation and sends an analog signal to Arduino Nano. Arduino Nano calculates the fault distance based on programmed logic. Node MCU (ESP8266) transmits fault data via Wi-Fi to a remote server. The LCD module displays fault type and distance locally. A buzzer provides an audible alert for quick field response.

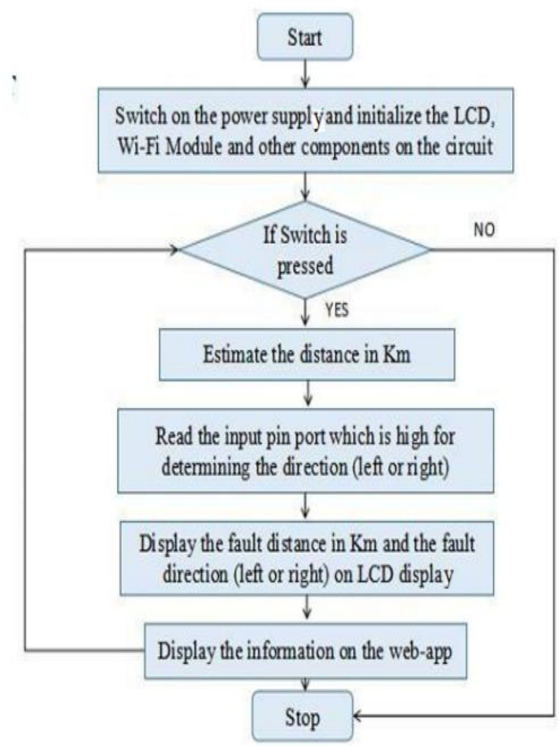

FIG 2: FLOW CHART OF THE PROPOSED IOT-BASED FAULT DETECTION SYSTEM

As in flowchart, initially Start the system and initialize the microcontroller modules. Then read analog input from fault sensing circuit. After getting the input value, compare voltage levels to predefined threshold values. Finally Determine fault occurrence and calculate location and LCD will display fault data. After this, send data to IoT server via Node MCU then to trigger buzzer and LED for visual and audible alert.

When a switch is pressed to simulate a fault, current flow in that segment changes. The voltage drops across the corresponding resistor changes proportionally. The Arduino reads the signal through its ADC pins, determines the fault type (short circuit, open circuit, or earth fault), and estimates distance using the calibration logic. The result is displayed on the LCD and simultaneously uploaded to the IoT platform.

Fig 3, shows the proposed circuit diagram for the Underground Cable Fault Detection System using an Arduino Nano and a Node MCU (ESP8266) module. This design is developed for simulation and planning purposes to demonstrate the detection of faults in different sections of an underground power cable. The Arduino Nano acts as the central processing unit, while the Node MCU module enables wireless communication for IoT based monitoring.

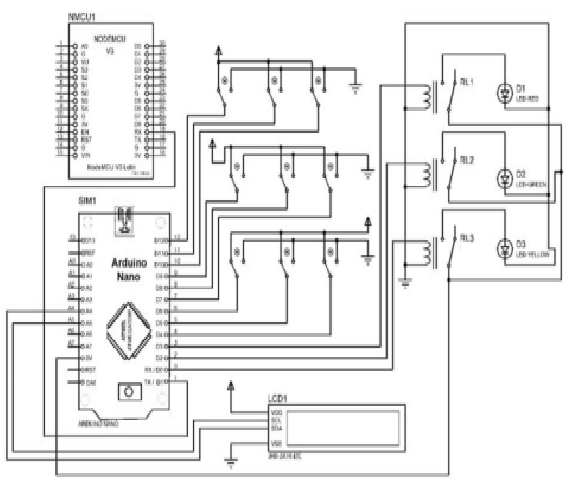

FIG 3: CIRCUIT DIAGRAM OF THE PROPOSED IOT-BASED FAULT DETECTION SYSTEM

The underground cable is conceptually divided into multiple sections, each represented by a switch and relay pair. Under normal operating conditions, all switches remain closed, allowing current to pass through all cable sections. When a fault occurs, the corresponding switch is opened, resulting in a voltage drop across that segment. The Arduino Nano detects the change in voltage or current through its analog input pins and determines the faulted section. The corresponding relay is deactivated, causing the associated LED to illuminate, thus indicating the fault location. The Arduino transmits the fault information to the Node MCU via serial communication. The Node MCU sends the data wirelessly to a web server or IoT dashboard for remote monitoring. The LCD module simultaneously displays messages such as ‘‘Fault in Section 2’’ to assist in local identification.

IV. SOFTWARE IMPLEMENTATION OF PROPOSED SYSTEM

The system is programmed in C/C++ using Arduino IDE as in Fig 5. It defines input/output pin configurations, fault sensing thresholds, and communication routines for Wi-Fi. The data collected from Node MCU is transmitted to an IoT dashboard for visualization and analysis. Parameters such as fault occurrence time, type, and distance are logged for maintenance tracking. Table 1 shows the faults to be identified with the system.

Fault Type	Description
Open Circuit Fault	A break in the cable; no current flows.
Short Circuit Fault	Conductors touch each other, causing high current.
Ground Fault	A phase conductor touches the ground.
Intermittent Fault	Faults appear and disappear randomly (simulated using switches).
High Resistance Fault	Partial break causing increased resistance in the line.

TABLE 1: FAULTS TO BE IDENTIFIED WITH THE HELP OF PROPOSED SYSTEM

As in operation scheme, connect Arduino Nano to ESP8266 via serial UART. Design the fault detection circuit with switches/relays representing different fault types. Connect voltage/current sensors to Arduino for cable monitoring. Arduino continuously monitors cable parameters. On detecting a fault (open, short, or ground), Arduino sends an alert to ESP8266. ESP8266 transmits the data to a server or cloud platform for logging and visualization. In simulation software, introduce faults via switch toggling to test system response.

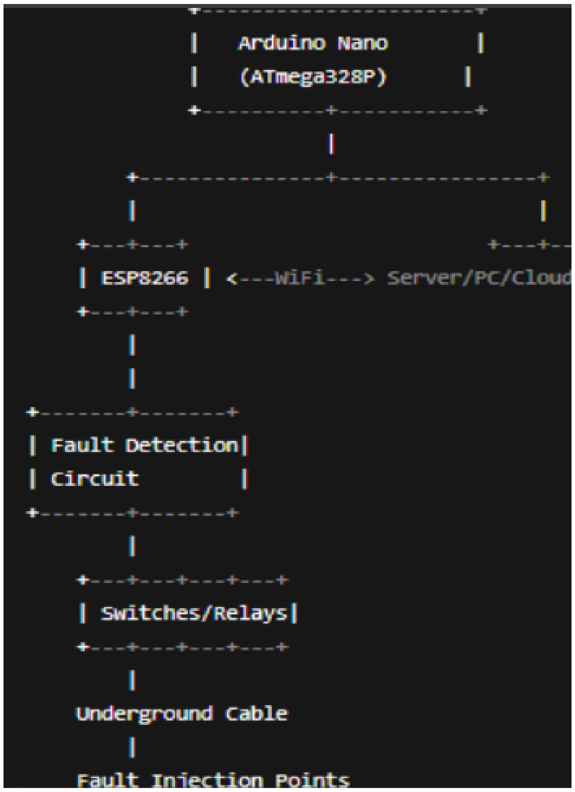

FIG 4: PROPOSED SIMULATION DIAGRAM CONCEPT

V. CONCLUSION AND FUTURE SCOPE

Completed the simulation and validated fault detection accuracy for various fault types. Proteus and Tinker CAD environments are used to validate the results in software side. Proposed system along with hardware prototype development have to be implemented based on verified simulation results. Using software environment, different fault conditions are tested and including open circuit, short circuit, and earth fault.

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