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IoT-Based Underground Cable Fault Detector

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Abstract: *The rapid growth of urban infrastructure and industrialization has increased the demand for reliable and uninterrupted power supply systems. Underground cables are widely used in modern power distribution networks due to their safety, reduced environmental impact, and improved aesthetics compared to overhead lines. However, detecting faults in underground cables is a complex and time-consuming task because the cables are not visible and require extensive manual effort for inspection.*
This paper presents an advanced IoT-based underground cable fault detection system that can detect, locate, and monitor faults in real time. The proposed system utilizes a microcontroller, voltage sensing techniques, and IoT modules to identify faults such as short circuit, open circuit, and earth faults. The system determines the fault location using resistance-based fault detection methods and transmits the data to a cloud-based monitoring system.
The integration of IoT enables remote monitoring, instant fault alerts, and improved maintenance efficiency. Experimental results demonstrate that the system provides accurate fault detection with reduced response time and improved reliability. This approach contributes to the development of smart grid systems and intelligent power distribution networks.

Keywords: IoT, Underground Cable, Fault Detection, Smart Grid, Arduino, Real-time Monitoring

I. INTRODUCTION

The continuous expansion of electrical power systems has led to an increased reliance on underground cables, especially in urban and densely populated areas. Underground cables offer several advantages over overhead transmission lines, including reduced exposure to environmental hazards, improved safety, and minimal visual impact. Despite these benefits, fault detection in underground cables remains a major challenge.

Faults such as short circuits, open circuits, and insulation failures can occur due to aging, moisture, mechanical damage, or manufacturing defects. Identifying the exact location of these faults is difficult because the cables are buried beneath the ground. Traditional fault detection methods involve manual inspection and require significant time and manpower, leading to increased downtime and maintenance costs.

With the advancement of the Internet of Things (IoT), it is now possible to develop intelligent monitoring systems that can detect faults automatically and provide real-time information. IoT-based systems enable remote access, continuous monitoring, and faster decision-making.

In this research, an IoT-based underground cable fault detection system is proposed. The system uses voltage sensing and resistance measurement techniques to determine the location of faults. The collected data is transmitted to a cloud platform, allowing engineers to monitor the system remotely. This approach enhances system efficiency, reduces downtime, and supports the development of smart and automated power distribution networks.

1.1 OBJECTIVES

The primary objective of this research is to design and implement an efficient IoT-based system for detecting and locating faults in underground cables with high accuracy and reliability. One of the key objectives is to identify various types of faults, including short circuit faults, open circuit faults, and earth faults, using electrical parameter analysis. The system aims to determine the precise location of the fault based on voltage drop and resistance measurement

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techniques. Another important objective is to enable real-time monitoring of cable conditions using IoT technology. The system continuously transmits data to a cloud-based platform, allowing users to monitor the system remotely through mobile or web applications.

The project also aims to reduce maintenance time and operational costs by providing instant fault alerts and accurate fault location information. Furthermore, it enhances the safety, efficiency, and reliability of power distribution systems.

1.2 MATHODOLOGY

The hardware implementation involves the selection and integration of various electronic components required for fault detection and monitoring.

1.2.1 Microcontroller (Arduino UNO)

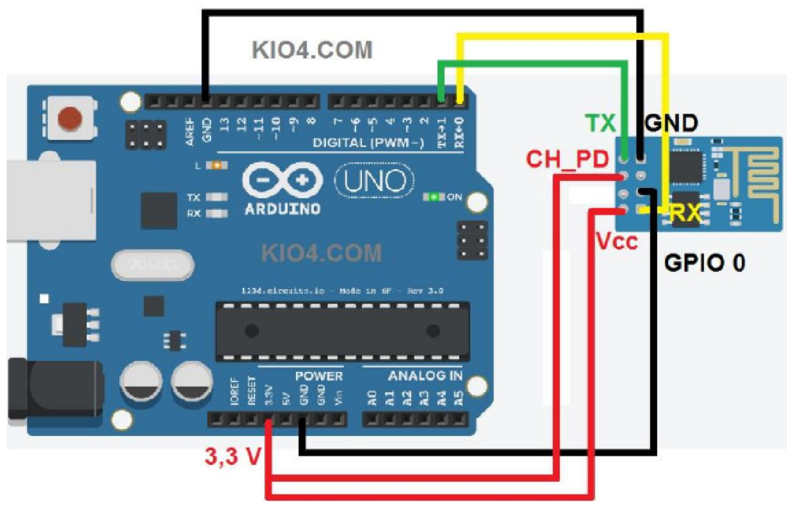

Fig 1.2.1 Arduino UNO

The Arduino UNO acts as the central processing unit of the system. It collects data from sensors, processes it, and controls the overall operation of the system.

1.2.2 Resistor Network (Cable Model)

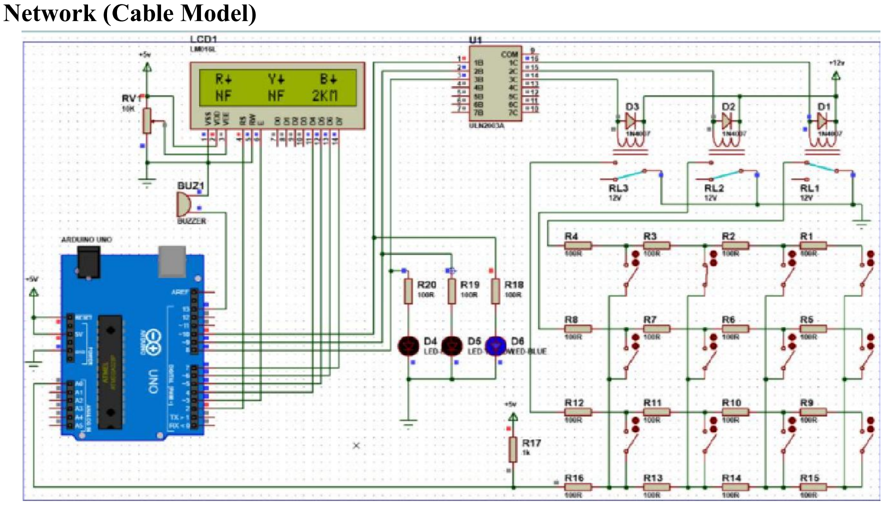

Fig 1.2.2 Resistor N/W

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A series of resistors is used to simulate the underground cable. Each resistor represents a segment of the cable. The voltage drop across these resistors helps in determining the fault location.

1.2.3 Voltage Sensing Circuit

Fig 1.2.3 Voltage Sensing Circuit

The voltage sensing circuit measures the voltage at different points of the cable. This data is used to calculate the distance of the fault.

1.2.4 IoT Module (ESP8266 Wi-Fi Module)

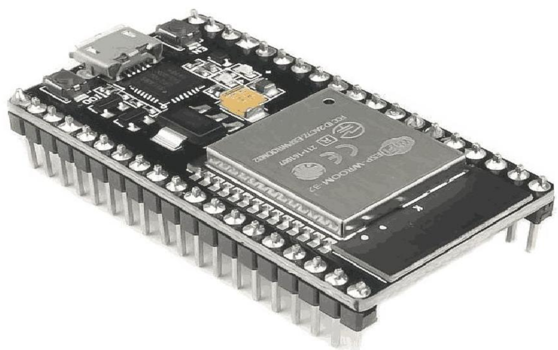

Fig 1.2.4 ESP Module

The ESP8266 module enables wireless communication and sends real-time data to a cloud server such as ThingSpeak or Blynk.

1.2.5 LCD Display (16×2)

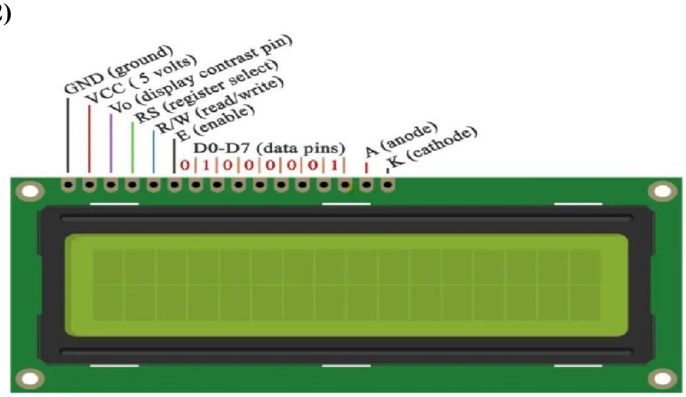

Fig 1.3.5 LCD Display

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The LCD display shows the fault type and its location locally for easy monitoring.

1.2.6 Power Supply Unit

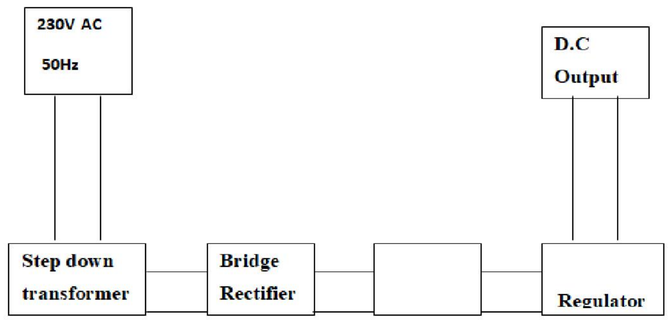

Fig 1.2.6 Block Diagram of PSU

A regulated DC power supply is used to power the entire system.

1.3 SOFTWARE REQUIREMENTS

The software required for this project is the Arduino IDE, which is used to write, compile, and upload the program into the Arduino microcontroller. It provides a simple interface where code is written in C++ language and then converted into machine code using a built -in compiler. In this project, Arduino is used for battery monitoring. It plays an important role in measuring the battery voltage, processing the data and displaying the results on an LCD screen. The Arduino continuously monitors the battery condition and provides real-time information such as voltage level and charge percentage. This helps in understanding the battery status and ensures efficient operation of the system.

1.4 APPROACH

The proposed IoT-based underground cable fault detection system operates on the fundamental principle of Ohm's Law and voltage drop analysis. In this system, the underground cable is modeled using a series combination of resistors, where each resistor represents a fixed length of the cable. This representation allows the system to estimate the fault location based on changes in electrical parameters.

Initially, a regulated DC voltage is applied across the cable model. Under normal operating conditions, the voltage drop across each section of the cable remains uniform. However, when a fault occurs—such as a short circuit, open circuit, or earth fault—the electrical characteristics of the cable change significantly. These changes result in variations in voltage distribution along the cable.

A voltage sensing circuit is connected at specific points in the cable model to continuously monitor the voltage levels. The sensed analog voltage signals are fed into the analog input pins of the microcontroller (Arduino UNO). The microcontroller converts these analog values into digital data using its built-in Analog-to-Digital Converter (ADC).

The system then processes the acquired data using predefined algorithms based on Ohm's Law. By comparing the measured voltage values with reference values, the system calculates the distance of the fault from the source. The fault location is determined using the proportional relationship between resistance and cable length, as resistance increases linearly with distance.

Once the fault location is calculated, the result is displayed on a 16×2 LCD screen, providing immediate information to the operator. At the same time, the IoT module (ESP8266) transmits the fault data, including fault type and location, to a cloud-based platform such as ThingSpeak or Blynk.

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The cloud platform stores and visualizes the data in real time, allowing users to monitor the system remotely through a web interface or mobile application. In case of a fault, the system can also generate alerts or notifications, enabling quick response and reducing downtime.

Furthermore, the system is designed to operate continuously, ensuring real-time monitoring and early detection of faults. This proactive approach helps prevent major failures, improves maintenance efficiency, and enhances the overall reliability of the power distribution system.

Overall, the proposed approach integrates sensing, processing, and communication technologies to create an intelligent and automated fault detection system suitable for modern smart grid applications.

1.5 ADVANTAGES , DISADVANTAGES & APPLICATIONS

1.5.1 Advantages of the Proposed System

- Real-Time Monitoring: The system continuously monitors the cable condition and detects faults instantly.
- Accurate Fault Location: Fault position is calculated using voltage drop and resistance principles with good accuracy.
- Reduced Maintenance Time: Faster fault detection helps in quick repair and minimizes downtime.
- Remote Accessibility: IoT integration allows monitoring through mobile or web applications from any location.
- Instant Alerts: The system provides immediate notifications when a fault occurs.
- Cost-Effective Solution: Uses simple and affordable components like Arduino and ESP8266.
- Improved Reliability: Enhances the overall performance and stability of power distribution systems.
- Enhanced Safety: Early detection of faults prevents major electrical hazards.
- Automation: Reduces the need for manual inspection and increases system efficiency.

1.5.2 Disadvantages of the Proposed System

- Simulation-Based Model: The system is based on a resistor model which may not fully represent real underground cable conditions.
- Accuracy Limitations: Fault detection accuracy may be affected by noise, environmental conditions, or sensor errors.
- Internet Dependency: IoT features require a stable internet connection for proper functioning.
- Limited Scalability: The system is more suitable for low-voltage or small-scale applications.
- High-Voltage Adaptation Required: Cannot be directly used for high-voltage systems without additional protection.
- Initial Setup Complexity: Requires proper calibration and configuration before operation.
- Component Dependency: Performance depends on the reliability of electronic components used.

1.5.3 Applications of the Proposed System

- Power Distribution Networks: Used for monitoring underground cables in electrical distribution systems.
- Smart Grid Systems: Supports real-time monitoring and automation in modern smart grids.
- Industrial Applications: Useful in factories and industries for maintaining cable health.
- Railway & Metro Systems: Helps in monitoring underground electrical wiring in transport systems.
- Residential & Commercial Areas: Applicable in underground wiring systems of buildings and complexes.
- Oil & Gas Industry: Ensures safety by detecting faults in critical cable networks.
- Power Plants & Substations: Used for efficient monitoring and fault management.
- Remote Areas: Suitable for rural electrification where manual inspection is difficult.

1.6 RESULT, FUTURE SCOPE & CONCLUSION

1.6.1 RESULT

The proposed IoT-based underground cable fault detection system was successfully designed, implemented, and tested under different fault conditions. The system was able to accurately detect various types of faults such as short circuit faults, open circuit faults, and earth faults in the simulated underground cable model.

During experimental analysis, it was observed that the voltage drop across the resistor network changed proportionally with the location of the fault. The microcontroller effectively processed the sensed voltage values and calculated the fault distance with good accuracy. The results displayed on the LCD screen were consistent with the expected fault positions.

The IoT module (ESP8266) successfully transmitted real-time data to the cloud platform. The system provided continuous monitoring and allowed users to access fault information remotely through a web interface. Instant updates and fault notifications improved the response time for maintenance.

Overall, the system demonstrated reliable performance, fast fault detection, and accurate fault location. The integration of IoT technology significantly enhanced monitoring capabilities and reduced the need for manual inspection.

1.6.2 FUTURE SCOPE

The proposed system provides a strong foundation for further advancements in smart fault detection technologies. In the future, the system can be enhanced by integrating advanced algorithms such as machine learning and artificial intelligence for predictive fault analysis. This would allow the system to predict faults before they occur, improving preventive maintenance.

The accuracy of fault location can be further improved by incorporating advanced sensing techniques such as Time Domain Reflectometry (TDR). Additionally, the system can be extended to support long-distance underground cable networks used in high-voltage transmission systems.

Integration of GPS technology can enable precise geographical fault location tracking, which will be highly useful in real-world applications. The system can also be connected with smart grid infrastructure for centralized monitoring and automated control. Furthermore, mobile applications can be developed to provide user-friendly interfaces, real-time alerts, and data analytics. Wireless communication can be upgraded using technologies such as LoRa or 5G for better range and reliability.

1.6.3 CONCLUSION

This research presents an efficient and reliable IoT-based underground cable fault detection system that addresses the limitations of traditional fault detection methods. The system successfully detects and locates faults in underground cables using voltage drop analysis and resistance measurement techniques.

The integration of IoT enables real-time monitoring, remote accessibility, and instant fault alerts, significantly reducing maintenance time and operational costs. The system improves the reliability, safety, and efficiency of power distribution networks.

The experimental results confirm that the proposed system is accurate, cost-effective, and suitable for practical implementation. It reduces manual effort and enhances fault management in underground cable systems.

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