

Detection of Cable Breakage Underground System

D. Aamani Bai¹, T. Shashi², D. Sneha³, M. Sruthi⁴,
J. Sai Teja⁵, K. Zubair⁶

Department of ECE, Tadipatri Engineering College, Tadipatri

Abstract:

Underground power cables are increasingly preferred in modern distribution systems due to their improved safety, reduced exposure to environmental conditions, and better suitability for urban infrastructure. Despite these advantages, identifying faults such as cable breakage remains a difficult task because the lines are not directly visible. Conventional fault detection methods are often time-consuming and rely heavily on manual inspection, which delays maintenance and affects supply continuity. The proposed system presents an automated approach for detecting cable faults in underground three-phase distribution lines. It incorporates switching units, an Arduino-based control system, and a NodeMCU module for communication. Each phase line is continuously monitored, and any abnormal variation in electrical conditions is captured through the switching mechanism and processed by the controller. Once a fault is identified, the system determines the affected phase and displays the information locally while also initiating protective actions through relay.

Keywords: Underground Cable Fault Detection, IoT-Based Monitoring, Arduino Microcontroller, NodeMCU, Smart Power Distribution, Fault Identification, Three-Phase System, Relay Control, Real-Time Alerts, Cloud Integration.

I.INTRODUCTION:

Underground cable networks play a vital role in modern power distribution, especially in densely populated and urban regions where overhead lines are less practical. These systems offer several advantages, including improved safety, reduced exposure to weather conditions, and better visual integration with the environment. However, fault detection in underground cables remains a complex task. Since the cables are not directly accessible, identifying issues such as breakage or phase failure requires significant time and effort. Traditional techniques often depend on manual inspection or basic electrical testing, which can delay restoration and increase maintenance costs. With the growth of smart grid technologies, there is a need for automated systems capable of detecting faults quickly and accurately. Recent advancements in embedded systems and IoT have made it possible to continuously monitor electrical parameters and respond to abnormal conditions in real time. Despite this progress, many existing solutions lack integrated mechanisms for both local fault indication and remote communication. The proposed system addresses these limitations by combining sensing, processing, and communication into a unified framework. As illustrated in the block diagram, the system monitors three-phase input lines through switching units, which provide status signals to an Arduino controller. The controller processes these inputs to identify any irregularities associated with cable faults. Once a fault is detected, the system immediately indicates the affected phase and initiates necessary actions through a relay module to manage connected loads. To extend functionality beyond local monitoring, a NodeMCU module is incorporated for wireless communication. This allows fault information to be transmitted to a cloud platform, where it can be accessed remotely. In addition, alert messages are generated to notify maintenance personnel,

ensuring a faster response. Supporting components such as GSM, GPS, and buzzer units further enhance the system by enabling communication, location tracking, and audible warnings. Overall, the integration of IoT with embedded control provides a reliable and efficient solution for underground cable fault detection. The system reduces detection time, improves operational safety, and supports continuous monitoring, making it suitable for modern power distribution applications.

II. LITERATURE SURVEY:

The authors Viatcheslav P. Shuvalov, Boris P. Zelentsov, and Irina G. Kvitkova published this work in the domain of optical communication system reliability. The method involves developing a mathematical reliability model for fiber-optic cables that considers both gradual degradation and sudden failures along with restoration through reconnection at breakage points. The problem addressed is that fiber-optic cables experience aging-related attenuation as well as unexpected physical damage, which affects communication availability. The model also includes the impact of repeated repairs and control errors on system performance, showing how increased connection points raise attenuation and reduce reliability over time [1]. The authors Bin Liang, Wenshuo Li, Boyang Lin, Lei Yan, Xueqian Wang, and Wenfu Xu published this work in the domain of cable-driven robotic systems and control engineering. The method proposed is a Hybrid Tension-Position Control (HTPC) strategy that integrates tension regulation with position control to improve accuracy and prevent cable slack or breakage. The problem addressed is that cable-driven manipulators suffer from instability due to improper tension, hysteresis, and friction, leading to motion errors and possible mechanical failure. The proposed system uses neural network-based tension prediction and a dual-loop control structure to ensure safe and precise operation [2]. The authors Chuanbiao Zhang, Xiongyan Tang, Zelin Wang, Shikui Shen, He Zhang, and Yan Shi published this work in the domain of optical fiber monitoring and fault detection. The method involves real-time monitoring of vibration signals in live optical networks to detect external disturbances and potential cable breakage. The problem addressed is that optical cables installed in outdoor environments are highly vulnerable to external damage from construction activities and environmental factors, leading to communication failures. The study demonstrates that spectral analysis of vibration data can effectively identify abnormal events and improve early fault detection and maintenance planning [5]. The author Takashi Kurihara published this work in the domain of power cable insulation and thermal analysis. The method involves experimental investigation of temperature rise and burning characteristics in XLPE cables under constant AC current when the shielding layer is damaged. The problem addressed is that breakage of the shielding layer leads to abnormal current flow and heat generation in the semiconducting layer, which can accelerate insulation failure and reduce cable lifespan. The study highlights the thermal risks associated with shielding defects and their impact on cable reliability and safety [4]. The authors Viatcheslav P. Shuvalov, Boris P. Zelentsov, and Irina G. Kvitkova published this work in 2024 under the domain of fiber-optic communication reliability and network performance analysis. The method proposed involves developing a mathematical model to evaluate the reliability of fiber-optic cables by considering both gradual failures due to aging and sudden failures caused by external disturbances. The model also incorporates the restoration of communication through reconnection at the breakage point and analyzes the resulting increase in signal attenuation. The problem addressed is that fiber-optic cables experience performance degradation over time due to increasing attenuation, and sudden failures require repair through splicing, which further reduces signal strength and increases the unavailability factor. Additionally, the study considers the effect of control errors of the first kind on reliability estimation, which can impact system monitoring accuracy. The results show that repeated repairs and additional connection points significantly affect system availability and long-term performance. This work provides a useful framework for

analyzing, predicting, and improving the reliability of fiber-optic communication systems and helps in better maintenance planning and network management [3]. The authors Luwei Zhang, Jiawei Wang, Fan Yang, Lijun Wan, Lei Zhang, and Dongming Li published this work in 2024 under the domain of submarine cable monitoring and marine communication safety. The method proposed involves developing a temperature–depth (T–D) model to estimate the burial depth of shallow buried optical cables based on mud temperature measurements. This approach enables remote monitoring by analyzing the relationship between seabed temperature variations and cable depth without requiring complex underwater survey techniques. The problem addressed is that submarine cables are highly vulnerable to damage when insufficiently buried, exposing them to risks such as anchor strikes, seawater erosion, and marine interference. Existing detection methods are expensive and difficult to perform underwater, making continuous monitoring challenging. The results demonstrate that the proposed model provides accurate depth estimation with an error of approximately 0.7 m, proving its feasibility for practical applications. This study offers a cost-effective and efficient solution for real-time monitoring, improving the safety, maintenance, and risk assessment of submarine cable systems [10].

III. PROPOSED SYSTEM:

The proposed system is designed to detect faults in underground three-phase cable networks and provide both local indication and remote alerts. The architecture integrates sensing, control, communication, and protection units to ensure reliable operation. Three-phase input lines are connected to the system through slide switching units, which simulate and monitor the condition of each phase. These switches provide input signals to the Arduino controller, representing the status of the cable lines. Under normal conditions, all phases operate continuously, and the controller receives stable input signals. When a fault such as cable breakage occurs, the corresponding phase signal changes, allowing the controller to identify the affected line. The Arduino acts as the central processing unit, continuously analysing the input data from all phases. Once a fault is detected, it determines the exact phase where the issue has occurred. Based on this condition, the controller activates the relay module to isolate or control connected loads, preventing further damage. The system also provides local indication using buzzer alerts for immediate awareness. For remote communication, the NodeMCU module transmits fault information to a cloud platform using Wi-Fi. Additionally, a GSM module is integrated to send alert messages directly to authorized personnel. The inclusion of a GPS module allows the system to share location details, which is useful for identifying the exact fault area in large-scale networks. Overall, the system offers a fast and efficient method for underground cable fault detection, combining real-time monitoring, automatic response, and remote notification.

BLOCK DIAGRAM:

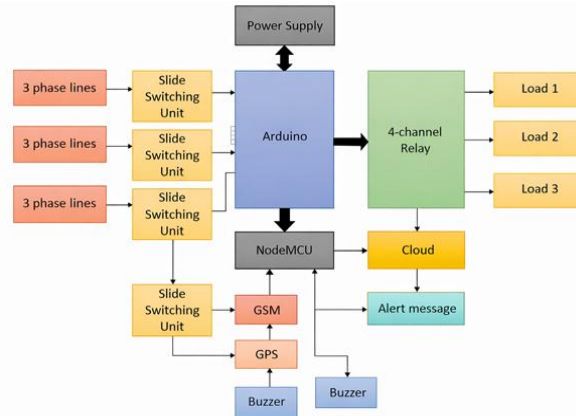


FIG: 1 BLOCK DIAGRAM

IV.HARDWARE WORKFLOW:

ARDUINO MICROCONTROLLER:



The Arduino serves as the main control unit of the system, responsible for processing all input signals and making decisions based on fault conditions. It receives data from the slide switching units representing the status of each phase line. Using programmed logic, the controller continuously compares the inputs to detect any abnormal condition such as phase interruption. Once a fault is identified, the Arduino triggers output actions including relay activation and alert generation. Its simplicity, reliability, and ease of programming make it suitable for real-time embedded applications. It ensures proper coordination between sensing, control, and communication modules.

SLIDE SWITCHING UNIT



FIG: 2 SLIDE SWITCHING UNIT

The slide switching unit is used to represent and monitor the condition of each phase line in the system. It acts as a manual interface that simulates normal and fault conditions by changing the input state supplied to the controller. Each switch corresponds to a specific phase, and any change in its position indicates a

disruption in that line. This setup helps in testing and demonstrating the behaviour of the system under different fault scenarios. The switching unit provides a simple and effective way to feed input signals without requiring complex sensing hardware during initial implementation.

NODEMCU



FIG: 3 NODEMCU

The NodeMCU module provides wireless communication capability to the system through built-in Wi-Fi support. It receives processed fault data from the Arduino and transmits it to a cloud server for remote monitoring. This allows users to access system status from anywhere using internet-connected devices. The module is compact, energy-efficient, and easy to interface with microcontrollers. It supports multiple communication protocols, making it flexible for IoT applications. By enabling real-time data transfer, the NodeMCU enhances the system's ability to provide timely updates and improves overall responsiveness.

GSM MODULE



FIG: 4GSM MODULE

The GSM module is used to send alert messages directly to users when a fault is detected. It operates using a cellular network, allowing communication even in areas without internet access. Once the Arduino identifies a fault, it sends a command to the GSM module, which then transmits an SMS containing fault details. This ensures that maintenance personnel are informed immediately. The module is particularly useful in remote locations where quick response is necessary. Its integration improves system reliability by providing an additional communication channel alongside IoT-based monitoring.

GPS MODULE



FIG: 5 GPS MODULE

The GPS module is incorporated to provide location information of the fault occurrence. It retrieves real-time geographic coordinates, which can be shared along with alert messages. This feature is especially useful in large underground cable networks where identifying the exact fault location is difficult. By combining location data with fault detection, the system reduces the time required for maintenance teams to reach the affected area. The module operates using satellite signals and provides accurate positioning data under normal conditions, enhancing the practicality of the system.

4-CHANNEL RELAY MODULE

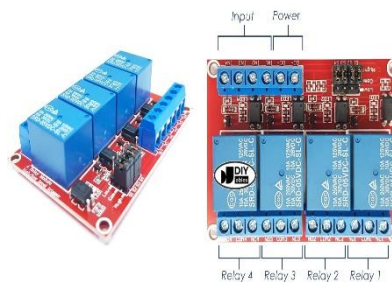


FIG: 6 4-CHANNEL RELAY MODULE

The relay module is used to control electrical loads connected to the system. It acts as an electrically operated switch that can isolate or connect loads based on commands from the Arduino. When a fault is detected, the controller activates the relay to disconnect affected loads, preventing further damage. The use of multiple channels allows control of several loads independently. Relays provide electrical isolation between control and power circuits, ensuring safety. This component plays an important role in implementing load protection and management within the system.

BUZZER

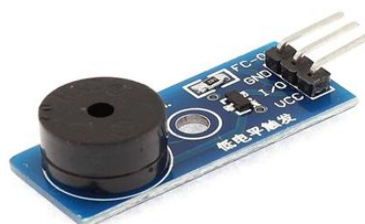


FIG: 7 BUZZER

The buzzer is used to provide an audible indication when a fault occurs. It is activated by the Arduino immediately after detecting an abnormal condition. This helps in alerting nearby personnel without the need for visual monitoring. The buzzer is simple in design but effective for quick local notification. It is especially useful during testing and in environments where immediate attention is required. Its inclusion enhances the overall alert system by adding an additional layer of indication.

POWER SUPPLY UNIT



FIG: 8POWER SUPPLY

The power supply unit provides the required operating voltage to all components in the system. It converts the available input power into regulated DC output suitable for the Arduino, NodeMCU, and other modules. Stable voltage is essential for accurate operation and to prevent malfunction of electronic components. The design ensures proper isolation and filtering to reduce noise and fluctuations. A reliable power supply supports continuous system operation and improves overall performance and durability.

V.RESULTS AND DISCUSSION

The system was implemented and tested under different simulated fault conditions using the slide switching units. Each phase line was operated independently to observe system response during normal and fault scenarios. When all switches were in normal condition, the system operated without any interruption, and no alerts were generated. Fault conditions were introduced by changing the state of individual switches to simulate cable breakage. The Arduino successfully detected the affected phase and triggered appropriate responses. The relay module responded by isolating the corresponding load, ensuring protection against potential damage. Simultaneously, the buzzer produced an audible alert, confirming local fault indication. The NodeMCU module transmitted fault data to the cloud platform without significant delay, enabling real-time monitoring. SMS alerts were also successfully delivered through the GSM module, ensuring that users were informed instantly. The GPS module provided location data, which was accurate enough for identifying the fault region during testing. Overall, the system demonstrated stable performance and reliable fault detection. Minor delays were observed in message transmission due to network conditions, but they did not affect the overall functionality. The results confirm that the proposed system can effectively detect underground cable faults and provide timely alerts, making it suitable for practical implementation.

CONCLUSION:

The proposed system provides an effective solution for detecting faults in underground cable networks using a combination of embedded control and IoT-based communication. It enables quick identification of faulty phases, supports load protection through relay operation, and ensures timely alerts via cloud and GSM communication. The system demonstrated reliable performance under different test conditions with minimal delay. In future work, the design can be enhanced by integrating automatic fault location

techniques, advanced sensors for precise measurement, and data analytics for predictive maintenance. Expanding the system for large-scale grid applications and improving network security can further increase its practical usability.

REFERENCES:

1. R. Wang, H. Mu, X. Zou, C. Song, Z. Cheng and K. Fan, "Analysis of Electric Field Characteristics and Defect Diagnosis for Local Cable Breakage," *2024 IEEE 7th International Electrical and Energy Conference (CIEEC)*, Harbin, China, 2024, pp. 3002-3007, doi: 10.1109/CIEEC60922.2024.10583781.
2. H. Lei, X. Haining, S. Lingbin, J. Qiang and S. Qingye, "Design and Application of New Technology for Intelligent Inspection and Early Warning of Submarine Cables against External Breakage," *2024 4th Asia-Pacific Conference on Communications Technology and Computer Science (ACCTCS)*, Shenyang, China, 2024, pp. 696-701, doi: 10.1109/ACCTCS61748.2024.00129.
3. P. Shuvalov, B. P. Zelentsov and I. G. Kvitkova, "A Model of the Fiber-Optic Cable Reliability with the Restoration of Communication by Connecting at the Breakage Point Caused by a Sudden Failure," *2024 International Scientific and Technical Conference Modern Computer Network Technologies (MoNeTeC)*, Moscow, Russian Federation, 2024, pp. 1-6, doi: 10.1109/MoNeTec60984.2024.10768163.
4. B. Liang, W. Li, B. Lin, L. Yan, X. Wang and W. Xu, "Hybrid Tension-Position Control of Cable-Driven Serial Manipulator to Improve Accuracy and Avoid Cable Slack and Breakage," in *IEEE/ASME Transactions on Mechatronics*, vol. 30, no. 2, pp. 1072-1083, April 2025, doi: 10.1109/TMECH.2024.3406920.
5. C. Zhang *et al.*, "Field Test Research of External Breakage Monitoring Based on Live Network Optical Cable," *2024 IEEE 12th International Conference on Information, Communication and Networks (ICICN)*, Guilin, China, 2024, pp. 140-143, doi: 10.1109/ICICN62625.2024.10761878.
6. T. Kurihara, "Duration of Current Application Until Outer Semiconducting Layer Started Burning and Temperature Increase across Gap in Samples Simulating Breakage of Shielding Layer in 6.6 kV XLPE Cable Under Constant AC Current," *2023 International Symposium on Electrical Insulating Materials (ISEIM)*, Shimane, Japan, 2023, pp. 01-04, doi: 10.23919/ISEIM60444.2023.10329196.
7. B. Tian, Z. Tan, P. Li, Z. Wang, Z. Liu and Q. Lv, "Fault Location Method of Power Cable Based on Distributed Fiber Optic Vibration Sensing Technology," *2023 IEEE 3rd International Conference on Data Science and Computer Application (ICDSCA)*, Dalian, China, 2023, pp. 1231-1236, doi: 10.1109/ICDSCA59871.2023.10393707.
8. H. Ma, Y. Wang, Z. Wu and Q. Wang, "Study on the Influence of Multiple Coaxial Cable Breaks on Ground Circuit Current," *2024 2nd Power Electronics and Power System Conference (PEPSC)*, Singapore, Singapore, 2024, pp. 46-50, doi: 10.1109/PEPSC63375.2024.10823590.
9. T. Oda, K. Makino, T. Hosome, M. Miyazaki and H. Hashimoto, "Thermal Imaging-Based Localization Technique for Fiber Breakpoints in Drop Cables," *2025 Optical Fiber Communications Conference and Exhibition (OFC)*, San Francisco, CA, USA, 2025, pp. 1-3.
10. L. Zhang, J. Wang, F. Yang, L. Wan, L. Zhang and D. Li, "Mud Temperature and Depth Modeling Based on the Detection of Shallow Buried Optical Cables," *2024 OES China Ocean Acoustics (COA)*, Harbin, China, 2024, pp. 1-6, doi: 10.1109/COA58979.2024.10723553.