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Stm32-Based Intelligent Underground Cable Monitoring, Fault Localization and Automatic Isolation System: A Literature Review

Chandana K., Deepa K., And Dharanya V.
Department of Electronics and Communication Engineering, PMC Tech, Hosur, Tamil Nadu, India

Under the Guidance of **Mrs. J. Roshini,** M.E., Assistant Professor, ECE

Abstract **-** Underground power cables are widely used in cities, industries, and electrical distribution networks because they provide a safer and more organized method of power transmission. However, insulation damage, moisture, ageing, excessive loading, and accidental excavation can cause cable faults that are difficult to locate because the cables are buried beneath the ground. This paper presents a focused literature review supporting the development of an STM32-based intelligent underground cable monitoring, fault localization, and automatic isolation system. The review examines microcontroller-based voltage/resistance fault localization, IoT-enabled remote monitoring, distributed sensing, and condition-assessment approaches. Existing IoT prototypes demonstrate the use of resistor networks, voltage measurement, analogue-to-digital conversion, embedded processing, local display, and wireless reporting to estimate fault distance. Complementary sensing approaches can provide additional information about cable condition, while data-driven assessment can support maintenance prioritization. The reviewed material also indicates limitations related to fault-type coverage, calibration, field validation, communication availability, and integration of detection with protective isolation. Based on these findings and the project requirements, a conceptual STM32-centred architecture is outlined. The proposed prototype is intended to acquire electrical measurements, estimate fault distance, display and transmit fault information, generate local alerts, and command an isolation stage after suitable validation. The review identifies research gaps and design considerations for a cost-conscious embedded monitoring prototype. The automatic isolation function is a proposed project feature and requires independent protection testing before any practical power-network application.

Index Terms **-** Underground cable; STM32; fault detection; fault localization; automatic isolation; IoT; ESP8266; ADC; condition monitoring.

I. INTRODUCTION

Underground cables are widely used in cities, industries, and electrical distribution networks. They reduce exposure to environmental disturbances and provide an organized method of power transmission. Despite these advantages, underground cables may develop faults due to insulation deterioration, moisture ingress, ageing, excessive loading, and accidental damage during excavation. Since the cable is buried, direct visual inspection is difficult. Technicians may need to inspect a large route to identify the damaged section, increasing maintenance time and cost.

A monitoring system that detects abnormal electrical measurements and estimates the distance to a fault can help maintenance personnel narrow down the section requiring inspection. IoT connectivity can additionally provide remote information, while local alarms can alert nearby operators. The project presentation proposes the use of an STM32 microcontroller for sensor-data acquisition and fault calculations, an ESP8266 Wi-Fi module for IoT communication, an LCD for local display, and a buzzer and status LED for fault indication [1].

This review evaluates the research background relevant to the project titled “STM32-Based Intelligent Underground Cable Monitoring, Fault Localization and Automatic Isolation System.” It focuses on techniques and limitations reported in the supplied project presentation and reference paper, and on research directions relevant to the proposed design.

II. REVIEW SCOPE AND APPROACH

The review is based on the project presentation supplied by the authors and the accompanying reference material on IoT-based underground cable fault detection. The presentation identifies the project objectives, hardware roles, and selected references [1]. The accompanying 2025 paper, “IoT Based Underground Cable Fault Detector,” provides a more detailed description of a resistor-network model, ADC-based acquisition, microcontroller processing, LCD indication, and IoT reporting [2].

The review organizes the available information under four themes: electrical measurement and distance estimation; embedded and IoT-based monitoring; complementary sensing and condition assessment; and fault isolation and practical implementation considerations. Where the supplied sources provide only a title or short summary, the discussion is limited to that information. Unreported experimental results are not assumed.

III. LITERATURE REVIEW

('A. Microcontroller-Based Voltage/Resistance Fault Localization', 'The 2025 IoT-Based Underground Cable Fault Detector paper describes a cable model represented by a set of resistors, with switches placed at known positions to simulate faults. A voltage change produced by the fault condition is measured by a sensing circuit and supplied to the analogue-to-digital converter (ADC). The microcontroller processes the digital value to estimate the distance of the fault from the monitoring point. The result is displayed on an LCD and can be uploaded to an IoT web application [2].', 'The reported prototype distinguishes no-fault and fault conditions and illustrates a yellow-phase fault at 8 km. Its architecture is divided into power-supply, cable-simulation, control, and display sections. The paper demonstrates the usefulness of Ohm’s-law-based measurement and embedded processing for a model cable. However, the use of a resistor-and-switch representation does not by itself establish accuracy on a real buried cable. Calibration, conductor and insulation characteristics, fault resistance, temperature, joints, and network topology can affect practical measurements. The paper also identifies extension to open-circuit, line-to-line, and double-line-to-ground faults as future work [2].')

('B. IoT-Based Monitoring and Remote Fault Reporting', 'The project presentation identifies remote monitoring as an important requirement because systems that rely only on local displays provide limited

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information to maintenance personnel. It proposes an ESP8266 Wi-Fi module to transmit the estimated fault distance and status to an IoT cloud platform. The local LCD provides immediate information, while the remote platform is intended to retain fault readings and event history [1].', 'The 2025 detector paper similarly describes wireless upload of fault information to an IoT application. This allows phase, fault distance, and event information to be viewed remotely and can help technicians focus inspection on the suspected section [2]. However, wireless monitoring depends on network availability. The project presentation explicitly notes that Wi-Fi interruption can prevent cloud connectivity [1]. A practical design should therefore preserve local detection and indication when the network is unavailable, and should consider buffering event data for later transmission.')

('C. Distributed Sensing and Alternative Fault-Detection Approaches', 'The project presentation includes a literature entry on field-validated distributed acoustic sensing for real-time fault detection and localization in medium-voltage underground cables. The summarized method uses distributed acoustic sensing with existing communication fibres, while the listed limitation is the need for specialized sensing equipment and suitable communication fibres [1]. This approach differs from a low-cost electrical measurement prototype: it offers a distributed sensing concept but has additional infrastructure and equipment requirements.', 'The other supplied review sources discuss distributed temperature sensing and data-driven underground cable health assessment. Temperature profiles can provide information about thermal loading and abnormal heating along a cable route. Data-driven assessment can combine cable-circuit information and condition measurements to support maintenance prioritization. These approaches complement rather than replace electrical fault localization. They are treated here as related research directions, not as components already included in the proposed hardware.')

('D. Multi-Type Fault Detection and Protection', 'The project presentation lists a reference titled “Detection and Monitoring of Multi-Type Underground Power Cable Fault using IoT” and summarizes the need to evaluate communication performance and fault-location accuracy [1]. The accompanying detector paper identifies open-circuit, line-to-line, and double-line-to-ground fault detection as possible extensions beyond its demonstrated short-circuit localization [2]. These findings indicate that a useful monitoring system should define the fault types it can reliably detect and validate each condition separately.', 'Fault detection and fault isolation are distinct functions. Detection identifies an abnormal condition; localization estimates the affected section; isolation operates a switching or protective device to disconnect the faulty section. The supplied project presentation names automatic isolation as part of the project title, but its listed hardware includes the STM32, fault-simulation circuit, ESP8266, LCD, buzzer, and status LED and does not provide a detailed relay/contactor driver design or protection coordination procedure [1]. Consequently, automatic isolation should be treated as a proposed function requiring a separately engineered and tested output stage, not as an experimentally demonstrated result.')

IV. COMPARATIVE SUMMARY OF THE REVIEWED WORK

Study / approach	Technique described	Contribution	Limitation / consideration
IoT-Based Underground Cable Fault Detector, 2025 [2]	Resistor network, voltage sensing, ADC, microcontroller, LCD and IoT reporting	Reference for voltage-based distance estimation and remote display	Model-based demonstration; field calibration and additional fault types require validation
IoT-based smart cable fault detector, IEEE 2024 [1]	Listed in project references	Relevant prior work for embedded and IoT monitoring	Full methodology and performance details must be checked from the complete paper
Underground Cable Fault Analysis using Microcontroller and GPS, 2025 [1]	Listed in project references	Relevant to distance estimation and location reporting	Detailed method and results are not included in the supplied presentation
Multi-Type Underground Power Cable Fault Detection using IoT, IEEE 2025 [1]	Multi-type fault monitoring, as indicated by title	Highlights need for broader fault coverage	Fault-wise performance should be verified from the full paper
Distributed acoustic sensing, 2025 [1]	Sensing through existing communication fibres	Alternative distributed sensing approach	Specialized equipment and suitable fibres required

V. RESEARCH GAP

The reviewed work and the project requirements indicate several issues that motivate the proposed system:

- Controller-specific implementation: The reference prototype uses a different microcontroller platform. The project proposes STM32 for voltage acquisition, processing, and distance calculation; its ADC configuration, sampling, calibration, and firmware performance must be documented and tested.
- Combined local and remote indication: A local LCD, buzzer, and status LED are proposed alongside ESP8266-based cloud reporting. The system should continue local operation during Wi-Fi or cloud interruption.
- Distance-estimation validation: The voltage/resistance relationship must be calibrated against known simulated fault positions. Estimation error should be measured across different positions and fault conditions.
- Automatic isolation: The project title includes automatic isolation, but the supplied presentation does not yet detail the switching hardware or its protection logic. A safe, isolated driver stage and appropriate protection design must be developed and tested independently.
- Event recording: Recording fault status, estimated distance, phase/line, and event time can improve later analysis, but the storage method and data format must be specified.

Accordingly, the proposed contribution is the integration of STM32-based acquisition and processing with local indication, ESP8266-based remote reporting, event recording, and a planned isolation output in one prototype. This is a project-level design contribution; it should not be described as proven superior to existing systems until comparative experimental results are obtained.

VI. PROPOSED STM32-BASED SYSTEM ARCHITECTURE

The proposed system is organized around the STM32 microcontroller. A fault-simulation circuit, consisting of calibrated resistors and switches, represents cable sections and allows faults to be introduced at known positions. The voltage measurement circuit conditions the sensed signal to a range suitable for the STM32 ADC. The STM32 samples the input, compares it with calibrated reference values, identifies a possible fault condition, and estimates the distance to the fault.

The LCD displays the fault status and estimated distance. The ESP8266 Wi-Fi module transmits fault information to an IoT platform for remote monitoring. A buzzer and status LED provide local audible and visual alerts. An additional isolation-control output may command a suitably rated switching device through an isolated driver circuit. The isolation function must be interlocked and validated; a microcontroller output must never drive a power relay or contactor coil directly.

Conceptual signal flow: Fault-simulation circuit / voltage sensing → signal conditioning and protection → STM32 ADC and processing → fault decision and distance estimation → LCD + buzzer/LED → ESP8266 and IoT platform → event storage. Proposed protection branch: validated fault decision → isolated driver → appropriately rated switching device.

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The supplied presentation identifies the STM32, fault-simulation circuit, ESP8266, LCD, buzzer, and status LED and states their intended roles [1]. Exact STM32 model, pin numbers, ADC resolution, voltage-divider values, relay rating, isolation components, cloud service, and calibration equation should be added only after the actual hardware design is finalized.

VII. EXPECTED OUTCOMES AND EVALUATION

The project is intended to produce a working low-voltage prototype that detects selected fault conditions in a cable model, estimates the distance to the simulated fault, displays the result locally, transmits the event to an IoT platform, and provides audible and visual alerts. If the isolation stage is implemented, its operation should be evaluated separately using a safe test setup.

Evaluation should include: (i) no-fault baseline readings, (ii) known fault positions along the model, (iii) repeated measurements at each position, (iv) distance-estimation error, (v) response time, (vi) behaviour under Wi-Fi disconnection, (vii) correct event logging, and (viii) isolation-stage response and fail-safe behaviour. Numerical accuracy, response time, and reliability values should be reported only after measurements are completed.

VIII. LIMITATIONS

The present manuscript is a literature review and project design rationale, not a report of completed experimental validation. The supplied presentation provides project objectives and component roles but does not include a complete circuit schematic, finalized pin mapping, calibration dataset, measured error values, or verified isolation test results. Several references are listed by title and DOI without their full papers being supplied. Their detailed methods and findings must be checked against the publisher versions before final journal submission.

IX. CONCLUSION

The reviewed literature shows that underground cable fault monitoring can be approached through electrical measurement, embedded processing, IoT communication, and complementary distributed sensing. Resistor-network and voltage-based methods provide a straightforward basis for estimating fault distance in a prototype, while IoT connectivity enables remote reporting. Distributed sensing and data-driven assessment offer broader condition-monitoring directions but may require additional infrastructure and data. The proposed project brings together an STM32 controller, fault-simulation and voltage-sensing circuit, ESP8266 communication, LCD, buzzer, and status LED, with automatic isolation planned as an additional protection function. The key research and engineering tasks are accurate calibration, validation across selected fault types, robust operation during communication loss, and safe isolation-stage design. Experimental measurements are required before claims about accuracy, reliability, or field readiness can be made.

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