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A Literature Survey on Underground Cable Fault Detection using IoT

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Abstract: *The rise in use of Underground Cables for power Transmission is recent times due to its less maintenance and lower susceptibility to damage by weather, means that detection of any other faults that occur in them must be swift and efficient to ensure lower down-Time in transmission and supply. The survey goes through various fault detection methods that have been proposed, to find potential pros and cons and attempts at bettering them. While using various AI models in detection can be highly accurate to the cause, it still has some error margins to it. On the other hand using IoT (Microcomputers and sensors) make up for near perfect detection increasing the efficiency of the system. This requires a wide range of understanding on the topics of electricity and the working of these lines which is the goal of this paper.*

Keywords: Underground cables, Transmission Lines, Fault Detection, Voltage

I. INTRODUCTION

Steady and Dependable supply of energy is of utmost importance in smooth operation of modern society , identifying and fixing defects in electrical systems is of the highest priority. The foundation of electricity distribution networks is made up of the transmission lines and underground cables, however these components are prone to a number of problems that could endanger public safety as well as interrupt service. This literature survey investigates a wide range of methods and tools targeted at improving fault detection, diagnosis, and mitigation procedures in order to meet these issues.

An overview of current developments in fault detection and management in electrical systems is given , with an emphasis on underground cables. This overview illustrates the techniques and approaches used to address the difficulties of fault detection in these vital power infrastructure components by looking at a number of research papers.

From traditional methods relying on fundamental principles of electrical engineering to technologies such as machine learning and deep learning algorithms, the surveyed literature showcases the breadth and depth of research in this field. Each study offers unique insights and contributions, shedding light on different aspects of fault detection and management, including fault location techniques, diagnostic methodologies, and real-time monitoring systems.

It also draws attention to new directions, obstacles, and chances for further study and development in this important field of electricity transmission. In the end, the knowledge gathered from this survey can guide the creation of a stronger, more dependable, and resilient electrical infrastructure, guaranteeing society's continuous access to a safe and effective supply of power.

II. LITERATURE SURVEY

2.1 Identification of Electrical Faults in Underground Cables Using Machine Learning Algorithm.

The study presents a unique method for fault identification in buried transmission lines that makes use of a hardware system and a portable, intelligent device that is fitted with a thermal imaging camera. A system-on-chip device interfaces with an 8x8 array of infrared thermal imaging sensors to collect thermal photographs of cables in real-time. After that, a machine learning algorithm based on convolutional neural networks (CNNs) and built on 200 thermal photographs is used to process and evaluate these images. Numerous indicators are used to assess the CNN classifier's performance, showcasing its accuracy in locating problems in underground transmission lines.

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The Mentioned system in [1] has a number of benefits, including cloud connectivity, low material degradation, shorter working times, and non-contact defect detection. Thermal imaging improves fault identification capabilities by allowing the detection of problems based on differences in temperature. Nonetheless, the system might be limited for particular kinds of errors or in specific environmental circumstances. The quantity and quality of training data may also have an impact on the accuracy and performance of the CNN classifier, necessitating periodic calibration and maintenance to guarantee dependable results.

The CNN-based system achieves an accuracy of 93%, sensitivity of 91%, specificity of 95%, PPV of 95%, NPV of 90%, and an F1 score of 0.93 according to [1]. These metrics indicate the high performance and reliability of the adopted CNN classifier in accurately classifying faulty conductors in underground transmission lines.

2.2 Detection Of Fault Location in Transmission Lines

This research studies The travelling wave idea for the fault location technique for transmission lines . It highlights how crucial quick defect finding is to protecting devices and enhancing reliability. The process entails capturing current signals and analysing traveling wave behaviour using the Karrenbauer transformation. Faults in [2] are tested and simulated using MATLAB simulation, which uses a single-ended travelling wave technique to make fault location easier.

The application of the travelling wave principle, which is useful for transient problems, the simplicity of the single-ended travelling wave method, and realistic MATLAB simulation are only a few of the method's benefits. The technique's drawbacks, however, include difficulties like current signal recording and processing's sensitivity to noise and distortion in signals as well as possible restrictions on accurately simulating real-world settings. For implementation, proficiency with MATLAB and signal processing methods is also necessary.

2.3 Underground Cable Fault Distance Locator

This paper describes a system that utilizes a microcontroller for finding faults in underground cables. The voltage drop that the fault causes, which changes with respect to where the fault occurs, is used by the system to determine fault distances by utilizing Ohm's law. In [3] Cable lengths are represented by a sequence of resistors, with a DC voltage applied at one end. An analog to voltage converter is used to measure the voltage change, and an LCD that is attached to the microprocessor shows the fault distance.

The suggested technique in [3] provides an easy-to-use digital fault detection mechanism that can lead to faster repairs, increased system dependability, and lower operating costs. Benefits include increased system availability and quicker repair times. However, it might not be appropriate for recognizing all fault kinds or complex cable networks because it depends on the assumption that the voltage drop accurately represents fault distance. Furthermore, the microcontroller's regular scanning may make it more complex and consume more power, which would limit its use in some situations.

2.4 Fault location in underground cables using ANFIS nets and discrete wavelet transform

This paper presents an Adaptive Neuro-Fuzzy Inference System (ANFIS) and Wavelet Transform-based fast fault identification method for buried cables. In [4] Wavelet Transform collects features using a simulated 9 km, 11 kV, 50 Hz power line with one line to ground fault to train ANFIS. The process involves modeling the wiring system, using the Discrete Wavelet Transform to identify fault signs, and using the dataset produced by the wavelet analysis to train ANFIS. An accuracy of 99.94% shows that the combination of Wavelet Transform and ANFIS provides for effective fault identification. Regardless, the complexity of these strategies' application and their reliance on the quality of the dataset present obstacles. Although the method has potential for locating faults in subterranean cables, it is labour-intensive and computationally challenging, and its precision is highly dependent on the training set.

2.5 Deep learning techniques for transmission line fault classification

Despite technical developments, power system failures continue to cause interruptions in the provision of electric power. The paper [5] addresses this topic and emphasizes the importance of promptly classifying and clearing faults. Deep learning techniques, such as artificial neural networks (ANN) and long short-term memory (LSTM), are proposed for fault classification. According to experimental results, LSTM and LSTM with Window Regression (LSTM-WR) achieve accuracy, exceeding ANN. The processes involved in real-time implementation include data collection and preparation, managing real-time data streaming, integration, model deployment, and decision-making for failure detection and recovery while continuously verifying and modifying the system.

Offers a thorough examination of deep learning techniques that address challenges like capturing long-term dependencies in sequential data and handling temporal features effectively, and presents advantages in advancing energy system fault classification. The study also offers a full grasp of the application of deep learning in power system failure analysis by providing in-depth insights into label encoding, data preparation, and fault categorization methods. Nevertheless, the paper also highlights certain drawbacks that could compromise the effectiveness of the suggested methods, such as the requirement for substantial preprocessing, possible difficulties with hyperparameter adjustment, and the potential for dataset imbalance. Practical implementation needs careful awareness of these limits. High accuracy rates achieved in[5] by LSTM (99.98% training, 100% testing) and LSTM-WR (99.99% training, 99.98% testing), surpassing those of ANN (42.98% training, 42.33% testing).

2.6 Fault diagnosis of voltage sensor and current sensor for lithium-ion battery pack using hybrid system modelling and unscented particle filter

In this paper, a novel fault diagnostic technique using hybrid system modelling and the unscented particle filter (UPF) algorithm is presented for the voltage and current sensors in lithium-ion battery pack circuits. The battery system is modelled to include both discrete dynamics and continuous variables using stochastic hybrid automata. Then, discrete and continuous states are estimated using the UPF algorithm, making precise sensor defect diagnosis possible. A serial-parallel configuration battery pack is used for experimental validation under various fault scenarios, proving the efficacy of the suggested approach in properly identifying defects and tracking system changes.

The suggested fault diagnostic approach in [6] has a number of benefits, such as the capacity to process continuous variables and discrete dynamics concurrently, accurately diagnose problems without the requirement for residuals or thresholds, and efficiently track system changes. In addition, when compared to conventional particle filter techniques, the UPF algorithm performs better and reduces particle impoverishment. However, there are still issues, especially with relation to particle impoverishment's enduring nature, which may cause a false positive. Because of the methodology's intricacy, practical adoption may also require theoretical comprehension and experimental validation.

2.7 Sensor Degradation Detection using Visual Timeseries and Deep Convolutional Neural Networks

The study presents a novel approach, especially for identifying sensor degradation in industrial assets. The suggested method in [7] achieves recognition of sensor failures by utilizing deep convolutional neural networks (CNNs) for fault detection and feature extraction, and turning 1-D time-series information into 2-D pictures using Grammian Angular Fields. The process consists of splitting time-series data, turning it into pictures, training the CNN model, and then looking for errors in data that hasn't been seen before.

The suggested approach has a number of benefits, such as reduced subjectivity in defect recognition, improved generalizability to unseen sensors, and automated fault recognition. However, there are several significant drawbacks that point to areas that still need to be improved, like the need for labeled training data, possible computing complexity, and reliability restrictions when used with new sensors. Across a range of sensor varieties, the CNN-based model in [7] identified sensor problems with an accuracy of over 85%. The model performed somewhat worse when applied to previously unseen sensors, even though it was useful in detecting faults.

2.8 Power System Frequency Monitoring Network (FNET) Implementation

This paper studies the implementation Frequency Monitoring Network (FNET) system, which seeks to deliver precise wide-area frequency observations in real-time. FNET is made up of an Information Management System (IMS) and Frequency Disturbance Recorders (FDRs) that use an online GPS-synchronized network. FDR devices in [8] collect frequency readings and send it to the IMS over the Internet. They are outfitted with a variety of sensors and microprocessors. Through a web-based user interface, the IMS processes, stores, and makes the data accessible in real time. The synchronized observations of the whole US power network made possible by this design, make power system management and analysis easier.

The FNET system offers several benefits, such as precise dynamic frequency measurements in the event of issues, extensive coverage enabled by strategically positioned FDR units, economical deployment, and instantaneous data access through the IMS web interface, which improves situational awareness for researchers and operators. However, drawbacks include the need for Internet connectivity for data transmission, periodic issues with data transmission reliability that result in missing data, and the possibility of estimation mistakes in event location because different sites have varied frequency wave speeds.

In the 52–70 Hz band, it shows almost negligible algorithm error, highlighting the accuracy of frequency estimate algorithms created for FNET. It is anticipated that future developments, such as multi-resampling methods, would increase precision even further by striving for zero algorithm error throughout a larger frequency range.

2.9 Signal Behaviours of Power Transmission Line During Fault

The study models a 330kV transmission line using simulation methodologies and the Simscape Power Systems tool in the Simulink environment to examine how electricity lines behave during faults. To understand the transmission line's behaviour in [9], different failure scenarios are simulated and voltage and current waveforms are captured and studied. Using distributed parameter modelling, the system injects faults at various points along the transmission line to properly simulate real-world situations and track dynamic behaviours.

One of this method's benefits is that, thanks to distributed parameter simulation, it can accurately depict the behaviour of cables. Without the need for actual investigation, simulation allows the examination of various fault conditions and provides visual insights via voltage and current waveforms. Fault types that can be recognized and researched include single line-to-ground, line-to-line, and three-phase faults. However ,The dependence on the precision and constraints of the simulation environment, as well as the possible influence of assumptions made during modelling and simulation, are the drawbacks. Difficulty in the procedure may arise from the need for simulation tool and electric system expertise in the analysis of the outcomes.

2.10 scheduling and routing algorithms for connected coverage of wireless sensor networks,Ad Hoc Networks

The goal of the study is to maximize Wireless Sensor Network (WSN) operation periods under energy and budget limitations by introducing a new mixed-integer linear programming (MILP) model called SPSRC. SPSRC solves the NP-hard problem by combining judgments about sink and sensor locations, activity scheduling, and routing for linked coverage in a unique way. It does this by offering heuristics and algorithms. Decision variables and constraints are included in the MILP formulation, and two heuristic algorithms—Constructive Heuristic (CH) and Disjunctive Heuristic (DH)—as well as Local Search (LS) and Tabu Search (TS) are used to generate and optimize solutions.

When compared to other approaches, the comprehensive approach of SPSRC provides efficient solutions by enabling the simultaneous resolution of important WSN design concerns within a single model. SPSRC is still difficult to solve for massive networks, and its relevance in situations where sink placement is uncertain or dynamic is limited by the assumption of known sink locations.

2.11 Degradation Study of Power Cables Insulation under AC Electric Field, Based on Electrical Measurements and Physico-chemical Analysis

The paper studies The effect of electrical field stress on crosslinked polyethylene (XLPE) insulating material, which is utilized in high-voltage electrical lines. [11] considers The dielectric parameters, electrical resistivity, and physico-chemical features of XLPE exposed to a 5 kV/mm electrical field as the main subjects of the experimental analysis. To assess the behaviour of the insulator under stress, standard XLPE plates were used along with techniques like dielectric characterisation, FTIR spectroscopy, and SEM examination.

The study's extensive experimental methodology, which addresses every element of XLPE insulation behaviour under electrical stress, is one of its advantages. Using a variety of approaches improves comprehension, especially when it comes to determining degradation factors. The study's concentration on a particular commercial XLPE polymer and the absence of a consideration of long-term consequences are among its weaknesses, which may restrict its generalization and broader relevance.

2.12 Study of High Voltage AC Underground Cable Systems

The effects caused during cable energization and de-energization are the main focus of this paper's study of phenomena related to the growing usage of high-voltage cables for the transfer of electric energy. It describes the goals of a thesis that looks at issues in high-voltage transmission systems, suggests fixes, and offers grid planning principles. To show and examine numerous phenomena,[12] uses models based on actual cable/system parameters, with a focus on temporary analysis and detailed electromagnetic interactions during cable connection and separation.

A detailed investigation of phenomena associated with high-voltage cable systems is one of the study's many benefits, which is made possible by simulations using actual parameters. Prevention strategies are required where operators are able to detect possible threats to cable and network equipment through the use of clear explanations and visual figures. The study is limited, though, by its exclusive focus on systems that consist of just two cables, a transformer, and a shunt reactor. As a result, it might not accurately capture the complexity of actual grids. Modelling simplifications may leave out important details seen in real-world situations, and the study's conclusions may not be as applicable in practice if there is no discussion of particular prevention strategies for hazards that have been discovered.

2.13 An Overview of Machine Learning Techniques and Tools for Predictive Analytics

This paper investigates predictive analytics, In order to anticipate future events based on past information, which makes use of data, statistical methods, and machine learning approaches. It offers a range of machine learning approaches and resources designed to help novices choose the best strategies for optimizing prediction accuracy. [13] provides an overview of the methodology used in predictive analytics, covering data collection, preprocessing, transformation, model construction, and user reporting of predictions. With a focus on sequential pattern analysis, data profiling, and time series monitoring, it offers an in-depth understanding of the predictive modelling process from project conception to model management. Finding trends in current and historical data, helping to identify opportunities and risks, and offering sophisticated features like time series projection and classification-regression are just a few benefits of predictive analytics. There are obstacles to overcome, too, including the time-consuming nature of data preparation, the difficulty of choosing and interpreting models, and inconsistent methodologies used to quantify prediction inaccuracy. Predictive analytics is nevertheless a useful tool for planning and making decisions in spite of these shortcomings. The accuracy statistics of several machine learning approaches on a student dataset are provided in [13]. Notably, PNN (85.89%), Random Forest (87.70%), Decision Tree (87.85%), Naïve Bayes (86.43%), and Logistic Regression (89.15%) have the highest accuracy percentages. These measures reflect how well machine learning algorithms work in predictive analytics by demonstrating their capacity to offer precise forecasts using past data.

2.14 Working Principle od Arduino and using it as a Tool for Study and Research

The paper explores the practical applications and underlying principles of Arduino boards, emphasizing their significance in educational and research contexts. It delves into Arduino's status as an open-source microcontroller platform, particularly highlighting its utility in rapidly developing VLSI test benches, especially for sensor-based experiments. Methodologically, [14] extensively examines Arduino's hardware and software components, elucidating fundamental operational concepts such as setup procedures, programming techniques, and the functionality of the Arduino Integrated Development Environment (IDE). Additionally, [14] provides insights into the diverse range of Arduino boards available and their respective specifications, aiding readers in understanding the platform's versatility.

Arduino presents numerous advantages, including its user-friendly nature, adaptability, and robust community support. Its open-source framework facilitates easy programming, appealing to hobbyists, students, and professionals alike. Furthermore, the platform's availability of free software contribute to its widespread adoption. Additionally, Arduino's versatility enables it to support various applications, from simple sensor interfacing to complex projects like unmanned aerial vehicles. However, inherent limitations, such as restricted processing power, hardware constraints, and a learning curve for novices, may impede its suitability for certain advanced applications or large-scale industrial deployments.

III. CONCLUSION

In conclusion, this literature review includes a wide range of research on a variety of fault identification, diagnosis, and management in electrical systems, especially in underground cables. The research covered in the survey ranges from state-of-the-art approaches like machine learning algorithms and deep learning models to more conventional ones like defect distance calculation using Ohm's law. Each study adds to our understanding of fault detection and mitigation techniques in electrical networks by presenting distinct approaches, methodologies, and conclusions. Numerous common topics can be found in the literature, such as the value of swift fault detection in improving system dependability, the application of high end technologies , and the necessity of precise modelling and simulation methods in recognizing system behaviour during faults. A number of studies also emphasize functional factors including affordability, simplicity of deployment, and real-time monitoring capabilities.

Despite the advantages and disadvantages encountered in the survey papers, the need to make these fault detection systems more efficient is on the rise as never before as underground power transmission is gaining more popularity around the globe.

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