A Smart Way of Detecting Underground Cable Fault using a Robot

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Abstract - Underground cable issues are consistently the most prevalent faults that workers encounter. This technology's benefits are discussed, including both financial and time savings as well as reduced harm to local infrastructure. The detector's operation is discussed, including how it sends a signal into the underground wire and measures the time it takes for the signal to bounce back in order to locate the problem. Prospective applications of the technology are also discussed, including those for industrial settings, emergency response teams, and utility companies. It would be incredibly beneficial if this technology was deployed in major cities for the sake of the future.

Keywords - Underground Cable Fault Detection, Fault Location, Subterranean.

I. INTRODUCTION

Underground cables are commonly used for power transmission and telecommunication. However, for a variety of reasons, such as failing insulation, mechanical damage, and natural calamities, these cables are prone to collapse. Determining the location of a defect in subterranean cables is a challenging process. The demand for dependable power supply and effective communication networks has increased considerably in recent years. Underground cables are the preferred solution because to their dependability, visual attractiveness, and safety. These wires require substantial maintenance due to their deep location, which makes it difficult to detect faults. The Time Domain reflectometer is the industry standard for finding faults in underground cables (TDR). This approach involves putting a signal into the wire and analyzing the signal that is reflected back to find any faults.

Nevertheless, there are significant disadvantages to this method, including its high cost, inability to discover many problems, and difficulties locating the specific location of the issue. These disadvantages are overcome by the proposed underground cable fault detecting robot, which provides a more effective and cost-efficient technique of locating faults in the subsurface cables. The article details the system's many components, such as the detectors, the autonomous platform, and the analysis and processing of data algorithms.A collection of algorithms is used to process and interpret the data collected by the sensors. Based on the data acquired by the sensors, the algorithms are intended to detect and categorize various sorts of problems in the wire. The algorithms evaluate the data using machine learning techniques to discover patterns that signal the presence of a defect. The analytical results are then utilized to pinpoint the location of the cable problem. Localization is accomplished through the use of triangulation techniques based on sensor data.

The accuracy of localization is increased by employing a Kalman filter that accounts for the uncertainty in sensor data[1].There are several ways for detecting faults in subterranean cables, including older techniques such as Time Domain Reflectometry (TDR) and contemporary approaches such as Acoustic Emission (AE) and Fiber Optic Sensing (FOS). Traditional techniques, on the other hand, have limits in terms of precision and speed, whereas current methods are more exact but also more costly. This research presents a new way for utilizing a robot to detect defects in subterranean cables. The robot is outfitted with a webcam, microphone, temperature probe, and gas sensor, among other things. The robot goes down the length of the line, collecting data from the sensors to locate defects. The camera captures photos of the wire's surface in order to identify major harm or rust. The microphone detects any auditory emissions generated by the cable as a result of defects. The temperature sensor detects temperature variations induced by electrical resistance produced by defects. The gas sensor serves the purpose of identifying any gas leaking from the cable owing to insulation failure. The proposed approach of fault detection in subterranean cables utilizing a robot may be a superior option. The robot-based system has the potential to be extremely precise, cost-effective, and efficient. The robot may be operated remotely, removing the requirement for human interaction in potentially dangerous areas. A robot can swiftly gather data from multiple sensors throughout the cable's length, reducing the time and expense necessary for issue identification [2].The suggested structure integrates a robot that can travel the tunnel and identify flaws in subsurface electrical wires. The robot is outfitted with a camera, temperature sensor, and gas sensor, among other things. The camera takes photographs of the surface of the cable, which are then analyzed using image processing algorithms to detect any obvious problems, such as actual injury or oxidation. The temperature sensor monitors the surface temperature of the cable, which is then evaluated to detect any temperature fluctuations related to electrical resistance produced by defects. Any gas leaking from the cable caused by insulation failure is detected by the gas sensor.

The humanoid also has a GPS device and an inertial measurement unit (IMU), which allow it to properly track its location and orientation. The robot moves in a predefined sequence throughout the tunnel's length to guarantee that it covers the whole cable length. The robot travels slowly so that the sensors can collect data properly. The gathered data is wirelessly transferred to a centralized control system for interpretation and analysis. The control system comprises of a database for storing information, an user interface with graphics for presenting data, and fault detection and analysis algorithms. The algorithms examine the data and discover flaws using several signals processing as well as machine learning approaches. The sensors allowed the robot to detect problems correctly, and the findings were confirmed using an oscilloscope. Thus these algorithms play a vital role in the formation of robots for the underground cable fault detection which is very useful for the workers to find the faults in the underground [3].The suggested system is made up of three modules, a sensor module, a data collecting device, and localization plug-in. A camera, an IR sensor, and a magnetic sensor are all part of the sensor module.

The camera takes photographs of the pipeline's exterior, which are then analyzed using image processing algorithms to determine the location and direction of the pipeline. The infrared sensor measures temperature differences on the pipeline's surface, which are then evaluated to determine the curvature of the pipeline. The magnetic sensor can detect the magnetic field created by the pipeline and uses it to adjust the alignment of the robot.The INS is used to correct inaccuracies in magnetic sensor array measurements. The INS calculates the robot's location and orientation by monitoring the robot's acceleration and angular velocity. The INS measurements are then merged with the magnetic sensor array measurements to produce a more precise estimate of the robot's location along the pipeline [4].Robots that can be operated remotely and used to check subterranean cable networks include those that include cameras and sensors. These robots can detect cable defects very rapidly, eliminating the requirement for human inspections and perhaps saving labourexpenses. Advanced machine learning techniques can increase the accuracy of defect detection and decrease false positives when they are applied to acquired data. These algorithms can save needless excavation or repairs, which can reduce costs and increase overall efficiency.

II. BLOCK DIAGRAM

The hardware configurations of the components which are in the block diagram include Arduino nano, Power supply, IR sensor, Motor driver, DC motor as shown in **Fig 1**. Arduino is a free and open-source electronics platform with simple hardware and software. This system is a straightforward method for obtaining a 12V and 5V DC source of power from a single circuit.IR LEDs emit light in the infrared frequency band. We cannot see infrared light because its wavelength (700nm - 1mm) is substantially longer than that of visible light. A direct current motor is any motor in a group of electrical equipment that converts dc electrical power into mechanical power.L293D is a common motor driver or servo IC that allows a DC motor to operate in either direction.

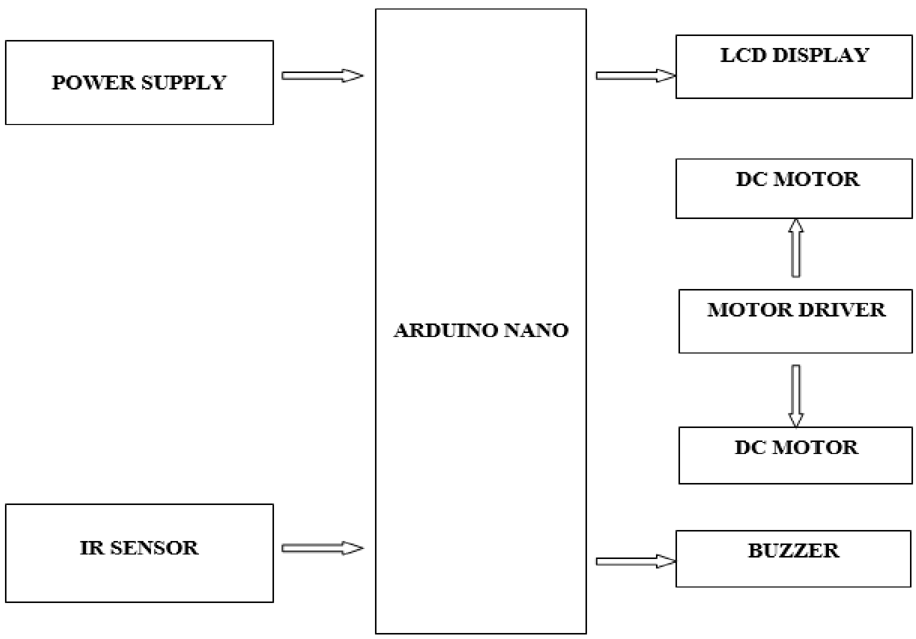

Fig 1. Block Diagram.

Technical Workings
Robot Design
The underground cable fault detection robot is often outfitted with a variety of detectors, communication devices, and locomotion mechanisms suited for navigating subterranean conditions. It may be wheeled or tracked in order to travel along the subsurface infrastructure.

Sensing Technologies
To discover and analyze cable defects, the robot uses advanced sensing technologies. These Electromagnetic environment Sensors detect irregularities in the electromagnetic environment around the wires, which might signal defects like insulating failure or short circuits. Acoustic sensors detect anomalous sound rhythms generated by arcing, corona discharge, or wire deterioration by collecting sound waves.

Infrared Imaging Cameras
These devices monitor temperature fluctuations over the length of the wire, allowing hotspots or overheating to be identified.

III. WORKING PROCEDURE OF TLU

P-GPS delivers two services: long-distance tracking of robotic movement and relatively close localization of pipeline defects. The tracing technique is the same for both robotic systems. TLU emits an ELF-EP signal when the robot moves inside the pipeline (as seen in **Fig 2**).

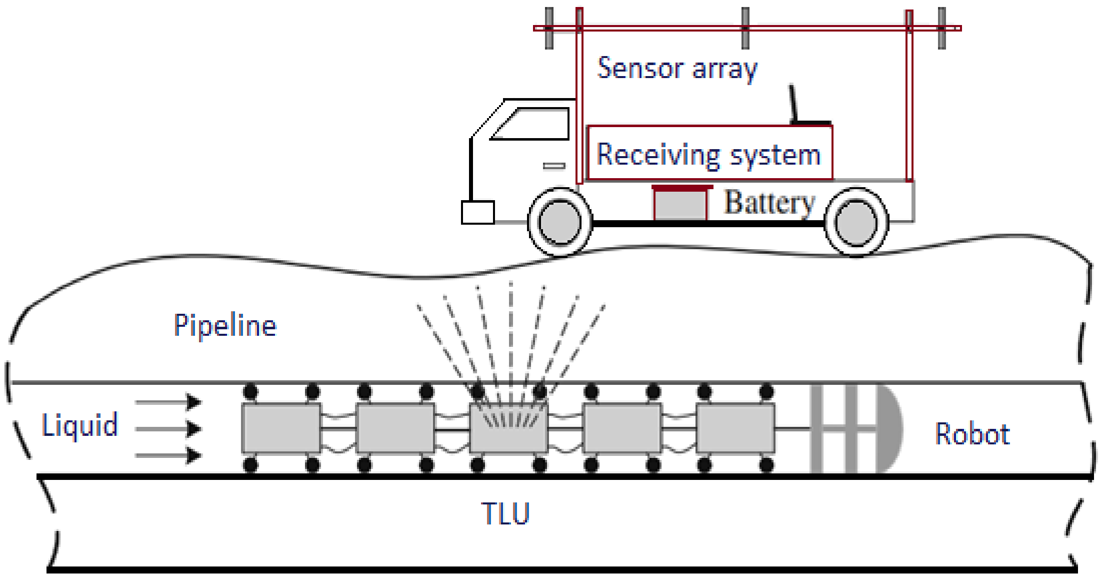

Fig 2. Working procedure of TLU[4]

Workers can scan the track outside using the sensor array's received signals. Nonetheless, there are certain changes in the technique for localization. The odometer wheel in the pig system generates pulses on a regular basis while moving. If there isn't pulse generation for more than 5 seconds, it is recognized that the pig is blocked within. The central controller will then issue an alert command to TLU.

IV. ROBOT TEST

A speed sensor was put at both the driving and driven wheels, and the recorded data were compared and evaluated to identify whether the robot was locked, rotated, or skidded throughout the operation. **Fig 3**depict theangular velocity curve of driving wheel. The robot was programmed to move inside the bent pipe based on different attitude degrees. The walking test demonstrates that the machine can travel through the elbow with ease. Furthermore, the layout comparison and data analysis demonstrate that the shaft speed has a superior following the sliding and movement interference do not happen in the steering wheel [6].

Remote Operation and Monitoring
A robot designed for cable fault detection can be operated remotely, reducing the need for human personnel to physically access hazardous underground environments. Operators can control the robot from a safe location, analyse real-time data, and make informed decisions regarding fault detection and repair.

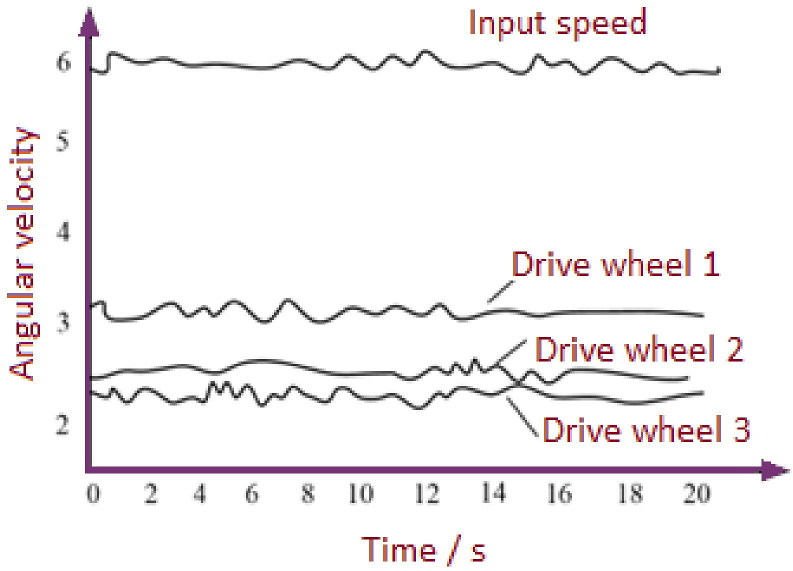

Fig 3. Angular velocity curve of driving wheel[6]

V. IMPLEMENTATIONS

This study examines fault detection and reliability approaches in robotic systems. Several elements of the robot, including sensors, motors, and the control system, might fail. Fault detection strategies must identify the existence of a defect, whereas fault tolerance approaches must sustain acceptable performance despite the existence of faults [5].Using a microcontroller-based device, this research provides a fault detecting solution for undetectable subsurface damaged transmission lines. The suggested system identifies the presence of a defect by monitoring the current and voltage signals at the transmission line's input and output [7].This study describes an Internet of Things-based system for detecting and locating defects in subterranean cables. The suggested system monitors the cable and detects any faults using an Arduino Uno and an ESP8266 module. Whenever a malfunction takes place, the system will send an alarm to the distribution firm's control centre, which may then dispatch a maintenance personnel based on the location data [8].A controller-based system for detecting defects and insulation issues in low-voltage cables is presented in this research. The suggested method employs a pulse echo approach to calculate the length to the defect or fault and a TDR method to assess the cable's impedance. The system is meant to identify problems such as circuits, tripping, and insulation issues in single and multi-core cables [9].It explores the multiple techniques to robot consciousness, covering symbolic & sub-symbolic methods, as well as their advantages and disadvantages [10].They discuss the many types of robots employed in hazardous environments, including such remotely operated vehicles (ROV's), unmanned aerial vehicles (UAV's), & autonomous systems, as well as their benefits and limits. It discusses the many detecting and imaging techniques used in hazardous situations, including such laser scanning, radar, and gamma-ray detectors, as well as the issues related to analyzing and analyzing the resulting data [11].**Fig 4&5** depicts the schematic diagram having loop test for earth and short circuit fault.The suggested architecture is to use a PIC microcontroller 18F4520 to determine the right location of the fault in an underground connection. In this project, we employed the notion of Ohms law, which states that if a low Voltage output is linked at the feeder end through an arrangement resistor suggests Cable lines, current would fluctuate according on the area of fault in the connection [12].This article describes a custom-designed in-pipe inspection robot for a pipe with a diameter of 0.203 m, which is often encountered in the oil and gas sector. The robot has many pressure sensors on board that are used to identify leaks. The robot includes a rotor configuration that not only propels the machine forward but also simulates flow inside an empty pipe, assisting in leak identification [13-14].The use of multilayer perceptron (MLP) neural network models as a classifier is proposed in this paper. Among other classifiers, MLP neural networks are strong and efficient. The specifications of the amount of layers that are concealed and the amount of neurons in the MLP have a significant impact on its performance. These settings must be chosen with care. As a result, this research suggests that we employ an imperialist competitive algorithm (ICA) to determine the optimal value of these parameters [15-17]. The modelling findings demonstrate that the suggested intelligent method performs and is accurate very well.**Table 1** depicts the various researchers' concepts and their findings.

Infrastructure for Quick Deployment

It's crucial to provide an efficient environment for rapid implementation. The robot and any accompanying tools, such as power sources, replacement parts, and gadgets for communication, can be stored and transported in specialised transport trucks or containers. The system of support must be simple to use and swift in its ability to deliver a robot to the troubled location.

Effective Defect Identification
Underground wire failures can be difficult to find and fix, resulting in extended outages and higher maintenance expenses. A robot with cutting-edge sensing capabilities with AI algorithms can precisely identify the defect, allowing for quicker repairs with fewer downtime.

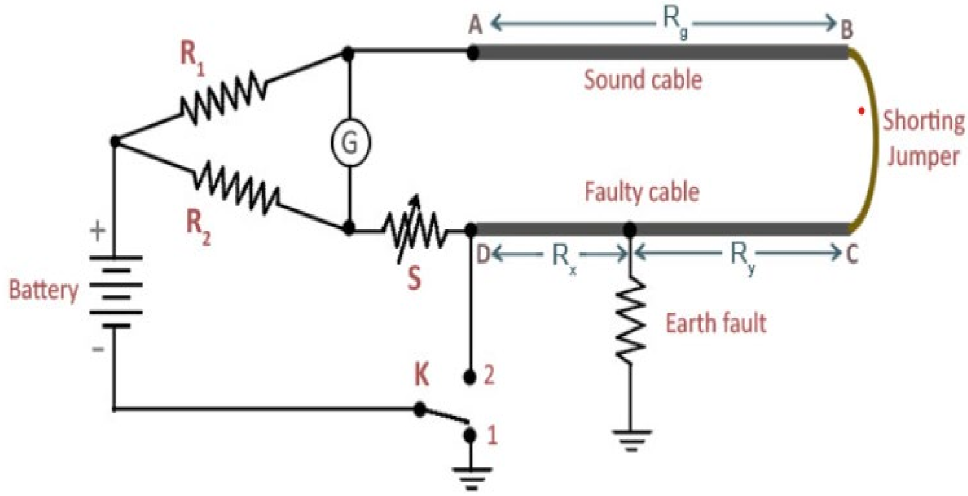

Fig 4. Schematic showing varley loop test for earth fault[11]

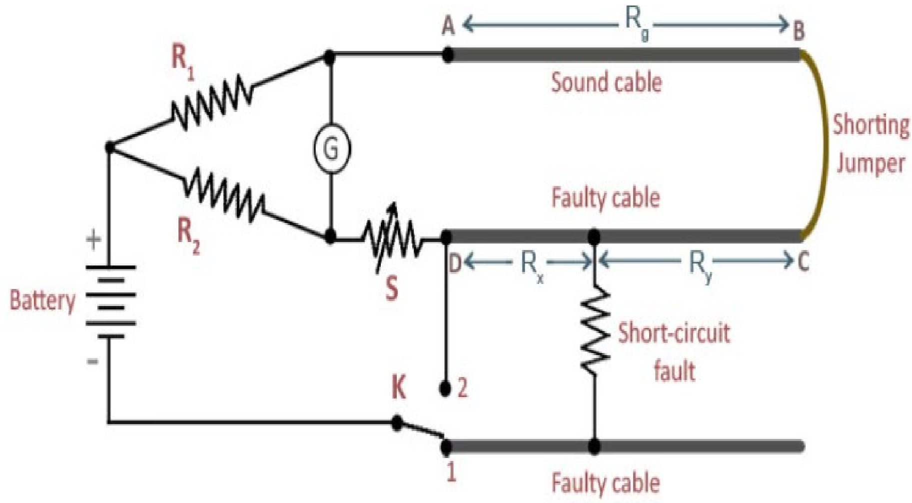

Fig 5. Schematic showing varley loop test for short-circuit fault[11]

Safety Standards
Underground cable fault detection robots are frequently supplied with a range of sensors, communication devices, and movement mechanisms designed for subterranean circumstances. It may navigate along the subterranean infrastructure via wheeling or tracking.

Sensing Technologies
The robot uses advanced sensing technologies to detect and examine cable problems. These environmental Electromagnetic Sensors detect shifts in the electromagnetic field around wires, which may indicate flaws such as failures in insulation or short circuits. Acoustic sensors gather sound waves to detect abnormal sound patterns resulting from arcing, corona discharge, or wiring degradation.

Infrared Imaging Cameras
These detectors monitor temperature swings over the length of the wire, identifying hotspots or overheating.

One of the key advantages of deploying robotics for underground cable fault identification is the ability to decrease or eliminate the requirement for human personnel to access potentially dangerous subsurface locations. This greatly enhances worker safety by reducing their exposure to hazards such as electrical risks, tight spaces, and poisonous fumes.

Table 1. Researchers Concepts and Finding

Sl. No.	Title	Researchers	Concept
[1]	Cable inspection robot for cable-stayed bridges: Design, analysis, and application.	Xu et al. [18] (2011).	On cable-stayed bridges, a cable inspection robot with a safety landing mechanism examines stay cables. It has a tiny volume and a fast speed, and it employs safety features to prevent landing mishaps and assure energy-efficient recovery.
[2]	Insulation Fault Detection in Underground Cables Using Arduino.	Sumathy et al. [19] (2022).	A dependable electrical power supply needuninterrupted transmission lines. The study created a fault detection and localization system based on smart technology employing Arduino technology to provide rapid and accurate problem identification and location for system dependability.
[3]	An Optimized Solution for Fault Detection and Location in Underground Cables Based on Traveling Waves.	Tariq et al.[20] (2022).	For subterranean cable distribution networks, a system for defect detection and localization based on travelling waves was created. The model enables quick and precise fault detection and placement, as well as over current and timing relay coordination techniques for NRA optimisation.
[4]	Design of Robotic Vehicle for Detection of Human Based On Internet of Things.	Singh et al. [21] (2021).	The COVID-19 epidemic has been designated a public health emergency, affecting over a million individuals. To preserve social distance in the workplace, engineers designed an Identity card with just an ultrasonic measuring and alert system based on a buzzer and GSM module.
[5]	IoT based underground cable fault detector.	Sampathrajaet al. [22] (2018).	A fault finding system was built utilising Ohms law and the PIC 16F877A & ESP8266 Wi-Fi modules to show the phase, distance, and time of a short circuit error on a website for efficient rectification. Precise problem location increases power system maintenance time and performance while lowering operating costs.
[6]	Underground Cable Fault Detection Using Robot.	Althafet al.[23] (2013).	Digging to verify cable issues is a time-consuming and inconvenient process. The proposed idea is to make a cable fault detecting robot is a low-cost, user-friendly remedy for this issue.
[7]	Multicycle incipient fault detection and location for medium voltage underground cable.	Zhang et al. [24] (2016).	A multi-cycle incipient defect identification and localization strategy for medium voltage cables is suggested, which makes use of an arc fault detection approach that utilizes voltage distortions research and a distance estimate method based on parameter estimation. High accuracy and robustness are demonstrated through simulation and laboratory testing.
[8]	Arduino based Underground Cable Fault Detector.	Jagtap et al. [25] (2017).	The goal is to discover flaws in rural subterranean wires. The usage of Arduino has various advantages over standard microcontrollers, which makes it a superior choice. Hence this method is more beneficial for the workers to make use of the technology provided with it.

VI. EXISTING SYSTEM

There are already a lot of technologies and procedures available to analyze subterranean cables, however there is frequently little correlation between both the diagnostics findings and the real detraction. Underground electrical distribution cable breakdowns pose a severe danger to the dependability of electricity infrastructure. Maintenance must be done deliberately because cable replacement is costly, costing hundreds of thousands of dollars per kilometer of cable in a region.

Robots can be used to create accurate maps and documentation of underground cable networks. By autonomously navigating through underground infrastructure, robots can capture detailed images, videos, and sensor data, providing valuable information for network planning, expansion, and maintenance.

Cost-Effectiveness

Live-line bots have been developed to detect and fix cable faults without having to de-energise the wires. These solutions can help utility companies save money by reducing outages and associated revenue losses. Some technologies provide integrated surveillance systems that incorporate multiple sensors, statistical analysis of data, and continuous monitoring capabilities. These technologies can identify cable defects early, allowing for preventive maintenance and reducing the need for costly emergency repairs. For visual examination of subterranean cable networks, remote-controlled bots that have cameras and sensors can be utilised. These robots can detect visual signs of cable defects quickly, eliminating the requirement for human inspections and potentially saving labour expenses.

Robots for detecting underground cable faults should be built to last. This involves the use of tough materials that can survive adverse circumstances, including dampness, dirt, vibrations, and temperature fluctuations that are prevalent in subterranean locations. Robots should have proper environmental sealing to protect critical electronic parts from humidity, dirt, and other pollutants. To guarantee the reliability of the robot's internal components, sealing compounds, protective barriers, or conformal coatings may be used. Corrosion protection: Moisture and corrosive substances can be abundant in underground habitats. As a result, the components and coatings used in the robot's construction should be corrosion-resistant.

The feasibility of deploying robots for underground cable fault detection depends on a variety of factors, including the complexity of the underlying infrastructure, environmental conditions, technological improvements, and regulatory constraints. As a result, performing a thorough analysis of the current research, case studies, reports from the industry, and practical applications is critical to understanding the technique's practicality in various circumstances. Academic research articles can shed light on the viability of deploying robots to identify subterranean cable faults. Sensor technology, data analysis techniques, robot layout, and field testing have all been investigated by researchers. Examining relevant research articles will help you obtain a better grasp of the technology's practicality and potential obstacles.

Alternative to awaited a problem to arise, robots may be used to inspect underground cables on a regular basis. The robot can help with preventative maintenance practises and stop outages by keeping an eye on the state of cables, spotting early symptoms of decline or possible failures, and passing the information to service workers

Additional possibilities as technology advances include integration with machine learning for real-time defect analysis, better remote operating capabilities, and the creation of autonomous machines capable of conducting repairs. These developments have the potential to significantly expedite detection and repair operations, resulting in more cost-effective and dependable subterranean cable infrastructure.

Cost Savings and Improved Safety

By automating the fault detection process and minimising the need for manual labour, utility companies can achieve cost savings in terms of labour, equipment, and outage durations. Additionally, using robots for fault detection can enhance safety by reducing human exposure to hazardous conditions and improving response times to emergencies.

VII. PROPOSED SYSTEM

To deal with these issues, we are developing a robot with sensors, motors, and other components that will detect cracks and other circumstances. The robot also detects the temperature, pressure, and other parameters of the pipes through which the cable is routed. The robot is equipped with an air sensor and an LCD monitor. This approach may also be used to detect fractures and flaws in pipelines carrying gas and oil. The current proposal is less costly and more resilient than prior systems because it incorporates all of the elements required to detect temperature, pressure, and wire defects into a single device. It makes good use of resources.

VIII. CONCLUSION

Compared to conventional fault detection techniques, the underground cable fault detection using robot is a useful technology that has numerous advantages. It can save time, money, and lessen impact to adjacent infrastructure by promptly and precisely locating defects in subterranean cables. Utility firms and other organization that depend on dependable power transmission may find this device to be an appealing alternative since it may considerably save downtime and repair costs related to cable problems. Utility companies, emergency response teams, and underground cable fault vehicle distance detector are just a few of the possible users of the technology. It will also become a crucial maintenance and repair tool for subterranean cables. This invention is poised to grow and gain widespread use with additional study and development.

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