

INTELLIGENT FAULT DETECTION AND ALERTING SYSTEM FOR UNDERSEA & UNDERGROUND CABLE NETWORK

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Abstract: The fault detection and alerting system for undersea and underground cable networks is designed to monitor, detect, and report faults in long-distance industrial cable infrastructures such as power and communication lines. These networks are critical yet difficult to access and maintain, making timely fault detection essential to prevent energy loss, data disruption, and costly downtime.

The proposed system employs a combination of IOT-based sensors, microcontrollers, and real-time data transmission to continuously monitor key parameters such as voltage, current, temperature, and insulation resistance. When abnormalities indicating potential faults such as short circuits, open circuits, or insulation failures are detected, the system intelligently locates the fault position and sends instant alerts through a wi-fi or gsm module to a centralized monitoring platform or mobile application.

This smart fault detection and alerting system enhances the reliability and safety of industrial cable networks, minimizes maintenance time, and reduces operational costs by enabling early fault identification and rapid response. The solution can be applied in submarine communication cables, underground power grids, and industrial data networks where continuous monitoring is crucial. Therefore, there is a need for an intelligent, automated system that can continuously monitor, detect, and locate faults accurately in real time and send instant alerts to maintenance personnel through wireless communication. The proposed intelligent fault detection and alerting system for undersea and underground industrial cable networks aims to address these challenges by integrating iot sensors, microcontrollers, and communication modules to provide efficient, reliable, and timely fault detection and reporting.

Keywords: Flex Sensor, ESP32, Vibration sensor, Aurdino IDE.

I. INTRODUCTION

An intelligent fault detection and alerting system for undersea and underground cable networks addresses the critical need for real-time monitoring and proactive maintenance of vital infrastructure. Unlike traditional reactive methods that require manual inspection, these intelligent systems leverage advanced sensor technologies, the Internet of Things (IoT), machine learning, and AI to enhance network reliability, safety, and efficiency. A cable is a bundle of electrical conductors used to transmit electricity. An underground cable generally has one or more conductors covered with appropriate insulation and a protective sheath. Varnished batiste or impregnated paper are usually used for insulation. A fault in a cable can be any defect or inhomogeneity that redirects the current path or affects the performance of the cable. It is difficult to locate the fault in the underground cable. We find the exact location of the error. We find the exact location of the error. Since the world is now digitized, the project consists of finding the exact location of the error in digital form. Underground wiring systems are a more common practice in many urban areas. When a fault occurs in the system the distance located on liquid crystal display (LCD). Until the last decade, cables were designed to be placed above the head and, at present, there is no underground cable that is higher than the previous method. adverse weather conditions such as storms, snow, torrential rains and pollution does not affect on underground lines But when a fault occurs in underground lines it is difficult to locate the fault in underground cable. We will find the exact

location of the fault. Now the world has become digitized so, the project is to detect exact location of the fault in digital form. Underground cabling system is a more common practice in many urban areas.

Although the fault occurs for some reason, at that time, the repair process for this particular cable is difficult because of not knowing the exact location of the cable breakdown. Fault in cable can be classified in two groups: Open circuit fault, In open circuit fault there is no current because there no conducting complete loop for current flowing that is $I=0$. In this fault supply voltage is equal to the output voltage. Open circuit fault is better than short circuit fault, Short circuit fault, In this fault output voltage is zero but current is same Further short circuit fault can be categorized in two types: Symmetrical fault, In this fault equal lead current and equal phase shift. Unsymmetrical fault, In this fault magnitude of current is not equal & phase shifting is not equal by 120 degree. Terminal method, in this method used to detect the fault location in underground lines without any effort This method used to locate the type of circuit occurs; the voltage drop varies with the default length on the cable, as the current varies.

A plurality of resistors is used to represent the cable and a DC voltage is supplied at one end and the defect detected by detecting the voltage variation the defect area to accelerate the tracking of the buried cable.

II. LITERATURE SURVEY

The use of underground and undersea cables has become increasingly important for power transmission and industrial communication networks due to their enhanced reliability, safety, and protection from adverse weather conditions. Unlike overhead lines, these cables are less prone to environmental damage, storms, or accidental contact. However, when a fault occurs in such systems, it becomes very difficult to locate and repair because the conductors are not visible and are often laid deep under the ground or sea. Many researchers have worked on various fault detection techniques such as Time Domain Reflectometry (TDR), impedance-based methods, and partial discharge detection to identify and locate faults accurately.

These systems can detect abnormalities in real time and immediately alert maintenance teams via GSM or Wi-Fi communication. Integration of GPS and data analytics further improves accuracy in identifying fault locations and speeds up the restoration process. Literature also highlights the potential of machine learning algorithms to classify different fault types and enhance system reliability.

Therefore, the proposed Intelligent Fault Detection and Alerting System aims to combine the advantages of IoT, real-time monitoring, and automated alerting to ensure efficient detection, localization, and reporting of faults in undersea and underground industrial cable networks, thereby minimizing downtime and maintenance costs.

III. IOT SYSTEMS

An IoT system refers to an interconnected network of devices, sensors, and software that work together to collect, exchange, and analyze data to automate processes and improve decision-making. At the core of an IoT system are devices, which include sensors and actuators. Sensors collect data from the physical world, such as temperature, humidity, or motion, while actuators respond to the data by performing actions, like adjusting a thermostat or turning on a light. These devices communicate via various connectivity options, such as Wi-Fi, Bluetooth, Zigbee, or cellular networks, to send data to other systems. In many cases, edge computing allows for processing data locally on the device or near the source, reducing latency and minimizing the load on central servers. When needed, the data is sent to the cloud, where advanced data processing and analytics are performed. This analysis can help identify patterns, make predictions, and trigger actions based on real-time insights. For example, in a smart home

system, data from temperature sensors might trigger the heating system to adjust the temperature automatically. The system is often managed through a user interface such as a mobile app or web dashboard, where users can monitor and control devices remotely. Security and privacy are also crucial, as IoT systems must ensure that the data being transmitted is encrypted and that only authorized users can control devices. Overall, IoT systems are transforming industries by providing enhanced automation, improved efficiency, and the ability to make data-driven decisions across various domains such as smart homes, healthcare, industrial automation, and more.

IV. PROPOSED SYSTEM

The main components that the proposed system consists of are Vibration Sensor, ESP32, Flex Sensor, Current Sensor.

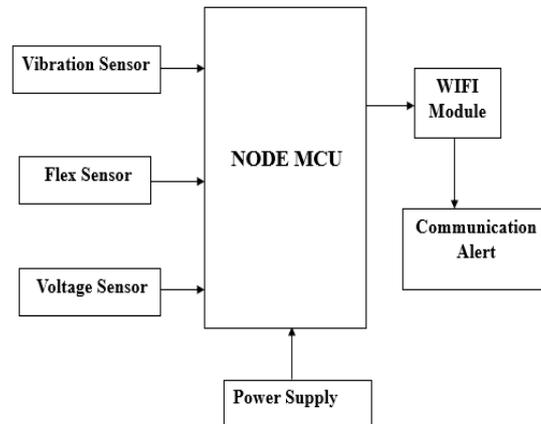


Fig: Block Diagram

This IoT-based monitoring system integrates various sensors (vibration, flex, and voltage) with a Node MCU to collect data from the environment, process it, and trigger communication alerts through a Wi-Fi module. Here's a breakdown of the components and their function:

1. **Vibration Sensor:** This sensor detects vibrations in the environment, which could be indicative of movement, shock, or disturbances in the system. It provides real-time data to the Node MCU for processing.
2. **Flex Sensor:** The flex sensor measures bending or flexing. This could be used to detect physical deformation or movement, such as changes in the angle of a device or structure, indicating possible mechanical stress or failure.
3. **Voltage Sensor:** This sensor monitors the voltage levels of a system or device. It helps detect overvoltage or undervoltage conditions, providing insights into the electrical health of the system.
4. **Node MCU:** The Node MCU acts as the central **Microcontroller Unit (MCU)** that collects the sensor data, processes it, and makes decisions based on predefined conditions (e.g., alerting the system when certain thresholds are exceeded).
5. **Wi-Fi Module:** The Wi-Fi module facilitates communication by transmitting the processed data from the Node MCU to a remote server, database, or cloud platform. This is crucial for remote monitoring and data analytics.
6. **Communication Alert:** Once the Node MCU processes the sensor data and detects an anomaly or predefined event, it triggers a communication alert (such as an email, SMS, or app notification) to notify the user of any changes or system malfunctions.
7. **Power Supply:** The system is powered by an appropriate power supply, ensuring continuous operation of the sensors and Node MCU.

V. CASE STUDY

Case-1:

The project is performed on the various cases like Current Sensor, Vibration Sensor, Flex Sensor the results are as follow:

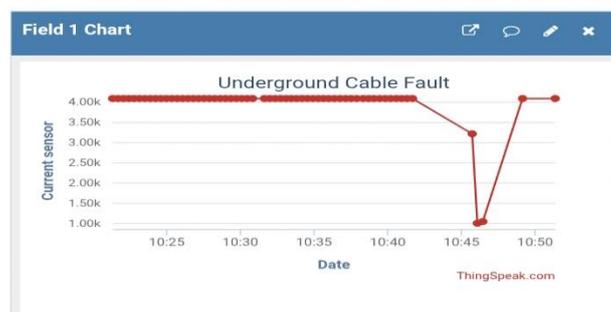


Fig 1: Current sensor

Underground cable fault detection using current sensors is an effective method for identifying abnormalities in power distribution systems. In this approach, a current sensor continuously monitors the current flowing through the

underground cables. Under normal operating conditions, the current remains stable within a predefined range. However, when a fault such as a short circuit, open circuit, or insulation failure occurs, the current either spikes or drops suddenly. These sudden changes are detected by a microcontroller, which processes the data and sends it to an IoT platform like ThingSpeak for real-time monitoring and analysis. This system allows for quick fault detection, reducing downtime and improving the reliability of power supply. Additionally, alerts can be generated automatically to inform maintenance teams, making the system efficient and responsive.

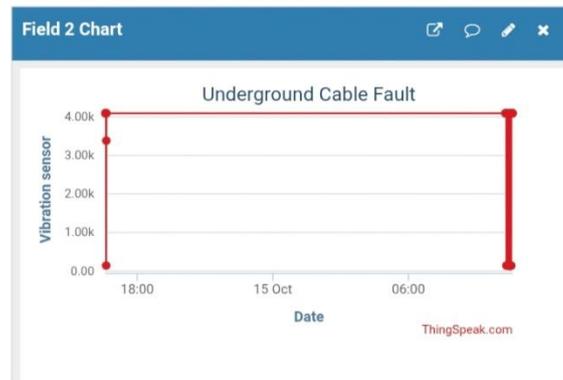
Case2:

Fig 2: Vibration sensor

Underground cable fault detection is an important aspect of maintaining the integrity of electrical and communication systems. When underground cables, often used for power distribution or telecommunication lines, fail or become damaged, it can lead to power outages or service interruptions. Detecting these faults early helps prevent extensive damage, minimizes downtime, and ensures the safety of the infrastructure.

One of the most effective ways to detect faults in underground cables is through vibration sensors, as illustrated in the chart you provided. These sensors can detect disturbances or vibrations caused by faults or failures in the cable, such as short circuits or physical damage. By continuously monitoring vibrations along the cable's path, any anomaly can be identified quickly. The sensor's readings are analyzed, and if they exceed a certain threshold (as seen in the chart), it indicates a fault in the underground cable.

The data collected from these vibration sensors is often displayed on a monitoring platform, such as ThingSpeak, which allows engineers or technicians to track and respond to potential issues in real-time. In the chart example, a sudden spike in vibration sensor data could be indicative of a fault, helping identify the location and severity of the problem. These systems help ensure quicker responses to faults, reducing repair times and improving the overall reliability of underground cable systems.

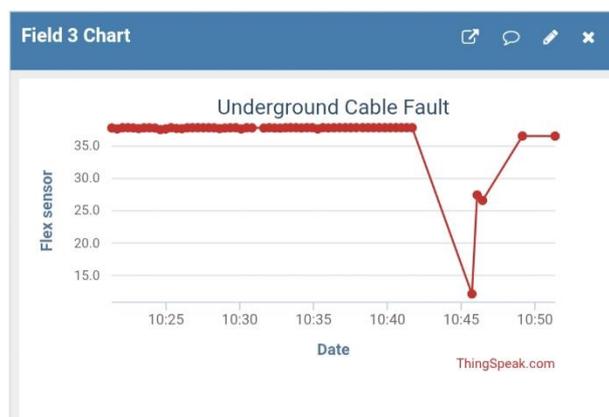
Case3:

Fig3: Flex Sensor

Underground cable fault detection is a crucial process for ensuring the reliability of electrical and telecommunication systems. These systems often rely on underground cables, which are prone to faults such as cuts, shorts, or breaks due to various factors like aging, environmental conditions, or external mechanical damage. Timely detection of faults is essential to minimize downtime, prevent further damage, and maintain service continuity.

One of the key methods of detecting faults in underground cables is by using flex sensors, as shown in the chart you've uploaded. Flex sensors are used to monitor any physical changes in the cable, such as bending or stretching, that can occur when a fault is developing. In this case, the chart displays data collected from a flex sensor, where the value stays steady at a certain level before a sudden drop occurs, followed by an immediate spike.

This indicates a significant event, likely related to the fault in the underground cable. The drop in the flex sensor value suggests that the cable has experienced a significant shift or break, which is often indicative of a mechanical failure or fault.

The data from flex sensors is typically displayed on monitoring platforms like ThingSpeak, which helps engineers or technicians identify the exact time and severity of the fault. By analyzing the data from sensors such as vibration and flex sensors, they can pinpoint the location of the fault, assess the type of damage, and prioritize repairs. The earlier a fault is detected, the quicker the system can be restored, preventing more serious issues from developing. This method of using flex and vibration sensors for underground cable fault detection offers a reliable and real-time approach to maintain the integrity of essential underground infrastructure.

VI. SOFTWARE USED

After learning about the main parts of the Arduino UNO board, we are ready to learn how to set up the Arduino IDE. Once we learn this, we will be ready to upload our program on the Arduino board.

- 1. Download and Install Arduino IDE:** If you haven't already, download and install the Arduino IDE (Integrated Development Environment) from the official Arduino website: <https://www.arduino.cc/en/software>
- 2. Connect your ESP32:** Plug ESP32 into your computer using a USB cable. Make sure the cable is firmly connected to both the ESP32 and your computer.
- 3. Select Board and Port:** Open the Arduino IDE. In the Tools menu, under the Board submenu, select "ESP32". Then, under the Port submenu, select the port that your ESP32 is connected to. If you're not sure which port to choose, you can check in the Device Manager (Windows) or System Information (Mac).
- 4. Test Connection (Optional):** To make sure everything is set up correctly, you can upload a simple sketch to your ESP32. Open the "Blink" example sketch (File -> Examples > 01. Basics -> Blink). This sketch will make the onboard LED on pin 13 blink on and off. Click the "Upload" button (the right arrow icon) in the Arduino IDE toolbar. If the upload is successful, you should see the LED on your ESP32 blinking.
- 5. Start Programming:** Now you're ready to start writing your own Arduino sketches! You can find plenty of tutorials and examples online to help you get started with different projects and components.

VII. CONCLUSION

The presented model effectively demonstrates a system for detecting faults in both underground and undersea cable lines using embedded electronics and sensor technology. These types of cables are critical for transmitting electricity, internet, and communication signals over long distances, often through challenging terrains like deep seas or buried underground pathways. In such environments, detecting faults manually is extremely difficult, time-consuming, and costly.

This project shows how using a microcontroller (like Arduino or NodeMCU) combined with sensors can help automatically locate the position of a fault in a cable—whether it's a short circuit, open circuit, or insulation failure. The setup helps monitor cable health continuously and sends real-time data to alert authorities when and where a fault occurs. This early detection and accurate localization of faults can significantly reduce downtime, improve safety, and lower maintenance costs.

By combining low-cost electronics with smart fault detection logic, this model highlights a practical solution for modern infrastructure challenges, ensuring reliable and efficient power or data transmission across both land and sea.

VIII. FUTURE SCOPE

The underground and undersea cable fault detection system can be significantly enhanced with the integration of advanced technologies. It holds great potential for real-time monitoring, improved fault accuracy, and wider industrial applications.

□ Real-Time Monitoring with IoT Integration:

By integrating IoT (Internet of Things) modules, the system can transmit fault data in real-time to control centers or mobile devices. This allows authorities to take immediate action and improve response times.

□ GPS-Based Fault Location:

Adding GPS functionality can help pinpoint the exact geographical location of the fault. This would be extremely useful for long-distance cables spread over vast land or sea areas.

□ Wireless Communication:

Instead of using wired connections, the system can be upgraded with wireless communication technologies (e.g., Wi-Fi, LORA, or GSM modules), making the design more scalable and easy to deploy in remote areas.

□ Machine Learning for Predictive Maintenance:

By using AI and machine learning algorithms, the system can analyze historical fault data to predict future faults before they occur, thus supporting preventive maintenance strategies.

□ Environmental:

Additional sensors (temperature, moisture, pressure, etc.) can be used to monitor environmental conditions that might affect the cables, especially in undersea areas where pressure and corrosion are critical issues.

□ Scalability for Industrial Use:

The project can be scaled to monitor hundreds of kilometers of cable in real-time, making it highly valuable for power transmission companies, telecom industries, and marine communication systems.

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