Simulation on Detecting and Locating Underground Cable Faults Using GPS and GSM Modules

Usha.M[1], Jaya Sai Kumar.S[2], C.N. Sri Balaji Vara Prasad.M[3], Grey Benhin.J[4]

[1]Assistant professor, [2]B. Tech Student, [3]B. Tech Student, [4]B. Tech Student,

[1,2,3,4] Department of Electronic and Communication Engineering, Dr. Y S R ANU College of Engineering and Technology (ANUCET), Acharya Nagarjuna University, Guntur, India.

Abstract: *This presents a revolutionary method of fault finding in Subterranean cables. Employing microcontroller-driven cartography, the system meticulously maps the faults in underground cables. The microcontroller quickly detects anomalies through continuous monitoring of cable resistance, and the integration of GPS and GSM coordinates guarantees accurate localization and real-time tracking of faults. The innovative fusion of technology provides an efficient and reliable means for cable fault detection, minimizing downtime and optimizing repair efforts. Cable cartographers not only revolutionize fault detection but also contribute to the development of a smart, responsive power infrastructure. This research underscores the synergy of microcontroller precision, cartographic visualization, and GSM-GPS accuracy in enhancing the resilience of underground power distribution systems.*

***Keywords*:** **Underground Cable, Micro-controller, Arduino Uno, Detection, GSM & GPS service, Google map, Ohm's law, Murray & Varley Loop.**

1. INTRODUCTION

Uninterrupted and dependable distribution of electrical power is an essential component of contemporary infrastructure. Subterranean power cables as shown in fig(1) are essential for maintaining this uninterrupted power supply. Nevertheless, faults in these underground cable networks can interrupt the power supply and present difficulties for prompt detection and resolution; therefore, effective fault detection is essential to minimize downtime, cutting repair costs, and improve the overall dependability of power distribution systems [3].

There is an urgent need for creative solutions that can successfully handle these difficulties as t he requirement for more responsive and resilient power distribution networks increases. A new dimension in the field of cable failure detection was introduced by the combination of GPS and GSM technologies. GPS makes exact defect location identification easier, allowing for quick repairs and efficient maintenance. Simultaneously, real-time communication capabilities of GSM modules enable prompt notification and remote monitoring of the fault state [12]. The identification, localization, and remediation of Subterranean cable faults could be completely transformed by this.

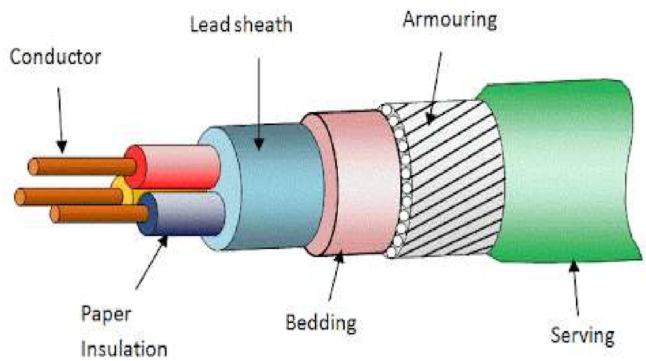

Fig 1: Layers in Under Ground Cables.

In the subsequent sections, we will conduct a comprehensive review of existing literature to contextualize our research within the current landscape of cable fault detection methods. We will then elucidate the proposed system's architecture, detailing the incorporation of GPS and GSM modules and the underlying fault detection algorithm[6]. Through systematic experimentation and analysis, we aim to evaluate the efficacy and reliability of our system, presenting results and insights that contribute to the ongoing discourse on enhancing power distribution network resilience[7].

2. Literature Survey

Saranya.A and Ajithkumar.P et al. has introduced underground cable fault detection using Arduino Paper aims to locate faults in underground cable lines using a microcontroller-based system, displaying fault details on LCD and web interface. The fault sensing circuit detects faults like line-to-ground and is interfaced with the ATmega328 microcontroller for precise fault location determination. ATmega328P microcontroller processes analog data from the circuit, providing fault location in kilometers, phase information, and displays it on an LCD and web interface through IOT Wi-Fi Module. [1]

Rohit Khandu Jarande and Juhi Liladhar Dawale et al. can be proposed Distance Locator for an Underground Cable fault A microcontroller-based underground cable fault distance locator is proposed, aiming to determine fault distance from the base station in kilometres. Utilizing Ohm's law, variations in voltage drop indicate fault length, detected by a group of resistors representing cable length. An analog-to-voltage converter captures voltage changes, displayed on an LCD interfaced with the microcontroller for real-time fault distance calculation. [3]

Burra Shivaram and Sarabu Vinay Kumar et al. developed GSM based Underground Cable Open and Short Circuit fault detection. This project aims to locate underground cable faults from the base station in kilometres using Arduino and GSM, employing Ohm's law and voltage division rule. Fault distance and phase details are displayed on an LCD, while fault occurrence information is transmitted to control areas via GSM. [6]

Sanaullah Memon and Riaz Ahmed Shaikh et al. implemented Hidden Cable Fault and Remote Locator by Using Arduino Methodology involves using Arduino circuit with rectified electricity, switches for fault creation, relay-operated relays, and LCD display. Findings indicate Arduino's role in locating hidden cable faults in kilometers from base station, addressing difficulties in pinpointing underground cable defects for repair. [11]

P. Hari Chandana and M. Venkataramana et al. Detect faults in underground cables using Arduino based on Ohm's law, calculating fault distance from base station and displaying on LCD. Method: Utilizes DC voltage application, current variation, ADC processing, and resistor-based fault simulation to determine fault location. [12]

3. Methods of Locating the faults in underground cables

(1) Online method:

Fault identification utilizes sampled voltage and current data to detect faults within a system in real-time. By continuously monitoring these electrical parameters, deviations from normal operating conditions can be identified, enabling prompt intervention and maintenance to prevent further damage or disruptions. This method is rarely used in underground cable fault detection.

(2) Offline method:

This method is based on instrumental application and particular apparatus is used for fault detection. Tracer method and terminal method are the core of offline methods and are used combined for identification and detection.

(3) Tracer method:

The fault identified from an audio signal or electromagnetic signal by a tracer. By strolling along the cable lines, the failure spot is found using this technique. An electromagnetic or auditory signal might identify a fault spot. It is employed to locate faults with extreme precision.

(4) Terminal method:

This method is utilized to detect the fault location of the cable from the one- side terminal or both-side terminal ends. The online and offline methods can only check fault for Line to Line (L-L) or Line to Ground (L-G) or Double Line to Ground fault at a time.

4. Classifications of Cables

Cables for underground service may be classified in two ways according to
a) The type of insulating material used in their manufacture
b) The voltage for which they are manufactured [4].

However, the latter method of classification is generally preferred, according to which cables can be divided into the following groups:
1) Low-tension (L.T.) cables — up to 1000 V
2) High-tension (H.T.) cables — up to 11,000 V
3) Super-tension (S.T.) cables — from 22 kV to 33 kV
4) Extra high-tension (E.H.T.) cables — from 33 kV to 66 kV
5) Extra super voltage cables — beyond 132 kV.

4. Faults in Underground Cables

Short Circuit Faults: An anomalous connection of very low impedance, whether created on purpose or by accident, between two locations of differing potential is known as a short circuit. These faults, which cause abnormally large currents to flow through equipment or transmission lines, are the most prevalent and severe. The equipment will sustain significant damage if these defects are allowed to continue, even for a short period of time. Another name for short-circuit faults is shunt faults. These defects result from insulation failure between earth and phase conductors, phase conductors, or both. There are several potential short circuit fault scenarios, such as three phases to the earth, one phase to the earth, two phases to the earth, one phase to the phase, and phase to phase as referred in fig (2).

Open circuit Faults: When one or more conductors fail, these defects happen. The failure of one or more circuit breaker phases, as well as combined failures of cables and overhead lines, are the most frequent causes of these problems. As a result of a conductor or fuse melting in one or more stages. Series faults are another name for open circuit faults. With the exception of three phase open faults, all of them are asymmetrical or unbalanced fault types.

Earth Faults: An unintentional contact between an electrified conductor and the equipment frame or earth is known as an earth fault. The grounding system, as well as any people or equipment that joins it, are the fault current's return path.

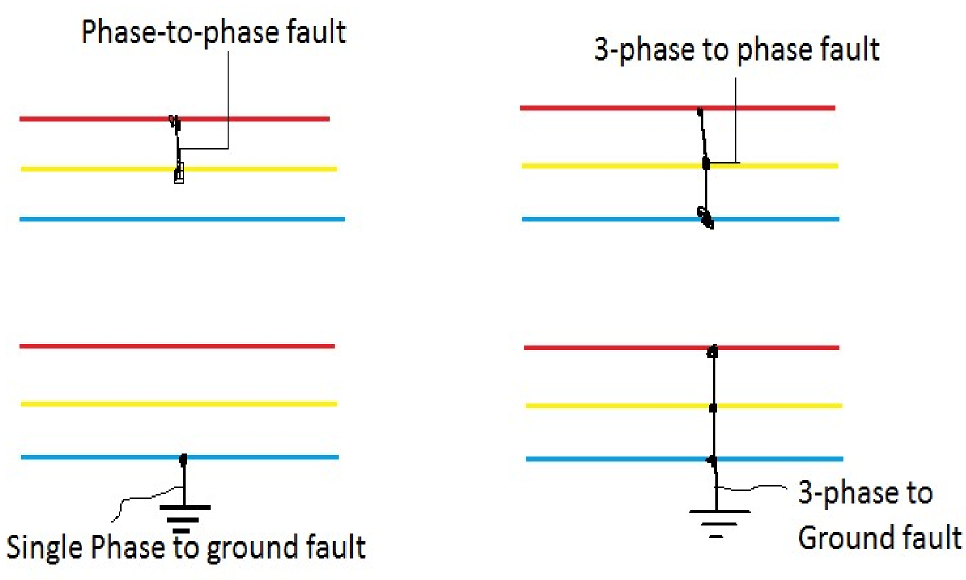

Fig 2: Types of Short Circuit of Faults

5. Proposed System

The process involves several key steps, from data acquisition to the application of embedded system for fault detection. This proposed method is implemented using of Arduino Uno microcontroller. Verifying and compiling the code to the Arduino Uno microcontroller for preparing to detect the fault in underground cable fault. An electrical switching device and a relay is used as a disconnecting switch that will disconnect the line if any faults occur. Then the relays give feedback to the microcontroller and the display unit is connected to the Arduino Uno microcontroller show the various types of faults and fault location.

Using a GPS module, the microcontroller detects the location of the fault. Subsequently, the microcontroller sends the location data in a short messaging service (SMS) form by utilizing the GSM module. In the Arduino Uno microcontroller, the input and output ports as well as GSM and GPS modules are setup as shown in fig (3). Our methodology for finding the accurate cable fault location from the base station, an underground cable fault detector is utilized.

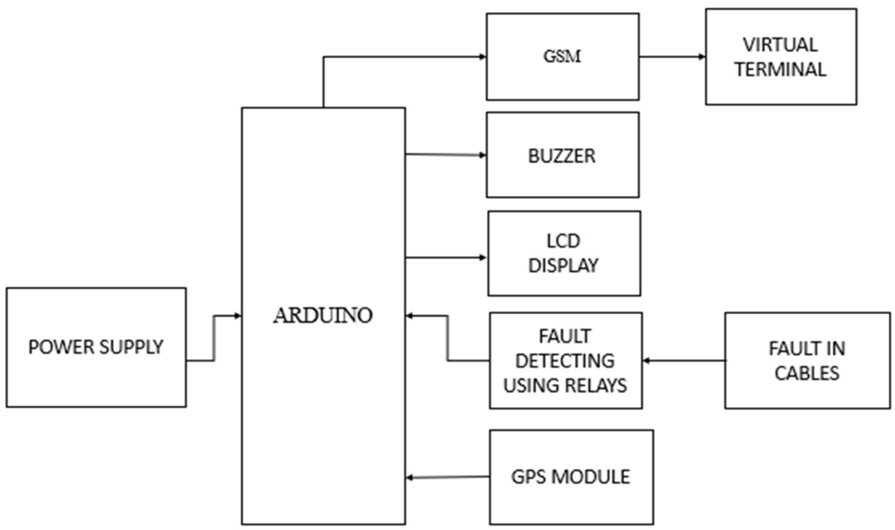

Fig 3: Block Diagram

The fundamental Ohm's law is applied at the feeder end via a series resistor if a short circuit of Line-to-Line or Double-Line-to-Ground or Line-to-Ground occurs the current flowing in The sections of the line that are faulty will differ depending on the length of the line.. The resistance of a cable varies depending on its length. As the length increase, the resistance value increases as well. If there is a difference in the resistance value, it refers to a fault point. With the help of a microcontroller, the fault point can be identified and detected. The display unit displays the value of that fault point, which indicates the standard of distance in kilometres, from the base station.

The controller will issue an alert if a fault occurs. The results are displayed on the LCD. The fault distance is sent to the respective person through mobile. Also, the fault distance will be displayed on the Google maps.

6. SIMULATION SOFTWARE: Proteus 8 Professional

Proteus 8 Professional is a popular software package used for circuit design and simulation. It allows users to design, test, and troubleshoot circuits before building them in real life.

The Proteus Design Suite is a proprietary software tool suite used primarily for electronic design automation. The software is used mainly by electronic design engineers and technicians to create schematics and electronic prints for manufacturing printed circuit boards.

We used CAD connected to simulate the project where we had included library of Arduino UNO R3, GPS and GSM to run the simulation.

6.1 Simulation

The proposed system is designed and tested in PROTEUS version 8.10 software. The simulation diagram of the proposed system. For 12V AC and 12 V DC source, respectively. The simulation is coded using the Arduino tool. The simulation results reveal that the proposed system successfully tracks and identify the underground faults. An Arduino, a 4-line display, a power supply, and a resistance measuring circuit make up the circuit. Fault switches are used to manually introduce faults into the kit Utilized. There are around twelve fault switches utilized, grouped into three rows of four switches each. The three rows stand for the three phases—R, Y, and B. There are two locations on the fault switches: fault position (F) and no-fault position (NF). Low value resistance measurement is the primary part of the subterranean cable failure detection circuit. It is built using a 100mAmp continuous current supply. Because the cables have a resistance of about 0.01 Ohm per meter, it may monitor very low values of resistance. A 10-meter cable's resistance decreases to 0.1 ohm. This circuit has a maximum wire length of 4 kilometers and can measure resistance up to 50 ohms. Thus, four sets of resistances are arranged in series, beginning at the reference point. These four resistance settings stand for the three stages as well as the neutral. This approach may be used to identify symmetrical and unsymmetrical short circuit defects. Three sets of resistance, such as R10-R11-R12-R12, R17-R16-R14-R21, and R20-R19-R18-R25, are used in series for this project, one for each phase. Four resistances in series here signify 1-4 km, and each series resistor symbolizes the resistance of the subterranean cable for a certain distance. Every resistance has a value of 1kΩ. Three relays are employed, one for each of the phase’s R, Y, and B. The NO points of the relays are connected to the inputs of R17, R21, and R2 and are grounded. Input from the three-phase wire. Relay drivers are used to increase supply and give it to the relays since the supply required for the relays is more than that of the Arduino. The transformer receives a 230 VAC supply, which is then reduced to 12 V AC. When the alternating electricity from the transformer travels through a bridge wave rectifier, it is transformed into direct current. The voltage regulator is the next step when the 12V DC is changed to 5V DC. The fluctuating DC supply is also changed into a constant DC supply by using a voltage regulator. The Arduino and the LCD are powered by this 5V DC supply. The voltage regulator provides the LCD with power. Conditions such as LG, LL, and LLG fault according to the switch are imposed when fault is caused by activating any of the 12 switches (to the F position). Action. The voltage value changes as a result of the failure. The Arduino's ADC receives this voltage value that was measured across the resistance. The Arduino calculates the distance using this value.

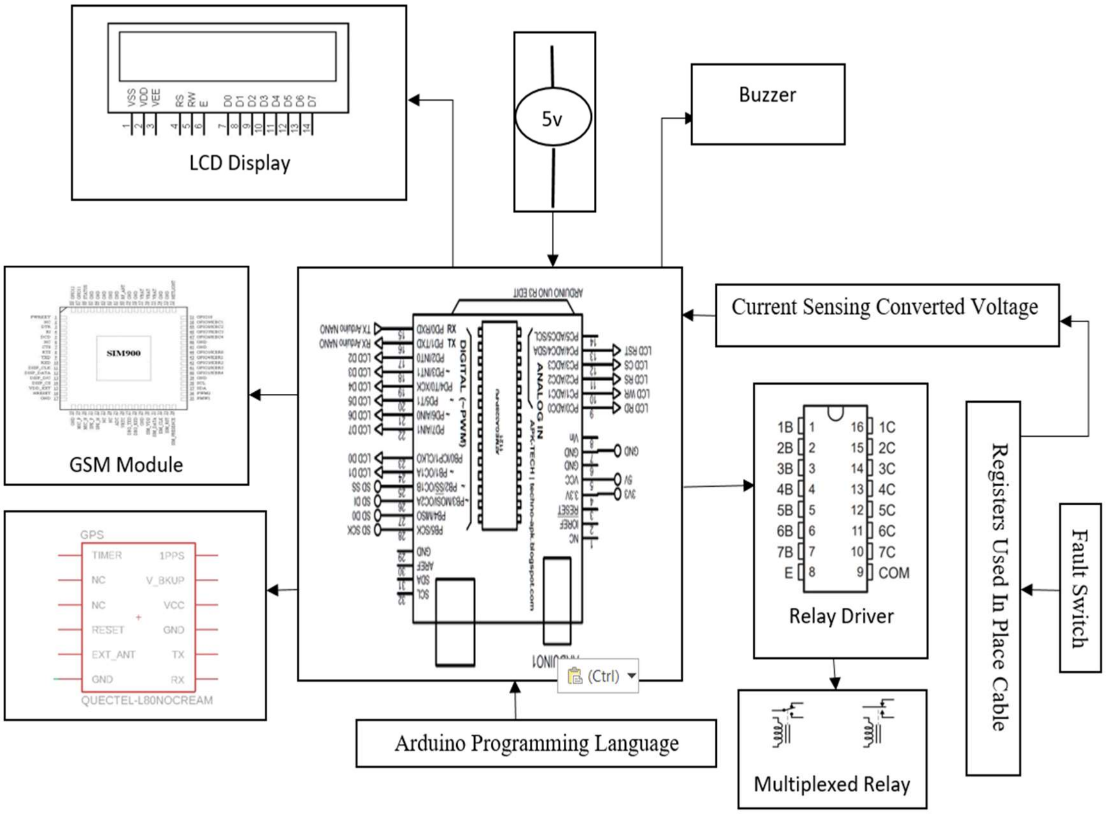

Fig 4: Circuit Diagram

When programming is done in the Arduino IDE, where the code is compiled and executed, as shown in Fig (4) above, we have connected the components to the Arduino Uno R3. If we want to dump the code to the Arduino, we may connect the cable to the Arduino, choose the port, and dump the code.

6.2 Hardware Prototype and Testing

A. COMPONENTS

The major components that are utilized to develop the hardware prototype are listed below:

1) ATmega328-based Arduino Uno microcontroller
2) LM2596, 150kHz buck converter module
3) ULN2003A, 500-mA, 50-volt Darlington array IC
4) Single Pole Double Throw (SPDT) 12V relay………056
5) SIM800L GSM / GPRS module
6) NEO-6M GPS module
7) 16×2 Character, 4/8-bit parallel interface LCD display modules
8) 220/12V, 3A transformer
9) 12V AC/DC bridge rectifier with filter circuit
10) Mini SPST 2 slide SW

B. Components Ratings

COMPONENTS	RATINGS
Diode	IN4007
Capacitor	22pF
Resistor	1KΩ
Resistor	470Ω
Resistor	10kΩ
Led	3
BJT	BC547
Arduino	UNO R3
Crystal	16MHZ
Relay	12v
Push buttons	
IC base	
PCB	
Wires	2 METERS

Table 1: rating of various components

6.3 Operation and Working

The primary function is based on the knowledge that when the each of the three sets of lines has a set of series resistors through which current passes, and the current would fluctuate.Based on how far the cable is from the site of the issue, whether there is a short circuit failure. The series resistors' voltage drops alter correspondingly, and the microcontroller's inbuilt ADC receives the fault signal to produce accurate digital data.The microcontroller will then process the digital data, and depending on the programming parameters, the result will be shown in kilometers on the LCD that is attached to the microcontroller.The circuit is supplied with a 230 V AC power source, which powers a step down transformer (12 V-0-12 V), which reduces the voltage from 230 V to 9 V. The full wave bridge rectifier then rectifies the ac voltage into a pulsing dc voltage.

• A 1000 microfarad electrolytic capacitor is then used to eliminate the ripple in the rectified output. Additionally, voltage regulator (7805) receives it.

• The filtered output is converted to a constant supply voltage of 5V by these voltage regulators. The set of series resistors, LCD, and microprocessor get voltage from the first voltage regulator, U2. While the relay and relay driver IC ULN2003A are fed by the second voltage regulator U3. Additionally, this variant has three relays that are powered by the IC ULN2003A relay driver.To indicate that a fault has occurred in the pertinent phases, in this case the relay trips the power supply to the set of series resistors and drives the bulb load.

• A collection of switches is used to create the fault production environment at each known equivalent kilometer, as indicated by a set of series resistors used to cross-check the correctness of the same.

• Current travels via the shorted line and develops drops across the associated phase resistors when a fault occurs at a distance in one, two, or three phases.

• The microcontroller's built-in ADC senses this dip through Port and translates it into equivalent digital data.

• The microcontroller then processes this data in accordance with the fault circumstances that it has been preprogrammed with.

• It transmits display signals to the LCD, which displays the fault location in kilometers at the end. At the same time, the signals are sent to the relay driver IC, which drives the bulb load that is linked to the relay.

• For each phase of the cable line, the model utilizes four sets of resistors in series: R1, R2, R3, R4 for phase R, and R5, R6, R7 and R8 for phase Y.

As indicated by the circuit diagram, R9, R10, R11, and R12 are used for phase B, while R13, R14, and R15 are utilized in series with the supply line of each phase.• For a given distance of 4 km, each pair of four series resistors represents the resistance of the Subterranean cable divided evenly into 1 km for each resistor.

• The resistors R13, R14, and R15 experience comparable voltage dips when a ground fault occurs in one, two, or three phases. Resistors R1, R3, and R5 are wired to ground on their opposite ends.

6.4 Algorithm for Short Circuit Fault Detection:

- Step 1: Declare timer, ADC, and LCD routines and initialize the ports.
- Step 2: Start an infinite loop by setting pin 0.0 high, which activates relay 1.
- Step 3: Put the phase name at the beginning of the LCD's first line.
- Step 4: Invoke the ADC function. The fault position is shown on the LCD based on the ADC output.
- step 5: call data function, which invokes the sendsms function
- Step 6: Give Delay a call
- Step 7: For the other two phases, repeat steps 3 to 6.

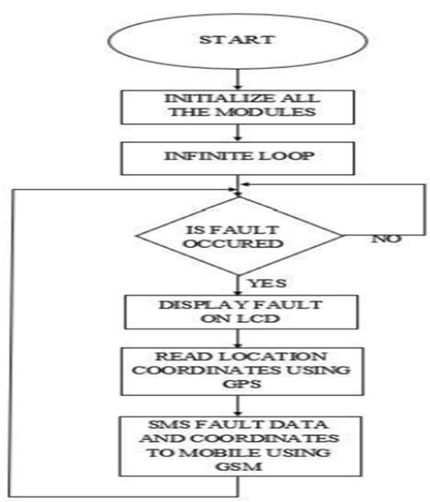

Fig 5: Flow Chart

7. Result Analysis

This prototype can be able to sense the precise location of different faults like earth, short and open circuit fault in UG cables from the feeder end which has been confirmed by the results from testing the hardware prototype as shown in Figs(6-11). The Arduino microcontroller triggered the relay to continue the search for the fault in tree lines. The fault switch turns off means there is no fault occurs and the relay grounded the current flow in the lines. When the fault switches turn on, the Arduino microcontroller detects the Line-to-Ground fault and illustrates the fault in the LED display. For the line-to-line fault, the device system will continue to check again. If any fault occurs, it will identify the fault and track it as shown in Fig.9, and the system will generate SMS with the distance of the fault and inform the dedicated person's cell phone number as shown in Fig.10. The microcontroller will continuously check for the distance and location of the fault and send it to the dedicated cell number using GSM and GPS modules.

STEP 1: Install proteus and import libraries and the schematic diagram.

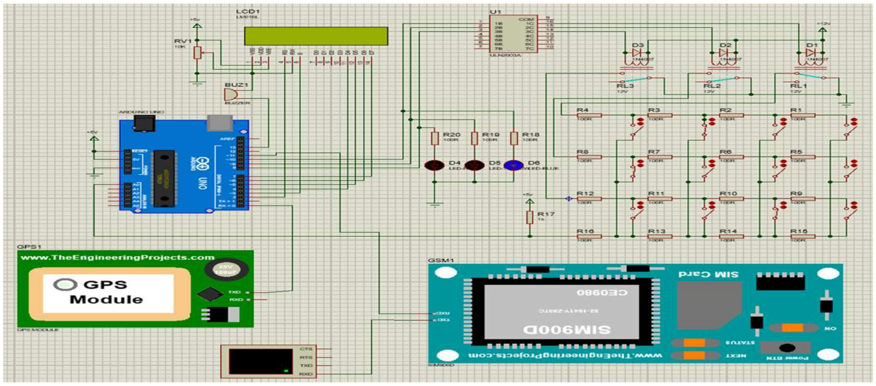

Fig 6: Schematic Diagram

STEP 2: Select edit properties by right clicking on the Arduino Uno and dump the code by inserting the hex file in that was compiled in Arduino IDE.

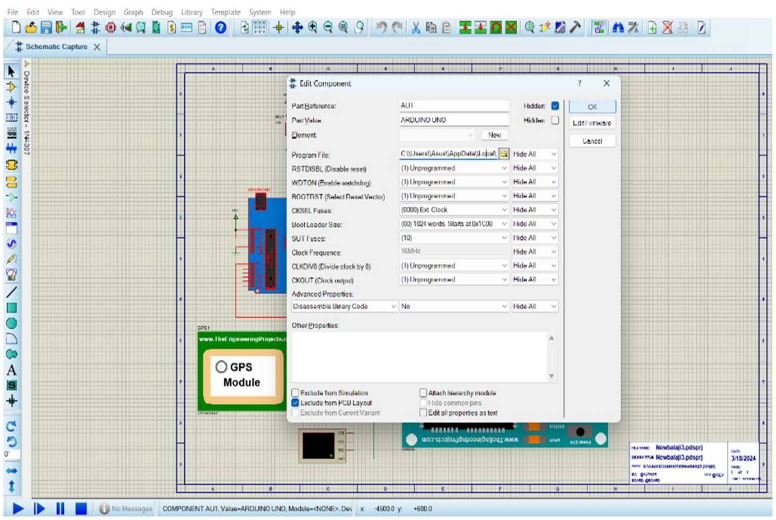

Fig 7: Linking Hex File

STEP 3: Run the simulation.

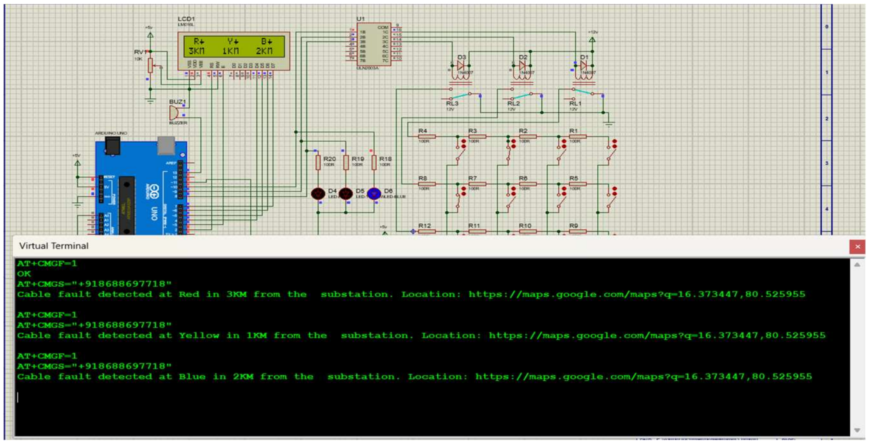

Fig 8: Simulation Output

STEP 4: View result and the Google maps link that was shown in virtual terminal we can use Google lens to scan the link form the virtual terminal.

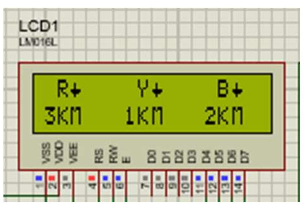

Fig 9: LCD Display Output

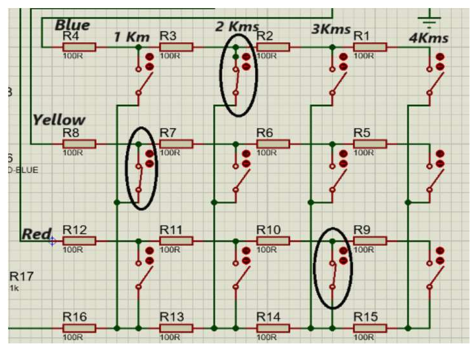

Fig 10: Faults Switches

Fig 11: Virtual Terminal Output

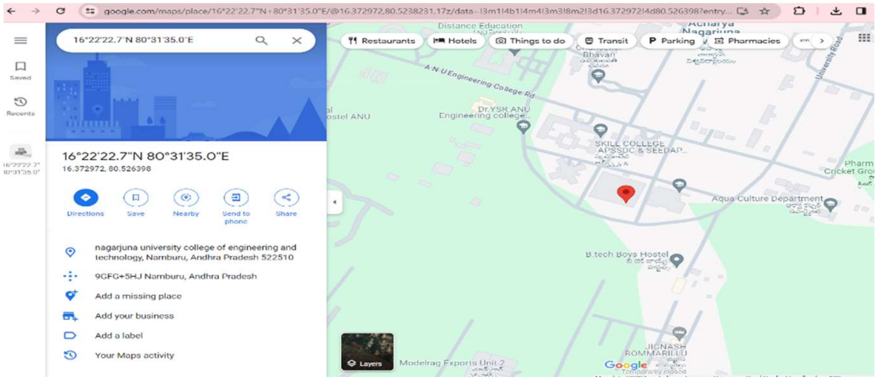

Fig 12: Fault Detected Location

8. Conclusion

The circumstances below earth, deterioration, rats, etc., can cause a wide range of problems in subterranean cables. Additionally, finding the cause of a fault might be challenging. To examine and correct problems along the whole line, excavation must be done. Consequently, we are proposing this idea to use an Arduino microcontroller to precisely locate a short circuit defect in subterranean cables starting at the feeder end and measuring kilometers. Relays aid in isolation the healthy line from the problematic line. This enables faster underground cable maintenance while also saving a significant amount of time, money, and effort.

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10. Future Scope

Subterranean cable defect detection with Internet of Things capabilities offers a game-changing way to improve electrical distribution networks. Real-time monitoring is made possible by the integration of IOT sensors into s4149ubterranean cable networks, which allows for continuous data collection for preemptive defect identification. With this method, utilities may quickly locate and address issues, reducing downtime and enhancing network dependability. By utilizing machine learning algorithms on the gathered data, predictive maintenance tactics are strengthened, leading to the optimization of resource use and network performance. By streamlining maintenance procedures and eliminating the need for human inspections, remote access to problem data via IOT systems improves operational efficiency. In addition, the integration of smart grids facilitates the easy coordination of IOT devices, guaranteeing prompt fault management and grid optimization. When downtime is reduced and maintenance cycles are streamlined using IOT information, operational cost-efficiency increases. Furthermore, prompt defect identification and proactive maintenance uphold adherence to safety norms and regulatory requirements, therefore enhancing public safety and customer confidence. Future developments in Subterranean cable failure detection might lead to significant improvements in grid resilience and energy sustainability as IOT technology develops.

11. References

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