

FAULT ANALYSIS ON UNDERGROUND CABLES

Submitted in partial fulfillment of the requirements for the award of

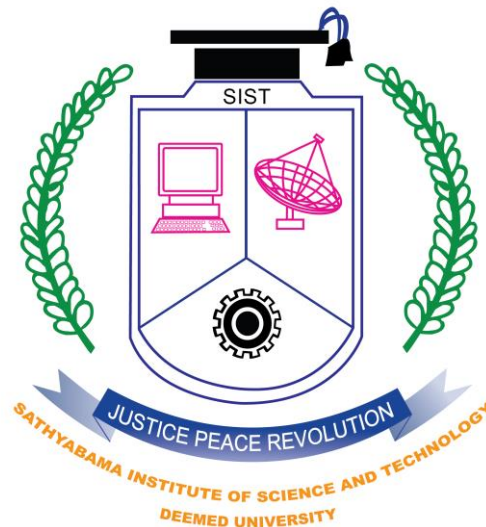
Bachelor of Engineering Degree in
Electrical and Electronics Engineering

by

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**DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING
SCHOOL OF ELECTRICAL AND ELECTRONICS ENGINEERING**

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

Accredited with Grade "A" by NAAC

JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI - 600 119

APRIL 2023



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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of B.HARI KRISHNA (Reg. No. 39140007) , K.M.V.AKHILESH (Reg. No. 39140021) and K.KRISHNABABU (Reg No. 39140025) who carried out the project entitled "FAULT ANALYSIS ON UNDERGROUND CABLES" under our supervision from December 2022 to April 2023.

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ABSTRACT

The project aim is to determine the distance of an underground cable fault from the base station in kilometers using an Arduino. The underground cable system is widely used in urban areas, but repairing a cable fault is often challenging due to not knowing the exact location of the fault. The proposed system includes a set of resistors representing the cable length in kilometers and a set of switches located every known kilometer to check the fault. When a fault occurs at a particular distance, the respective phase and distance are displayed on an LCD and sent over the Internet of Things (IoT). The system provides an efficient and accurate method for locating underground cable faults, improving the repair process and minimizing the downtime.

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LIST OF SYMBOLS AND ABBREVIATIONS

RX	-	Receiver
TX	-	Transmitter
LCD	-	Liquid Crystal Display
LED	-	Light Emitting Diode
DC	-	Direct Current
AC	-	Alternating Current
AVR	-	Automatic voltage regulator

CHAPTER 1

INTRODUCTION

1.1 GENERAL

In this project we proposed a fault localization model for the underground cable lines with Arduino. The purpose of this project is to determine the distance from the base station's underground cable fault in kilometres. In this project we used a simple concept of ohms law. 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 an underground cable that is higher than the previous method. adverse weather conditions such as storms, snow, torrential rains and pollution does not effect 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

In short circuit there are 3 faults-

1. Line To Line Fault – When line to line fault occurs when two lines are short with each other and in which line fault occurs with providing the distance of the faults.
2. Line To Ground Fault – When any of the single line is short circuit with the ground wire single line to ground fault occurs and in which line fault is occurred with providing the distance of the fault.
3. Double Line To Ground Fault - the double line to ground fault occurred when two lines are short with each other and are in contact of ground wire and in which line fault occurred with providing the distance of the faults.

CHAPTER 2

LITERATURE SURVEY

2.1 MAJOR FINDINGS FROM LITERATURE SURVEY

Thameur Aloui et al., (2012) Power underground cables have many advantages compared to the overhead lines. Indeed, they practically do not require maintenance and especially are not affected by the unfavorable climatic conditions. However, when a fault takes place, the restore time is relatively long due to the various stages of fault identification, classification and location estimation in differed time using usual echometric methods. To guarantee the continuity of the electric power, the electricity companies request to identify and locate with precision and rapidity the faulty segment in order to reduce the interruption duration. This target can be reached only by the implementation of simple, fast and accurate techniques of fault prelocalization. The paper aim is to develop a decision assistance tool to prelocate rapidly and precisely short-circuits to ground affecting single phase underground cables. Benefiting from the opening of the university on the industrial environment, this study is made in collaboration with the Tunisian Company of Electricity and Gas (STEG) on the occasion of the new project of underground cable connecting HTB substations of Tyna, Taparoura and Sidimansour in Sfax city. In this work, we are interested in a configuration of an underground shielded HTB single-phase cable. The cable modeling is based on the distributed parameters theory. The per-unit length parameters are calculated according to the physical laws.

Haidar Samet et al., (2021) Undetectable fault circumstances for the protection system lead to damage to the power system component and consequently, may lead to failure of the power system components. Incipient faults in underground power cables are known as one of the most significant types of faults that may not be detected by the conventional protection equipment. This type of fault occurs in shorter durations, and lower peak voltages in comparison with the other faults and so it is undetectable by the existing

protection schemes. The incipient faults mainly occur in parts of power cables having mechanical or insulation failure. These failures are generally developed as a result of the power cable aging, undesirable atmospheric conditions, or physical contact of the cable with other equipment. It is widely accepted that the occurrence of incipient faults is accompanied by an electric arc. Although electrical arcs also occur in overhead lines, in this paper the underground power cables are addressed. In the case of the aforementioned conditions such faults can occur repeatedly within time intervals. The insulation condition of the cable is damaged by each fault occurrence making the fault duration longer each time and consequently, resulting in a permanent fault. Considering that the capacitive switching, sudden system load changes and also harmonic loads produce conditions similar to incipient fault incipient, the need for a powerful method, capable of detecting the incipient faults quickly and with high accuracy is expressed. It should be mentioned that the detection of an incipient fault before turning into a permanent fault, helps to provide the necessary preparations for replacement of the faulty section of the cable (usually the junctions). It also helps to reduce the power supply interruption and its consequent expenses as well as collateral costs. Several articles have been published in the areas of the incipient fault, regarding the characteristics localization and detection . In it is expressed that the incipient fault is associated with an arc. The authors in proposed a sub-cycle incipient fault detection algorithm to prevent cable damage considering transient arcs. Utilizing wavelet transform and frequency analysis, an algorithm to detect incipient faults was proposed in. Fault detection is conducted experimentally, using a special relay in. In the procedure is conducted by the extraction of the voltage wave and the current wave reactances.

Wenhai Zhang et al., (2022) In order to realize the fault anticipation in underground cable, a significant number of studies have been conducted on underground cable incipient fault detection. Many incipient fault detection methods have been proposed, including signal analysis and machine learning based methods. Different types of incipient fault features were utilized for the detection, including its short duration (1/4 cycle to 4 cycles) feature arc distortion feature etc. However, the incipient fault detection can confirm whether there is an incipient fault here only. The incipient fault location is much more important for clearing the

fault in practice. Fault location is a traditional tough problem for the distribution system. There are lots of methods have been proposed in previous studies, including impedance-based methods traveling-wave based methods intelligent methods and wide-area methods. Impedance-based methods use the amplitude and phase angle of the fundamental frequency signals for distance estimation. However, they are only suitable for the permanent fault with steady-state and inapplicable for the transient fault without steady-state. Traveling-wave-based methods is less affected by the fault resistance. However, they are susceptible to the arrival time errors, environmental noise and attenuation of traveling wave. So far, there is no method has been widely used in practice. Due to advances in measurement and communication technologies, a large quantity of monitoring devices, such as PMU, smart meters and power quality monitoring devices, have been widely utilized in distribution systems. Many new fault location methods based on wide-area measurements have been proposed in recent years. However, all of these methods can only solve the problem of permanent fault location with steady state. In order to figure out incipient fault location problem, incipient fault mechanisms and waveform characteristics are analyzed in previous studies.

C.F. Jensen et al., (2014) Several issues such as high frequency attenuation in the cables as well as the ability of instrument transformers to represent the measured high voltage signals in the secondary are of great importance for the accuracy of a travelling wave-based fault location method. The standard instrument transformers used today alter the transient signals in the secondary due to inductive, capacitive and non-linear elements in the devices. The result is a distorted signal and the introduction of a possible time delay. The sheaths of a crossbonded cable system are short circuited and grounded at each end of the transmission line. This makes the use of low voltage current transducers possible. The Rogowski type of coil is cheap and solid and has a high bandwidth. This type of sensor has been used to capture the surge through surge suppression capacitors for fault location purposes on DC-systems with success. In this paper, the use of the sheath currents for a travelling wave fault location purpose is examined. The fault surge arrival instance is found through a visual inspection method (VIM) and by the use of the Wavelet Transform method (WTM). Furthermore, to gain knowledge on whether simulations can be trusted for fault location studies done on cables, a highly detailed simulation model is constructed in

PSCAD/EMTDC and the results are compared to the measurements. During the installation of the electrical connection to the 400 MW off shore wind farm An holt, it was possible to perform measurements on a 38.4 km cross bonded cable system. The 245 kV electrical connection to the An holt offshore wind farm is divided into three cable sections. The first section is a 59.6 km cross bonded land cable from the substation Trigger to a newly constructed shunt reactor station close to the beach by the Danish city Grenaa-. From the reactor station, a 0.5 km underground cable is used to connect the land cable to the submarine cable. The submarine cable is a three phase cable with a length of 24.5 km.

Haidar Samet et al., (2021) By the employment of specially designed relays, the authors in have presented a practical technique for incipient fault detection. The method presented in is based on specifying the fault location by deriving the reactance. The authors in have taken into consideration three various scenarios for incipient fault localization. In localization has been carried out with the use of wavelet spectrum analysis of the first and second waves reaching the cable ends. The localization of the single and three-phase incipient faults has been proposed to be conducted with the use of impedance measurement in and with the use of capacitive effects in. A method has been presented in for incipient fault localization in overhead, and cable lines. The thermal model has been utilized for cable hot-spot detection in. The authors in have employed mathematical algorithms and a circuit model for the cable to localize incipient faults. In the voltages and the currents have been analyzed to derive the impedance for incipient fault localization. In the reactance concept in a similar manner as has been employed to accurately specify the location of the incipient fault. In some sensor based frameworks for fault detection and location were presented that were focused on smart dis tribution networks equipped with data loggers. In through fast filtering of the voltages and currents in the sending end of the cable, incipient fault detection has been carried out in two stages. The authors in have employed a mathematical model similar to the model in for the detection of the incipient fault. Wavelet analysis and artificial intelligence methods have been employed for incipient fault detection in. Taking into consideration the rotational current flows in the circuit, and also three different scenarios of three-phase cable junctions, the incipient fault detection has been put forward in. Employing

system identification based approaches and parameter estimation algorithms, incipient fault detection and location have been investigated in.

M. Seppanen et al., (2012) Faults caused by icing are often recurrent and they can lead to long-lasting and widespread power outages that cause significant harm to the customers. Moreover, ice accumulation can cause physical damage to the overhead line structures. Due to the importance of electricity for heating and lighting during the cold season, the reliability of electricity supply is critical. In some areas, it may be reasonable to build transmission lines without overhead ground wires due to the icing problems. However, the electrical safety of these unconventional overhead lines must be taken into consideration during the line planning process. The electrical safety instructions and regulations are defined in the national and international standards such as and . If the transmission lines were not equipped with ground wires, the magnitudes of touch-and-step voltages and the ground potential rise of the faulted tower would increase, causing a potential electrical hazard. This phenomenon is created when the total ground fault current flows to the soil through the individual grounding of the faulted tower. A possible solution to decrease hazardous voltages is to use an underground ground wire connected to the grounding of each tower. The underground ground wire is a buried bare conductor that creates a wide-ranging grounding system for the towers and operates simultaneously as a reduction conductor. The purpose of this paper is to investigate the ground fault and electrical safety of overhead lines equipped with an underground ground wire. The characteristics of long external grounding electrodes have been studied extensively in the past. Furthermore, ground faults of transmission lines equipped with overhead ground wires have been profoundly examined. However, underground ground wires have not been widely investigated. The objective of the authors is to present novel calculation methods that describe the electrical behavior of the underground ground wire during a ground fault. The validity of the methods is verified by measurements. The measurements were conducted on a 110-kV overhead line equipped with an underground ground wire situated in Northern Finland. The safety and general feasibility of overhead lines equipped with an underground ground wire can be evaluated based on the results of this paper.

CHAPTER 3

AIM AND SCOPE OF THE PROJECT

3.1 PROBLEM IDENTIFICATION

Through literature survey the problem we identified is:

1. It is difficult to locate the exact location of the fault in cables in underground system due to this entire line is to be dug in order to check entire line and fix faults
2. If there are fluctuations in voltage, it can indicate a problem with the cables.
3. There is an issue to calculating types of faults occurring in underground
4. High resistance in the cables can indicate a problem with the insulation or damage to the cables.
5. In the overall system the current consumption is more

3.2 SCOPE OF THE PROJECT

In this work, we improved fault analysis on underground cables has been proposed. The fault which is caused due to closed loop in line to line or line to ground prevented by open circuiting in relays .Here the data is analyzed by the automatic control system which is programmed. The data is communicated through IOT(Inter net of things) based from Wi-Fi module to laptop or mobile The communication between Wi-Fi module and laptop takes place wirelessly.

3.3 COMPONENTS

3.3.1 Arduino Board

Arduino is an electronic creation platform. Which is free, adaptable and simple to involve equipment and programming for creators and engineers. This allows you to make

various kinds of single-board microcomputers to which the community of creators can give various sorts of utilization. A microcontroller board based on the ATmega2560 is called an Arduino Mega. It has 54 digital I/O pins (14 are for pulse width modulation), AI pins, serial ports for hardware, crystal vibrator, power or USB connection along with the reset button. Thus, this board is a complete package to support the microcontroller. 21 Powered with the help of a computer, laptop AC-DC adapter or a battery. It is compatible with most of the devices and can perform a lot of functionality. It is widely used for multiple purposes because of ease of handling and a number of functions which this board provides.

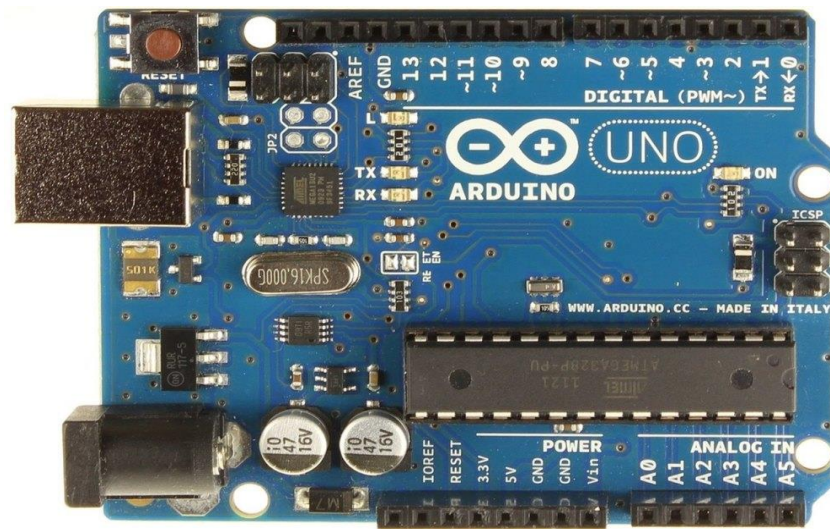


Fig:3.1 : Arduino UNO

3.3.2 NEO-6MV GPS Module

The GPS (Global Positioning System) module transceivers is a family of stand-alone with the exceptional 'u-blox' 6 positioning engines having great performance with accurate detection of position is the 'NEO-6' package series. In a compact (16 x 12.2 x 2.4) millimeter package, these enhanced, powerful, and inexpensive receivers provide various communication options. Their portable design including processing and storage capabilities makes NEO-6 modules suitable with very low cost and space constraints on battery-operated smart phones. A "TTFF" (Time-To-First-Fix) works in a time frame of less than 1 second features the 50-channel 'u-blox' 6 positioning engines. With two million correlation receivers,

the specific acquisition unit has the capability of huge parallel frequency upper space operations, allowing it to locate satellites promptly. One configurable 'UART' interface for serial communication is included in the NEO-6 M module, however the standard 'UART' (TTL) baud rate in this NEO-6 module is 9600. The design of this GPS NEO-6 module antenna would be distinct from the various typical whip antennas utilized for 'linear polarized signals' 26 since the received signals of GPS module is "Right-Hand Circular Polarized" (RHCP). The patch antenna is now the most prominent antenna type. Patch antennas are smooth and possesses a ceramic and metal body and are installed on the surface plate of the metal. Note, for the optimum efficiency of the GPS receiver, the antenna installation location is very critical, and response is always depending on the position of the antenna. It should be orientated parallel to the geographical horizon while using the patch antenna. The antenna would provide a full view of the horizon, providing as many visible satellites as possible with a clear line of sight. Advanced architecture and innovation vanquish the sources of jamming and minimizes the impacts of multi-path. This module provides the exceptional navigation efficiency to 'NEO-6M GPS' receivers even in the worst and harsh circumstances under various climatic conditions.



Fig:3.2 : NEO-6MV GPS Module

3.3.3 Liquid crystal display (16x2)

Seven segment and multi segment are the widely used displays which are prove to be beneficial for its low cost, simple programming and uncountable abilities and special Claymation. Such type of devices are mostly used in the circuit of computers, calculators and cell phones.



Fig:3.3 : 16x2 LCD display

3.3.4 ACS712 Current Sensor Module

The ACS712 module consist of an IC which record the current by fulfilling a Hall Effect Theory. Always prefer to use IC then the module since IC is derived from module. These ACS712 have a range lies between (5 to -5), (20 to -20) and (30 to -30) for Alternate current. It is always recommended to select optimum range for the project. It is easy to link it with any microcontroller because ACS712 produce analog voltage ranging from 0 to 5V depending upon the current through conductor.

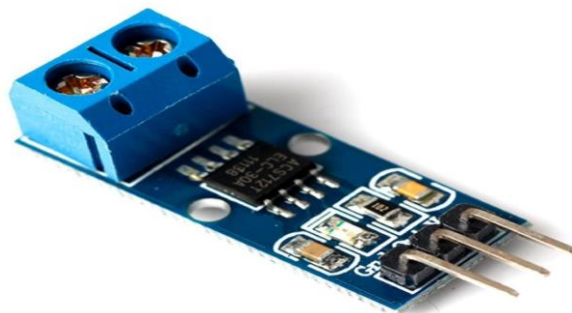


Fig:3.4 : ACS712 Current Sensor Module

3.3.5 NodeMCU ESP8266

NodeMCU ESP8266 is created and produced by Espressif Systems, it is built around a low cost System on a Chip (SoC). It is an open source platform used for developing both software and hardware. NodeMCU makes a great choice for all types of Internet of Things (IoT) projects 32 as it includes all the essential computer components which includes CPU, RAM, Wi-Fi etc. It is difficult to operate and gain access to ESP8266. Even performing

simple operations such as switching it on or sending keystroke to the computer needs the person operating it to solder wires with proper analogue voltage to its pins. Moreover, for the chip to understand the operator's instructions, the instructions have to be given in low level machine instructions. This causes it to be a burden for people who wish to use it in their own IoT projects. Things which make Arduino different from NodeMCU is that the Arduino board can include a number of types of memory chips, CPU chips and a range of programming environments.

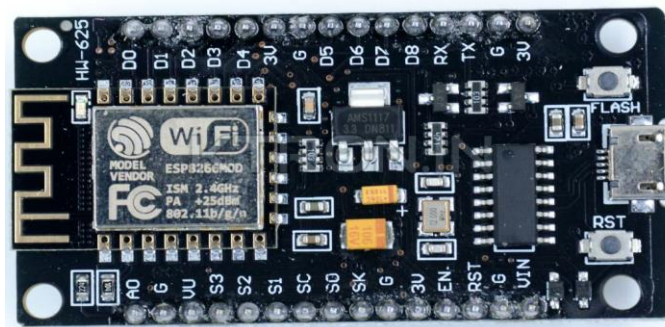


Fig:3.5 : NodeMCU ESP8266 Wi-Fi module diagram

3.3.6 SWITCHS

In electrical engineering, a switch is an electrical component that can disconnect or connect the conducting path in an electrical circuit, interrupting the electric current or diverting it from one conductor to another.



Fig:3.6 : Diagram of switch

3.3.7 Arduino IOT Cloud

An online platform which allows to connect, monitor and control Arduino based IoT projects. It offers a number of services for free and has paid extensions as well. In the designed prototype, its work is simple and easy to understand. Arduino is the main centralize unit (In terms of monitoring of system and detection of faults). The calculated values from Arduino are shown on Arduino IoT cloud desktop using NodeMCU. NodeMCU is providing necessary internet connectivity here. Arduino IoT cloud's interface is easy to use and understand. It is fulfilling the purpose of displaying a number of parameters including

- Fault type.
- Fault distance.
- Current in all three phases.
- Fault location by GPS.
- Record of faults along with time.

Arduino IoT cloud offers a number of useful services which are more efficient and has lesser technical limitations (problems) in comparison to GSM sensor.

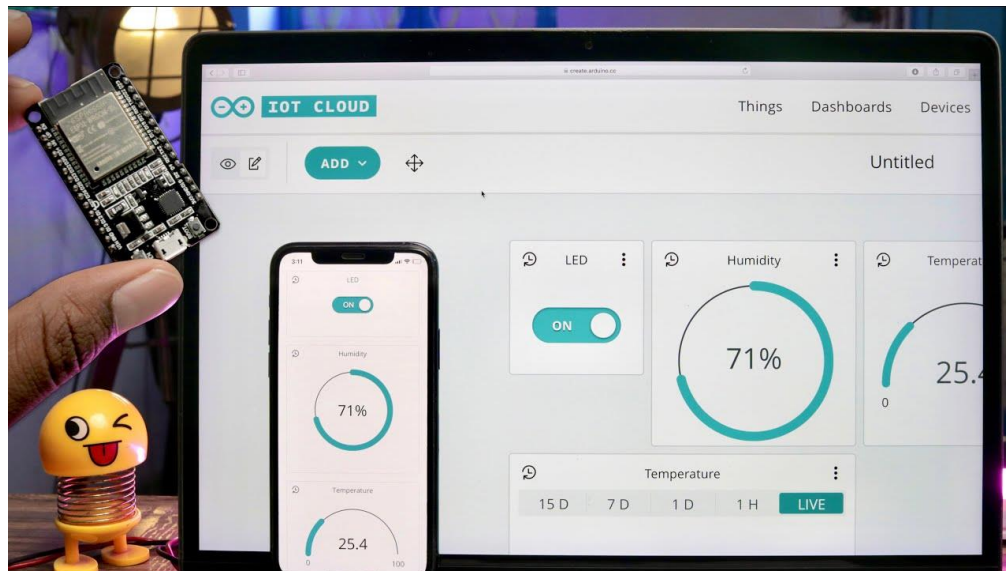


Fig:3.7 : Arduino IoT Cloud

3.4 RISK ANALYSIS

a) TIME PERIOD AND EXERTION SAVING

The analogous relaying devices implements the related circuit breakers to de-empower the faulted regions after fault. Once they took an interest faulted phases are showed up and faults are cleared, the received fault finder is not able to find the fault location. At that point, the support troops might be educated regarding that spot so as to fix the resultant failure. Afterward, after finishing the upkeep task, the line ought to be recovered once more. Based on different geographical and environmental conditions, the transmission line networks are made to spread for few hundreds of km, finding these types of flaws arranged on the human comprehension and the accessible information about the states of all kinds of breakers in the faulted spot isn't enthusiastic and time ruling. These expectations may sufficiently help to sectionalize the faults (affirm the faulted line territory) as opposed to recognize explicitly the fault location. Since, the need of utilizing submitted fault area frameworks are self-evident

b) IMPROVING SYSTEM ACCESSIBILITY

There are no uncertainty that quick and successful maintenance measures straightforwardly lead to improve power accessibility to the users. This thusly upgrades, the overall power system efficiency. These ideas of (accessibility, efficiency, quality) have an inexorably significance these days because of the new marketing approaches coming about because of liberation and advancement of power as well as energy markets. 15

c) HELPING FUTURE SUPPORT PLANS

It is completely right that transitory faults (the more transcendent fault on the overhead transmission framework) are cleared and in this manner, the stability of system isn't perpetually influenced. Be that as it may, examining the faults area can assist with pinpointing the wake spots on overall transmission nets successfully. This ideally helps the tentative arrangements of support plans and

therefore prompts stay away from further issues later on. These procedures of preventive maintenance upkeep empower to dodge those huge issues, for example, power outages and help to expand the overall power system efficiency.

d) FINANCIAL FACTOR

All the referenced advantages can be audited from the economical viewpoint. There is no uncertainty that time and exertion sparing, expanding the power accessibility and keeping away from future accidents can be straightforwardly deciphered as a cost decrease or a benefit expanding. It is a fundamental concept for aggressive marketing.

3.5 IEEE STANDARDS

The IEEE Standards Association has published several standards related to fault analysis on underground cables. Some of the relevant standards are:

1. IEEE 1584-2018: IEEE Guide for Performing Arc-Flash Hazard Calculations - This standard provides guidelines for performing arc-flash hazard calculations for electrical systems, including underground cables.
2. IEEE 493-2007: IEEE Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems (Gold Book) - This standard provides recommendations for the design of reliable power systems, including underground cables.
3. IEEE 141-2019: IEEE Recommended Practice for Electric Power Distribution for Industrial Plants (Red Book) - This standard provides recommendations for the design, installation, and operation of electric power distribution systems, including underground cables.
4. IEEE 1015-2019: IEEE Guide for Applying Cable Ampacity Ratings - This standard provides guidelines for applying cable ampacity ratings for various types of cables, including underground cables.

5. IEEE 1366-2012: IEEE Guide for Electric Power Distribution Reliability Indices
 - This standard provides guidelines for measuring and evaluating the reliability of electric power distribution systems, including underground cables.

3.6 CONSTRAINTS

Fault analysis on underground cables can be challenging due to several constraints, including:

1. Access: Underground cables are buried beneath the ground, making access difficult. It can be challenging to locate the exact location of the fault, and the excavation process required to access the cables can be time-consuming and costly.
2. Safety: Working with high-voltage underground cables can be dangerous. There is a risk of electrical shock or electrocution, especially if proper safety procedures are not followed.
3. Environmental concerns: Excavating the ground to access underground cables can have environmental implications. The excavation process can disrupt the soil and vegetation, and there may be concerns about the disposal of any hazardous materials that are encountered during the excavation.
4. Cost: Repairing underground cables can be expensive, particularly if the fault is located in an area that is difficult to access. The cost of excavation, repair, and replacement of damaged components can quickly add up.
5. Time: Fault analysis on underground cables can be time-consuming, particularly if the fault is difficult to locate. This can lead to prolonged downtime, which can be costly for businesses that rely on a continuous power supply.

3.7 TRADEOFF

There are several tradeoffs to consider when performing fault analysis on underground cables. Some of the main tradeoffs are:

1. Time vs. Accuracy: The accuracy of fault analysis is directly proportional to the time spent on it. However, spending too much time on the analysis can result in increased downtime and reduced productivity. Thus, there is a tradeoff between accuracy and the time taken to complete the analysis.
2. Cost vs. Safety: Safety is a critical concern when working with high-voltage underground cables. However, implementing safety measures can add to the overall cost of fault analysis. Thus, there is a tradeoff between cost and safety.
3. Repair vs. Replacement: When a fault is detected, the decision must be made whether to repair or replace the damaged component. Repairing the cable can be a cost-effective solution, but there is a risk that the fault may recur. On the other hand, replacing the entire cable can be expensive but ensures a longer-term solution. Thus, there is a tradeoff between the cost of repair and the long-term benefits of replacement.
4. Precision vs. Accessibility: Fault analysis requires precise knowledge of the location of the fault. However, gaining access to the underground cables can be challenging and time-consuming. Thus, there is a tradeoff between precision and accessibility.
5. Maintenance vs. Reactive Repair: Regular maintenance of underground cables can help detect faults before they cause significant downtime. However, maintenance can be time-consuming and costly. Reactive repair, on the other hand, involves addressing faults as they occur. This approach can be more cost-effective in the short term, but can result in increased downtime and loss of productivity. Thus, there is a tradeoff between regular maintenance and reactive repair.

CHAPTER 4

EXPERIMENTAL METHODS

4.1 OBJECTIVES

The objectives of the proposed work are as follows

- To prevent cables from fault through open circuit in relays
- To protect the cables from the occurrence of faults
- To determine the distance of underground cable fault from base station in kilometers and also find the location of that faulty place
- It can prevent the apparatus from faults

4.2 METHODOLOGY

When we supply three-phase power to the input of step down transformer at the starting of underground line to transmit it and 5 to 12 volt DC power to the arduino and other sensors then the system started. There are 5 possible cases in which first case is no fault during the no fault situation. Firstly close the circuit and power is transmitted to the load through the underground line the load is consists of three red , green and blue LEDs then the current sensor start taking readings. Firstly there is no fault so all the values of the current is less then pickup current (The value of current of which current is considered as fault current) and relay will open and isolate the system. For example we set the pickup current 5 ampere so if our load consume less than 5 ampere there is no problem but if our load consume greater than or equal to 5 ampere due to any fault or overloading it considered as fault current and relay will open or circuit breaker trip and isolate the system

First of all, connection of four current sensors in series of transmission line at the starting point is made, In which 3 current sensors are connected at three line wires (line 1,

line2 and line 3) and one connected at neutral wire and output of all current sensors are connected to the analog pins of microcontroller for the measuring of load and fault currents.

- A0 connected with current sensor of line 1.
- A1 connected with current sensor of line 2.
- A2 connected with current sensor of line 3.
- A3 connected with current sensor of line 4.

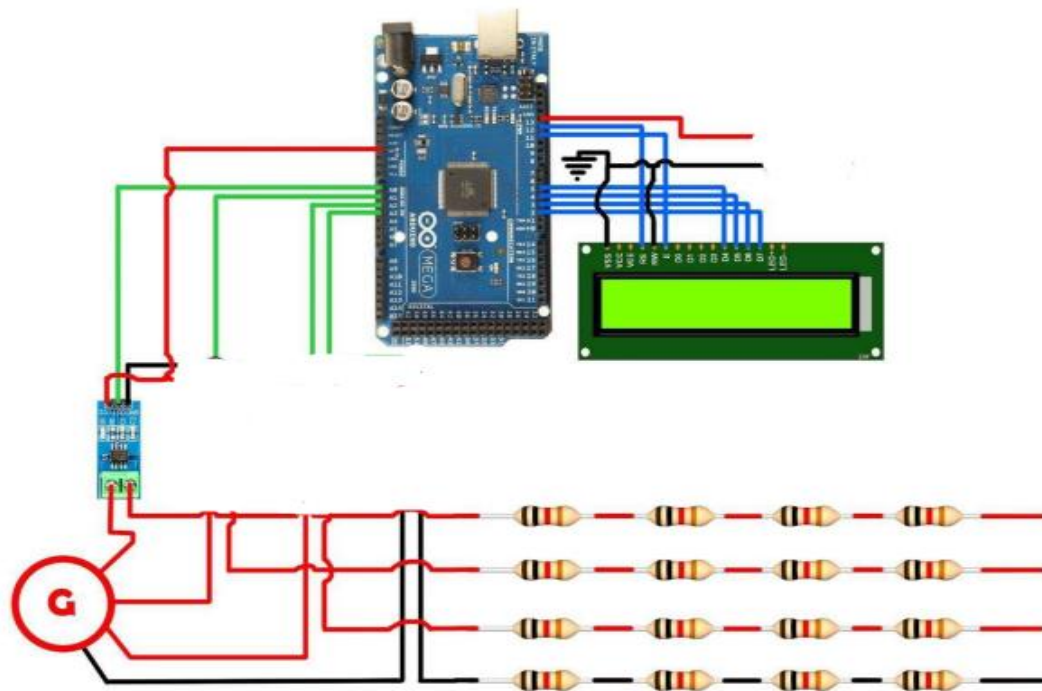


Fig :4.1 : current sensors connections Diagram

Then 5v power supply to current sensors Vcc input pins from Arduino 5v output pin and all ground pins of sensors are grounded. 5v buzzer is connected at pin no 13 of Arduino. Liquid crystal display (16x2) is interface with Arduino and transmission line is design which is consist of 100 ohms resistors. Four resistors are connected in series in every line and considering the resistance of transmission line is 100 ohms after ever two kilometers distance.

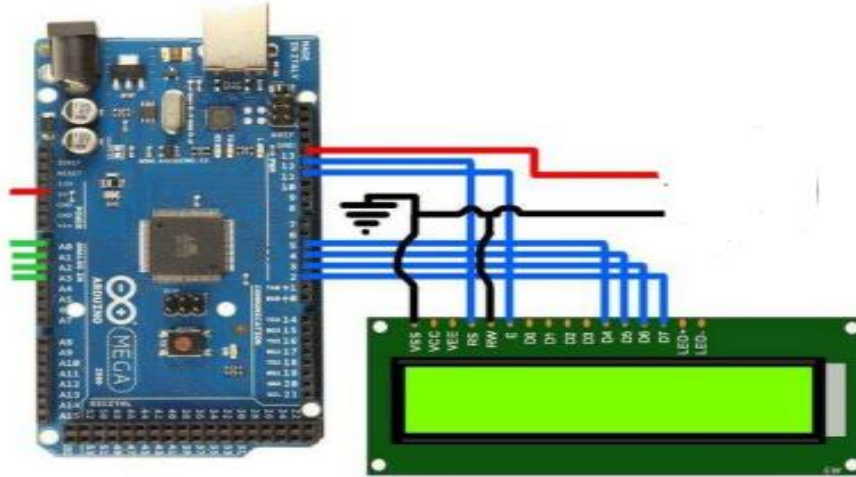


Fig: 4.2 : LCD Connections Diagram

4.3 Calculations.

As the resistance of conductor is calculated by the following formula.

$$R = \frac{\rho L}{A} \quad (1)$$

Here Specific Resistance ("p") is a property of any conductive material and is constant for conductors

"(A)" is area of inductor which is constant.

"(L)" is length of inductor.

So,

$$R \propto L \quad (2)$$

and according to ohm's law,

$$I = \frac{V}{R} \quad (3)$$

Suppose that voltage of underground is constant so,

$$I \propto \frac{1}{R} \quad (4)$$

When the length of conductor increases then resistance also increases and fault current decreases so when fault occur at far position from the starting of underground cable then length of conductor and resistance increases and fault current decreases. Similarly, when fault occur near at the starting of underground cable then length of conductor and resistance decreases so fault current increases. Firstly calculation of fault current through the input of current sensors is done then calibration of location according to the magnitude of fault current

4.4 FAULT CONDITIONS

4.4.1 case: 1 No Fault

If the circuit is connected with current if the lines are connected without any fault the type is no fault

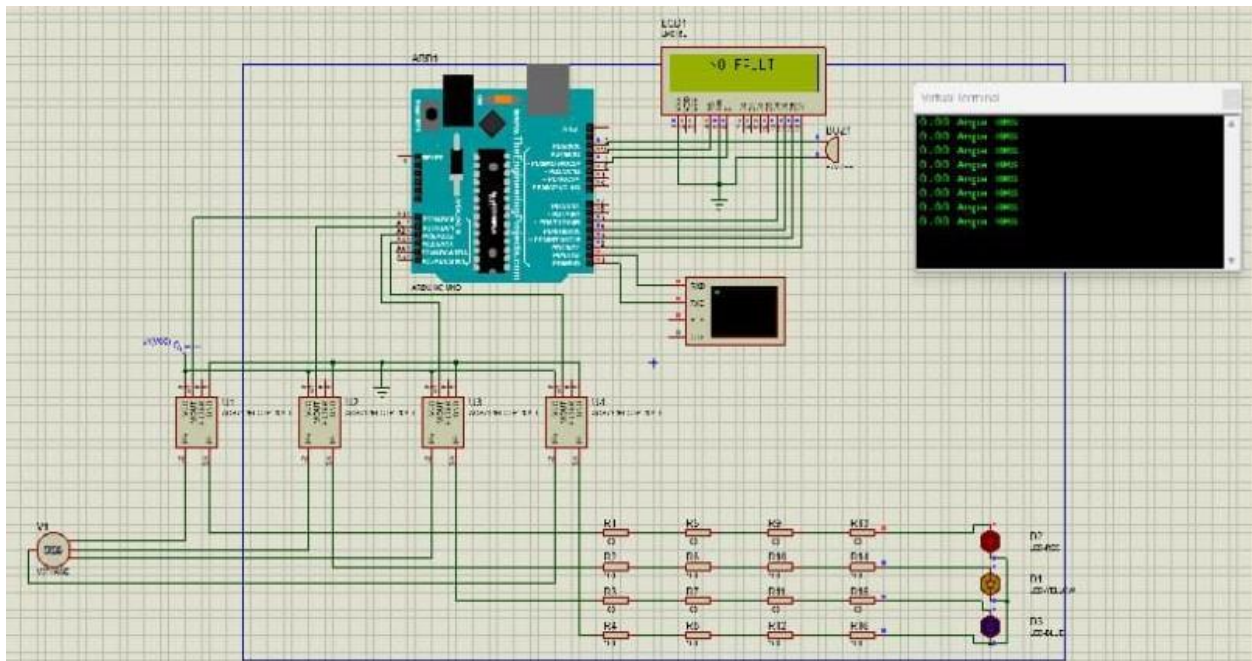


Fig:4.3 : L-G No Fault underground cables Software Simulation

4.4.2 Case: 2 Single Line to Ground Fault

Whenever any of the single line is short circuit with ground wire single line to ground fault occurs. The LCD shows type of fault (single line to ground fault) and in which line fault is occurred with providing the distance of the faults.

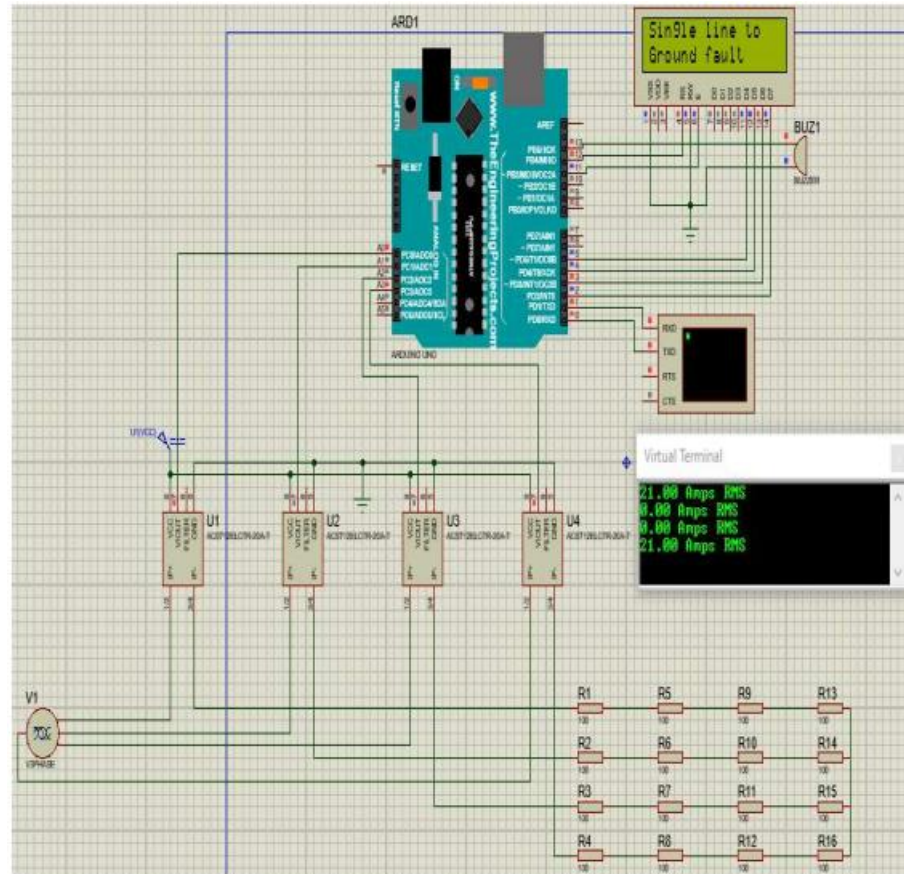


Fig:4.4 : L-G occurred in underground cables Software Simulation



Fig:4.5 : LCD display after delay during Line to Ground fault Software simulation

4.4.3 Case: 3 Line to Line Fault

The figure below shows that the line to line fault occurs when two lines are short with each other. The LCD shows type of fault (line to line fault) and in which line fault occur with providing the distance of the faults.

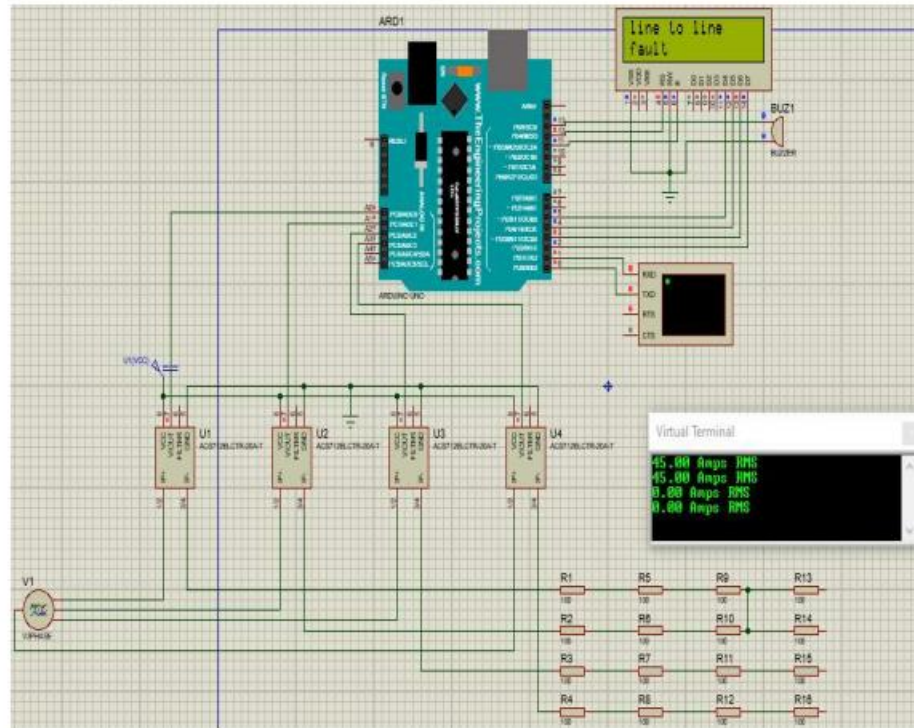


Fig:4.6 : L-L fault occurred in underground cables Software Simulation



Fig:4.7 : LCD display after delay during Line to Line fault Software simulation

4.4.4 Case: 4 Double Line to Ground Fault

The figure below shows that the double line to ground fault occurred when two lines are short with each other and are in contact of ground wire. The LCD shows type of fault (double line to ground fault) and in which line fault occurred with providing the distance of the faults.

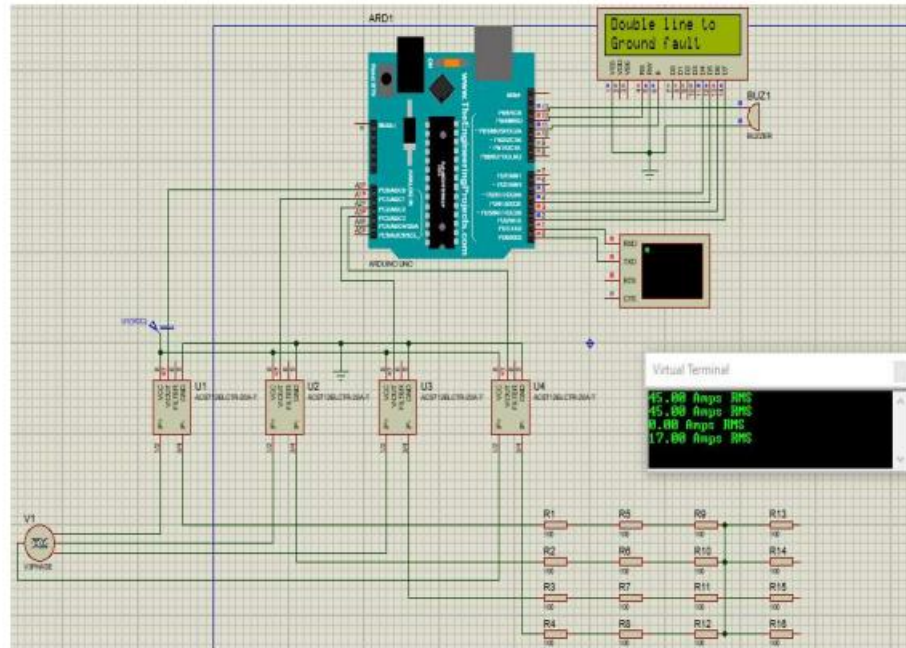


Fig:4.8 : L-L-G fault occurred in underground cables Software Simulation



Fig:4.9 : LCD display after delay during L-L-G fault Software Simulation

4.5 ARDUINO IOT CLOUD RESULTS



Fig 4.10 : IOT cloud results

4.6 APPLICATION

- The detection of underground cable fault which is very hard to detect as it is not possible to see such faults.
- The distance at which the fault has occurred can be calculated and then further action regarding the fault can be taken to overcome them.

CHAPTER 5

PROJECT DESCRIPTION

5.1 EXISTED UNDERGROUND CABLE EXPLANATION

The 'Fault analysis on underground cables' in this existed block diagram at firstly we take the 230volts supply and connected to the step down transformer from transformer we connected to the relays as phases or lines we taken is connected to the arduino uno . As LCD and microcontroller are connected to the same arduino board and a buzzer is connected to arduino .For a single phase we are connecting the four switches as per the kilometers concern for three phases we are connecting the 12 switches for every switch we are connecting one resistance to calculate the current. In the circuit we are using the step down transformer to reduce the current from 230volts to 12volts , LCD is used to display the faults when it will occur otherwise it shows no fault detected , Buzzer is used when any fault is indicated in the phase then it will sounds , We use LED to glow when there is no fault in system we have to take one bulbs for every phase , switches are used to create the faults and resisters are used to identify the fault where we get and the microcontroller we used is arduino uno to do the whole process.

After giving all the connections we have to upload the code into the arduino uno and we can give the supply 230volts current the step down transformer it will reduce the current to 12 volts when the power is supplied to arduino the will switch on and compile the code as per given and implement the code . When there is no fault is detected in the circuit then LCD display shows NO FALT when the switch is on in the circuit the resistance value will changes and indicate the fault then the buzzer will beeps until the fault is rectified and the LCD display shows the fault where it was occurred until it rectifies. When which switch we operates the distance will shows as same as per the connections given .

5.2 PROBLEMS OF EXISTING SYSTEM

- Insulation failure occurs during a single phase to ground faults
- Earth fault protection for the unearthed system is difficult
- Voltage due to lightning surges does not find a path to earth
- less flexible compared to overhead lines
- Laying (or) burying cost of underground cables are higher compare to overhead lines

5.3 PROPOSED UNDERGROUND CABLE EXPLANATION

The 'Fault analysis on underground cables' Designing an underground line monitoring and fault detection system for an underground line that is capable of monitoring underground line load current and detecting four types of fault in underground line and finding their location and distances using GPS and display result on LCD and arduino IOT cloud dashboard with alert message on IOT cloud dashboard messenger. We also use four relays to work as a circuit breaker that isolates or break the underground cables during the fault and a buzzer that gives an alarm for alert When we supply three-phase power to the input of step down transformer at the starting of underground line to transmit it and 5 to 12 volt DC power to the arduino and other sensors then the system started. There are 5 possible cases in which first case is no fault during the no fault situation.

Firstly close the circuit and power is transmitted to the load through the underground cables the load is consists of three red , green and blue LEDs then the current sensor start taking readings. Firstly there is no fault so all the values of the current is less then pickup current (The value of current of which current is considered as fault current) and relay will open and isolate the system. For example we set the pickup current 5 ampere so if our load consume less than 5 ampere there is no problem but if our load consume greater than or equal to 5 ampere due to any fault or overloading it considered as fault current and relay will

open or circuit breaker trip and isolate the system . So, during no fault LCD display shows no fault and all the load current will display on arduino cloud. The second case is single line to ground fault in this situation the system detect in line 1 and ground wire is greater than pickup current so relays break or isolate the underground cables and buzzer is on for an alert and LCD displays line fault occur with providing their distance of fault location then arduino iot cloud update their current values and display type of fault distance of fault location in google map link. After fault correction reset the relay by using push button so release closed and current sensor start taking readings if the system detect there is no fault so relays will remain closed and lcd display shows no fault.

The third case is line to line fault by shorting line 1 red with line 2 green at six kilometer to create a line to line fault in this situation the system detect current in line 1 red and current in line to green is greater than the pickup current so relay break or isolate the underground cable buzzer is on for an alert and LCD display shows fault line to line fault then after a delay of 5second it display in which line fault occur with providing their distance of fault location red is short with green at a distance of 6 kilometer then again arduino IOT cloud update their current values and display type fault distance of fault location and Google map link that locate for location and also send these messages for an alert the fourth case is double line to ground fault by shoting line 1 red and align to green with ground is connected to ground wire at 4 kilometer to create a double line to ground fault then I reset the relays so relays closed and current sensor start taking reading in this situation the system detect current in line to green and current in ground wire is greater than the pickup current so relays break or isolate the underground cables buzzer is on for an alert and LCD display shows fault as double line to ground fault then after a delay of 5 second it display in which line fault occur with providing their distance of fault location red and green is short with the ground at 4 kilometer of distance similarly again arduino iot cloud update their current value and display type of fault distance of fault location and google map locate the location and also send these messages for an alert and the fifth and last case is in line fault so in shorting line1 red line to green and line 3 blue with each other at 2 kilometer to create a three phase fault then reset the button so release closed and current sensor start taking reading in this situation the system detect current in line 1 red current in line to green and current in line 3 blue is greater than the pickup current so release break or isolate the under ground cables, buzzer is on for

an alert and LCD display show type of fault in three phase then after a delay of 5 second it display in which line fault occur at a distance of 2 kilometer similarly again arduino iot cloud update their current location and google map locate the fault location and also send these messages for an alert then by copying these fault location link and search on web browser so it gives us a distance of 2.5 kilometer noted here.

5.4 ADVANTAGES OF PROPOSED SYSTEM

- Less maintenance
- Less complexity
- It has high efficiency
- Get outputs through IOT
- We can calculate all types of faults
- It can detect other types of cable faults such as short circuit fault, cable cuts
- Consume low power
- Provide precise accuracy to determine the location of fault

5.5 ARDUINO CODE

```
#include <LiquidCrystal.h>

LiquidCrystal lcd(2,3,4,5,6,7);

#define sensor A0

#define relay1 8

#define relay2 9
```

```
#define relay3 10
```

```
#define buzzer 13
```

```
int read_ADC,r,y,b;
```

```
int distance;
```

```
byte symbol[8] = {
```

```
    B00000,
```

```
    B00100,
```

```
    B00100,
```

```
    B00100,
```

```
    B11111,
```

```
    B01110,
```

```
    B00100,
```

```
    B00000};
```

```
void setup() {
```

```
    Serial.begin(9600);
```

```
    pinMode(sensor,INPUT);
```

```
    pinMode(relay1, OUTPUT);
```

```
    pinMode(relay2, OUTPUT);
```

```
    pinMode(relay3, OUTPUT);
```

```
pinMode(buzzer, OUTPUT);
```

```
lcd.createChar(1, symbol);
```

```
lcd.begin(16, 2);
```

```
lcd.clear();
```

```
lcd.setCursor(0, 0); // set the cursor to column 0, line 2
```

```
lcd.print("Welcome to Cable");
```

```
lcd.setCursor(0, 1); // set the cursor to column 0, line 2
```

```
lcd.print("Fault Detection");
```

```
delay(2000);
```

```
lcd.clear();
```

```
}
```

```
void loop(){
```

```
for(int jj = 0; jj < 8; jj++){
```

```
lcd.setCursor(1,0);
```

```
lcd.print("R");
```

```
lcd.write(1);
```

```
lcd.setCursor(7,0);
```

```
lcd.print("Y");
```

```
lcd.write(1);
```

```
lcd.setCursor(13,0);
```

```
lcd.print("B");
```

```
lcd.write(1);
```

```
digitalWrite(relay1,HIGH);
```

```
digitalWrite(relay2,LOW);
```

```
digitalWrite(relay3,LOW);
```

```
delay(500);
```

```
data1();
```

```
lcd.setCursor(0,1);
```

```
if(distance>0){lcd.print(distance); lcd.print("KM ");}
```

```
else{lcd.print(" NF ");}
```

```
digitalWrite(relay1,LOW);
```

```
digitalWrite(relay2,HIGH);
```

```
digitalWrite(relay3,LOW);
```

```
delay(500);
```

```
data2();
```

```
lcd.setCursor(6,1);
```

```
if(distance>0){lcd.print(distance); lcd.print("KM ");}
```

```
else{lcd.print(" NF ");}
```

```

digitalWrite(relay1,LOW);
digitalWrite(relay2,LOW);
digitalWrite(relay3,HIGH);
delay(500);

data3();

lcd.setCursor(12,1);
if(distance>0){lcd.print(distance); lcd.print("KM ");}
else{
    lcd.print(" NF ");
}

}

lcd.clear();
lcd.setCursor(0,0);
lcd.print("sending to IOT.....");
Serial.print(";");
Serial.print(r);
Serial.print(":");
Serial.print(y);
Serial.print(":");
Serial.println(b);
delay(3000);
lcd.clear();

```

```
}
```

```
void data1(){  
  read_ADC = analogRead(sensor);  
  distance = read_ADC/100;  
  //Serial.print(distance);  
  if(distance>9)distance = 0;
```

```
  if(distance>0){  
    //Serial.println("  R phase ");  
    //Serial.println(distance);  
    r = distance;  
    digitalWrite(buzzer,HIGH);  
    delay(200);  
    digitalWrite(buzzer,LOW);  
    delay(200);
```

```
  }
```

```
  else
```

```
{
```

```
  r = 0;
```

```
}
```

```
}
```

```

void data2(){
  read_ADC = analogRead(sensor);
  distance = read_ADC/100;
  //Serial.print(distance);
  if(distance>9)distance = 0;

  if(distance>0){
    // Serial.println("  Y phase ");
    //Serial.println(distance);
    y = distance;
    digitalWrite(buzzer,HIGH);
    delay(200);
    digitalWrite(buzzer,LOW);
    delay(200);
  }
  else
  {
    y = 0;
  }
}

```

```

void data3(){
  read_ADC = analogRead(sensor);
  distance = read_ADC/100;

```

```

//Serial.print(distance);

if(distance>9)distance = 0;


if(distance>0){
    //Serial.println("  B phase ");
    //Serial.println(distance);
    b = distance;
    digitalWrite(buzzer,HIGH);
    delay(200);
    digitalWrite(buzzer,LOW);
    delay(200);
}
else
{
    b = 0;
}
}

```

5.6 IOT CODE

```

#include <ESP8266WiFi.h>

#include "secrets.h"

#include "ThingSpeak.h" // always include thingspeak header file after other header files and
custom macros

char ssid[] = SECRET_SSID; // your network SSID (name)

```

```

char pass[] = SECRET_PASS; // your network password
int keyIndex = 0;          // your network key Index number (needed only for WEP)
WiFiClient client;

unsigned long myChannelNumber = SECRET_CH_ID;
const char * myWriteAPIKey = SECRET_WRITE_APIKEY;

// Initialize our values
int number1 = 0;
int number2 = 0;
int number3 = 0;
int number4 = 0;
int number5 = 0;
String myStatus = "";

String myString;
char c;
int Index1,Index2,Index3, Index4,azi,Index5,Index6;
String secondValue, thirdValue,fourthValue,fifthValue,sixthValue;
int secondValueInt, thirdValueInt, fourthValueInt,fifthValueInt,sixthValueInt;

void setup() {
  Serial.begin(9600); // Initialize serial
  while (!Serial) {
    ; // wait for serial port to connect. Needed for Leonardo native USB port only
  }
}

```

```

}

WiFi.mode(WIFI_STA);

ThingSpeak.begin(client); // Initialize ThingSpeak
}

void loop() {

    // Connect or reconnect to WiFi
    if(WiFi.status() != WL_CONNECTED){
        Serial.print("Attempting to connect to SSID: ");
        Serial.println(SECRET_SSID);
        while(WiFi.status() != WL_CONNECTED){
            WiFi.begin(ssid, pass); // Connect to WPA/WPA2 network. Change this line if using open
or WEP network
            Serial.print(".");
            delay(5000);
        }
        Serial.println("\nConnected.");
    }

    while(Serial.available()>0)
    {
        delay(10);
    }
}

```

```

c = Serial.read();
myString += c;
Serial.println(myString);
}
if (myString.length()>0)
{
Index1 = myString.indexOf(':');
Index2 = myString.indexOf(':', Index1+5);
Index3 = myString.indexOf(':', Index2+8);
Index4 = myString.indexOf(':', Index3+22);
Index5 = myString.indexOf(':', Index4+3);
Index6 = myString.indexOf(':', Index5+42);

secondValue = myString.substring(Index1+1, Index2);
thirdValue = myString.substring(Index2+1, Index3);
fourthValue = myString.substring(Index3+1, Index4);
fifthValue = myString.substring(Index4+1, Index5);
sixthValue = myString.substring(Index5+1, Index6);

secondValueInt = secondValue;
thirdValueInt = thirdValue;
fourthValueInt = fourthValue();
fifthValueInt = fifthValue();

```

```
sixthValueInt = sixthValue();
```

```
Serial.println(secondValueInt);
```

```
Serial.println(thirdValueInt);
```

```
Serial.println(fourthValueInt);
```

```
Serial.println(fifthValueInt);
```

```
Serial.println(sixthValueInt);
```

```
myString="";
```

```
// set the fields with the values
```

```
ThingSpeak.setField(1, secondValueInt);
```

```
ThingSpeak.setField(2, thirdValueInt);
```

```
ThingSpeak.setField(3, fourthValueInt);
```

```
ThingSpeak.setField(4, fifthValueInt);
```

```
ThingSpeak.setField(5, sixthValueInt);
```

```
// figure out the status message
```

```
myStatus = String(Gps:LAT:LONG);
```

```
// set the status
```

```
ThingSpeak.setStatus(myStatus);
```

```
// write to the ThingSpeak channel
```

```
int x = ThingSpeak.writeFields(myChannelNumber, myWriteAPIKey);
```

```
if(x == 200){
```

```
    Serial.println("Channel update successful.");
```

```
}
```

```
else{
```

```
    Serial.println("Problem updating channel. HTTP error code " + String(x));
```

```
}
```

```
delay(20000); // Wait 20 seconds to update the channel again
```

```
}
```

```
}
```

5.7 OUTPUT

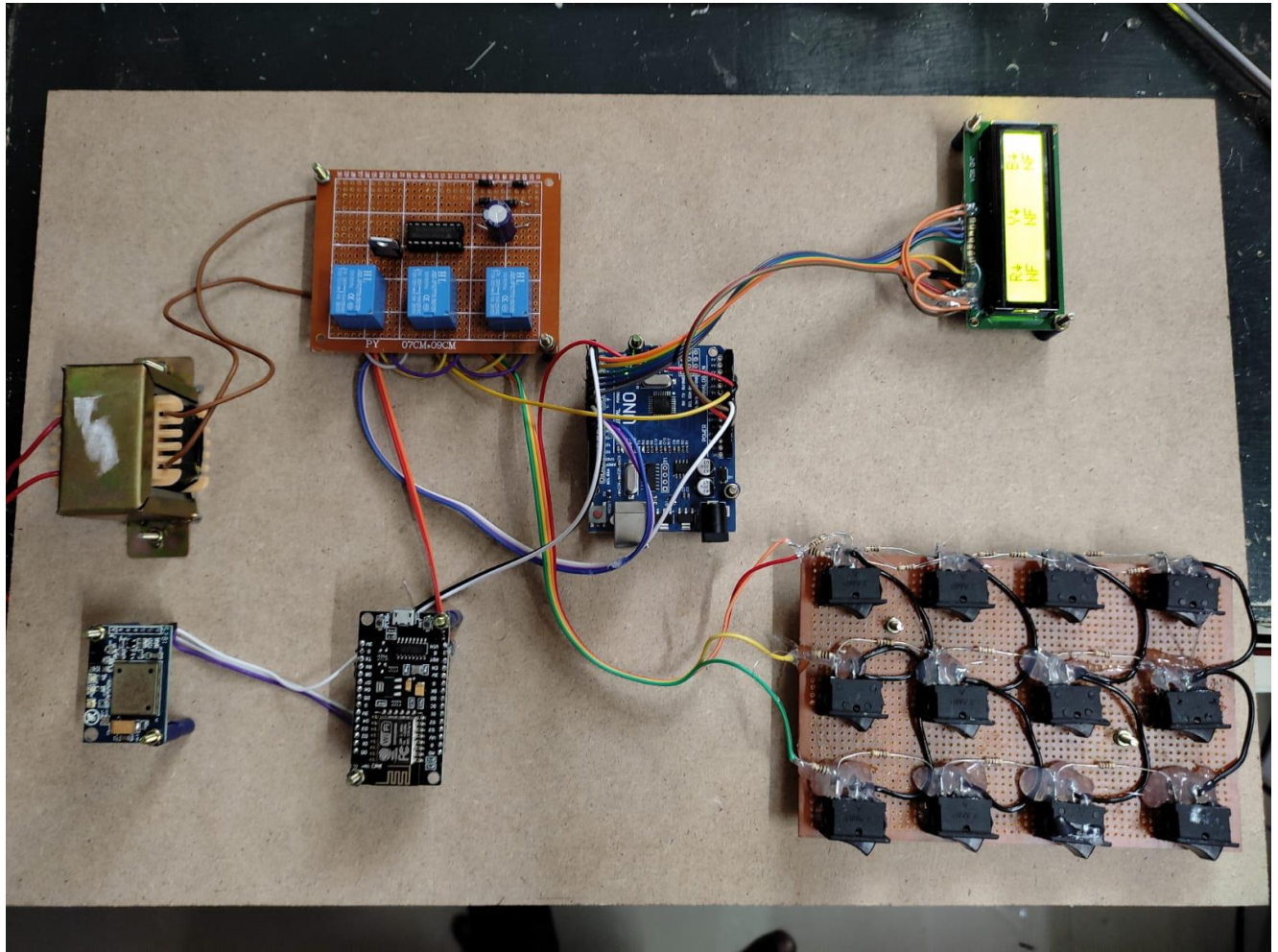


Fig:5.1 : when the circuit is working

CHAPTER 6

SUMMARY AND CONCLUSION

6.1 SUMMARY

In this chapter authors describe methodology, observation and their calculation for the system of operation. As the location of fault is changes then length of conductor change accordingly which change the resistance of underground cables as a result of this changes occur in fault current also. So, calibration of fault current to find the location of fault in underground cables is done.

6.2 CONCLUSION

Preliminary researches which have recommended strategies for the protection of transmission lines, mostly rely upon the travelling waves. Even though such systems have the potential and ability to distinguish and find faults on the distribution lines yet these systems are unable to determine the exact location of the fault. Simple analog methods were introduced by various researchers in the past and they were mostly based on waves to detect the faults in the system. The methods using analog advancements have various limitations which is the reason for working on new innovations. The approach used in this project, for the development of fault detection system, uses a variety of hardware equipment's including GPS, NodeMCU, Arduino, ACS712 Current Sensor Module, LCD display. The system can determine the fault location accurately by using the GPS module. Faults which can be identified by the system are: single line fault, single line to ground fault, double line fault and double line to ground fault. Consequently when a fault occurs in the transmission line, GPS will detect the location of the fault and then a message will be sent to the control room via NodeMCU for immediate response and all this information will also be displayed on the LCD screen.

6.3 FUTURE RECOMMENDATIONS

In future, it is recommended to utilize further advance algorithms such as Artificial Intelligence, Machine Learning or Deep Learning in the monitoring of power systems and detection of fault location in underground cables accurately

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