UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Electrical and Electronic Engineering Technology

ASSESSMENT OF EARTH ELECTRODE RESISTANCE IN RESIDENTIAL BUILDING BY USING 3 POLE METHOD TEST

MUHAMAD AMIR SYAHIR BIN JAMAL ABANA

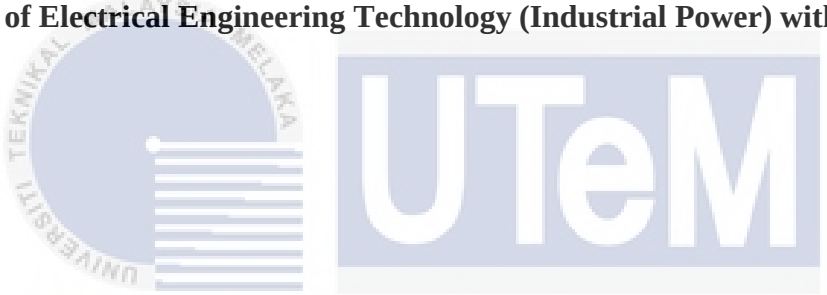
Bachelor of Electrical Engineering Technology (Industrial Power) with Honours

2022

ASSESSMENT OF EARTH ELECTRODE RESISTANCE IN RESIDENTIAL BUILDING BY USING 3 POLE METHOD TEST

MUHAMAD AMIR SYAHIR BIN JAMAL ABANA

A project report submitted
in partial fulfillment of the requirements for the degree of
Bachelor of Electrical Engineering Technology (Industrial Power) with Honours



Faculty of Electrical and Electronic Engineering Technology

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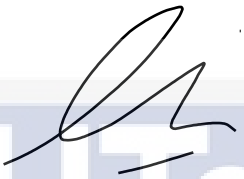
2022

DECLARATION

I declare that this project report entitled “Bachelor of Electrical Engineering Technology (Industrial Power) with Honours” is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : 

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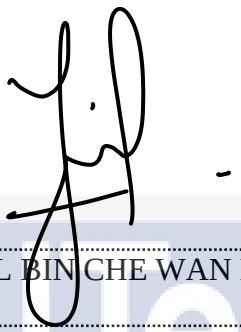
Date : 14 JANUARI 2023

APPROVAL

I hereby declare that I have checked this project report and in my opinion, this project report is adequate in terms of scope and quality for the award of the degree of Bachelor of Electrical Engineering Technology (Industrial Power) with Honours.

Signature : 

Supervisor Name : CHE WAN FAIZAL BIN CHE WAN MOHD ZALANI

Date : 17/2/2023

DEDICATION

I dedicate this project to my loving mother, Faudziah binti Che Pi, along with my supervisor, Sir Che Wan Faizal bin Che Wan Mohd Zalani, and my housemates, Muhammad Zhahir Zainal bin Zainal Abidin, Nasrullah Zikri bin Zulkiflee, Qadir Jailani bin Mahadzir, Muhammad Hafiz Zulfarhan bin Muhmmad Shah, Ammar Zakuan bin Mohd Razali, Alif Najmi bin Ahmad, Akmal Saufi bin Rosli for their continuous support and encouragement in completing this. I am expressing my gratitude to all of them because without them, I would not have progressed as far as I have.

ABSTRACT

An earthing system is an electrical system that provides a direct electrical connection to the Earth. The primary function of an earthing system is to ensure safety and avoid accident to people and equipment. The project objectives are to study the earth electrode system in Malaysia, Next, to inspect and investigate the earth resistance using 3 pole method test and evaluate and analyze the earth resistance in various location are following the regulation of Suruhanjaya Tenaga. The most common way to measure earth resistance is full 3 pole method, a number of tests are made at different distances of Potential and the resistance curve is plotted and also using simplified 3 pole method test. This method was used by Suruhanjaya Tenaga to measure resistance. Three measurements were taken at certain distances of P, and average calculation was used to figure out what the resistance was. The evaluation in the hill area received a very high reading. One possible explanation is that the ground at the top of the hill is drier than the soil at the bottom, which increases the resistance to the flow of electric current. The earth's resistance was observed to be high regardless of the fact that the house had only recently been completed built, so the assumption was made that maybe because lack of knowledge when doing research, moisture of soil, temperature or the contractor who did the wiring of this house may have taken safety for granted. Overall, the main purpose of this assessment was to determine whether the earth electrode system was providing an adequate level of protection against electric shock and other hazards.

ABSTRAK

Sistem pembumian ialah sistem elektrik yang menyediakan sambungan elektrik terus ke Bumi. Fungsi utama sistem pembumian adalah untuk memastikan keselamatan dan mengelakkan kemalangan kepada orang dan peralatan. Objektif projek adalah untuk mengkaji sistem elektrod bumi di Malaysia, Seterusnya, untuk memeriksa dan menyiasat rintangan bumi menggunakan ujian kaedah 3 kutub dan menilai dan menganalisis rintangan bumi di pelbagai lokasi mengikut peraturan Suruhanjaya Tenaga. Cara yang paling biasa untuk mengukur rintangan bumi ialah kaedah 3 kutub penuh, beberapa ujian dibuat pada jarak Potensi yang berbeza dan lengkung rintangan diplot dan juga menggunakan ujian kaedah 3 kutub yang dipermudahkan. Kaedah ini digunakan oleh Suruhanjaya Tenaga untuk mengukur rintangan. Tiga ukuran telah diambil pada jarak P tertentu, dan pengiraan purata digunakan untuk mengetahui apakah rintangan itu. Penilaian di kawasan bukit mendapat bacaan yang sangat tinggi. Satu penjelasan yang mungkin adalah bahawa tanah di bahagian atas bukit adalah lebih kering daripada tanah di bahagian bawah, yang meningkatkan rintangan kepada aliran arus elektrik. Rintangan bumi diperhatikan adalah tinggi tanpa mengira rumah itu baru sahaja siap dibina, jadi andaian mungkin kerana kurang pengetahuan semasa membuat kajian, kelembapan tanah, suhu atau kontraktor yang melakukan pendawaian ini. rumah mungkin telah mengambil keselamatan begitu sahaja. Secara keseluruhannya, tujuan utama penilaian ini adalah untuk menentukan sama ada sistem elektrod bumi menyediakan tahap perlindungan yang mencukupi terhadap kejutan elektrik dan bahaya lain.

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First and foremost, I would like to express my gratitude to God for giving me good health, strength, and the opportunity to gain my knowledge successfully to complete this Final Year Project (FYP) within a given time. I would like to thank my parents for their support and patient in waiting for me to finish my degree. I also express my sincere thanks to my friends for giving timely pieces of advice to this research project. They are sharing a lot of knowledge related to proceed this research project. It helps me to complete this research project more efficiently.

Secondly, I am expressing my sincere appreciation and thanks to my beloved supervisor Encik Che Wan Faizal bin Che Wan Mohd Zalani for his helping, teaching, monitoring, support, and contribution. He has guided and assisted me patiently during two semesters in session 2022/2023. Also, I sincerely appreciate and thank Ts. Zaihasraf bin Zakaria and Ts. Adlan bin Ali as my panel research for sharing his knowledge and experience in Research Methodology. Their suggestions have been useful for me to proceed well this research project.

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LIST OF SYMBOLS

V	-	Voltage
Hz	-	Hertz
mm	-	Millimeter
cm	-	Centimeter
m	-	Meter
mA	-	Milliampere
D	-	Distance
ft	-	Feet
Ω	-	Ohm
P	-	Potential
C	-	Current

LIST OF ABBREVIATIONS

RCD	-	Residual Current Device
ELCB	-	Earth Leakage Circuit Breaker
RCCB	-	Residual Circuit Current Breaker
SPD	-	Surge Protection Device
PPE	-	Personal Protection Equipment
AC	-	Alternative Current
TNB	-	Tenaga Nasional Berhad
FEM	-	Finite Element Method

CHAPTER 1

INTRODUCTION

1.1 Background

Since electricity was discovered a long time ago, grounding is important part to any electrical system whenever large or small. Grounding was used as a safety measure to keep people from in contact with electrical hazards by accident. The circuits that connect electrical devices to the ground are called the grounding system or earthing system. They are part of the electrical system. The safety and electromagnetic compatibility of the installation might be affected by the choice of earthing system. The International Electrotechnical Commission's (IEC) recommendations on earthing systems are widely followed by governments around the world [1]. In addition to electric power systems, other systems may require grounding for safety or function. Lightning rods may be installed on tall buildings as part of a lightning protection system. A good grounding system should have a program for regular inspection and maintenance to keep it working well. Periodic maintenance is addedto make sure that the grounding system doesn't break down or get destroyed by accident. This is done by choosing the right material for the electrodes and installing them correctly. The way these electrodes work depends on things like the soil's type, composition, conductivity, moisture level, temperature, and so on.

However, circuits can break or malfunction just like everything else. It is possible for electricity to leak from a circuit due to damaged or broken wires. When a current flows,it can either shock you, harm your property, or cause a fire. This is prevented using grounding wires. Even if the closed-circuit system is broken, voltage always takes the shortest route to neutrality. This path of low resistance is provided by grounding wires. Theyare connected to a grounding rod that is buried in the ground beneath your transmission lines. The grounding wire "catches" any stray voltage and transfers it to the ground, where it can'tharm you. This is an important safety feature. That’s why it is very important to maintain grounding resistance 10 ohm or less for domestic installations.

Although the material is an excellent conductor and can be used as a grounding electrode, the lifespan of the material is a serious issue. Regardless of the material, a thicker coating provides better corrosion protection, resulting in a longer life expectancy for the material. Grounding system performance can be evaluated using the Finite Element Method (FEM) [2], which provides a more accurate and compact result than engineering formulas for the fast design of grounding systems, as well as being adaptable to large and complicated systems. It is difficult to determine which grounding system electrode is best for safe electrical grounding and effective operation.

Figure 1.1 Electrical grounding wire [8]

It is important to ground electrical circuits to prevent electrical accidents. An increase in voltage can cause electricity to jump across the system's wires during a power surge. Thiscan a fire, damage to equipment or even damage people surrounding if it is not grounded. Proper grounding protects your home's electrical system even in the event of a large power surge or lightning strike. To keep the voltage in your system from arcing into other conductive elements like water or metal, it is necessary to use grounding. Grounding wires help your appliances live much longer and perform better by preventing voltage overload and damage. Modern residential electrical systems are more protected by grounding than by any other method. The most important part of earthing is dealing with safety regulations. Earthing requirements for electrical system are well define in ELECTRICAL REGULATIONS, 1994. Earthing is important since it has to do with safety Tenaga Nasional Berhad (TNB) is responsible for the system's earthing, but the customer is responsible for the earthing of his own equipment [3]. On the other hand, in the event of an earth fault, sufficient current can flow quickly enough to activate the circuit protection devices. There are many reasons to install a grounding system. The most important purpose, however, is to

protect people. Protection of structures and equipment from accidental contact with energized electrical lines is a further concern. The grounding system must provide optimum protection against electrical system failures and lightning strikes. To maintain its efficiency,a proper grounding system must be inspected and serviced regularly. To ensure that the grounding system resists corrosion or accidental damage, good design, material selection, and installation techniques aid in ongoing or periodic maintenance. As a result, only minor repairs are required to maintain the structure's functionality over time.

The grounding system is used for three major factors [4]. The first one is to protect against over voltage. High voltages in the electrical distribution system can be caused by lightning, line surges, or accidental contact with higher voltage lines. In order to get around the building's electrical system, grounding is required. This keeps damage to a minimum. Second, the grounding system helps keep the voltage stabilize. It is known that an electrical system has more than one source of voltage. If there is no common point of reference for all of these voltage sources, it would be very hard to figure out how they relate to each other. Also, the earth is the most common conductive surface, so it was used from the beginning of electrical distribution systems as a standard for almost all electrical systems. The third reason for a grounding system is to provide a path for current so that overcurrent devices can work better. This is the most important reason for having a grounding system, because it keeps people and property safe in case something breaks. Electricity is an important part of everyone's day-to-day lives. Since being exposed to electricity by accident can harm you, any electrical wiring or installation needs to have proper earthing [5]. Most of us think of the earth electrode as a way to keep from getting shocked by electricity by accident, but that's not true. To protect people and equipment from earth faults, it's important to have a proper earth connection and other protection devices to disconnect the electric supply within the specified time.

1.2 Problem Statement

The main purpose of the earthing system is to ensure that the circuit protecting device operates properly. If a live conductor accidentally touches a metallic part because the insulation has broken, the current will flow through the earth conductor and not through the person's body in a properly earthing system. Earthing would not work if the earth's resistance were high because the human body is the path with the lowest resistance. Earthing is an important part of both high-voltage and low-voltage power networks. The earthing system is the whole set of actions taken to connect a part that conducts electricity to the ground. Not only does poor earthing cause unnecessary downtime, but it is also dangerous to people and their property. When RCD/ELCB/RCCB are employed as the circuit protecting device, earthing resistance of less than 10 ohm is usually sufficient to ensure that the RCD/ELCB/RCCB work properly. The lightning earthing system must be segregated from the installation earthing system and have a resistance of not more than 10 ohms. The goal is to have an earthing resistance of less than 10 ohm. In general, the lower ground resistance, the safer the system. Earth leakage current can lead to accidental personal safety or equipment and building protection. Because of the many benefits [6] that related to earthing,it has been a requirement in many nations to offer earthing in all types of installations, including those found in residential and industrial installations. Only a few research papers have been published in recent years that attempt to evaluate how successful earthing systems are. Many accidents [7] have occurred because of negligence in the interest of earthing. This study was conducted due to lack of awareness about the importance to have good earthing in residential buildings. By observing the data obtained at real situation problem, the resistanceof the earth electrode at an unidentified location will be evaluated using the 3 -pole method known after this study.

1.3 Project Objective

To achieve the aim of study, these objectives must follow to be fulfill:

i) To study the earth electrode system in Malaysia

ii) To inspect and investigate the earth resistance using 3-pole method test

iii) To evaluate and analysis the earth resistance in various location of residential building are following the regulation of Suruhanjaya Tenaga.

1.4 Scope of Project

The analysis is scaled down to be more specific, based on the following objectives, to havea clear view of the main points. The following are the scopes of this research:

i) This project is a study on the earth resistance in selected residential buildings are following the regulation in Malaysia.

ii) The resistance measurement was conducted at various suitable locations in Sungai Petani, Kedah with different types of experiment.

iii) The earth electrode resistance test is repeated at least 10 times or more and the resistance curve is plotted.

iv) An earth resistance tester was used to measure the earth's resistance.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter begins with an explanation of what an earthing system is and why it is necessary to implement. The next step is to choose the best material for the earth electrode. Characteristics such as good conductivity of electricity and resistance to rusting in soil over time. Then, soil resistivity and the earthing system are very responsible for the effective and correct operation of any electric power system's generation, transmission, and distribution. Other than that, we will discuss the main objective of earthing and hazard that could happen when facing with electricity. Next, the types of earthing system that commonly used and the method to reduce the earth resistance if it is higher than regulation. Methods to measure the earth resistance also been discussed. A lot of research from previous study were state that earthing system is important to prevent any damage on equipment and human.

2.2 What is earthing system

Electrical installations in residential building are becoming very important and it's significant to use modern ways to be installed. Earthing is a very important part of a power system, especially since most faults are caused by the ground or by storms and lightning. The terms "earthing" and "grounding" mean the same thing. It is a way to connect equipment to the earth's mass. The main goal of earthing is to reduce the amount of potential transient overvoltage, which is required by standards for the safety of people and to help detect and isolate faults rapidly [8]. Several ground electrodes are driven into the earth in different places to make a connection to the ground. Installing an earth electrode is an important part of making sure that an earthing system works well. Professionals who design and install electrical systems need to think about several different grounding systems for any building or structure they work on. Local Regulation [9] must be met by all earthing systems. Ground resistances can only be measured with special test equipment and technique. The fall-of-potential principle is used by almost all instruments and for equipment was commonly used earth tester such as Megger Earth Tester Kit. The objective of protective earthing is to keep parts of equipment that are not live from having too much voltage on them, which could cause shocks. The non-live parts are connected to electrodes or parts that are already grounded.

Figure 2.1 Example of residential buildings

The earthing system consists of materials that conduct electricity above ground, metal electrodes in the ground and the ground itself. Each of these will add to the resistance value. Use the right materials and installation methods to keep the contact resistance of joints as low as possible. The most important thing to consider when making a grounding system fora new installation is the soil's resistivity. The end of the main grounding wire must be easy to reach at the earth electrode. Mechanical soundness, corrosion resistance, and vibration isolation are all requirements for the main earthing wire connection. Stress on any part of the connection, as well as damage to the wire, must be avoided [10].

2.3 Earth electrode

Earth electrodes are metal plates, pipes, or conductors that are electrically connected to the ground. Copper, aluminum, mild steel, and galvanized iron are the most common materials for earth electrodes. Soil type, temperature, water content, and depth all have an effect on an electrode's earthing resistance. Under normal soil conditions, copper, iron, or mild steel are good choices for electrodes. To get a low overall resistance, the amount of current in the medium next to the electrodes should be as low as possible.

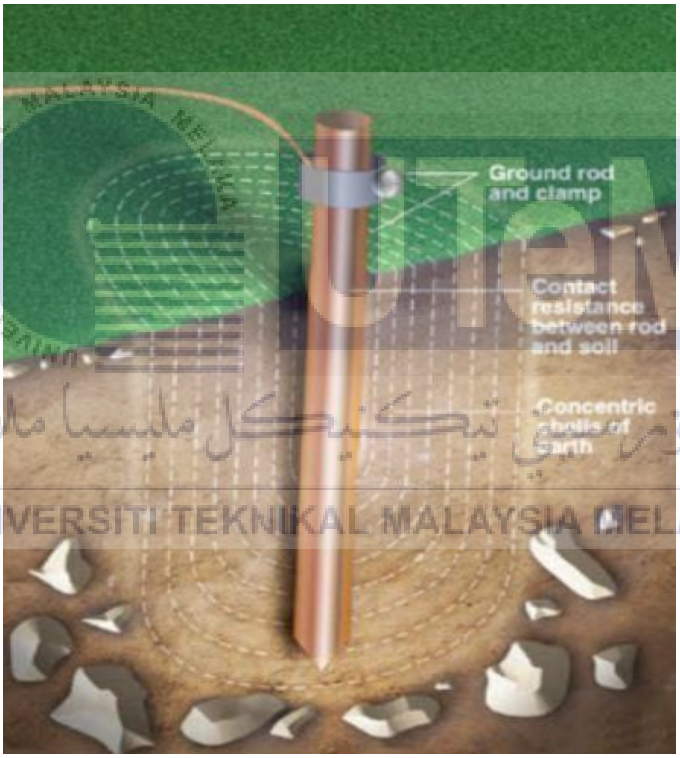

Figure 2.2 Grounding rod [11]

Earth electrodes can be made of cast iron, steel, copper, or stainless steel, among other things. They could look like plates, tubes, rods, or strips. Copper is the most common used material.It conducts electricity well, don't easily rust when exposed to most of the chemicals in soil, and is easy to work with. The driven rod is the type of earth electrode that can be used most often. This could be made of copper, steel covered with copper, galvanized steel, or austenitic iron. Standard sizes are between 1 m and 2.5 m length and 12 mm in diameter [10]. Copper-clad steel rods are better for driving because they can go through most types of soil up to 5-6ft. Make sure that the copper is actually bonded to the steel when using copper-clad steel rods. Other than that, an electrode's characteristics are the rod's end has a thread and can be attached to another rod with a coupler. The steel driving cap covers the thread from damage during the hammering procedure for planting the rod. Use an earthing conductor clamp to connect earth cable or an earth conductor. There is specification need to follow in process termination of earth. Firstly, minimum size of main conductor to the electrode is 10mm2 [9]. Suruhanjaya Tenaga's latest rule for installing a lightning protection system is that it must include an SPD (Surge Protection Device) along with the installation at a building or a home. The length of the electrode must be at least 5ft. When it comes to grounding, you need a grounding electrode, a grounding conductor, a grounding connector, and soil contact for the electrode to work.

2.4 Types of earthing system

Earthing in a low voltage electrical installation system can be done in a number of ways. In the British Standard (BS) 7671, there are five different kinds of earthing systems: TN-S, TN-C-S, TT, TN-C, and IT.

a) T = Earth

b) N = Neutral

c) S = Separate

d) C = Combined

e) I = Isolated

2.4.1 TT earthing system

There is s a system practiced in our country, and the phase and neutral conductors are taken from the supplier (TNB). Refer to guideline [9], TT systems are typically used in Malaysia. So, this section will onlyfocus the TT system. In this system [8], the power source is connected to the earth directly. This is shown in Figure 2.3. TT systems have one point thatis directly connected to earth, and all parts of the installation that can conduct electricity must be connected to earth electrodes. TT system is an earthing system used in electrical power distribution. It refers to the earthing system where the neutral point is earthed at the distribution transformer or substation. This means that the neutral point of the transformer is connected to the ground, providing a reference point for the electrical system.

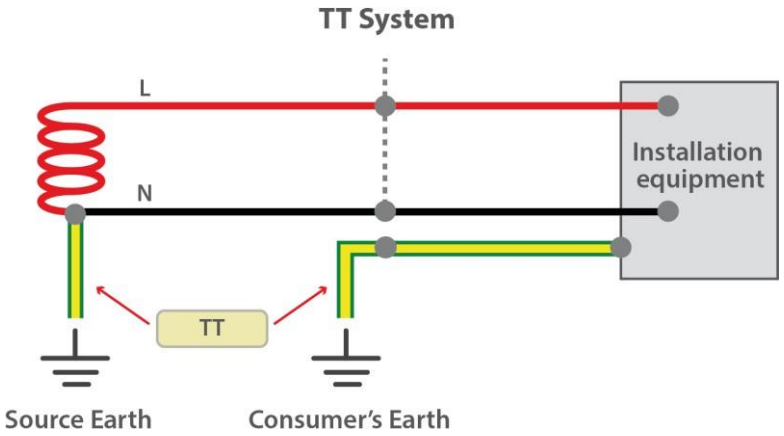

Figure 2.3 TT system [9]

This system is commonly used in residential and commercial buildings, as well as in industrial settings. The TT system is considered a safe earthing system as it provides a low impedance path for any stray current to return to its source. This reduces the risk of electrical shocks and fires. TT system is widely used in Malaysia in residential and commercial buildings, as well as in industrial settings. This is due to its cost-effectiveness, simplicity and good performance, even in situations where there is a high level of electrical noise present.

Table 2.1 Advantage and disadvantages of TT System

Advantages	Disadvantages
Low fault current	Dependence on quality of earth connection
Simple earthing of installation and simplest installation.	Cost of maintenance
Commonly used	The possibility of false tripping or an overcurrent

2.4.2 Termination to earth

The concrete earth chamber is built to protect the connection between the grounding systemand the lightning protection system. The chamber has a cover that can be taken off so that the grounding connection can be easily checked and fixed in the future. Next, an earth electrode is a conductor that is buried in the ground. It helps fault currents move toward the ground. This means earth electrodes are made of metal, and since they must be buried for a long time, they also have to be resistance to corrosion. Because of that, the material earth electrode is copper plated iron type [9]. So, they can be utilized to produce optimal earthing for distribution and transmission in both overhead and underground networks [12].The earth electrode resistance value of the installation shall be equal to or less than 10 Ω. [9].

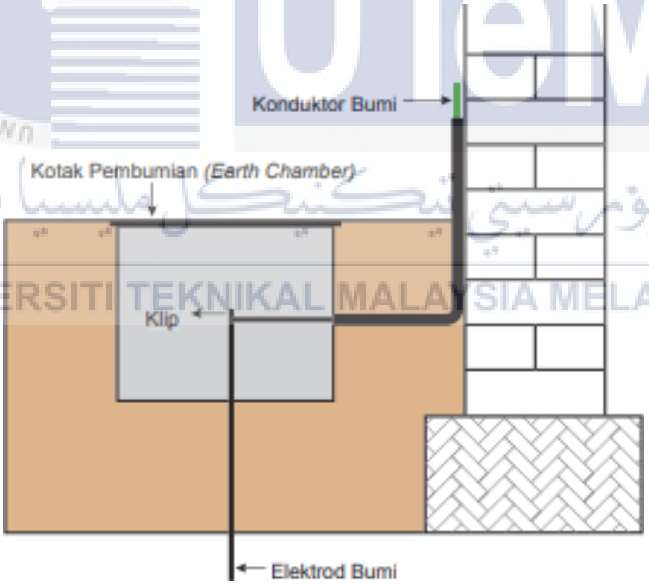

Figure 2.4 Earth chamber [9]

2.5 Purpose of earthing

Equipment grounding in a power system is important for equipment and the individuals house it. Some of them are discussed about below [13].

a) Safety for Human life / Building /Equipment

i) To keep a person from getting an electric shock or dying by blowing a fuse,or to give the fault current a way to flow that wouldn't put the user in danger.

ii) To keep buildings, machines, and appliances safe in the event of a fault.

iii) To make sure that none of the exposed parts that conduct electricity reach dangerous voltage.

iv) To give lightning and short circuit currents a safe way to flow away.

v) To give sensitive electronic equipment a stable place to work, to keep the voltage at any part of an electrical system at a known value so that overcurrent voltage doesn't damage the appliances or equipment.

b) Over voltage protection Lightning, line surges or unintentional

Lightning, line surges, or accidental contact with higher voltage lines can all cause the electrical distribution system to have voltages that are too high and could be dangerous. Earthing gives the electrical system another way to work so that it doesn'tget damaged as much.

c) Voltage stabilization

In a power system network, the electricity comes from many different places. For instance, each Transformer in the system could be thought of as a separate source. If all these voltage sources didn't have a common point of reference, it would be very hard to figure out how they relate to each other.

2.6 Surge Protection Device

The Surge Protection Device (SPD) is a part of the protection system for electrical installations. This device is connected in parallel to the power supply circuit of the loads it must protect. (Refer Figure 2.5). It can also be used at all levels of the power supply network. This is an additional accessory for the electrical installation system in residential houses to protect electrical equipment and other loads in the event of a lightning strike. Then, this is the most commonly used and most efficient type of overvoltage protection. The earth electrode resistance value of the lightning protection system is 10 Ω [9]. SPD installation should refer to the 'Panduan Sistem Perlindungan Kilat' (SPK) in Buildings issued by ST in accordance with the requirements of Malaysian Standards MS IEC 62305 [9].

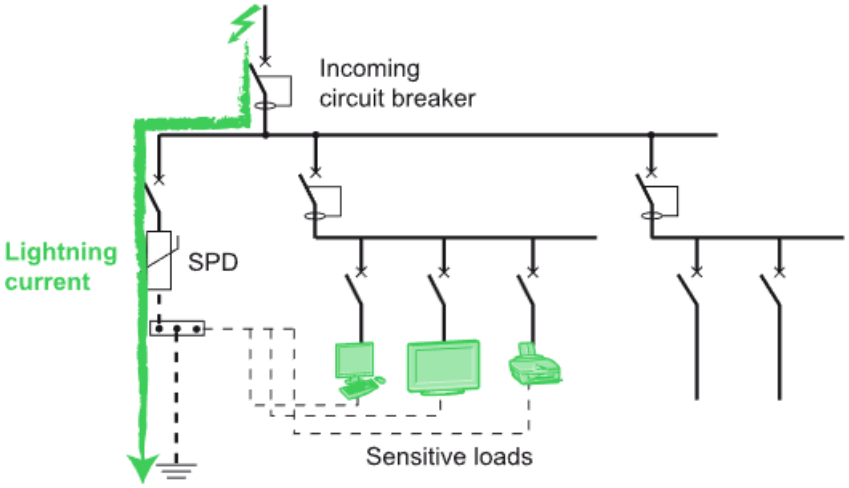

Figure 2.5 SPD Circuit

2.7 Method to measure earth resistance

There are many tests, like the 4-pole method, 3-pole, slope method, 2-pole and the star-delta method. Most of the time, the 4-pole method is used to measure soil resistivity. Then, Star-Delta method are required number of calculations and for Slope Method only use soil is not homogeneous. In this study, we only 3 that are commonly used to measure earth resistance [14].

2.7.1 The 3-pole method

The most common way to measure the resistance of an earth electrode system is the Fall- of Potential method or the 3-pole method [14]. However, when measuring large electrode systems, this method needs to be used in a different way. The 3-pole method, which is also called the "fall of potential" method, is made up of the Earth Electrode to be measured and two other test electrodes that are not connected to the Earth Electrode. These two test electrodes are usually labeled P (Potential) and C (Current). These test electrodes can be of lower "quality" (higher earth resistance), but they must be electrically separate from the electrode to be measured.

There are 3 basic types of the 3-Pole Method test [14]:

1. Full 3-Pole method - A number of tests are made at different distances of P and the resistance curve is plotted. For this method, equipment should have been an earth resistance tester, copper rod, spike, three wires to connect the spikes, a hammer, and a measuring tape.

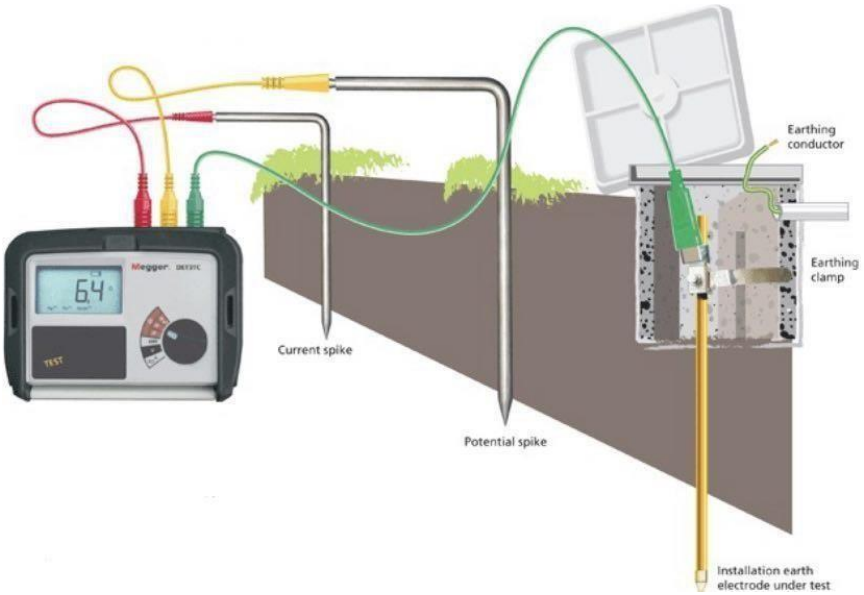

Figure 2.6 3-pole method [16]

Between the earth electrode and C, the potential probe, P, can be moved at various points along a straight line. At least 10 readings should be taken at evenly spaced intervals to obtain an ideal earth resistance curve. Resistance readings are logged for each of the points. A curve of resistance vs. distance, is then plotted using Microsoft Excel. The best resistance result [15] will be obtained where the curve flattens out 62% of the total distance from the earth electrode to C as shown in Figure 2.7.

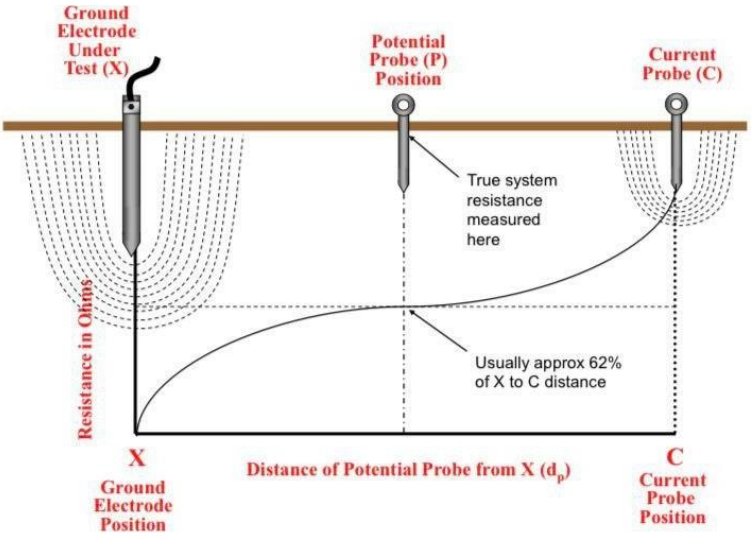

Figure 2.7 Example Graph of earth resistance Curve

2. Simplified Fall-of-potential – This method was used by Suruhanjaya Tenaga to measure resistance. Three measurements are taken at certain distances of P, and average calculation is used to figure out what the resistance is [9].

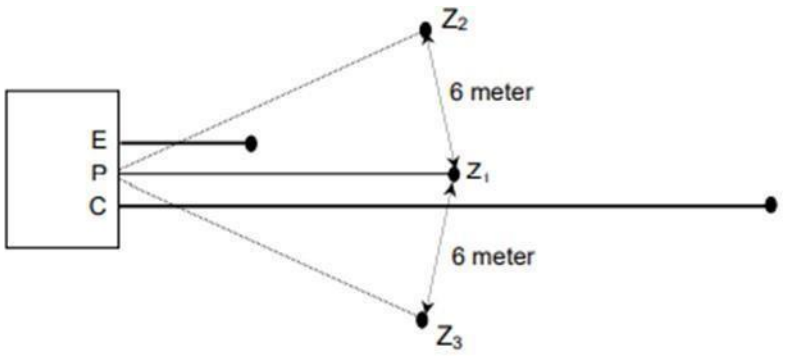

Figure 2.8 Simplified fall-of-potential measurement [9]

i) Record the first reading (Z1)

ii) Move the voltage spike so that it is 6 meters away from where it was before make another of the second reading (Z2)

iii) Move the voltage spike so that it is 6 meters away from where it was before. Write down the third reading (Z3). From the three resistance values, obtain the average value of the tested earth electrode resistance using equation below.

$$Z = \frac{(Z1 + Z2 + Z3)}{3} \quad (2.1)$$

$$Z = \_\_\Omega \quad (2.2)$$

3. 3-Pole Slope Method – This is an alternative solution for physically limited sites. P2 (Potential) spike position should be varied in regular steps along a straight line between the electrode under test and the C2 (current) electrode. Plot a graph of R versus distance after measuring resistance at each step. The calculation requires the use of the formula below and the reference of tables of values for the co-efficient of slope of slope versus real P spike distance.

$$Slope\ coefficient, m = (R3 - R2)/(R2 - R1) \quad (2.3)$$

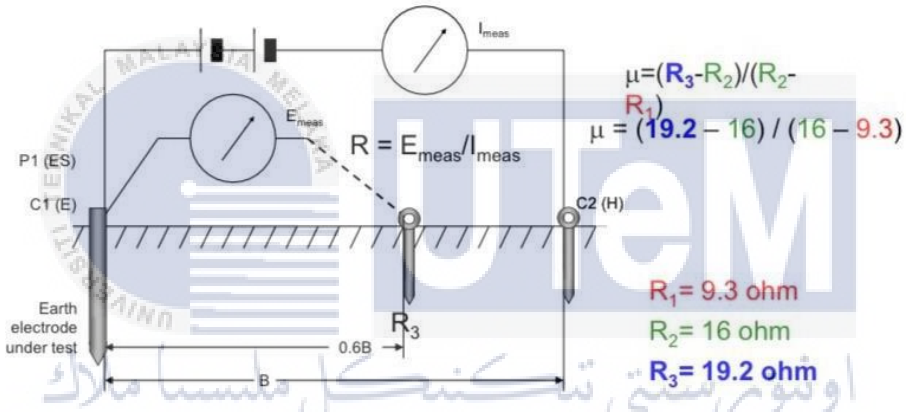

Figure 2.9 3-Pole Slope method

The disadvantage of this method is less accurate than the full of potential. Then, math calculation is required and must disconnected individual ground electrodes to record measure.

2.7.2 Two-point (dead earth) method

This method is used when it is not practical or possible to drive in ground spikes. We have access to a good, well-known ground for this test, such as an all-metal water pipe. The water pipe should be long enough and made of metal all the way through, with no connections or flanges that could cause heat loss. The dead earth method is the easiest way to get a ground resistance reading, but it is not as accurate as the three-point method and should only be usedas a last resort [14]. It is best for quickly evaluating the connections and conductors between connection sites. Required equipment is earth resistance tester, 2 No's of insulated wires and hammer.

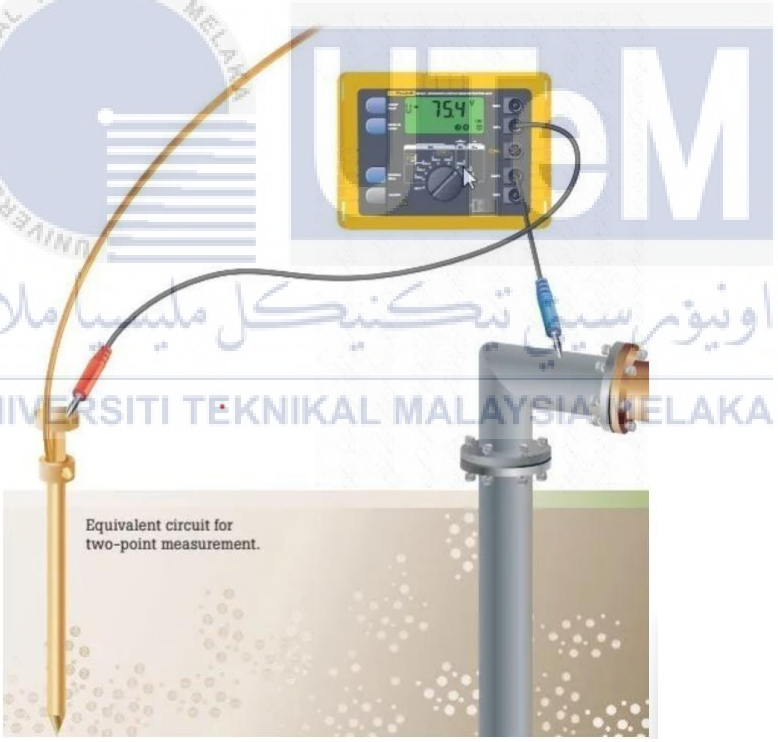

Figure 2.10 2 point or dead earth method [14]

2.7.3 Clamp on or stakeless

The clamp-on or stake-less ground test is a new way to figure out how good a ground system is [16]. The tester checks the whole path (loop) that the signal takes through the resistance. All the loop's parts were measured one after the other. One of the newest ways to test the resistance to ground of a grounding system or electrode is the induced frequency test,also known as the "clamp-on" test. This method is easy, quick, safe, and doesn't require anyequipment to be taken apart. With this test method, two clamps are attached to the earth ground rod or the connecting wire (Refer to Figure 2.11). There is no use for earth ground stakes. One clamp is used to measure a voltage that is already known, and the second clamp is used to measure the current. A clamp-on ground resistance meter and two insulated wires are the most important tools. Therefore, it cannot be used for installation checks new sites.

Figure 2.11 Clamp on attached to wire [16]

Table 2.2 Advantages and disadvantages method of earth resistance test

	ADVANTAGES	DISADVANTAGES
Full 3-Pole Method	- The most reliable and accurate test method - Most suitable test for large grounding systems.	- Extremely time consuming and need more energy because of more reading use - Need big space to setup probe
3-Pole Short Method	- This is the simplest way to obtain ground resistance reading. - Required Less Test Lead	- Not as accurate as less measurements are made
Clamp On	- Not dangerous to human life because no DC current injected in probe. - Convenient, quick, and easy	- Not suitable for new building or site installation checks - Will not give an effective reading

2.8 Electrical hazard

According to OSHA, one of the most common types of hazards that can be found on construction sites is electrocution. The identification of electrical hazards can contribute to increased awareness of the risks, the severity of those risks, and the ways in which workerscan be harmed by them [17].

Figure 2.12 Example of electrical hazards [17]

The most common electrical OSHA violation is when equipment is not properly connectedto the ground. Grounding can reduce the risk of being electrocuted if it is done correct. Workers can be very safe around electricity on the job site if they know how to find and control hazards. But if you don't have enough training, don't have enough experience, ordon't know how to spot potential dangers, you could get an electric shock or even die. In fact, 52% of all electrical deaths in the US workplace happen in the construction industry [17]. Most of these accidents and deaths were caused by workers coming into directcontact with machines, tools, or metal objects they were carrying. So, the most important thing is always to make sure safety first and do not underestimate about electrical hazards.

2.9 Method to reduce earth resistance

Earth resistance refers to the resistance that exists between the earth and a grounding system. It is important to reduce earth resistance because a low resistance value ensures that the grounding system can effectively dissipate electrical currents into the earth. There are a few ways to reduce earth resistance:

2.9.1 Use a larger grounding rod

A larger grounding rod will have a greater surface area in contact with the earth. This can also help to lower the earth resistance of the grounding system. To study in [18] larger diameter is used to reduce the resistance rather than bonding supplemental electrodes. Figure below, shows the results with the three different rod diameters.

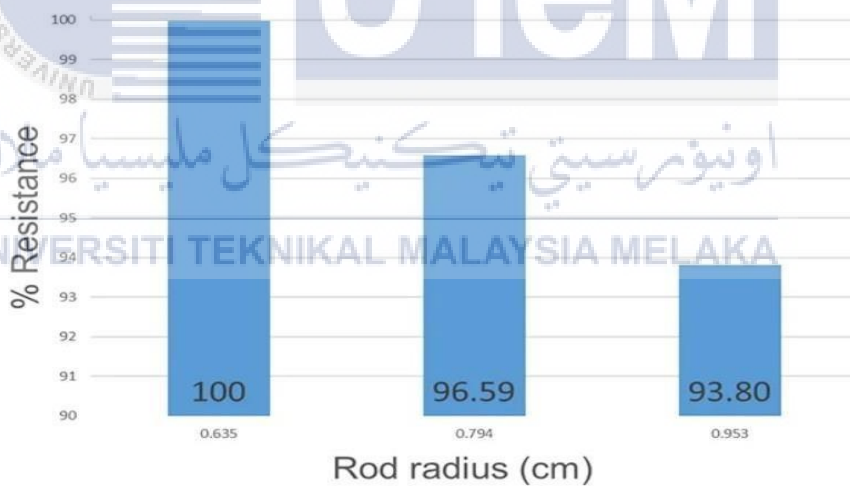

Figure 2.13 Effect increase the rod diameter [18]

Based on graph above, we can conclude from this analysis by increasing rod diameter will not very effective to reduce the resistance, so it is not the best method. This method reduces the earth's resistance, but it is less effective because only a small amount of resistance is reduced while the cost will rise with this method.

2.9.2 Increasing the length of the earth rod

The ground rods are stacked and joined together with a special clamp lengthen them deeperinto the earth [18].4 rods are used to get the result and as expected, driving grounding rods more deeply into the ground decreases their resistance. We can refer Figure below the impacts of lightning the grounding rod. The result shown higher reduction when the first electrode installed.

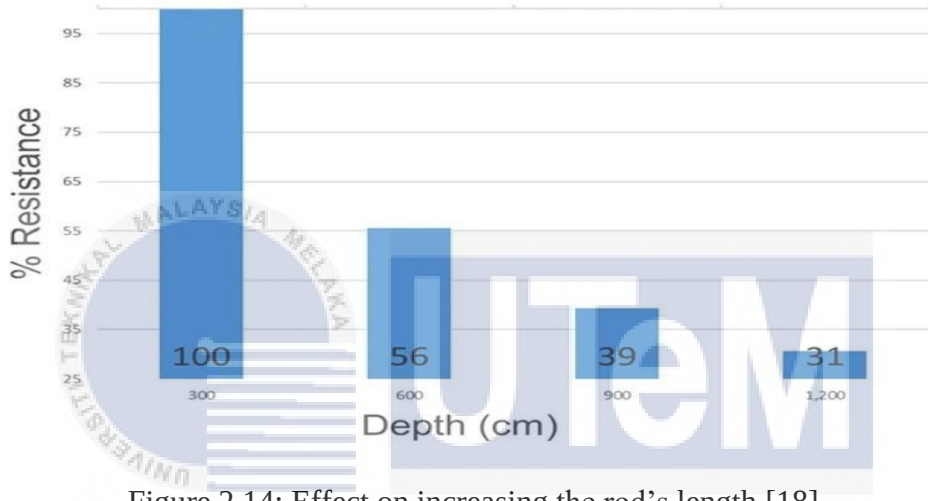

Figure 2.14: Effect on increasing the rod's length [18]

2.9.3 Using multiple rods in parallel

Multiple earth rods driven into the ground provide parallel paths and can effectively reduce the earth resistance. Using two earth rods of the same size and depth at equal distances, the overall earth resistance is reduced by approximately 40%. Second, if we use three rods, the earth resistance will go down by 60%, and if you use four rods, it will go down by 66% [19], as shown in figure below.

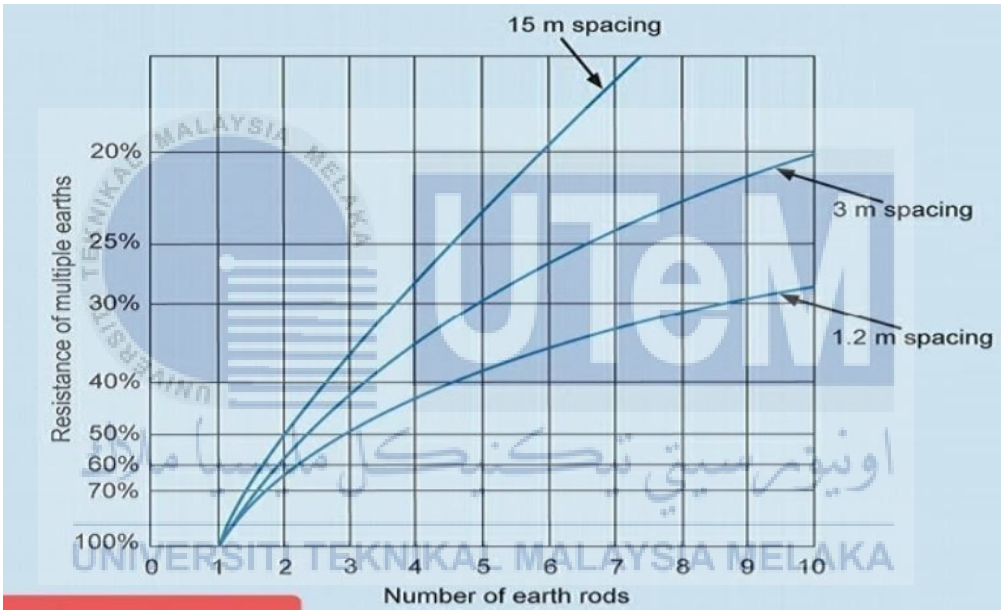

Figure 2.15 Effect using multiple rods [19]

2.9.4 Soil Treatment

When it is not possible to drive the grounding rods deeper, due to rocks or other causes, and adding rods does not achieve a reduction in ground resistance, chemical soil treatment is an excellent alternative [18]. The chemical treatment method modifies the nature of the soil around the electrodes. Referring to Figure 2.16, it shown the reduction in resistance as soil resistivity decreases. Magnesium sulfate is the most common chemical compound because it is cheap, has a high electrical conductivity, and causes the least amount of corrosion [18][19]. Potassium nitrate and sodium chloride are very corrosive. In addition, this method requires maintenance by adding chemicals periodically.

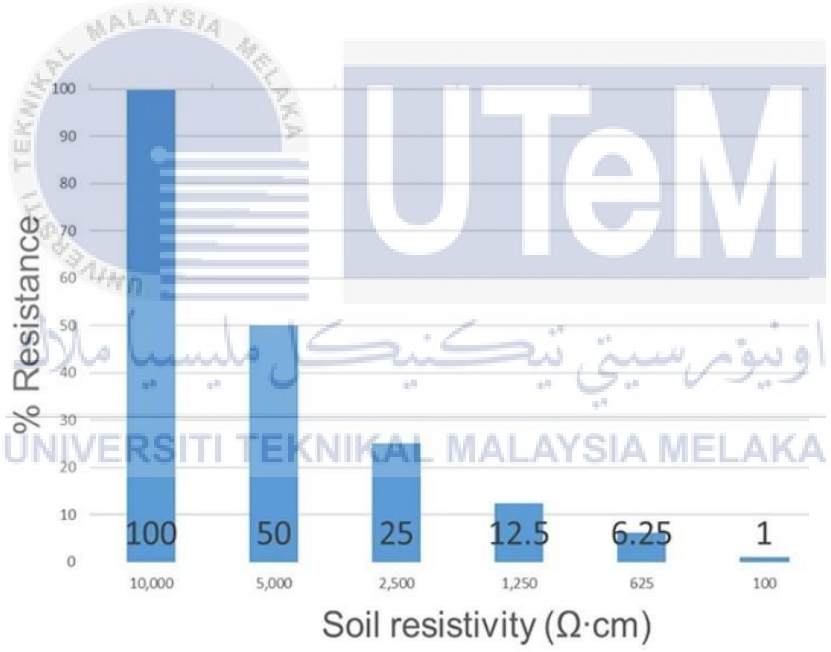

Figure 2.16 Effect of treating the soil [18]

2.10 Previous work

Based on previous study about electrical accidents analysis [20] shows that there are manythings that can happen such as including loss of power, damage to equipment, and injuries to operating personnel. The reason is that the earthing system was wrong or didn't exist at all. The fact that consumers and operators lack knowledge about electrical gadgets and don't know how to use them properly is also a factor. Earthing in electrical networks is mostly done for safety [8]. Most people who get an electrical shock end up with injuries like amputation, severe burns, cardiac arrest, arrhythmia, heart muscle damage, brain and other nerve damage, memory loss, permanent heart damage, hearing loss, seizures, respiratory failure, spine injury, deformity at point of contact, cataracts, loss of kidney function, and secondary injuries caused by falls after the shock [20].This shown that importance to have a proper earthing system to prevent damage.

The easiest way to measure earth resistance is with the Fall-of-Potential Measurement Technique [21]. This test method is used to measure how much energy is lost from a site by an earth ground system or a single electrode. With the Megger meter, a current is made in the tower footing earth electrode that is being tested. This voltage drop is directly relatedto how much current is flowing and how well the earth electrode is connected to the earth. This voltage drop is measured by the voltage probe (P), and the meter shows both the amount of current flowing and the resulting voltage drop. During the measurement, the current probe (C) is moved far enough away from the earth electrode under test so that the voltage probe (P) can lie outside the effective resistance areas of both earth electrode [21].

A well-designed earthing system is needed to protect people, cut down on electromagnetic interference, and keep the whole network of supply systems running well. So, if safety measures are to be put in place, every supply system must have problems. So, the system of every piece of electrical equipment must be earthed so that fault current can flow more easily into the ground. Also, the value of earth resistance is directly linked to the properties of the soil and the earthing electrode. By using an electrode with good conductivity and preparing the soil well, the value of earth resistance can be lowered.

There are many ways to measure grounding, but most of the time, the fall-of-potential method is used. This method is well-known and widely accepted, and it is often used to measure grounding systems. But as the traditional fall-of-potential method develops, it runs into many problems that it can't solve. This means that some of the technical steps ofthe fall-of-potential method need to be changed or improved. In this review [22], we will look at reviews of several other ways to measure grounding systems.

In this study [23], we tried to evaluate the performance of earthing in residential installation within the Sunyani Municipality. So, Megger was used to measure the earthing resistance of 1004 homes. The study showed that the earthing resistance is affected by the type of soil, the size of the earth rod, the size of the earthing conductor, the number of electrodes used, and where the earth pit is. Since poor earthing can cause unneeded downtime and makes it more likely that equipment will break or someone will get an electric shock, it is important to make sure it is done right. The recommendation [23] to assure that their rules are followed, the Energy Commission and the supply authorities should check the earth electrodes of different homes on a routine basis. Residual Current Devices (RCD) should be implemented in homes to keep people safe from indirect contact. For earthing, you mustuse a larger Earth Electrode with an average height of 4 feet or more. When building an earth pit, you should pay attention to its depth and width. Ground rods should be put as deep as possible into the ground because soil and water are usually more stable at deeper levels.

Next, in this work [24], the Fall of Potential Technique was used to test three points of ground contact. Based on an IEEE standard, this method provides a very accurate result if performed correctly. The earth resistance depends on how resistive the soil is where the electrode is buried. This means that the earth electrode resistance value for any power system in that area would be higher the more resistive the soil is. For good earthing of electrical systems, soil resistivities should be improved [24].

When an earth electrode system has been planned and put in place, the earth resistance between the electrodes usually needs to be measured and checked. The 3-point measuring technique is the most common way to measure the earth resistance of an earth electrode [25]. The Fall-of-Potential Method is used to figure out how resistance an electrode is. In the Fall of Potential method, the test electrode is checked to make sure it is in the right place in the ground [26]. To figure out the resistance of the earth electrode, it is important to know the electric potential of the area where it will be placed. Based on the results, it can be said that the earth has different resistivity values. This are proof that fall-of potential is the suitable method to measure earth resistance in residential building. From all previousworks, proven result through specific methodology finally validates the study of their research.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter describes the methodologies and methods used for this project. Methodology is a direction that must be adhered to complete the project. This chapter will outline the whole project process from beginning to end. This chapter will offer a detailed description of each procedural step in order to facilitate comprehension. To ensure the project's schedule and methodology. The project plan and schedule will include the duration of each activity in addition to necessary tasks. This is required to ensure the on-time completion of the project.

3.2 Methodology

The earth resistance on various location of residential building was determined with the useof an earth resistance tester kit. The full 3-pole method was then utilized to measure the earth resistance and the resistance curved were plotted. Results of the study were evaluated and will be compared with the regulation because a good earthing system is very important to minimize any damage to individual or equipment. Subsequently, Figure 3.1 shows the flowchart for overall project process and Figure 3.2 shows the measuring earth resistance procedure using Full 3-pole method also Figure 3.3 shows simplifies 3-polw method test procedure.

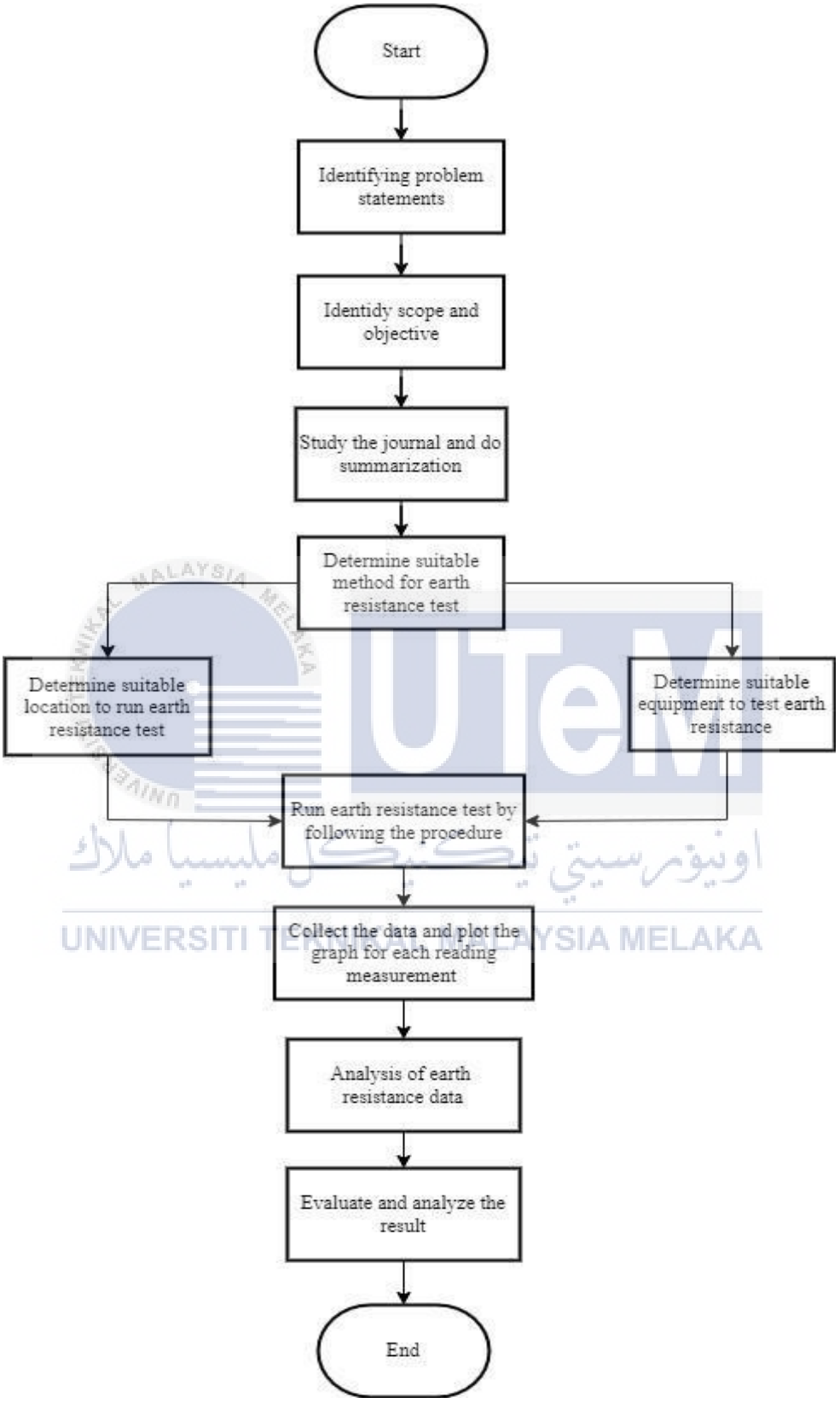

Figure 3.1 Flowchart for overall project process

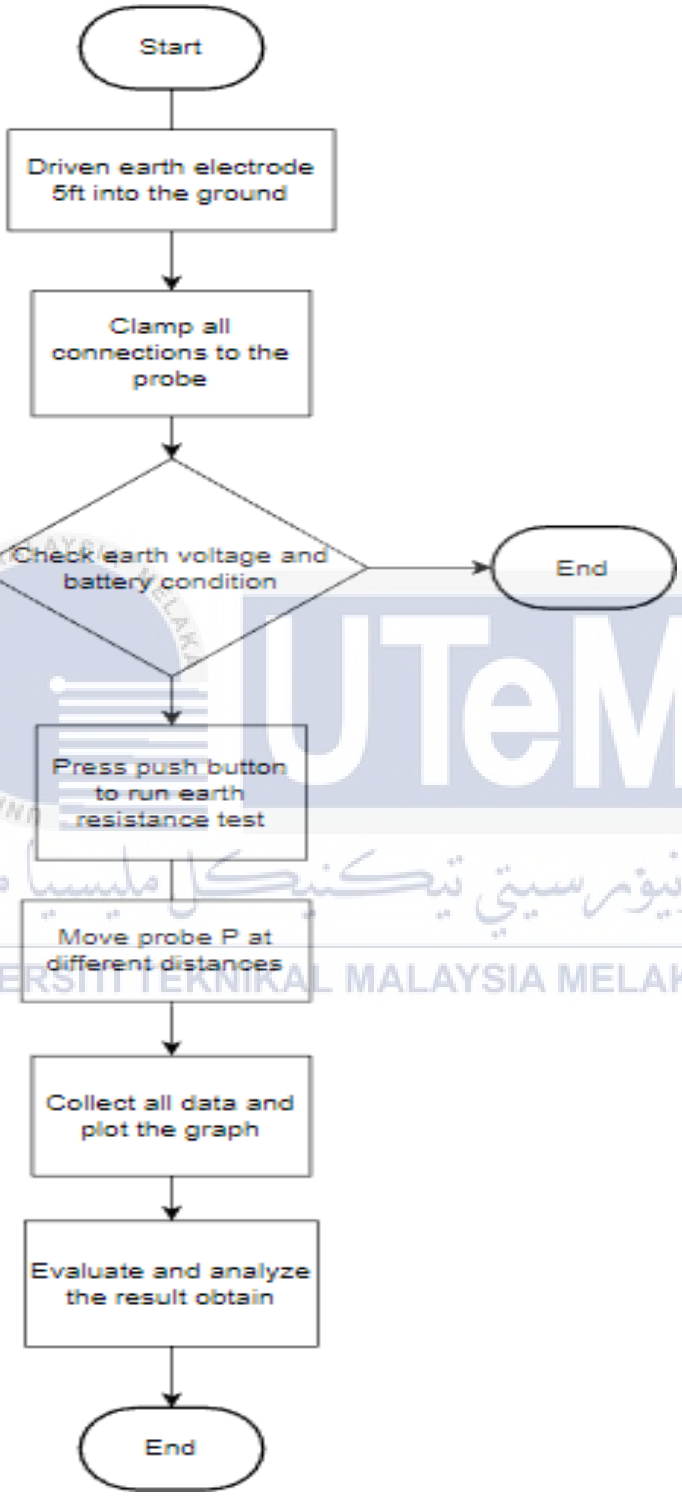

Figure 3.2 Flowchart for measuring procedure using Full 3-Pole Method Test

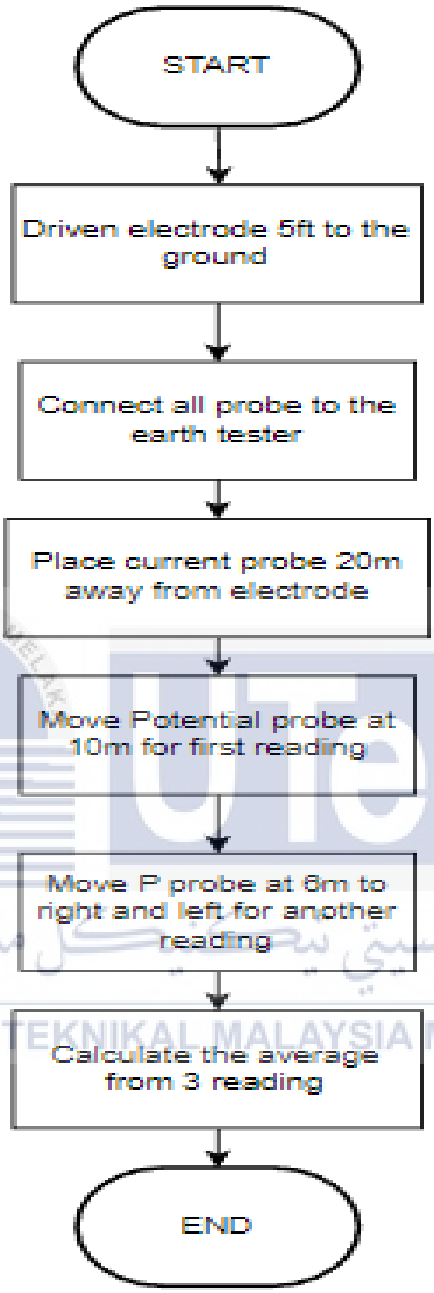

Figure 3.3 Flowchart for measuring procedure using Short 3-Pole Method Test

3.2.1 Experimental setup

The project presents the Full 3-pole method with a number of tests are done in 10 suitable different places and the resistance curve is plotted and simple 3-pole method also used to compare with ST regulation method. The objective is to evaluate the earth resistance in various location of residential building are following the regulation in Malaysia. The best method was used in this assessment to get the best accuracy of resistance.

3.2.2 Flowchart for overall project process

Refer to flowchart in Figure 3.1, firstly identify the problem statement for this project. Next, identifying the scope and objective that we need to find suitable method, use to measure the earth resistance. The goal is to have an earth resistance less than 10 ohm. In general, the lower ground resistance, the safer the system. Earth leakage current can lead to accidental personal safety or equipment and building protection. Based on study, the common way to measure earth resistance was Full 3-pole method and short 3-Pole method test, so a number of tests are done at 10 suitable locations in Sungai Petani, Kedah and the resistance curve were plotted using Microsoft Excel. Then,the earth electrode was forced driven into the earth using hammer. Next, use earth tester kit byMegger Earth Tester and attached the connection to the spike. The result will collect after run the tester by following the procedure and record the data so the graph were plotted. Based on the objective, data will be evaluated and analyze the result of earth resistance in various location of residential building are following the regulation.

3.2.3 Flowchart for measuring procedure using Full 3-Pole Method Test

Refer to flowchart in Figure 3.2 the Full 3-pole method were used to measure the earth resistance at various chosen suitable location are following the regulation. To measure the earth resistance, example earth tester will use such as Megger Earth Tester Kit. To get the data, we must follow the procedure below.

Procedure:

1. Set up the testing tool Megger earth resistance tester, spike, and hammer.
2. The earth electrodes were forced driven into the ground using hammer and electrode probe were attached to it.
3. Probe current, C placed 20m far from the copper rod and attached earth by clamp it on the top of spike.
4. Probe potential, P was then placed on a straight line between the earth electrode and attach potential wire by clamp on the top of spike.
5. Before starting the resistance test, firstly check battery and earth voltage, if voltage reading is 0V and battery in good condition, then can proceed with resistant test.
6. After that, probe P were moved away from earth electrode at least 10 distances in astraight line and record for each reading.
7. The spacing should follow the length of electrode use, for example length of rod is 5ft so the distance should be same as the length of rod driven to earth.
8. Collect the data and plot the graph resistance vs distance to C for each reading measurement.
9. Evaluate and analyze the result.

3.2.4 Flowchart for measuring procedure using Short 3-Pole Method Test

Refer to flowchart in Figure 3.3, the 3-pole method were used to measure earth resistance. This method was used to compare reading measurement with Full 3-pole method.

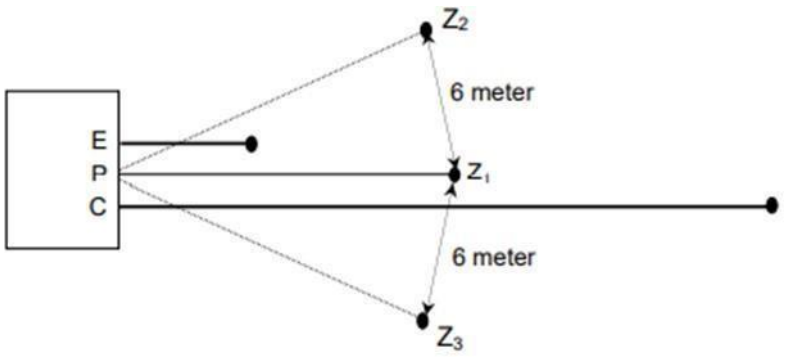

Figure 3.4 Simplified 3-pole method

i) The current probe was spike 20m far from the electrode.

ii) Record the first reading at 10m from electrode (Z1)

iii) Move the voltage spike so that it is 6 meters away from where it was before. Make anote of the second reading (Z2)

iv) Move the voltage spike so that it is 6 meters away from where it was before. Write down the third reading (Z3). From the three resistance values, obtain the average value of the tested earth electrode resistance using equation below.

$$Z = \frac{Z1 + Z2 + Z3}{3} = \_\Omega$$

3.2.5 Parameters

There are several parameters that are used to conduct an earthing test.

i) Earth resistance: A system's earth resistance is the resistance of the soil to the flow of electrical current. It is usually measured in ohms and is a key factor to consider when doing an earthing test.

ii) Earthing rod spacing: When performing an earthing test, the distance of earthing rods is an important parameter to consider. Proper rod spacing can help ensure a successful earthing system.

iii) Earthing rod material: When conducting an earthing test, the material of the earthing rods is an important aspect to consider. Different materials may have different levels of resistance and corrosion resistance.

iv) Material of the grounding electrode conductor: When conducting an earthing test, the material of the grounding electrode conductor is an important parameter to consider. Different materials may have various resistance levels and corrosion resistance.

v) Earthing system maintenance: When doing an earthing test, it is important to keep the earthing system in good condition. When relative to a poorly maintained system, a well-kept system may have reduced earth resistance.

3.2.6 Equipment

This section illustrates and describes the equipment that has been and will be utilized to make this project a success.

a) DET4TD2 Megger Earth Resistance Test

Figure 3.5 Megger Earth Tester Kit

The Megger ground resistance tester kit is a four-terminal ground resistance tester that measures earth ground resistance, soil resistivity, and ground voltage to assess the safety and reliability of electrical systems. The tester can perform ground resistance testing on 2, 3, or 4 poles. It can test the resistivity of various soil types and has a maximum resistance input of 20,000 ohms.

This ground resistance tester can be used both indoors and outdoors. A variety of probes, clamps, and leads can be used to connect the meter to a circuit or device. The DET4TD2 is powered by eight 1.5V alkaline AA batteries. A 49ft (15m) test lead, a 33ft (10m) test lead, a 10ft (3m) test lead, ground stakes right-angle terminal adaptors, 1.5V alkaline AA batteries, a calibration certificate instruction CD, and a polypropylene carrying box are included in the earth ground resistance tester kit.

b) Earth Electrode Rod

Figure 3.6 Copper Earth Electrode Rod

Material	Copper
Length	5ft

c) Copper Earth Clamp

Figure 3.7 Copper earth clamp

The function is to connect the wire to copper earth rod with this clamp and to install the clamp at copper earth rod together with earth rod.

d) Copper Earth Coupling

Figure 3.8 Copper Earth Coupling

The function is to joint the copper rod together.

e) Big hammer

Figure 3.10 Big Hammer

The rod is hammered with a big hammer to minimize the energy needed to hit the electrode rod.

f) Measuring tape

Figure 3.11 Measuring Tape

g) PPE, such as long-sleeved cotton protective clothing, safety shoes, and a safety helmet

Figure 3.12 PPE equipment

3.2.7 Project Costing

Project costs are the entire amount of money required to fund and finish a work project. This project was carried out using the electrical and electronic components listed below with the prices.

Table 3.1 Project Costing

Electrical and Electronic Component				
No.	Component	Unit	Price Per Unit (RM)	Total Price (RM)
1	Cable lug 2.5mm	5	0.25	1.25
2	2.5mm wire Green	12 meters	1.50	18.00
3	Eveready Battery x8	1	13.00	13.00
4	Copper Coupling 12mm	11	2.40	26.40
5	Copper Earth Rod 12mm	10	13.50	135.00
7	Copper Earth clamp	5	1.30	6.50
8	Copper Earth Rod 14mm	1	23.00	23.00
Total Cost				223.15

3.3 Limitation of proposed methodology

There are several limitations when conducting the proposed methodology. Earthing test can be affected by various factors, such as the type of soil, moisture levels, and the presence of other materials which can impact the accuracy of the results. Next, without proper training, it may be difficult to accurately interpret and use the results of an earthing test. Other than that, it is depending on the layout of the residence area, it may be difficult or impossible to access certain area for testing. Testing the earthing system at a residence area may be time consuming and may require coordination with the homeowners and earthing tests can be costly and there may be budget constraints that limit the scope of the test. Hence, if the residence area has an older or complex earthing system, it may be difficult to fully understand and test all aspects of the system because has limited understanding of the system. While conduct earthing system in residential area will be exposed to the privacy of the surrounding residents and worried about disturbing their peace and conducting earthing test at existing electrode rod there will be exposed to danger and hazard. Last but not least, soil characteristics can affect the reading, and it is hard to driving electrode and this can also lead to inaccurate measurements.

3.4 Summary

This chapter presents the proposed methodology in order to achieve the objective. The 3- pole method were used to measure earth resistance. By using earth tester kit, we must follow the procedure to determine proper result. Hence, safety is important to prevent any damage during the process. That's why we must wear PPE such as long-sleeved cotton protective clothing, safety shoes, and a safety helmet. The 3-pole method is a widely used technique for measuring earth resistance in electrical systems. The method involves measuring the potential difference between three electrodes driven into the ground at different locations. The first electrode, known as the reference electrode, is placed at a distance from the other two probes, known as the current probes. A current is passed through the current electrodes, and the resulting potential difference is measured between the reference electrode and current probes. The 3-pole method is considered a reliable and accurate way to measure earth resistance, as it can take into account variations in soil resistivity and other factors that can affect the measurement.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter will present the project's outcome and analysis on earth electrode resistance in residential building by using 3-pole method tests. As part of field study, data analysis is done to evaluate and analysis the earth resistance in various location of residential building is following the regulation of Suruhanjaya Tenaga by using Megger earth tester kit. Following that, this chapter discusses how data collected of earth resistance by conducting an outdoor experiment, and it concludes by analysis of every data were collected. The results of earth testing are displayed in the form of a table, graph and image during the project is underway. The data collected were divided to 10 result analysis depending on where the study conducted.

4.2 Result and Analysis

This project was carried out in 10 different locations, providing a variety of results, including the method to reducing resistances, park areas, village areas, and many more. To simplify the analysis process, each location will be measured using earth tester, and the data will be recorded into a table and plotted using a line graph. Each location of the experiment has a separate set of scenarios and readings. So, the results of the study, methods, and difficulties in interpreting the data will explain in this chapter.

4.2.1 Kampung Sungai Lalang

This project is carried out in the village's residential area and near the paddy fields, the ground is soft and easy to install more electrodes. Because of that, this project was engaged to increase the length of electrodes by adding up to 4 electrodes.

Figure 4.1 Study Area

Figure 4.2 Study Area

Figure 4.3 Copper Coupling

Figure 4.4 Rod attached to another rod using earth coupling.

For the series method, copper earth coupling was used to connect one electrode to another by twisting along the thread such as figure above. In this place, rods were driven next to this house, knocking 4 rods into the ground requires a lot of energy. The effect of adding one, two, three and four rods was represented in Table 4.1. As expected, driving grounding rods deeper into the ground can reduces resistance.

Table 4.1 Result experiment at Kampung Sungai Lalang

L(cm)	d(mm)	R(Ω)	R (%)
150	12	135.2	100
300	12	74.3	55
450	12	50	37
600	12	45	33

The earth's resistance is the resistance to the flow of electric current through the ground. The earth resistance was measured with rods of different lengths which was assumed that the resistance decreased as the length of the rods increased. This is due to the fact that the longer the rods are, the more surface area they have in touch with the ground, allowing more electrons to pass through the earth and lowering resistance.

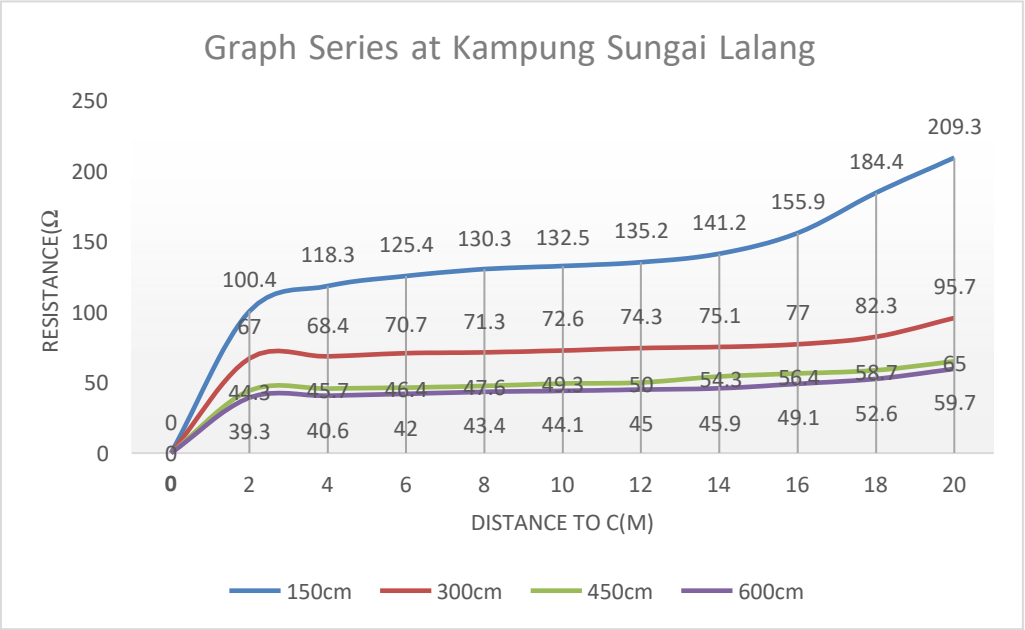

Figure 4.5 Graph of Resistance Vs Distance to C

Figure 4.5 shows the effect of increasing the length of the grounding rod as a percentage of the resistance. By using the full 3 pole method procedure, the data obtained referring to the graph shows the highest resistance reduction happens when the first rod is connected. As more rods are added, the percentage of resistance decreases progressively.

Based on the graph above, we consumed 100% resistance as initial reading (refer to the blue line) when the first 150cm depth to the ground electrode where installed. The resistance reading obtained is 135.2Ω, this indicates a high reading of resistance and may harm people or equipment because the regulation of ST is only 10Ω and below.

Next, the orange line then shows a very significant decrease, which is 55% of the initial reading. To investigation continued with two more electrodes were added, bringing the electrode length to approximately 450 and 600 cm. Problems occur when increasing the length of the rods because the deeper one installed, the more difficult it is to drive the electrode rods deeper into the ground. The observed result showed that the percentage of resistance decreases gradually, when 450 cm is 50% and 600 cm is 45%.

4.2.2 Bandar Perdana

This project is carried out in a free field in front of the terrace houses and next to the mosque, with self-driven electrodes planted 5ft into the earth. This field's ground is soft and easy to install electrodes in. This study was conducted to investigate the difference in earth resistance values when applying two different electrode diameters which is 12mm and 14mm.

Figure 4.6 Measure earth resistance process

Figure 4.7 Study Area

Table 4.2 Result for using difference diameter of rod

L (cm)	d(mm)	R	R (%)	Reduction (%)
150	12	624	100	-
150	14	589	94	6

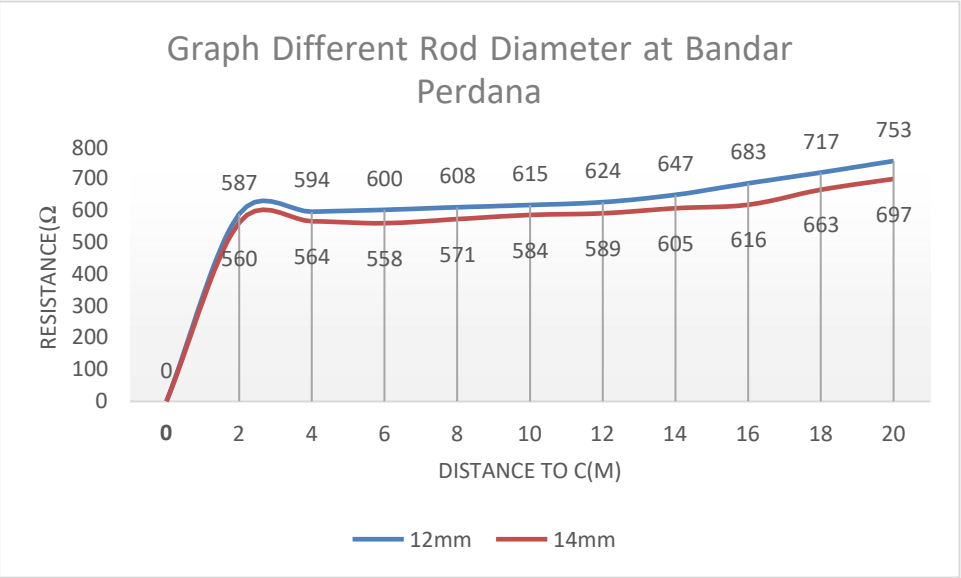

Figure 4.8 Graph of Resistance Vs Distance to C of Using Difference diameter rod

Refer to Figure 4.8 shows that the reading both of earth electrodes has no significant drop. By using same procedure, the Full 3 pole method test was used for both types of reading records and the graph shown above was obtained. Next, for 12mm the resistance is 624Ω while for bigger diameter electrodes which is 14mm is 589Ω. Based on the result obtained, the reduction of using bigger rod diameter is only 6%.

Furthermore, a 12 mm diameter electrode costs RM13.50, while a 14 mm diameter electrode costs RM23. Apart from that, it is difficult to get a 14mm size of copper earth rod at a nearby store. Hence, that 14mm rod was purchased in online to carry out this project and evaluate its effectiveness against the earth's resistance.

According to the study, this is not an effective option because doubling the rod diameter will increases the rod's weight and cost while reducing earth resistance by only 6%. This study comes to the conclusion that the rod diameter has no big effect on ground resistance reduction. The decision of a bigger diameter rod is not the best choice to reduce earth resistance.

4.22 Kampung Berapit

This project was conducted at night and the soil in moist soil. This house was completed build in a last month. Then, the earth resistance of this house was measured and below is the result.

Figure 4.9 Measure using Megger Earth Tester

Figure 4.10 Existing Copper Rod

The green wire was attached to the electrode were driven at earth chamber (Referring at Figure 4.10). The electrode was already in existence and did not disconnect that cable from the distribution box because of worried it would break or cause a trouble and the reading maybe different to actual value. Next, disconnecting the cable earth could potentially create a hazardous situation if a fault were to occur.

Table 4.3 Data collected at Kampung Berapit

Condition	L (cm)	D (mm)	R (Ω)	R (%)	Reduction (%)
Single rod	150	12	48.9	100	-
Parallel	150	12	25.5	52	48

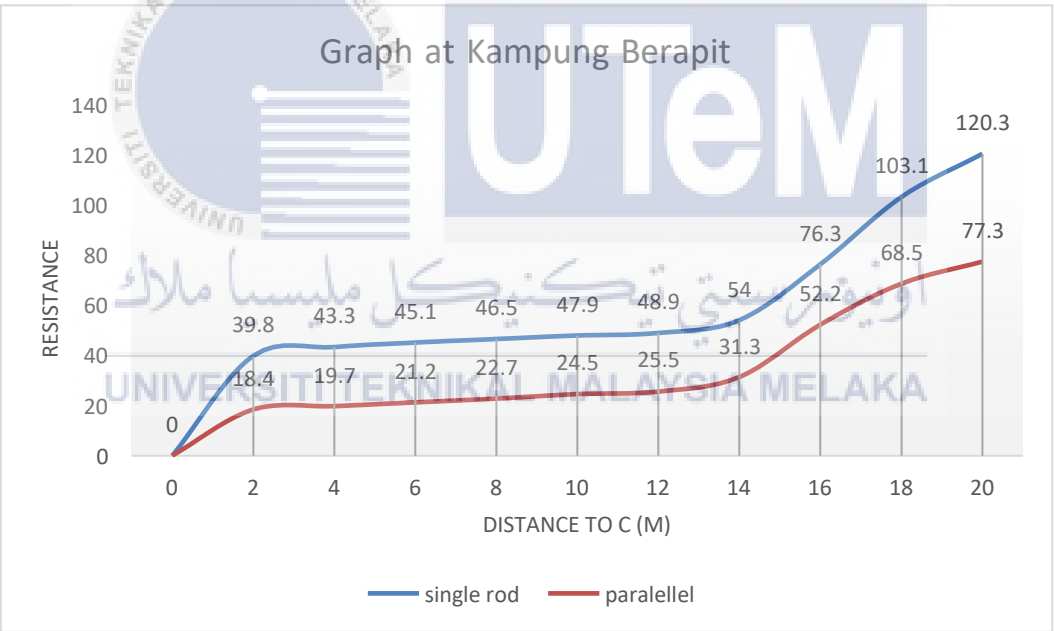

Figure 4.11 Graph Resistance Vs Distance between series and parallel

Refer to the graph, blue line is single rod readings while orange is parallel. An existing electrode rod has been tested for earth resistance value and the reading is 48.9 Ω, so that the readings did not meet the requirements of ST. The earth's resistance was observed to be high regardless of the fact that the house had only recently been completed built, therefore that maybe because of lack of knowledge when doing research, moisture of soil, temperature or the contractor who did the wiring of this house may have taken safety for granted. Because of this, the house, people, and equipment in that building will endanger every user and can cause serious accidents. The user must fix the house's earthing system for their own safety.

The parallel of multiple electrode rods was used in this study to study the decrease in earth resistance. Then, one electrode was driven into the ground to provide parallel paths, and the result below. Each two earth rods should be separated from each other by a distance not less than the depth to which they are driven.

Based on investigation, the size of the protective conductor cable that goes to the distribution box used by the contractor is 6 mm2 in size and not follow the standard size of Suruhanjaya Tenaga regulation. The protective conductor cable from the earth electrode to the distribution box must be 10 mm2 in diameter. For the result in Figure 4.11 after parallel the electrode between 2 meters apart and the result shown is decrease which is 25.5 Ω. The difference in earth electrode readings for one electrode and parallel is 48% (Refer Table 4.3).

4.23 Taman Delima

This time the project is carried out using the treatment to soil method. Many materials are suitable for this method such as Magnesium sulphate, calcium sulphate, sodium chloride and other useful products like charcoal or bentonite (natural clay). In this situation, Magnesium Sulphate or call Epsom salt was used because its low cost, low resistivity and low corrosivity. To install magnesium sulphate should follow this step.

i) Make a circular hole or hole beside the grounding electrode with a maximum distance of 10 cm and fill it with Epsom Salt (MgSo4) chemicals until 30 cm from the ground level, then cover it with soil.

ii) Add a little water into the hole on a regular basis to ensure optimum salt absorption.

Figure 4.12 Epsom salt around electrode rod

Table 4.4 Result obtains before and after Treatment the soil

Condition	L (cm)	D(mm)	R	R (%)	Reduction (%)
Before	150	12	18	100	-
After	150	12	15.05	84	16

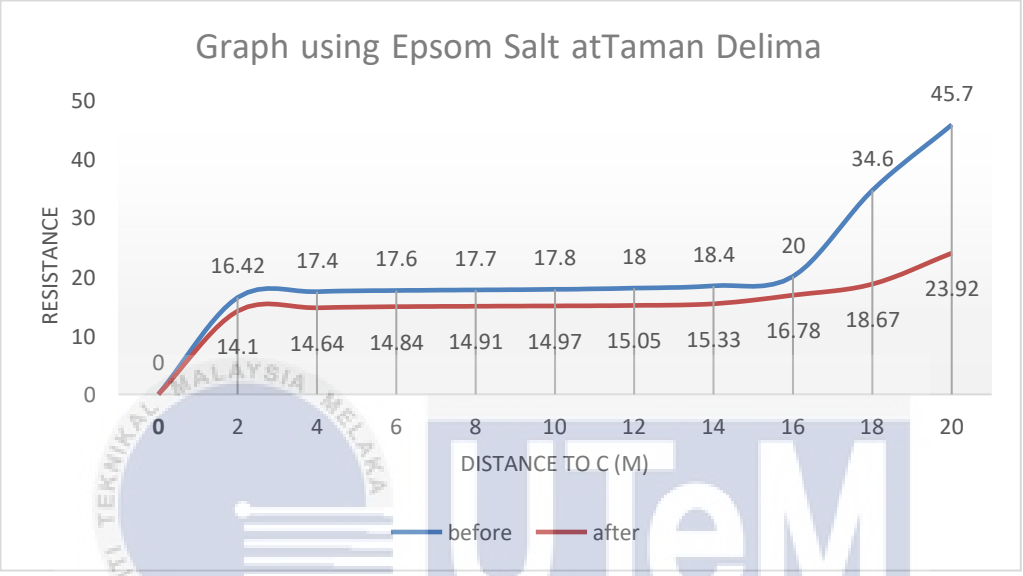

Figure 4.13 Graph Resistance Vs Distance Using Treatment of Soil

Using the Full 3- pole method, the data obtained shows that the reading before applying Epsom salt is 18Ω and the reading after soil treatment is 15.05Ω. This Epsom salt is only planted for 15 minutes and shows significant results. This method shows it can reduce the earth's resistance at least 16% can Refer to Table 4.4.

Because the objective of this study is to evaluate and analyse the earth resistance in various locations of residential buildings that follow to ST regulations, the simplified 3 pole method also was performed according to the procedure. This 3 pole method is carried out after Epsom salt is used. The data obtained using this method is as follows.

$$R = \frac{14.83 + 14.76 + 14.74}{3} = 14.78\ \Omega$$

Figure 4.14 Measurement using 3-pole method

This analysis shows that when using the Full 3-pole method the reading is 15.05Ω and the 3-pole method (ST method) is 14.78Ω. The difference from the reading is because of the different methods were used. The reading will be more accurate to the actual value when using the full method since the data obtained is more, which is 10 readings, however 3-pole just 3 reading points. Overall, measuring earth resistance using soil treatment can be a challenging task that requires careful consideration and proper equipment.

Chemical treatment of the soil is not a long-term solution for improving the electrode's grounding resistance because the chemicals can be erased by rainfall and natural drainage through the soil and the period for replacing these chemicals varies depending on the amount of rainfall and the porosity of the soil. When it is not possible to drive the grounding rods deeper due to rocks or other factors, and adding rods does not reduce ground resistance, chemical soil treatment is a good option.

4.24 Taman Seri Putra

In order to meet the objectives, the project was carried out in a populated park area. The project is carried out in a field surrounded next to terrace houses Referring to Figure 4.15. Due of time limitations, 5ft long rods were installed during the day but readings were taken at night.

Figure 4.15 Study Area at Playground Taman Seri Putra

Table 4.5 Result Obtain at Taman Sri Putra

Condition Rod	L(cm)	D (mm)	R(Ω)	R (%)	Reduction (%)
Single	150	12	25.4	100	-
Series (+1)	300	12	14.6	57	43
Series + parallel	-	12	8.5	33	67

Refer to Table 4.5, the data gained reveals that the resistance is not that high which is 25.4Ω at initial single rod reading. The residential playground areas receive slightly higher readings and require the addition of electrodes in series or parallel. The project analysis was conducted by using series and parallel methods to analyse the decrease of resistance with various ways. The lack of space makes it difficult to carry out the project and also the privacy of residents becomes a problem due to the production of noisy sound when hammering the copper rod.

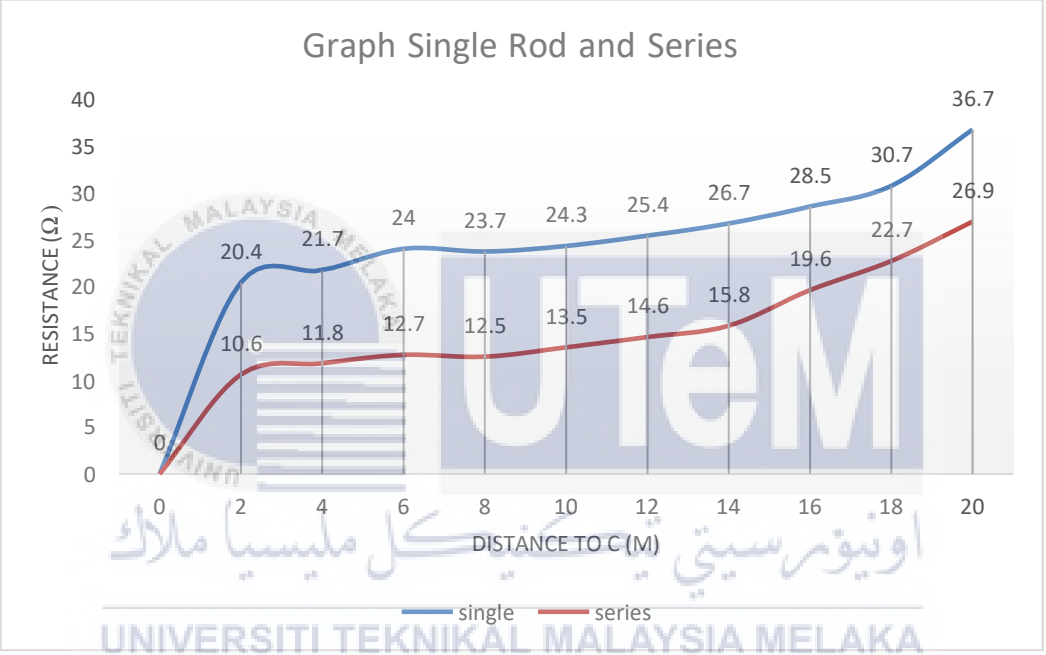

Figure 4.16 Graph Resistance Vs Distance of Single Rod and Series

Firstly, the observation was started by doing series method. To conducting the series technique, which is by adding the length of the electrode with connect the rod using an earth copper coupling and the two rods are then connected together following the thread. After doing this series, the length of rod will be 300cm. The result of the earth resistance reading shows a decrease from 25.4Ω to 14.6Ω. The earth resistance drop has decreased by 43% when increasing the electrode length.

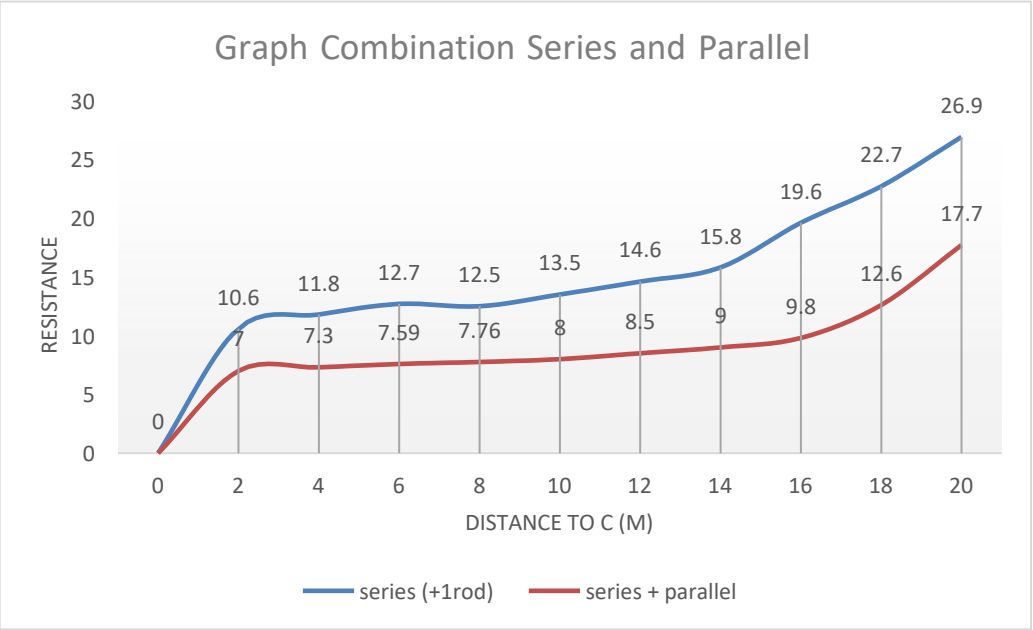

Figure 4.17 Graph Resistance Vs Distance of Series and Parallel

Next, the same procedure is followed but this time the electrode is driven parallel spacing to another one electrode. This study shown the reduction that occurred when combining electrodes using series and parallel method. Based on this study, the percentage on resistance drop has increase when combining the series and parallel of rods. As a result, the earth resistance reading has dropped from 25.4Ω to 8.5Ω. The conclusion is when installed the rods in parallel and combining of adding the length of rods, earth resistance is reduced by 67% which is high reduction.

Using multiple rods in parallel can also increase the reliability and effectiveness of the system, as it reduces the risk of failure due to a single broken or malfunctioning rod. It also allows for a more even distribution of current flow through the system, which can improve safety and performance.

4.25 Kampung Sepom

The project is carried out in two situations which is while the ground was moist after rain, and under hot sun and dry ground. The rod has been driven into the ground next to the village house.

Figure 4.18 Measure earth resistance when moist soil

By following the procedure to measure earth resistance using Full 3 pole method, below shown the result obtained. This is to compare and observe that weather changes will impact the earth resistance. The Megger Earth Tester is used to measure the earth's resistance at this point. Table 4.6 show result in dry soil and ground after rain and also resistance reduction after doing series on dry soil.

Table 4.6 Result of Resistance at Kampung Sepom

Condition	L(cm)	D (mm)	R (Ω)	Reduction (%)
Dry soil	150	12	412	100%
Moist soil	150	12	365	12%
Series on dry	300	12	212.4	48%

The evaluation shows that in dry soil is 412 Ω higher than the reading in moist soil which is 365 Ω. According to the table above, a 12% reduction was observed when the soil was moist. This shows that moist soil can affect the earth's resistance reading. When the soil is moist, the resistance is good, but only temporarily, until the soil dries out again.

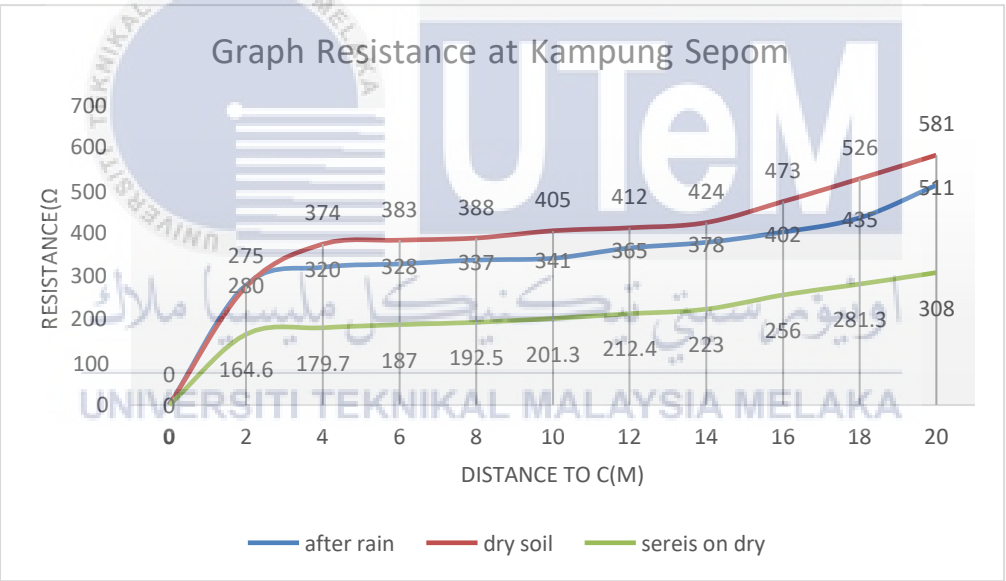

Figure 4.19 Result resistance vs distance for 3 reading

Readings are taken for the next time when the ground is dry by placing 1 rod of electrodes in series. Readings can be obtained that when using two electrode rods connected in series is 212.4 Ω which is 48% reduction. This shown that using series method can reduce more resistance but need more energy to driven 2 electrode rods into the ground.

Measuring the earth resistance can be difficult when the weather changes because the weather can affect the factors that determine the earth resistance. For example, rain can increase the moisture content of the soil, which can lower the earth resistance. Similarly, hot, dry weather can cause the soil to become dry and compacted, which can increase the earth resistance. These changes in the weather can make it difficult to accurately measure the earth resistance because the values can vary significantly over time. It is also important to use proper equipment and techniques to ensure that the measurements are as accurate as possible.

Other than that, the simplified 3 pole method was conducted according to the procedure. This 3 pole method is carried out during single rod and dry condition. The data obtained using this method is as follows.

$$R = \frac{494 + 474 + 487}{3} = 485\ \Omega$$

This analysis shows that when using the Full 3-pole method the reading is 412Ω and the 3 pole method (ST method) is 485Ω. The difference from the reading is because of the different methods were used. The reading will be more accurate to the actual value when using the full method since the data obtained is more, which is 10 readings, however 3-pole just 3 reading points.

4.26 Taman Bukit Banyan

The project is carried out in the hill area near the terrace house. The rods were planted to a depth of 150 cm. The project was carried out using the full 3 pole method according to the procedure. Measurements was carried out during the days, with the dry soil.

Figure 4.20 Study Area at Hill Beside Terrace House

Figure 4.21 Two Grounded Portions Connected in Parallel

Figure 4.21 shows two grounded portions connected in parallel during the experiment. The structure of the soil makes it difficult to carry out the project, but data needs to be obtained to study the earth's resistance. Measuring earth resistance on hard soil can be challenging because the soil may not provide a good connection to the earth. This can make it difficult to obtain an accurate measurement of the earth resistance. A project was conducted to study the decrease that occurs when using the parallel rod method.

Table 4.7 result of resistance single and parallel

Condition Rod	L (cm)	d(mm)	R	R (%)	Reduction (%)
Single	150	12	1590	100	-
Parallel	150	12	813	51	49

The evaluation in the hill area received a very high reading referring to Table 4.7. There are several reasons why earth resistance on a hill may be higher than usual. One possible explanation is that the ground at the top of the hill is drier than the soil at the bottom, which increases the resistance to the flow of electric current. Another cause could be that the ground at the top of the hill is more rocky or less conductive than the soil at the bottom of the hill. Other than that, metal, iron, tin, stone, and other materials have been buried in the hill soil.

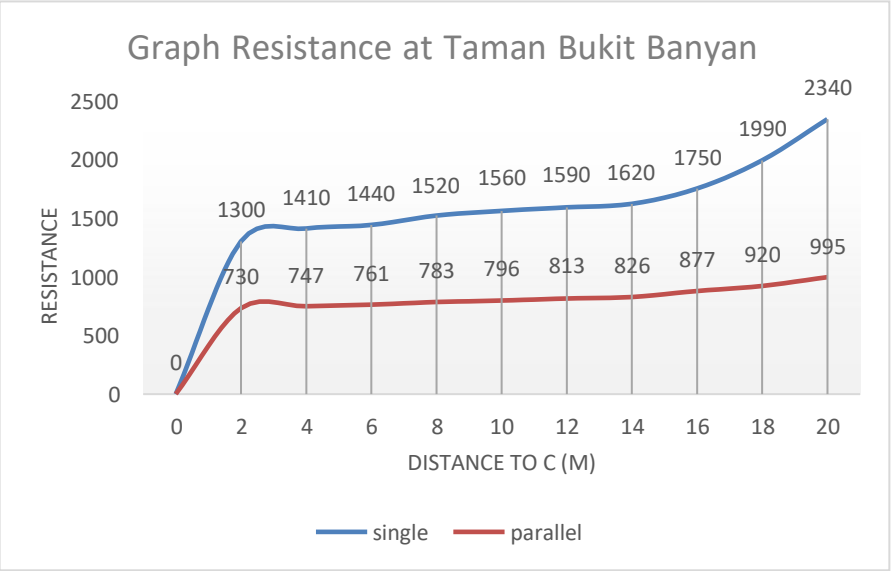

Figure 4.22 Graph of Resistance Vs Distance

A study was carried out applying the method of parallel an electrode and it was observed that the resistance reading decreased (Referring to The Red Line in The Figure 4.22). When performing this parallel method, the resistance reading difference between the one electrode rod and two parallel electrode is 49%. This reading however does not meet the standards requirement by Suruhanjaya Tenaga. If applying the parallel method, it was estimated that 7 or more electrode rods should be use if based on the data obtained. However, the study was not continued in that location because the land was too challenging and difficult to plant electrodes.

4.27 Taman Intan

The ground surface in this location was good and it easier to install the electrodes, but the limitation was that knocking the rod will emit a loud sound and worried that will disturbing the comfort of the residents there. This time, the project was carried out in the playground at Taman Intan. Because of concerned about disturbing privacy of the residents in that residential area, the electrode was installed a little far apart in the middle of the field like figure below.

Figure 4.23 Study Area

Table 4.8 Result of Resistance in Single and Parallel Electrode

condition	L (cm)	r (Ω)	R (%)	Reduction (%)
single	150	14	100	-
parallel	150	6.38	46%	54

After follows the procedure full 3-pole method, the reading obtained by installing one electrode is 14Ω. To get the true measurement, value resistance was usually approx at 62% of the distance between the electrode and the end of the C probe. Based on the graph below, the earth resistance is a little high compared to the earth resistance set by ST is below 10 ohm.

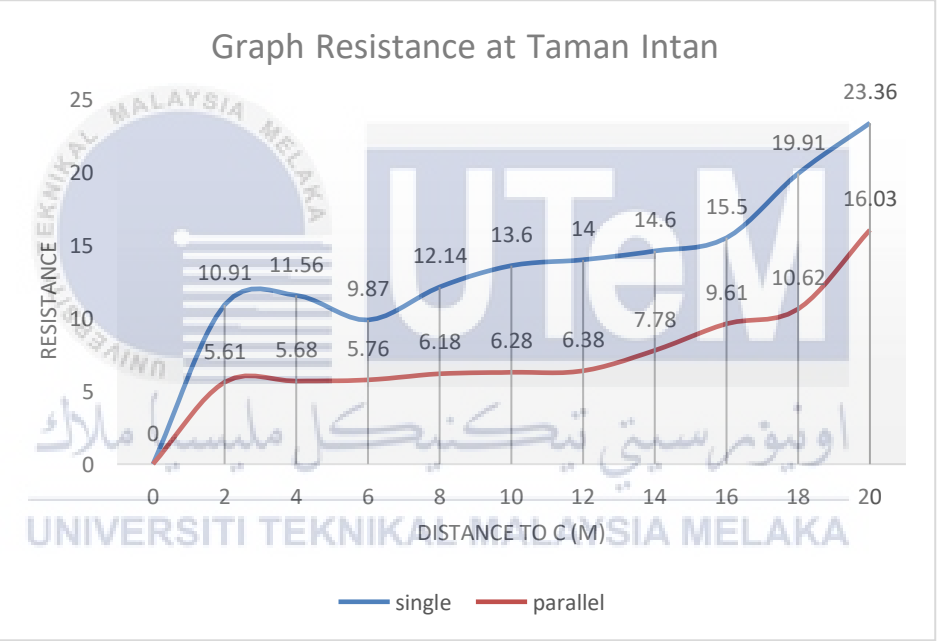

Figure 4.24 Graph of resistance vs distance to C

Referring to Figure 4.24 the reading at point 6m drops, this may be because there were stones or other compounds that affect the reading. Then, the electrode parallel method was also used to reduce earth resistance and compare with initial reading. When electrode was paralleled, the results obtained in Table 4.8 is 6.38Ω. This result shows that 54% decrease in earth resistance. As a result, the reading after paralleling will reduce the resistance reading and follow the ST standard regulation.

4.2.9 Kampung Telok Wang

This time the project was carried out in a village compound located near a rubber farm. This study area was clay loam soil and humid, which will easier to driven the electrode and evaluate the earth's resistance in this area. PPE equipment, such as gloves and closed shoes, was important for avoiding accidents when doing earthing tests.

Figure 4.25 Study Area at Kampung Telok Wang

Table 4.9 Data collection at Kampung Telok Wang

Condition	L (Cm)	R(Ω)	R (%)	Reduction (%)
Single	150	745	100	-
Parallel (+1)	150	424	57	43
Parallel (+2)	150	325	44	56

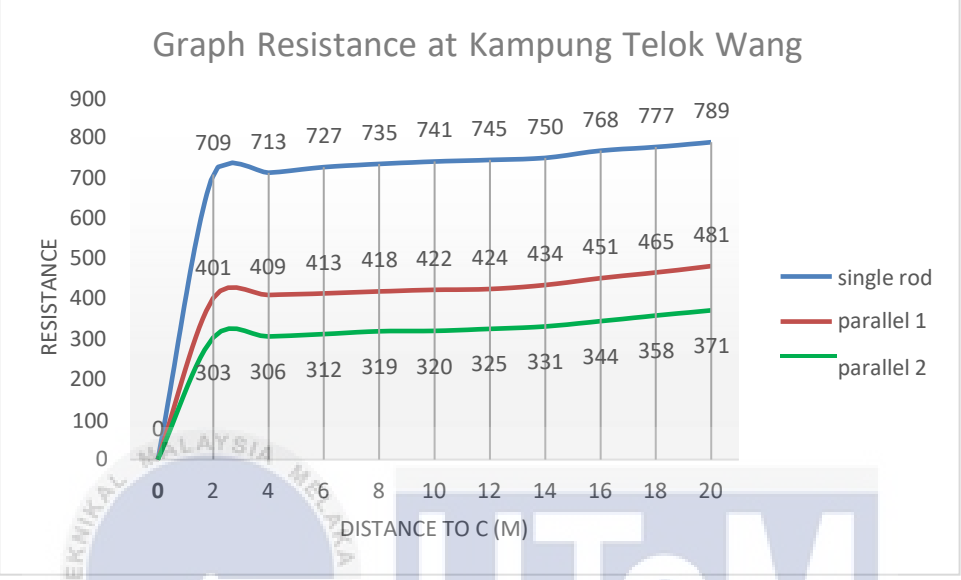

Figure 4.26 Graph Resistance vs Distance at Kampung Telok Wang

A rod has been installed 5 feet deep. The data obtained shows a very high resistance value of 745Ω on the single rod reading. The high value was most likely due to the structure and observation place factors affecting the reading. The following test was performed applying the parallel method to the electrode. Refer to The Orange Line in Graph, the parallel distance must be separated at least as far apart as the depth of the first rod planted. When one electrode is paralleled, the resistance percentage was reduced at 43%.

Figure 4.27 Copper Earth Clamp

This method required the use of an earth clamp or jacket to connect to the second electrode, as seen in the figure above. The third test was performed with another electrode in parallel (Refer Green Line in Graph), and the resulting measurement was 325Ω based on the graph. The resistance percentage increased by 56% when two electrodes were paralleled. This method was most suited for large areas, but if the area was small, use the series or another way.

The resistance of earth at rubber farm may be higher than usual due to several factors such as soil composition because the soil in the area may contain high levels of clay or other minerals that increase the resistance to electrical current flow. Other than that, chemical properties of soil also can affect for example high levels of organic matter, pesticides and fertilizers. The presence of metal objects such as pipes, wires, or equipment can also increase earth resistance.

4.2.10 Taman Nilam Sari

The study was done at Taman Nilam Sari. The rod was driven in front of the two-story terraced house's playground. The soft ground structure makes driving the electrode into the soil easier, and the investigation was carried out while the weather and soil are dry. Full 3 pole method and simple 3 pole studies were conducted in this place by following the procedure.

Figure 4.28 Study Area Taman Nilam Sari

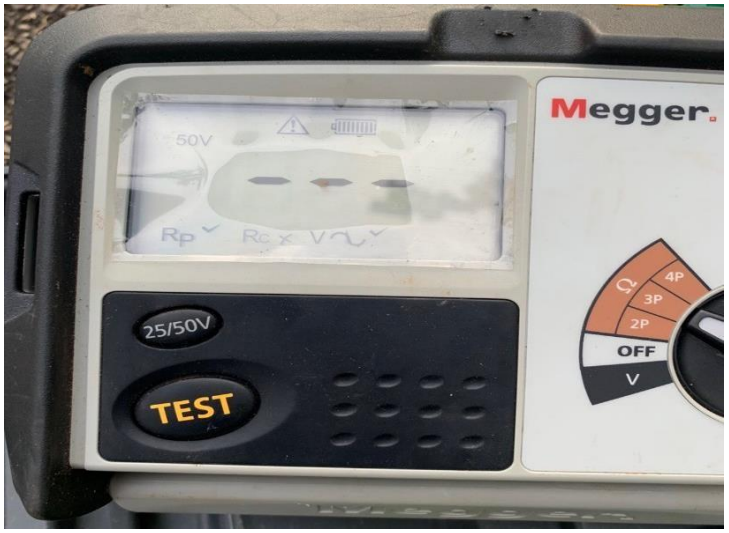

Figure 4.29 Test Error

The error shown above was because the earth tester does not detect the C probe. If this happens, find a solution, such as checking to see if the cable was disconnected or damaged. This always happens when the spike is planted in a rocky spot or in very hard soil. A spike probe that was broken or not detecting will not providing accurate or reliable measurements due to multifunction, damage, or lack of proper contact with the soil.

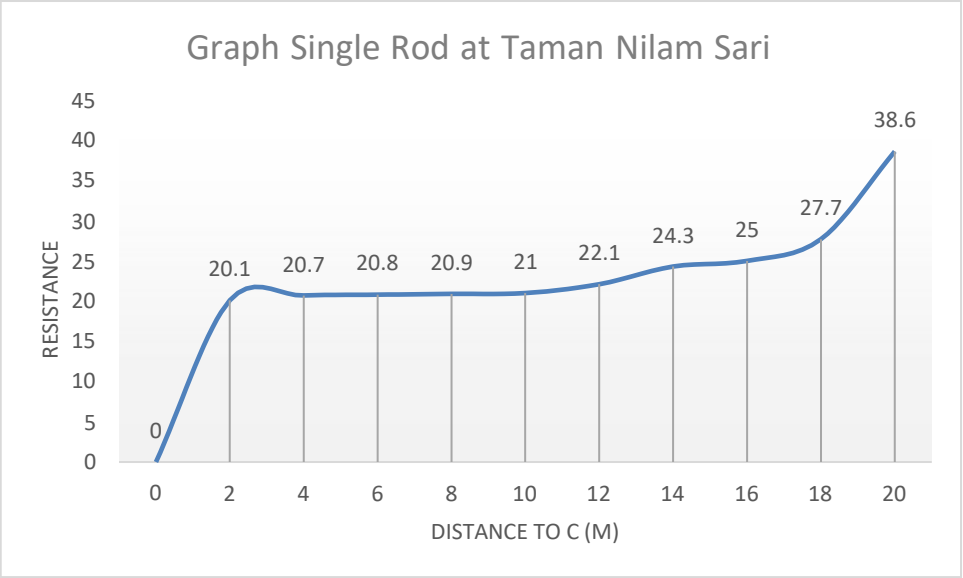

Figure 4.30 Graph Resistance vs Distance at Taman Nilam Sari

The full 3 pole method show that a reading is 22.1Ω. Following the standard 3 pole procedure, three readings were collected and divide by three and get 24.3Ω for the resistance. This shows that the readings obtained are not significantly different, and both procedures were acceptable to be used. The data collected shows a little high resistance, however this might be due to a number of factors, including the fact that the reading was taken a little distant from the house, and the reading could have been taken from the implanted electrode instead of the existing electrode.

4.22 Summary

Based on this chapter, the observation shows that if that any location has a very high resistance reading, the ideal technique to reducing the earth resistance is to apply a combination of series and parallel. This is because, according to our research, it can reduce resistance by 60%. Using the parallel method is also very effective to lower the resistance but requires a large space. When compared to other methods, the application is the highest, and this method can also last a long period. The Epsom soil treatment method can also significantly reduce resistance at a minimal cost, however it is just temporary and not permanent. Therefore, good earth resistance is very important to ensure the safety of peoples, equipment, and building. Although this full 3 pole method is more time and energy consuming, this method was use because it to get a more accurate value for the actual reading compared to the usual basic 3 pole, but the Suruhanjaya Tenaga method is easier and faster. Many studies have been carried out in various locations and on different kinds of the earth's surface. Many barriers and challenges were faced while operating on this case study such as hammer damage, hard ground, a lack of information, rain, and scorching heat.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In general, the conclusion of an assessment of earth electrode resistance in residential building would typically include a report of the measured resistance and a statement of whether it meets the standards set by the Suruhanjaya Tenaga regulations. The Malaysian earth electrode system analysis showed that it is an important component in assuring the safety and reliability of electrical systems. In Malaysia, copper rods are commonly used as earth electrodes, and this technology has been shown to be effective in providing a low-resistance path to ground. However, more research and development is required to optimise the design and installation of earth electrode systems in Malaysia, particularly in locations with high soil resistance. Earth electrode systems must also be maintained and checked on a regular basis to ensure their continuous effectiveness in protecting against electrical risks.

Other than that, the 3-pole method test is an effective and widely used method for measuring the earth resistance of an electrical system. It is a reliable method that provides accurate results and allows for easy identification of any issues with the earth electrode system. The test is easy to perform, and the equipment required is readily available. However, it is important to ensure that the test equipment is calibrated correctly and that proper safety precautions are taken during the test. It is also recommended to conduct regular inspections and investigations of the earth resistance using the 3-pole method test to ensure the safety and reliability of the electrical system. Overall, the 3-pole method test is a crucial tool for ensuring the proper functioning of the earth electrode system in any facility.

Furthermore, in evaluation and analysis of earth resistance in some locations of residential buildings were found to have higher resistance values, which may indicate a need for further investigation and improvement in the design and installation of the earth electrode systems. The study highlights the importance of regular testing and maintenance of earth resistance in residential buildings to ensure compliance with regulations and provide safe and reliable electrical systems. It is recommended that the building owners conduct regular earth resistance tests to ensure the safety of their building and comply with the regulations.

Next, from the study there were shown that village areas have higher earth resistance reading if compared to city or park. There were few reasons why that happens such as building in cities there was usually a better earthing system because of the need to handle more load and better infrastructure, which can lead to lower earth resistance. In villagers, the earthing system might be less sophisticated, resulting in higher earth resistance. Other than that, most villagers were unaware of the importance for having good earthing system in their houses, which was one of the reasons why the majority of data was collected in village areas were higher than usual.

Overall, the research presented in this thesis has succeeded in making a contribution to understanding the importance earth electrode system to providing an adequate level of protection against electric shock and other hazards and to identify any potential issues that need to addressed and using the 3 pole method has shown that this method is an effective and reliable way to measure earth resistance.

5.2 Future Works

This project is successful in meeting all stated objectives and satisfies all target requirements. Although, there are some limitations that can be overcome, improved, or upgraded in the future, including the following:

i) Regular testing: regularly testing and inspecting the earth system is important to ensure that it is functioning properly and that any potential issues can be identified and addressed before they lead to problems.

ii) Training: It is recommended that those performing earthing testing have proper training and knowledge of earth testing procedures.

iii) Consult with professionals: It is always recommended to consult with professional electrician or earthing test engineer to ensure that testing is done correctly.

iv) Proper documentation: Keep accurate records of all earth testing measurements that are made to the earth system. This will help with future testing and maintenance.

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APPENDICES