GROUNDING RESISTANCE IMPROVEMENT USING COCONUT HUSK

SITI NORNASUHA BINTI JAAFAR

A report submitted in partial fulfillment of the requirements for the degree of Bachelor of Electrical Engineering

FACULTY OF ELECTRICAL ENGINEERING

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2018

"I hereby declare that I have read through this report entitled "*Grounding Resistance Improvement Using Coconut Husk*" and found that it complies the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering"

Signature : ....

Supervisor's Name : ....

Date : ....

I declare that this report entitled "*Grounding Resistance Improvement Using Coconut Husk*" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....

Name : ....

Date : ....

To my beloved mother and father

For their boundless love, prayer and support

ACKNOWLEDGEMENT

All praises to almighty Allah for His kind gesture, love, protection, guidance, endurance, wisdom and privilege given to me to accomplish this research successfully.

Secondly, I would like to express my deepest gratitude to my supervisor, Dr Farhan Bin Hanaffi who has contributed valuable suggestions and great help to coordinate my research work. Without his guidance, precious advices and encouragement, this research might not be completed as presented here. Furthermore, I would like to express my appreciation to technical staff of Research Laboratory of High Voltage Engineering; Mr Mohd Wahyudi Bin Md Hussain for his assistance and permission to use all the required equipment and material as part of the research requirement.

My further gratitude goes to Universiti Teknikal Malaysia Melaka (UTeM) for providing the necessary infrastructure throughout my degree studies.

Last but certainly not least, my sincere appreciation to my parents, relatives and friends for their continuous support, patience, unfailing love, prayers and faith in my perseverance over the entire period of my studies.

ABSTRACT

A suitable grounding conductor for electrical installation is vital to ensure safety and grounding system performance over long term. A good grounding system has low ground resistance value to easily channel fault current straightly to the earth during fault condition. Without an effective grounding system, fault current may flow to personal or electrical appliances instead of flowing through grounding system. The purpose of this project is to investigate the effect of coconut husk as additive material on galvanized steel rod electrode and copper rod electrode. The performance of coconut husk as additive material in lowering ground resistance also will be investigated in this project. Ground resistance values are measured from different type of grounding configurations using Earth Ground Tester Fluke 1623. The ground resistance measured from this project for different type of grounding configuration which is for different type of electrode, different weight of coconut husk and different coconut husk layer configuration is continued from previous study. COMSOL Multiphysic software is used to investigate the performance of coconut husk as additive material. Model of grounding system is solved by using partial differential equation through Finite Element Method (FEM). Electrical field distribution is analyzed to compare performance of each grounding configuration. The magnitude of electric field distribution is diverged proportionally with ground resistance. This is because electric current easier to flow into lower soil resistivity. Thus, it will lead to grounding system improvement.

ABSTRAK

Pengalir yang bersesuaian bagi sistem pembumian pepasangan elektrik adalah penting untuk memastikan keselamatan dan prestasi sistem pembumian dalam jangka masa panjang. Sistem pembumian yang baik mempunyai nilai rintangan tanah yang rendah untuk memudahkan pengaliran arus berlebihan ke dalam tanah semasa keadaan tidak normal. Tanpa sistem pembumian yang berkesan, arus berlebihan boleh mengalir melalui manusia atau peralatan elektrik dan bukannya mengalir melalui sistem pembumian. Tujuan projek ini adalah untuk menyiasat kesan sabut kelapa sebagai bahan tambahan pada rod keluli bergalvani and rod tembaga. Prestasi sabut kelapa sebagai bahan tambahan untuk merendahkan nilai rintangan tanah juga akan dianalisis dalam projek ini. Nilai rintangan tanah daripada konfigurasi pembumian yang berbeza telah diukur dengan menggunakan Penguji Tanah Bumi Fluke 1623. Nilai rintangan tanah yang diperolehi daripada projek ini telah disambung daripada projek yang lepas. Perincian COMSOL Multiphysic telah digunakan untuk menyiasat prestasi sabut kelapa sebagai bahan tambahan. Model sistem pembumian telah diselesaikan dengan menggunakan persamaan pembezaan separa melalui kaedah Finite Element (FEM). Pengedaran medan arus telah dianalisis untuk membandingkan prestasi bagi setiap konfigurasi pembumian. Magnitud pengedaran medan arus adalah menyimpang secara berkadar dengan nilai rintangan tanah. Ini adalah kerana arus elektrik lebih mudah mengalir ke dalam tanah yang mempunyai nilai rintangan yang lebih rendah. Oleh itu, ia akan membawa kepada peningkatan prestasi sistem pembumian.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATION

UTeM	Universiti Teknikal Malaysia Melaka
GI	Galvanized
FEM	Finite Element Method

CHAPTER 1

INTRODUCTION

1.1 Research Background

An acceptable and safe grounding system is one of vital part to be considered and taken into account in electrical system installation at high-voltage infrastructures, commercial constructions and residential areas. The fundamental function of grounding system is to channel fault current instantaneously to the earth through grounding electrode. During system's malfunction, grounding system could prevent properties damage and provide a secure working environment for workers and people passing by [1]. In order to increase grounding system performance, the value of ground resistance should be low. The perfect value of ground resistance is zero impedance but this value is impossible to be achieved. A lot of methods have been done in practical situation to obtain ground resistance value as near as possible to zero value. Thus, the performance of grounding system is dependent on the ground resistance value. Ground resistance and soil resistivity surrounding the electrode should be lower compared to main electrical circuit. This is to enable the high in rush current to flow directly into ground as current always flows to path with lowest resistance. Soil resistivity is a main parameter to be considered in designing effective grounding and lightning protection systems. According to standard BS7430:2011, soil resistivity is measured by using Wenner Four Probe Method. This method is carried out by driving four test electrodes with equally spaced into soil to a depth of 1m in a straight line. The depth should not exceed 5% of their spacing between electrodes. Fall of potential 61.8% method is used in measuring ground resistance of the installed test electrodes.

1. 1 Problem Statement

In order to improve grounding system performance, ground resistance value must be reduced as near as possible to zero value. Soil resistivity is the most crucial factors in influencing ground resistance. Soil resistivity varies dependent on type of soil, moisture content, depth of soil, chemical composition, porosity, conductivity and temperature [3]. Moisture content of soil is the greatest effect on soil resistivity. Higher moisture content can be achieved when the depth of soil increases. The higher moisture content of soil, lower soil resistivity can be achieved. Since the soil resistivity is lower, ground resistance also will be lower. In order to achieve lower ground resistance value, driving a longer electrode deeper into soil and usage of multiple electrodes will not be a good alternative as it is costly. Therefore, soil treatment method can be implemented to solve this problem. Bentonite is usually used for soil treatment but it is expensive. As an alternative material, coconut husk can be used as additive material for soil treatment [14]. Coconut husk has hydrophilic properties that capable to store or absorb water into its structure. Thus, the moisture content of soil increases and lead to lower ground resistance value. Copper is usually used as grounding system but due to its high price in market, the number of theft activities is increased. This causes service and utility company has suffered great losses due to these theft activities. In this project, galvanized steel electrode is used as alternative to copper electrode. However, the use of galvanized steel in grounding system needs to be analyzed in term of its performance, ground resistance and economic value.

1. 2 Project Objectives

The objectives of this project are:

1. To investigate the effect of coconut husk as additive material on copper electrode and galvanized steel electrode.
2. To analyze the performance of coconut husk as additive material in lowering ground resistance.
3. To model and simulate analysis of ground electrode with coconut husk using Finite Element Method.

1. 3 Project Scope

The scopes of the research are:

1. The location where the project is conducted is at Vicinity of Faculty of Electrical Engineering, UTeM.
2. Type of ground electrode used is galvanized steel rod electrode (hollow rod) and copper rod electrode.
3. The site consist of 6 different type of ground electrode installations which is vertical copper electrode, vertical galvanized steel electrode without added with coconut husk and vertical galvanized steel electrode added with different type of coconut husk configuration. The vertical galvanized steel electrode added with different type of coconut husk configuration is by adding 1kg, 1.5kg, 2kg and addition of coconut husk layer-by-layer with local soil.
4. The apparatus used to measure ground resistance is Earth Ground Tester Fluke 1623.

5. Measurement method used to measure ground resistance is fall of potential method based on BS 7430:2011.

6. Coconut husk is used as additive material to reduce soil resistivity and ground resistance.

7. Finite Element Method using COMSOL Multiphysic Software is used to model and simulate analysis of grounding system with coconut husk.

8. The duration for this experiment is 7 weeks for ground resistance data collection and 4 weeks to simulate and analyze the ground electrodes with coconut husk.

CHAPTER 2

LITERATURE REVIEW

2. 1 Grounding system

Grounding system is a vital parameter in electrical system as it ensures overall electrical system facility is protected. Grounding of electrical installation is primarily concerned with safety. Security of people is influenced by performance of grounding system. If sudden ground fault occurs at vicinity or generating substations, the personnel involved will not exposed to critical electric shock when grounding system performance is good. Good grounding system has capability in limiting step and touch voltages to safe value. Not only that, grounding system will ensure equipment and electrical protection devices are operating correctly, capable to provide protection of building and insulation against lightning and providing good power quality and continuity of electrical equipment under extreme operation situations [7]. A good grounding system must able to provide low ground resistance path to channel fault current directly into the earth [6]. The resistance of the ground electrode itself must be lower compared to resistance of main circuit connection as current will flow through path with lowest resistanc

2.1. 1 Type of grounding system

According to Teo Cheng Yu [6], five types of grounding system can be categorized which are TT system, TN-S system, TN-C system, TN-C-S system and IT system. The first letter indicates an arrangement of earthing supply. Letter T abbreviated from French word Terre; which means earth, can be defined as the supply of one or more points directly connected to earth. Letter I represents impedance when supply system is not earthed or one of the supply points is earthed through fault-limiting impedance.

The second letter indicates an arrangement of earthing installation. Letter T represents earth is when connection of exposed conductive parts is directly to earth. Letter N indicates neutral is when exposed conductive parts are connected directly to neutral point of source supply. In this context, the exposed conductive parts means any metallic parts of electrical system that can be touched which is not live part but may become live under fault condition.

The third and fourth letter indicates the arrangement of earthing conductor. Letter S represent separate neutral and protective conductors while letter C represent combination of neutral and protective conductors in a single conductor. As shown in Figure 2.1, main type of grounding system used in residential area in Malaysia is TT system. TT network system has two earth electrode installations [5]. In TT system, the exposed-conductive-parts of the consumer’s installation are earthed through an installation earth electrode which is electrically independent of the source earth.

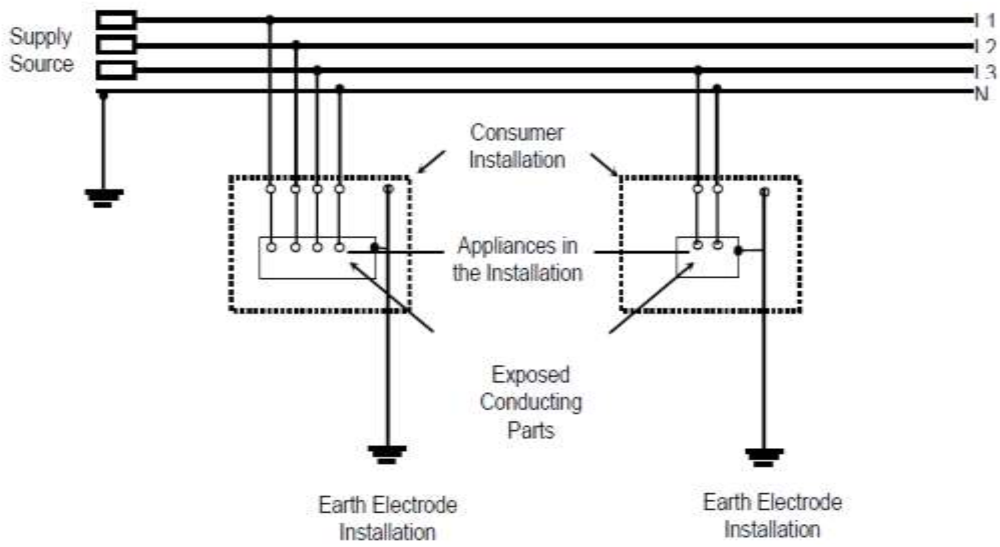


Figure 2. 1 Arrangement of TT network system [5]

2. 2 Grounding resistance

Ground resistance is one of major requirement for grounding system as ground resistance value determines the performance of grounding system. There are three components related to ground resistance which is resistance of electrode and connections to it, contact resistance between electrode and soil and resistance of soil surrounding the ground electrode. The characteristic and resistance of ground can be analyzed based on its structure, type of soil, soil resistivity, depth and type of buried ground electrode.

2.2. 1 Soil resistivity

. Soil resistivity represents the capability of volume of soil to carry electric current measured in ohm-meter [3]. In order to achieve and maintain low ground resistance value with minimum expenditure, knowledge of soil resistivity at particular site is very crucial. At different time of year, soil resistivity for different locations have different temperature, rainfall, dry spells and other seasonal variations. Soil resistivity varies depending on type of soil, temperature, moisture content, dissolved salt, porosity and conductivity.

The electricity flow in soil is largely electrolytic depending on transfer of ions dissolve in moisture. When moisture content increases, soil resistivity decreases. Furthermore, soil resistivity depends on type of soil. Table 2.1 shows different type of soil will have different soil resistivity value. Clay has soil resistivity range from 200 to 10,000 ohm-centimeters while sandstone has soil resistivity in a range of 2,000 to 200,000 ohm-centimeters. The moisture content in clay is higher compared to the moisture content in sandstone as the porosity and ionic content of pore fluid in soil is essential in governing resistivity. This causing soil resistivity for clay is lower compared to sandstone. Low soil resistivity will lead to low ground resistance value.

Table 2. 1 Soil resistivity depend on the type of soil [7]

Soil	Resistivity Ohm-cm (Range)
Surface soils, loam, etc.	100 – 5,000
Clay	200 – 10,000
Sand and gravel	5,000 - 100,000
Surface limestone	10,000 – 1,000,000
Shales	500 – 10,000
Sandstone	2,000 – 200,000
Granites, basalts, etc.	100,000
Decomposed gneisses	5,000 – 50,000
Slates, etc.	1,000 – 10,000

According to BS7430:2011, certain type of soil such as dry sand, gravel, chalk, limestone, whinstone, granite, any very stony ground and all locations where virgin rock is very close to surface is not the best location for grounding system. Moreover, the location of grounding system is ideally within the range of 15% to 20% of its moisture content. The location of grounding system where water flows over it such as bed of a stream should be avoided as beneficial salts from soil can entirely be removed by water flow [8]. Dissolved salts like sodium chloride, copper sulfate, and sodium carbonate contribute the crucial criterion to carry current. The resistivity will be lower when the amount of naturally occurring salts in the soil increases [7]. Table 2.2 shows that sandy loam soil with 15% moisture content has soil resistivity of 107 Ωm when no salt is added but the soil resistivity decreases to 99.07% when 20% of salt is added. This shows that when the soil is added with salt, the soil resistivity value decreases. The higher the content of salt in soil, the lower soil resistivity will be. Besides that, soil resistivity changes depending on variation of soil temperature. Temperature will affect the electronic and ionic conductivity of soil. When temperature of soil is low, the soil resistivity increases. Frozen ground will increase soil resistivity as freezing prohibit ionic. The soil resistivity continues to increase as temperatures go below freezing [7]. Therefore, the quantity of moisture content, mineral salt and temperature are parameters that influence the soil resistivity.

Table 2. 2 Soil resistivity value with different amount of salt [3]

For sandy loam, 15.0% moisture	
Salt content	Resistivity (Ωm)
No salt added	107
1.0% salt added	4.6
20.0% salt added	1

2.2. 2 Grounding electrode

Ground electrode can be defined as a metal conductor or other metal unit installed in the ground and electrically connected to it [5]. The electrode main purpose is to reach down into soil that is less exposed to moisture changes compared to the surface. When electrode reach down into soil, it will maintain ground resistance although there will be changes of season that might affect the temperature and moisture content of the soil. Long electrode is the most efficient as it increases surface contact with soil. The better the contact between soil and electrode, the lower the ground resistance value [9]. A vertical electrode is more effective compared to a horizontal electrode as current will be dissipated into soil at sufficient depth thus, reducing soil resistance [6]. Copper is usually used as ground electrode due to its high conductivity and high resistance to corrosion [16]. There are three types of copper rod commonly used in grounding system which is solid copper, copper clad steel rod and copper bonded steel core. Besides that, hot-galvanized steel, stainless steel, aluminum, copper-clad aluminum and lead also can be used as ground electrode. The shape of ground electrode may be in the form of rods, plates, strips, solid section wire or mats.

2. 3 Type of Grounding Electrode

There are three types of grounding electrode system which are single ground rod electrode, parallel ground rod electrode and grounding grid. The main purpose of grounding electrode is to channel fault current directly to the earth during faulty condition.

2.3. 1 Single Ground Rod Electrode

Single ground rod electrode is an electrode vertically driven into ground. Due to simple installation, vertical single ground electrode is always used in grounding system. The value of resistance for single ground rod electrode can be determined if soil resistivity is known. The resistance of single ground rod electrode can be determined from the following equation:

$$R = \frac{\rho}{2\pi L}[\left(\frac{8L}{d}\right) - 1] \tag{2.1}$$

From Equation 2.1, R represents the resistance of vertical electrode to earth (Ω), d is diameter of electrode in meters (m), ρ is soil resistivity in unit ohm meters (Ωm) and L represents electrode length in meter.

2.3. 2 Parallel Ground Rod Electrodes

When the used of single ground rod electrode does not achieved the desired ground resistance, parallel ground rod electrodes can be used. According to National Electrical Code, if a single electrode consisting of a rod, pipe, or plate that resistance to ground value is more than 25 ohms, an additional electrode must be installed at least 6 feet apart in parallel with the first electrode in order to reduce overall impedance of the system [5]. Multiple ground rod electrodes are placed if the ground resistance is not low enough to meet safety compliance. The resistance value for parallel ground rod electrode can be determined by the following equation:

$$R = \frac{\rho}{\pi L}[\ln(\frac{2L}{b}) - 1] \tag{2.2}$$

From equation 2.2, L is the length of buried electrode, ρ is the soil resistivity in ohm-meter (Ωm), b is the radius of electrode at the surface. The radius of electrode at surface can be expressed as:

$$b = (dhsS)^{0.25} \tag{2.3}$$

$$S = (4h_2 + s^2)^{0.5} \qquad (2.4)$$

Based on Equation 2.3, d is electrode's diameter in meter (m), h is buried depth of electrode in meter (m), s is distance between two parallel electrodes in meter (m) and S is distance from one electrode to the image of another electrode in meter.

2.3. 3 Grounding Grid

The major role of grounding grid is to ensure low earth potential rise (EPR) so that touch and step voltages is limited to safe value. Grounding grid also should be able to provide low resistance path to assist in absorption of lightning energy without creating unsafe condition [10]. Step voltage can be defined as voltage between two points that are one meter distant from each other on the earth's surface which is assumed to be the stride length of a person. Meanwhile, touch voltage can be defined as voltage between conductive parts when touched simultaneously and the voltage is influenced by impedance of person in electric contact with conductive parts [13]. Grounding grid is usually installed at one specific location such as substation.

2. 4 Measurement of Soil Resistivity

According to BS7430:2011, method used to measure soil resistivity is four probe method or Wenner method as shown in Figure 2.2. This method is developed in 1915 by Dr. Frank Wenner of U.S. Bureau of Standards [13]. The two outer pair of test electrodes is current spikes where current is injected into earth through one current spike and passed to another one. The two inner pair of test electrodes is voltage spikes. The voltage spikes are used to measure earth potential rise or the voltage of the two points due to the injected current [11]. Resistance R is taken as ratio between inner probe voltages and outer probe current which comply the Ohm's law (R=V/I). Resistance will be displayed directly by measuring instrument [8]. Soil resistivity can be calculated by following equation:

$$\rho = 2\pi a R \qquad (2.5)$$

From Equation 2.5, ρ is soil resistivity in unit Ωm, α is spacing between spikes in meters (m), π is constant 3.1416 and R is resistance reading from measurement instrument in unit Ω. Measurements of soil resistivity is conducted using the four probe method as follows [8]:

1) Four test spikes of equal distance is driven to a depth of less than 5% of spacing α to ensure that sphere of influence of each spikes do not overlap.
2) Current is injected between two outer current spikes.
3) The potential of earth is measured between the two inner voltage test spikes.

Wenner method is simple as entire test electrodes are placed with equal distances to each other and this test method is frequently used by the industry.

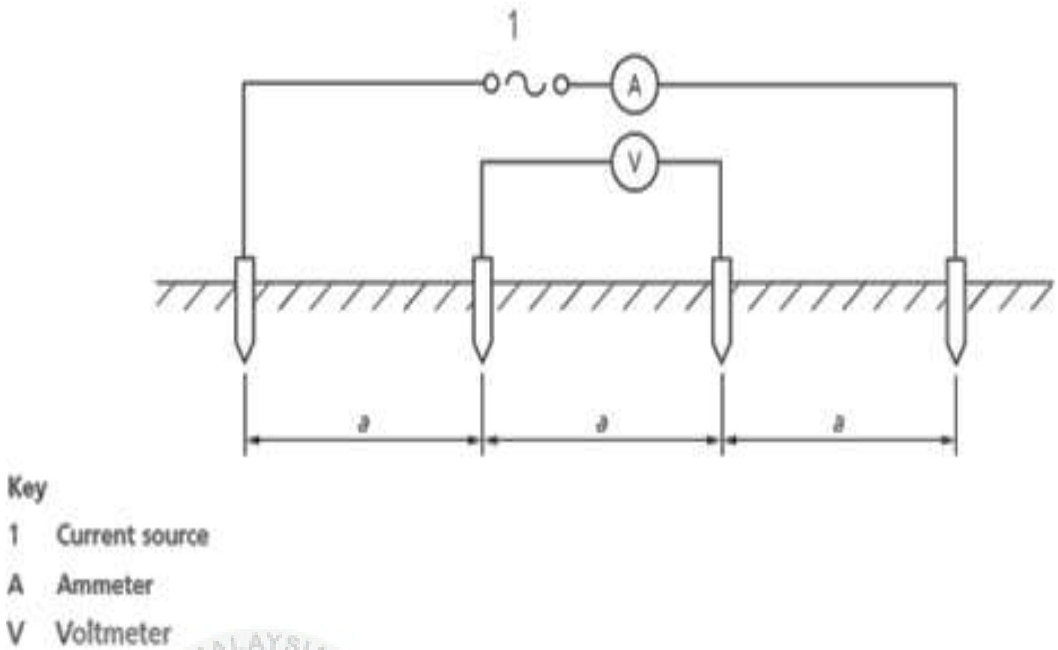


Figure 2. 2 Wenner four probe method configuration [2]

2. 5 Measurement of Ground Resistance

Fall of potential method was introduced by Dr. G.F. Tagg. It is one of method used to measure ground resistance [7]. Accurate result from fall of potential method will be obtained if test is conducted at a fairly uniform soil and the spacing between electrodes is large [1]. Figure 2.3 illustrates configuration of fall of potential method in order to measure ground resistance. From Figure 2.3, C represents current probe and P represents potential probe. Current source will be injected into current probe and the injected current will go down into grounding electrode. The potential probe is driven at certain distance and location between grounding electrode and current probe. While current is circulating, voltmeter will measure impedance at each potential probe location between grounding electrode and current probe. The impedance at that particular location of potential probe will become ratio between voltage difference and injected current. The impedance of potential probe is considered to be true ground impedance of system when potential probe location is at 61.8% of total distance between grounding electrode and current probe [12]. Fall of potential method will result an accurate ground resistance value if soil resistivity is uniform. Not only that, locating potential probe directly in straight line between grounding electrode and current probe during the measurement is taken will also give accurate ground resistance value.

By referring to BS 7430:2011, the first reading can be ensure accurate at 61.8% of total distance if the following procedure is tested:

1. Voltage probe is moved to 50% and 70% of total distance between the ground probe and current probe. Readings at that particular position is taken.
2. The first reading is considered as true value if these readings are within ±5% value from the 61.8% reading.
3. If the readings are not within the ±5% value from the first reading, the current probe shall be moved farther away.

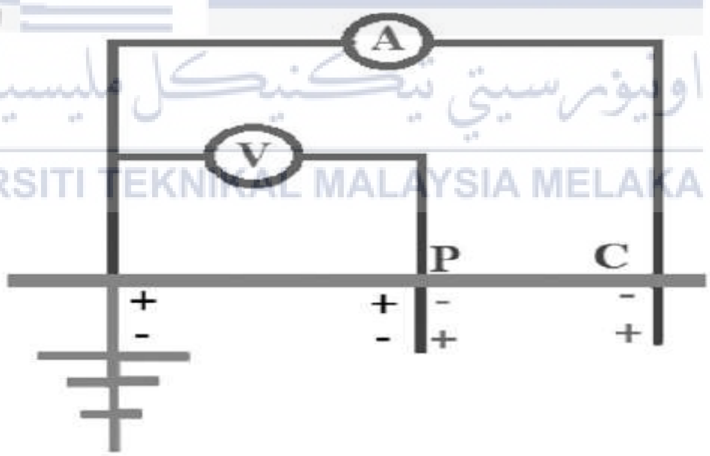


Figure 2. 3 Fall of potential method arrangement [1]

2. 6 Soil Treatment

According to standard BS7430:2011, soil treatment is one of method to improve soil resistivity and reduce ground resistance. Soil treatment method is used in high resistivity or rocky ground to improve ground electrode surface contact with soil. In grounding system, soil resistivity is the most important parameter to be considered. Additive materials are buried surrounding the electrode in order to increase water content in soil, hence improves soil resistivity and ground resistance. In soil treatment, ideal additive that modify the soil surrounding ground electrode must be non-corrosive, stable and will not undergo changes of characteristic gradually [9]. Counting on porosity of soil and rainfall amount, soil treatment method required gradual monitoring and replacement as the applied additives are continuously washed away by rainfall and natural drainage throughout the soil [7]. Leaching of the applied additives over time will reduce efficiency of soil treatment.

According to Nur Hanis Shuhada Binti Abu Hasim [13], bentonite can be used as backfill material to reduce soil resistivity and ground resistance value. The study is conducted by using different type of soil which is laterite soil and peat soil added with different weight of bentonite such as 50g, 150g and 250g to each soil. The ground resistance for laterite soil without added with bentonite is 3.27Ω and the ground resistance reduces to 3.98% when it is added with 50g coconut husk. The ground resistance for laterite soil undergoes further reduction by 14.08% and 13.15% when it is added with 150g and 250g of bentonite. Furthermore, the ground resistance for peat soil without added with bentonite is 5.21 **Ω** and the ground resistance reduces to 11.13% when added with 50g of bentonite,. When the peat soil is mixed with 150g and 250g bentonite, the ground resistance reduces to 9.4% and 11.71% respectively. The ground resistance for laterite soil without added with bentonite is lower compared to ground resistance for peat soil without added with bentonite. This is due to context of water holding capacity. Laterite soil has higher clay content than peat soil, thus it will affect ground resistance value.

Besides that, according to Ahmad Nurdin Ikhwan Bin Mohd Nor [14], coconut husk can be used to improve soil resistivity and reduce ground resistance. The study is conducted by using vertical copper electrode without addition of coconut husk, vertical galvanized (GI) steel electrode without addition of coconut husk and vertical galvanized (GI) steel electrode added with different coconut husk weight and configuration. The average ground resistance for GI steel electrode without added with coconut husk is lower compared to ground resistance for copper electrode without added with coconut husk. The GI steel electrode being used is hollow rod and its diameter is higher than copper electrode. Therefore, the total surface contact of GI steel electrode with soil is more compared to copper electrode. The average ground resistance for GI steel electrode when added with 1kg, 1.5kg and 2kg coconut husk is reduced to 37.27%, 26.4% and 65.82% respectively. Due to ability of coconut husk to hold and store water, the ground resistance decreases as the amount of coconut used increases. The average ground resistance for GI steel electrode added layer-by-layer with local soil is higher compared to ground resistance for GI steel electrode added with 2kg coconut husk. This shows that 2kg coconut husk at the upper hole is more affecting compared to 500g coconut husk at the upper hole in lowering the ground resistance.

Moreover, a study by Adee Zhafree Bin Ismail on rice straw ashes shows that when it is mixed with local soil, it gives better grounding performance. The experiment is conducted by measuring ground resistance for local soil, local soil mixed with rice straw ashes and local soil mixed with rice straw ashes and bentonite. The average ground resistance for local soil is 353.28Ω and when the soil is mixed with rice straw ashes, the ground resistance is reduced to 50.82%. The ground resistance is reduced since rice straw ashes are water absorbent polymer. It is a material in hydrophilic group and the presence of carbon in rice straw ashes contribute to better conductivity. This factor will lower the soil resistivity and thus lowering the ground resistance. When local soil is mixed with rice straw ashes and bentonite, ground resistance is further reduced to 67.17%. Bentonite has increases the rate of water holding capacity since bentonite has capability to retain and absorb available water into its structure thus, lowering soil resistivity. When the soil resistivity is lower, the ground resistance will also lower.

By using water absorbent polymer as an additive material in grounding system, the moisture content of soil surrounding the electrode can be retained. As the moisture content increases, the soil resistivity decreases thus will lead to lower ground resistance. Lower ground resistance value will reflect the performance of grounding system in dissipating fault current to earth. Table 2.3 shows the study of bentonite, coconut husk and rice straw ashes as additive materials in reducing soil resistivity and ground resistance value.

Table 2. 3 Previous study on soil treatment.

Item \ References	Nur Hanis Shuhada Binti Abu Hasim [13]	Ahmad Nurdin Ikhwan [14]	Adee Zhafree Bin Ismail [16]
Reference	Bentonite	Coconut husk	Rice straw ashes
Characteristic of additive material	Hold and draw available water and moisture into its structure.	Water absorbent polymer	Material that is in hydrophilic group.
Type of sample	Different quantity of bentonite which is 50g,150g and 250g is added.	GI steel with different quantity coconut husk of 1kg, 1.5kg, 2kg and coconut husk added layer-by-layer.	Local soil mixed with rice straw ashes and rice straw ashes with betonite.
Type of soil	Peat and laterite	Local	Local
Advantage of additive material	Able to lower soil resistivity and ground resistance.	Able to lower soil resistivity and ground resistance.	Able to lower soil resistivity and ground resistance.
Disadvantage of additive material	Bentonite shrunk due to hot and dry weather. Air gap is formed between soil and electrode, gives rise to soil resistivity	Leaching and migration of additive material over time reduces efficiency of soil treatment.	Leaching and migration of additive material over time reduces efficiency of soil treatment.

2. 7 Analysis using Finite Element Method (FEM)

Finite Element Method is used to obtain approximate solution of complex object and this method was developed in 1943 by R. Courant [18]. FEM is used in electrical engineering domain to find flux, potential and electric field distribution of objects. FEM allows approximation of complex equation with greater domain and estimation of partial equation solution that governs system behavior. FEM has been used in computing resistance for grounding grid by calculating grounding resistance of desired grid. To calculate current value, current flow analysis is used to determine grid current for grid potential set. Ground resistance is determined as quotient between voltages and calculated current. COMSOL Multiphysics software which is one of packages that work with FEM is used as a tool in grounding system design to determine the earth resistance. [17]. Three main matrices related to FEM are property matrix, the behavior matrix and action matrix.

$$\{K\}.\{u\} = \{F\} \tag{2. 6}$$

From Equation 2.6, {K} is property matrix that represents dielectric permittivity, {u} is behavior matrix representing electrical potential and {F} is action matrix representing electrical charge.

2.7.1 Laplace's Equation

Laplace Equation is a governing equation used for earthing system under design. The differential equation related to constant direct current is expressed as below:

$$\nabla . J = 0 \quad (2.\ 7)$$

From Equation 2.7, J is current density. Ohm's law at a point can be defined as

$$J = \sigma E \quad (2.\ 8)$$

From Equation 2.8, E is electric field and σ is the material's electrical conductivity.

$$E = -\nabla . V \quad (2.\ 9)$$

From Equation 2.9, V is electrical potential.

$$\sigma \nabla . V = E \quad (2.\ 10)$$

$$\sigma \nabla . (\nabla . V) = 0 \quad (2.\ 11)$$

Finally, the Laplace equation is

$$\nabla^2 V = 0 \quad (2.\ 12)$$

2.7.2 Finite Element in Grounding

According to a study conducted by Sajad et al [17], Finite Element Method (FEM) is used in grounding system to determine ground resistance. The grounding design takes account temperature and moisture behavior into soil resistivity. The design is divided into two parts which is electrode design and soil design. Each part is assigned with their designated criteria, parameters and constraints. COMSOL Multiphysic software is used to solve FEM and it is provided with built-in drawing toolbox to simulate the model. To start designing process, a space dimension is determined which is 3D space. Then, electrode radius, electrode length, soil radius and soil length is set. Concept of FEM is used to solve resistance of the model which consists of soil, electrode and contact resistance between soil and electrode.

For electrode design, the electrode is modeled as a cylindrical shaped element driven vertically into soil. The electrode's radius, length, conductivity or resistivity is determined based on designated criteria. For soil design, it is modeled as a cylindrical element surrounding the electrode with radius, length or height of electrode driven vertically into center of soil. In grounding system, soil is considered as a conductive medium and is assumed to be uniform with constant resistivity or conductivity. Governing equation for grounding system under design is solved by Laplace equation written as Equation 2.13.

$$-\nabla(\sigma\nabla V - J^e) = Q_j \qquad (2.13)$$

From Equation 2.13, V represents electrical potential, σ represents electrical conductivity, J^e represent external current density and Q_j represent current source density.

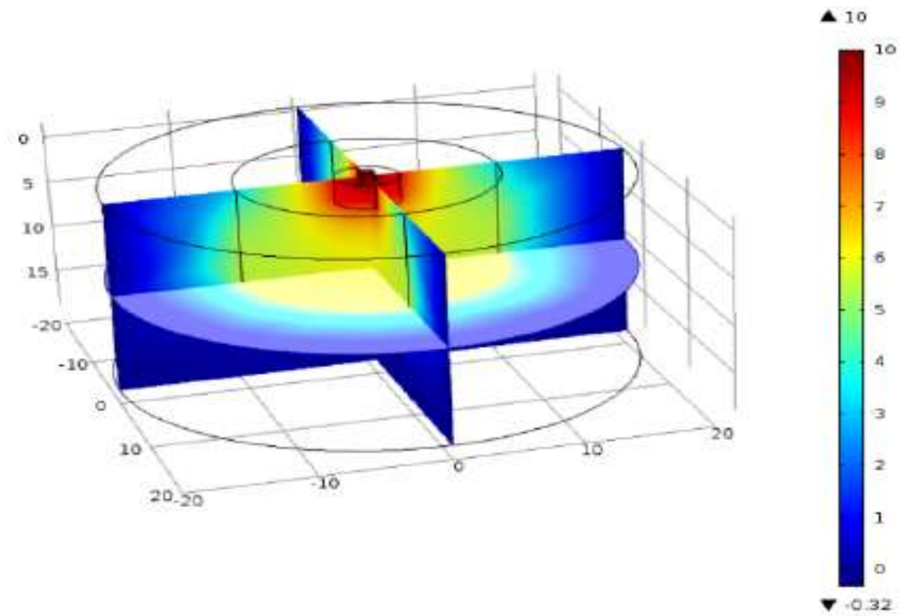


Figure 2. 4 Potential distributions on soil surface [17]

When the equation is solved, potential distribution on soil surface can be seen surrounding the model. Figure 2.5 illustrates the potential distribution on soil surface of copper plate with a depth of 0.5 meters. The potential distribution is the strongest at the copper plate. The potential distribution will becomes weaker as it is distributed farther away from the copper plate.

2. 8 Summary of studies

In grounding system, low ground resistance value is essential to ensure safety of overall electrical system. Lowest value of ground resistance need to be achieved to ensure fault current can flows directly to ground. There are few factors that influence the ground resistance value which are type of rod installations, soil resistivity, size and shape of earth electrode. Soil resistivity is primary parameter that affects the ground resistance value. Lower soil resistivity will lead to lower ground resistance value. The soil resistivity is dependent on type soil, temperature, dissolved salt and moisture content. Moisture content plays an important role in soil resistivity as higher moisture content will result in lower soil resistivity. The earth electrode must be driven at sufficient depth to reach moisture part in deep soil. However, driven ground electrode deeper into the rocky soil will cause cost issue. Therefore, an alternative method to reduce soil resistivity and ground resistance is by implementing soil treatment method with additive material. This additive material is a water absorbent polymer that capable to absorb and retain water surrounding the electrode. Next, the grounding system can be modeled using Finite Element Method (FEM) to observe the performance of grounding system. FEM has the capability to combine simple element equation into small subdomains. COMSOL Multiphysic software is used to work with FEM and solve the partial differential equation that governs the system behavior by using Laplace equation. As a result, the potential distribution of electrode can be observed.

CHAPTER 3

METHODOLOGY

3. 1 Experimental Procedure

This project is divided into two parts which is hardware part and simulation part. In hardware part, the type of ground electrode installation at the site is vertical ground electrode and material used for soil enhancement is coconut husk. The ground resistance for 6 different types of ground electrode installations are measured and taken. This 6 different type of installation is vertical copper rod electrode, vertical galvanized (GI) steel rod electrode without coconut husk addition and vertical galvanized steel rod electrode added with different coconut husk of installation. The different type of coconut husk installation is galvanized (GI) steel rod electrode added with different weight of coconut husk which is 1kg, 1.5kg, 2kg and GI steel rod electrode added with coconut husk layer-by-layer with local soil. The test instrument that is used to do the measurement is Earth Ground Tester Fluke 1623. Weather condition is taken as consideration as weather influence the value of resistance obtained. When the result is obtained and collected, the data is tabulated for further analysis and discussion on the performance of coconut husk.

Next, in the simulation part, the ground electrodes with 6 different types of installations are modeled and simulated using Finite Element Method (FEM). COMSOL Multiphysics; which is one of the packages that work with FEM is used as a tool to model and simulate analysis of the grounding. The ground resistance and electrical field distribution computed and simulated is analyzed and discussed. Figure 3.1 shows the flowchart of procedure for this project.

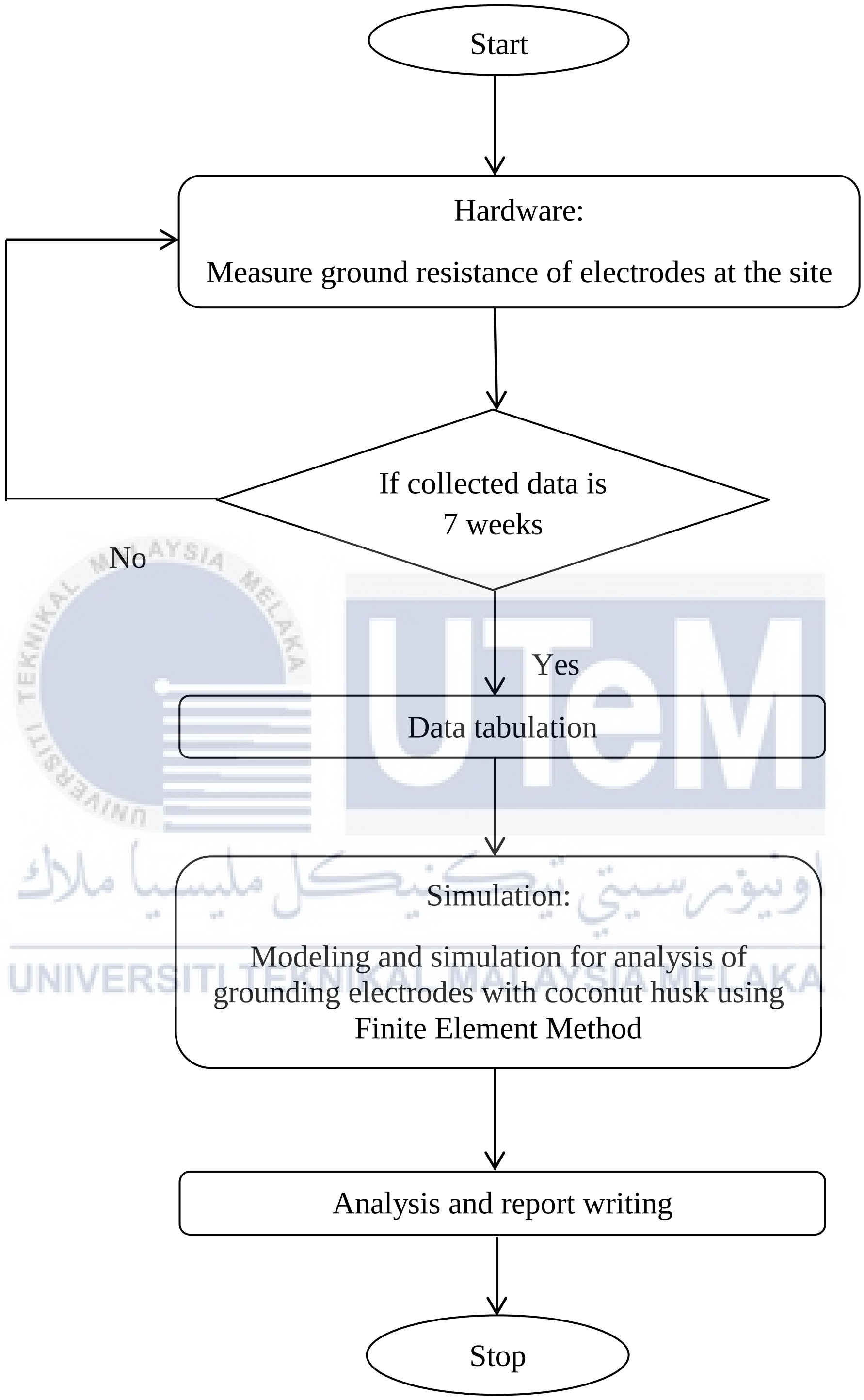


Figure 3. 1 Flowchart of project's procedure.

3. 2 Three-Point Ground Resistance Measurement

According to standard BS7430:2011, test method that is used in three-point ground resistance measurement is fall of potential method 61.8%. In order to carry out this test, distance A which represents distance between ground electrode and current test spike is set to be 12 meters. Meanwhile, distance B which represents distance between ground electrode and potential test spike is set to be 7.4 meters. Distance B is set to be 7.4 meters resulting from 61.8% of distance between the ground electrode and current test spike. Figure 3.2 illustrates the arrangement fall of potential using Digital Earth Tester (DET) Fluke 1623. The earth electrode represents ground electrode, the inner stake represents potential test spike and the outer stake represents current test spike. In order to measure ground resistance, all test spikes and ground electrode under test will be connected to DET terminal as illustrated in Figure 3.3. The rotary selector switch on DET Fluke 1623 instrument is set to RA 3-Pole function. C1 is the connection for ground electrode under test, P2 is connection for potential test spike and C2 is connection for current test spike. After all the test spikes are connected to terminal, the start button will be pressed and released. The “active” symbol displayed on the screen indicate that the measurement is in progress. When the measurement is completed, a marking sign (✓) and first ground resistance reading is displayed on the screen.

Figure 3.4 shows the flowchart procedure to measure three-point ground resistance using fall of potential method. Next, in order to ensure the accuracy of first reading at distance B which is at 7.5 meters, the position of potential spike is changed to 6 meters and 8.4 meters from the ground electrode under test. The accuracy of the first reading at 7.4 meters can be verified if the reading at 6 meters and 8.4 meters are within 5% from the first reading. If the reading is not within 5% of the reading at 7.4 meters test, distance A need to be increased by moving the current test spike further away from ground electrode under test.

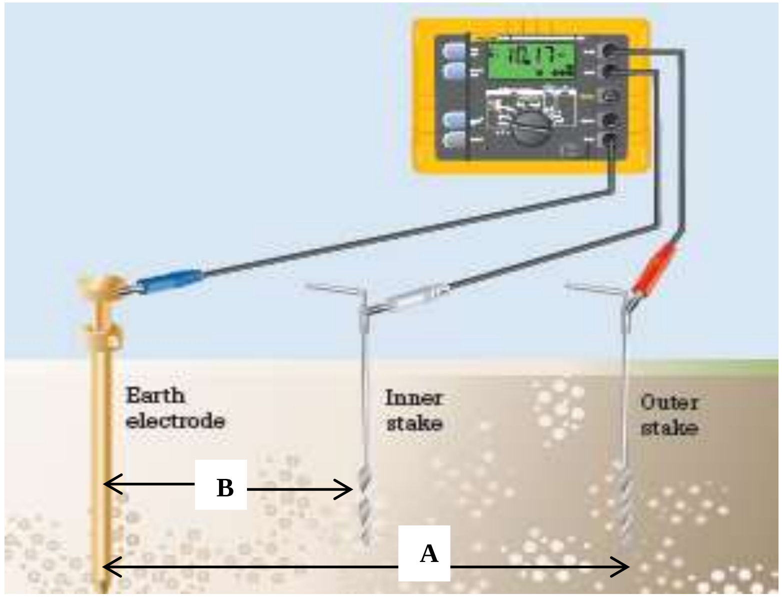


Figure 3. 2 Arrangement of Fall of Potential using Fluke 1623 [18]

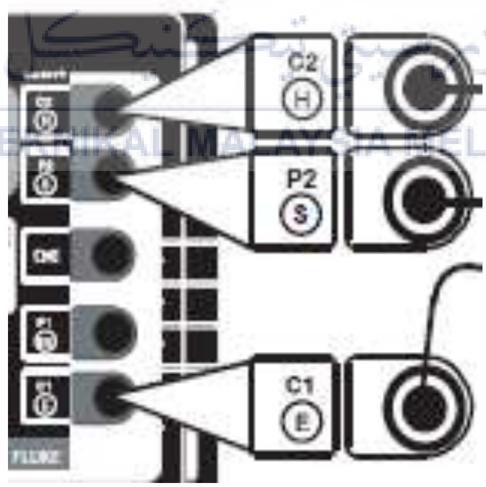


Figure 3. 3 DET terminal connection to test spikes and

ground electrode under test [18]

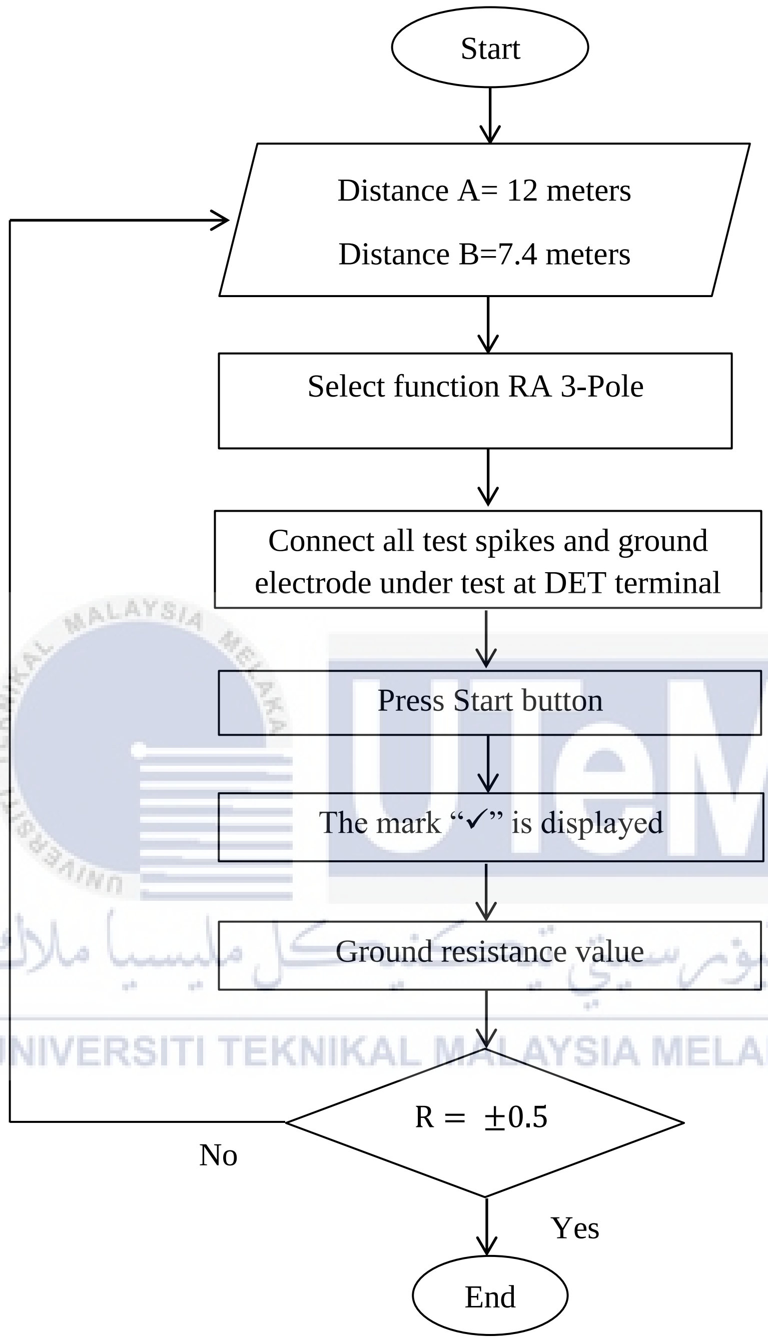


Figure 3. 4 Step to measure ground resistance using Fluke 1623 Earth/Ground Tester

3. 3 Type of ground electrode and installation.

Selection of good ground electrode is crucial as it is the most important part in grounding system. The ability of ground electrode to channel and dissipate the fault current directly into the earth will determine the performance of grounding system. According to Arfah Ahmad et al [15], copper is widely used as ground electrode in grounding system due to its high conductivity and resistance to corrosion. However, the value of copper in the market is high and has increased the number of thefts. To overcome this problem, a cheaper ground electrode such as galvanized steel (GI) can be used to replace copper in grounding system. In this project, copper electrode is used as reference grounding in order to compare ground resistance between copper electrode and galvanized steel electrode. Ground resistance influences the performance of grounding system as lower ground resistance will increase the grounding system performance.

Type of installation used in this project is vertical ground rod electrode driven vertically into ground. Figure 3.5 illustrates the arrangement of 6 ground rod electrode installation. The spacing of installation between each ground rod electrode is 3m. The depth and width for each ground electrode driven into the ground is 1m and 0.3m. Hole A is for vertical copper electrode and hole B is for galvanized steel electrode without coconut husk. Hole C is for galvanized steel electrode with 1 kg coconut husk. Hole D is galvanized steel electrode with 1.5 kg coconut husk. Hole E is for galvanized steel electrode with 2 kg coconut husk. Hole F is for galvanized steel electrode added with coconut husk layer-by-layer with local soil. There are four layer of coconut husk for this electrode system and each layer was added with 500g coconut husk.

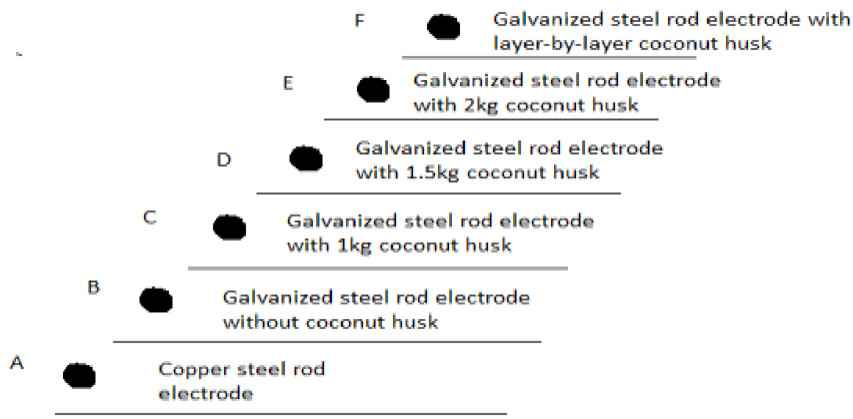


Figure 3. 5 Ground electrodes with different coconut husk configuration model design.

3. 4 Performance Analysis using Finite Element Method.

Finite Element Method (FEM) which is one of packages in COMSOL Multiphysic software is used to compute and analyze the performance of ground electrode. Ground electrode is modeled with exact consideration of materials characteristic, boundary condition, shape and size of the grid and soil structure. Soil structure is considered in details during the modeling procedure. Finite element modeling allows complex grounding system geometries. To investigate the performance of coconut husk as backfill material in grounding system, the ground resistance and electrical field distribution in the soil is studied. The analysis of Finite Element Method can be carried out by referring to Figure 3.6.

The ground electrode is designed based on the physical and mathematical specification such as height, diameter and radius. After that, boundary condition is set which will define the interface between model geometry and its surroundings. The terminal and ground boundary condition is set on the ground electrode model. Next, material properties is defined and assigned based on type of ground electrode, soil and additive material used. After selecting material properties, meshing process is done by selecting the predefined list such as extra coarse, normal and extra fine. Meshing is the most important operation in Finite Element Method as the accuracy of the result depends on the mesh size and orientation. After that, the design is computed and expression in global evaluation is selected. The selected expression is the parameter required to be evaluated such as resistance, current and voltage. In this scope, ground resistance is the required parameter to be evaluated. Post processing is where the result of the required parameter is displayed in various formats such as in value, table and graph.

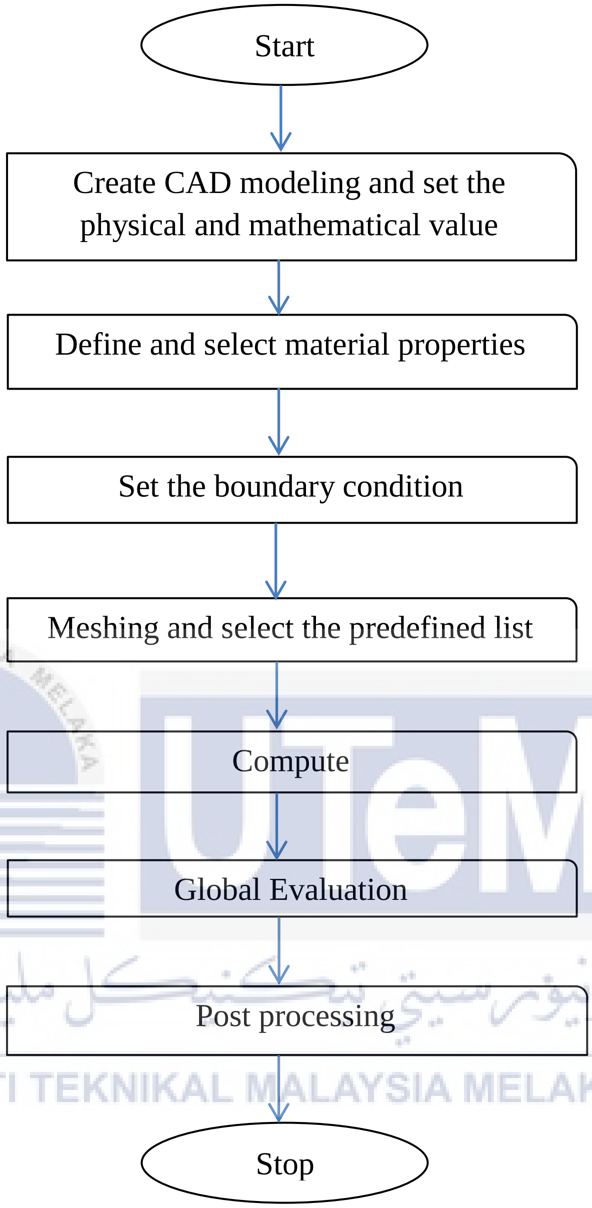


Figure 3. 6 Flowchart of procedure for ground electrode design planning

3. 5 Design Planning

The 6 different types of vertical ground electrode installations are modeled and simulated using COMSOL Multiphysic software. By using Finite Element Method (FEM) concept, the resistance and electrical field distribution of each model is obtained and computed. All the 6 different types of vertical ground electrode installations are modeled with constant soil resistivity which is set to 400Ωm.

3.5.1 Geometrical design and material properties

The ground electrode is designed as vertical cylindrical shaped element having radius and length. The copper electrode is set as solid rod having radius of 0.0075m. Galvanized (GI) steel electrode used is set as hollow rod having radius of 0.0115m. The length for both electrodes is 1m. The soil is designed as a rectangular shaped element having width and depth of 0.3m with height of 1.2m. At top of the soil, a rectangular shape element is designed representing air having same width and depth of the soil. The height of air is set to 0.1m. For GI steel electrode added with coconut husk, a rectangular shape element is designed representing coconut husk with same width and depth of soil. The height of coconut husk is set to 0.2m for 1kg coconut husk, 0.3m for 1.5kg coconut husk and 0.4m for 2kg coconut husk. Figure 3.7 illustrates the geometrical design for electrodes, soil and air added with 2kg coconut husk. For GI steel electrode added with coconut husk layer-by-layer with local soil, each layer of coconut husk is set to be 0.1m. Figure 3.8 illustrates the geometrical design for electrodes, soil and air added with coconut husk layer-by-layer with local soil. After designing the CAD geometry model, material properties is assigned for electrode, soil, coconut husk and air. The material properties can be selected from material library or by inserting the required material properties such as electrical conductivity and permittivity value. The electrical conductivity for GI steel electrode is set to 6.21×10^{6} S/m as GI steel material properties cannot be found in the material library. The conductivity of soil and coconut husk is set to 2.5×10^{-3}S/m and 51×10^{-3} S/m.

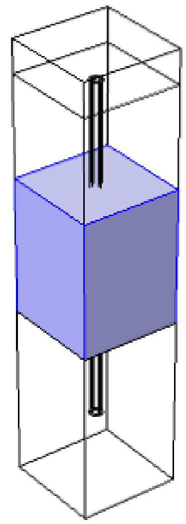


Figure 3. 7 Geometrical model of ground electrode added with 2kg coconut husk

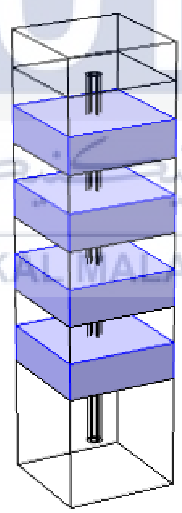


Figure 3. 8 Geometrical model of ground electrode added with coconut husk layer-by-layer

3.5.2 Boundary condition, meshing and global evaluation.

Boundary conditions used are meant to represent a connection to DC current source. After assigning material properties, one end of the electrode is grounded represent a current sink as shown in Figure 3.9. This is done by using Ground boundary condition. The other end of electrode is connected to a constant current source of 0.5A, using the Terminal boundary condition. Figure 3.10 illustrates the ground electrode is set to Terminal boundary condition. After that, meshing is applied on the CAD model. Meshing is an important part in simulation process to acquire accurate result. During meshing, CAD model is subdivided into small elements. True solution will be obtained when the elements are set to be smaller and smaller. Free tetrahedral is chosen as it is the simplex way in meshing any 3D geometry. Further refinement of the mesh size will increases the precision of the result computed. In this project, mesh sizes used for electrode is fine mesh while for the soil is normal mesh. Figure 3.11 shows the meshed CAD model and the electrode mesh size chosen is fine mesh. Next, the meshed CAD model is computed and default plot shows electric potential across the electrode. Figure 3.12 illustrates default plot of the CAD model with electric potential distribution. On the result toolbar, derived value is clicked and global evaluation is chosen in order to select the resistance expression. After the model is computed with the chosen expression, the resistance value is obtained.

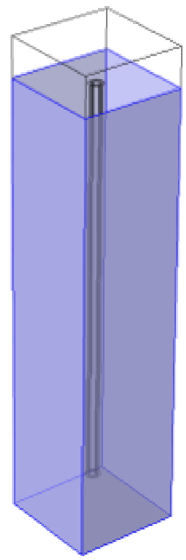


Figure 3. 9 Ground Boundary condition

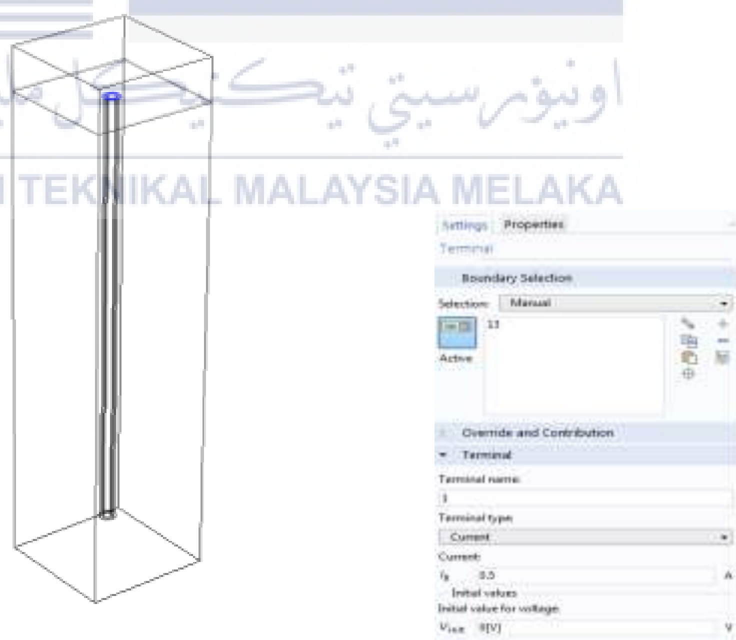


Figure 3. 10 Terminal Boundary condition

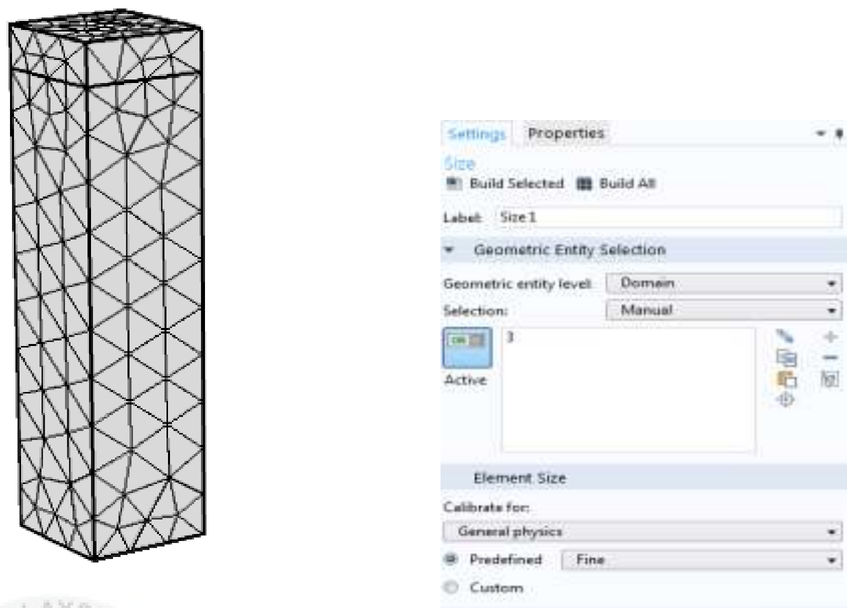


Figure 3. 11 Meshed CAD model and mesh setting for electrode

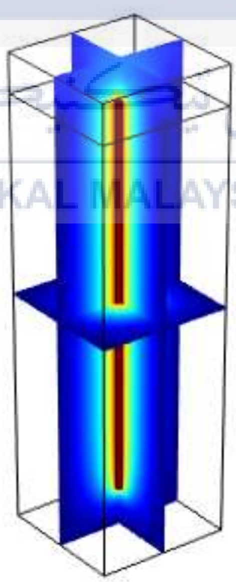
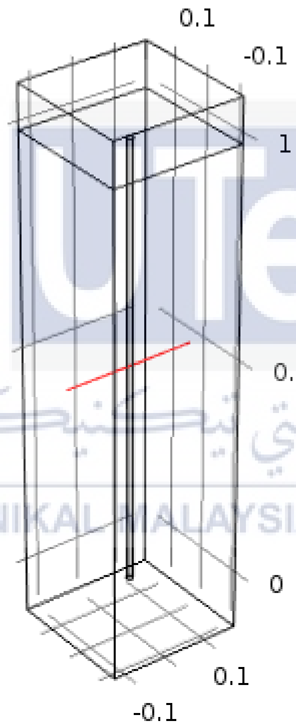


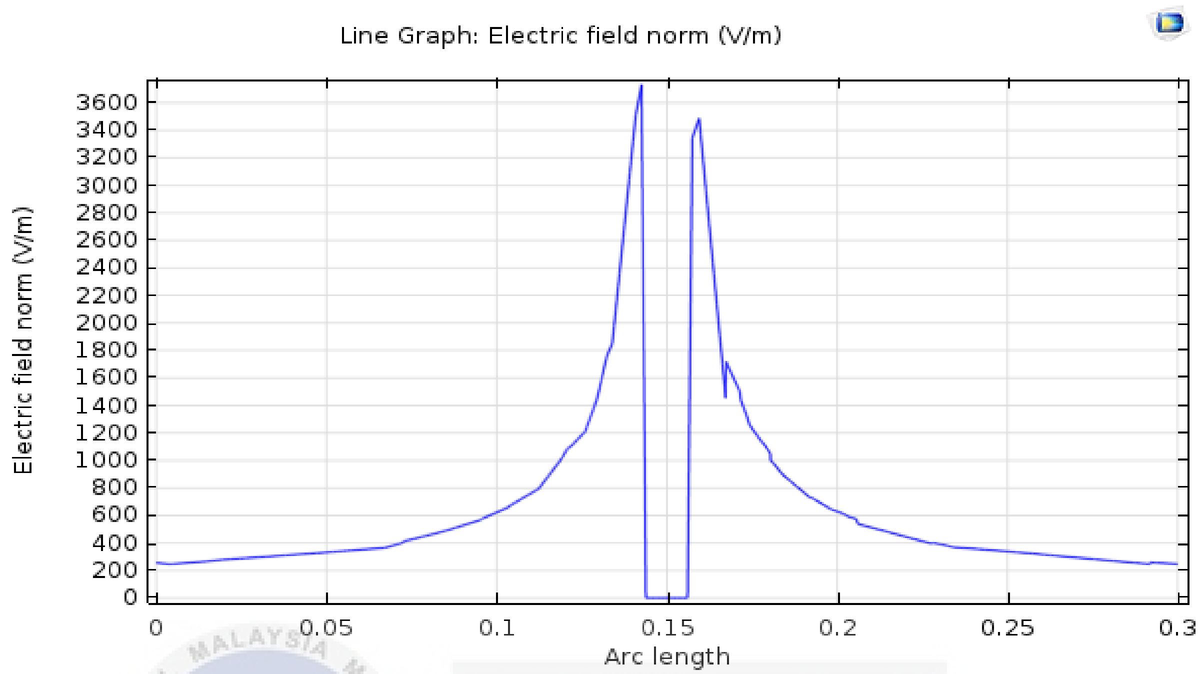
Figure 3. 12 Electric potential in the electrode region distributed to soil region.

3.5.3 Electric Field Distribution

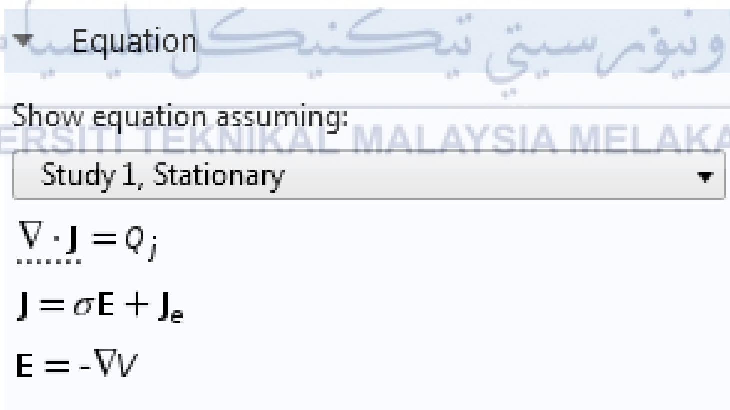
In order to obtain electric field distribution, Cut Line 3D on data set is fixed to be at the middle of the electrode and soil. Figure 3.10 shows CAD model with the specified Cut Line. On the result toolbar, 1D Plot Group is clicked and line graph is set as a way to show electric field distribution at the Cut Line region. Figure 3.11 shows the electric field distribution of the electrode. In this project, the governing equation used to solve the problem is Laplace equation as shown in Figure 3.14.



3.13 Position of cut line at the middle of electrode and soil



3.14 Electrical field distribution of electrode



3.15 Governing equation used in this project.

CHAPTER 4

RESULT AND DISCUSSION

4. 1 Introduction

This chapter discusses the result for ground resistance for different type of ground electrode, galvanized steel electrode with different coconut husk weight and galvanized steel electrode with different configuration of layer of coconut husk. The measurement is taken for a period of 7 weeks and the ground resistance is obtained through Fall of Potential method by using digital earth tester (DET) Fluke 1623. Next, each ground electrode is modeled and simulated by using COMSOL Multiphysic software, in order to obtain ground resistance and electrical field distribution in the soil respectively.

4. 2 Ground Resistance Value for Testing Site

The measurement of the ground resistance is conducted by using digital earth tester (DET) Fluke 1623 by implementing Fall of Potential method. Ground resistance for 6 different type of installations which are vertical copper electrode, vertical galvanized steel (GI) electrode without added with coconut husk, vertical GI steel electrode added with 1 kg coconut husk, vertical GI steel electrode added with 1.5kg coconut husk, vertical GI steel electrode added with 2kg coconut husk and GI steel electrode added with coconut husk layer-by-layer with local soil is taken.

4.2.1 Different Type of Ground Electrode and Ground Electrode with Enhancement Material

Copper is widely used in grounding system due to its high electrical conductivity and resistance to corrosion. However, for this project, the average ground resistance for copper is the highest which is 588.85Ω. Figure 4.1 shows the ground resistance for copper electrode is higher compared to galvanized steel (GI) electrode. This is because the GI steel electrode used is hollow rod and diameter of GI steel electrode is bigger than copper electrode. So, the total contact surface of GI steel electrode with soil is more compared to copper electrode, thus enabling the fault current to be dissipated easily to the earth. Compared to ground resistance of copper, the average ground resistance for GI steel electrode without coconut husk and average ground resistance for GI steel electrode added with 2kg coconut husk is reduced to 24.38% and 66.98% respectively. The ground resistance reduction by GI steel electrode added with 2 kg coconut husk shows the capability of the coconut husk in holding water and lowering the soil resistivity. Lower soil resistivity will lead to reduction of ground resistance. The lower the ground resistance, the easier fault current to be dissipated to earth hence, the better the performance of grounding system.

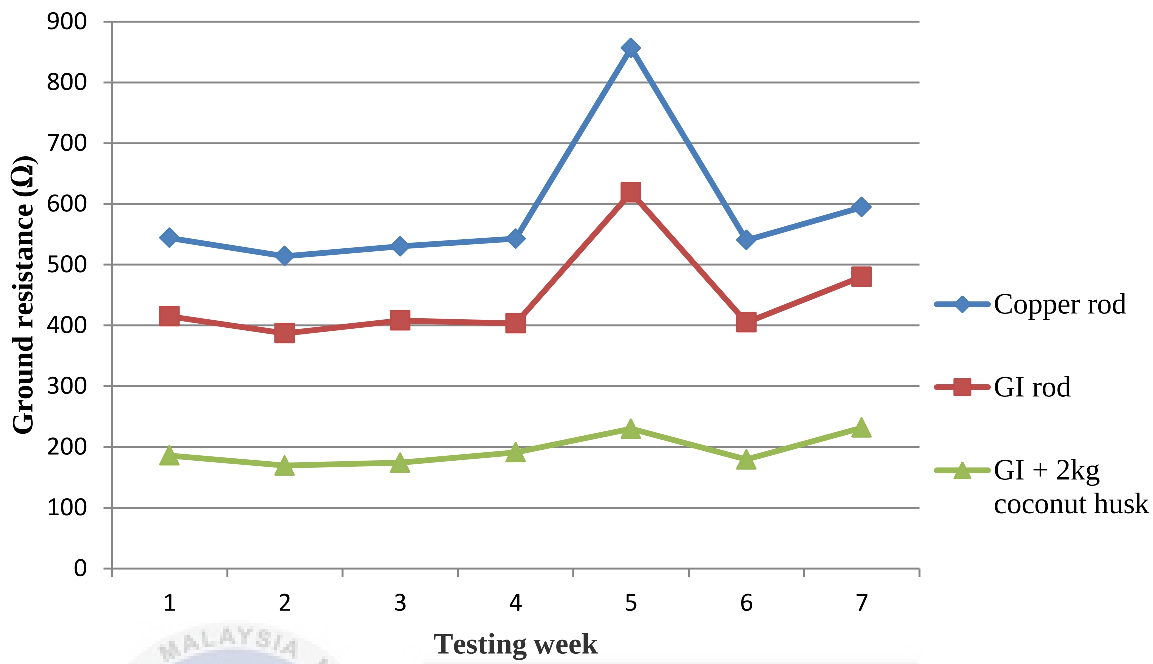


Figure 4. 1 Graph of ground resistance depending on type of electrode and electrode with enhancement material

4.2.2 Galvanized Steel Electrode with Different Weight of Coconut Husk

Coconut husk is a water absorbent polymer that has the capability to store and draw water into its structure. The moisture content of soil around the grounding system will increase when the coconut husk is buried around the grounding system. When the moisture content increases, the soil resistivity around the grounding system decreases and this will lead to ground resistance reduction. Figure 4.2 shows the line graph for ground resistance of galvanized steel (GI) with different weight of coconut husk. The average ground resistance for GI steel electrode is 445.29Ω and is reduced to 22.81% and 56.34% when added with 1 kg and 2 kg coconut husk. This is because different quantity of coconut husk will store different quantity of water. By increasing the coconut husk quantity, ground resistance will be reduced as the moisture content will increases.

However, the average ground resistance for GI steel electrode added with 1.5kg is the highest which is 462.76Ω. This might be due to the decay of the coconut husk and soil condition at the site where the electrode is buried. According to standard BS7430, ground resistance is affected by type of soil. The area where the GI steel electrode added with 1.5kg coconut husk is buried might contain hard rock that increases the soil resistivity.

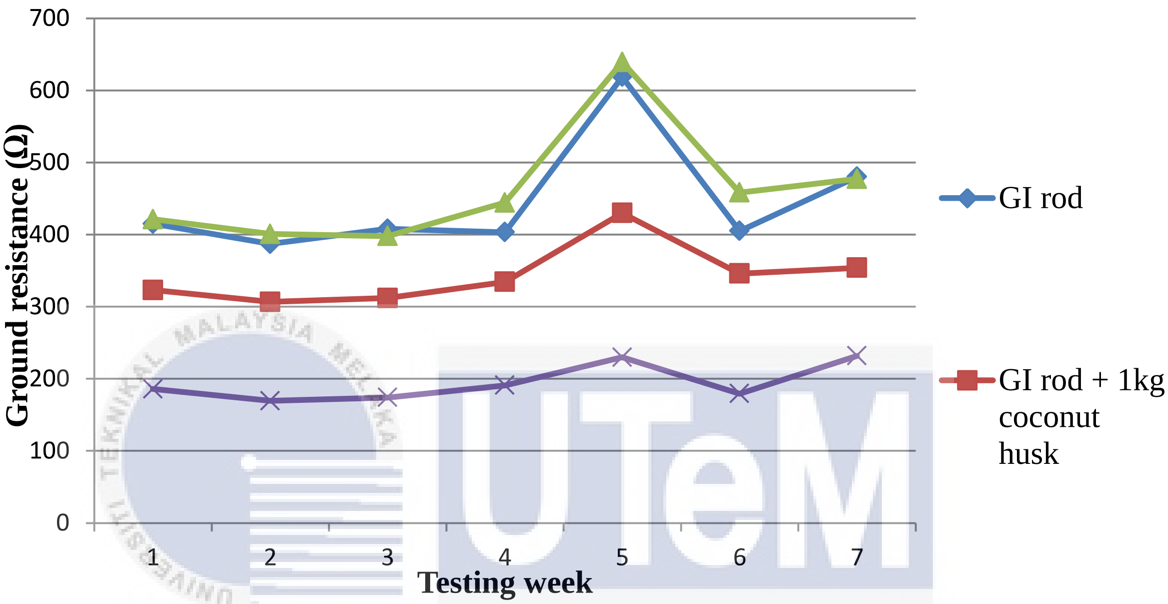


Figure 4. 2 Graph of ground resistance depend on different weight of coconut husk.

4.2.3 Galvanized Steel Electrode with Different Configuration of Layer

There are two configurations of layer in this project which are 2kg coconut husk added at the upper hole of GI steel electrode and 2kg coconut husk added layer-by-layer with the local soil. The ground resistance for GI steel electrode added with coconut husk layer-by-layer with the soil is higher compared to GI steel electrode added with 2kg coconut husk. The average ground resistance for GI steel electrode added with coconut husk layer-by-layer is 276.04Ω. The average ground resistance for GI steel electrode added with 2kg coconut husk is reduced to 29.57% of average ground resistance for GI steel electrode added with coconut husk layer-by-layer. This is because there is a different amount of coconut husk quantity at the upper hole of the GI steel electrode which is 2kg coconut husk and 500g coconut husk. Higher quantity of coconut husk will contribute in lowering the ground resistance due to higher moisture content. Hence, it can be said that 2kg coconut husk is more affected than 500g coconut husk in providing lower ground resistance.

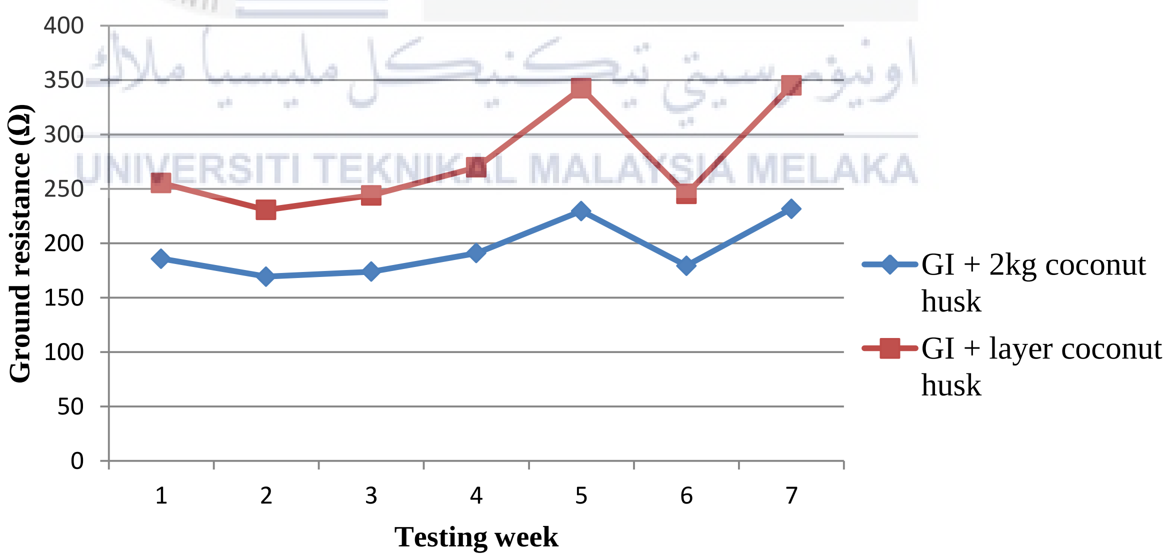


Figure 4. 3 Graph of ground resistance depends on different configuration of coconut husk.

4.2.4 Comparison with previous measurement

The average ground resistance measured 2 months after the ground electrodes are installed at the testing site is lower compared to average ground resistance measured 10 months after the installation. This is because the capability of the coconut husk to absorb water is higher when it is newly installed. Newly installed coconut husks do not undergo significant decay properties and is more effective in absorbing the water. The average ground resistance for GI steel electrode added with 1 kg, 1.5 kg and 2.5 kg coconut husk after 2 months of installations are 343.71Ω, 462.76Ω and 194.41Ω. After 10 months of installation, the average ground resistance for GI steel electrode added with 1 kg, 1.5 kg and 2.5 kg coconut husk increases to 16.35%, 27.17% and 19.41%. Ground resistance for GI steel electrode added with coconut husk layer-by-layer with the soil also increases from 258.26Ω to 276.04Ω. This is because coconut husk is a biodegradable polymer that undergoes decay process. As the decay process prolong, the quantity of coconut husk is reduced and water quantity absorbed by coconut husk also will be lower. Lower water quantity means higher soil resistivity that lead to higher ground resistance. This will reduces the effectiveness of the coconut husk as an enhancement material for the soil.

Furthermore, the average ground resistance for copper electrode and GI steel electrode after 2 months of installations is 771.19Ω and 458.02Ω. However, after 10 months of installations, the average ground resistance for copper electrode and GI steel electrode decreases to 23.64% and 2.78%. This is because the copper electrode and GI steel electrode has becoming more effective in lowering the ground resistance. After 2 months of installations, the soil has air gap and still loose in gripping the copper electrode and GI steel electrode. Therefore, the surface contact between soil and electrodes will reduces. The surface contact of soil has increases after 10 months of installations due to the soil has become more compacted and tightly packed with the driven electrodes. When the surface contact of the electrodes with the soil increases, the ground resistance will be decreases.

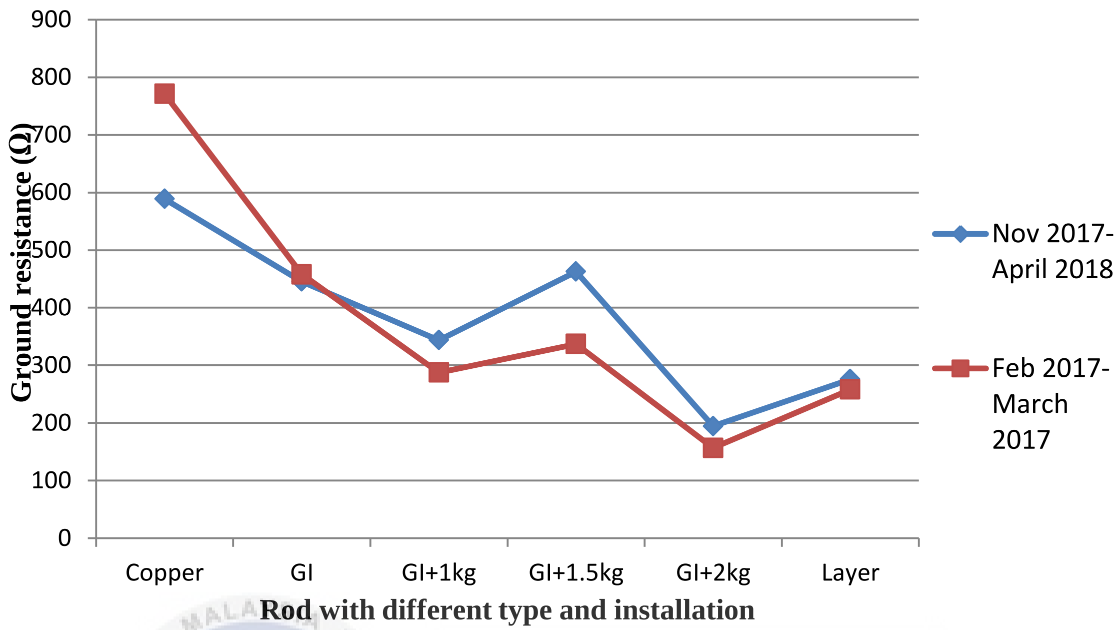


Figure 4. 4 Comparison with previous measurement

4.3 Modeling and Simulation of Ground Electrodes.

Modeling is one of inexpensive way in gaining knowledge of a system. The 6 different types of installation of ground electrodes are modeled using COMSOL Multiphysics software. By using this software, finite element method is used in order to determine the ground resistance values and electrical field distributions for each type of installation.

4.3.1 Ground resistance from simulation

Applying a voltage difference to a conductor creates a current flow and the intensity of current is usually a function of the applied voltage difference. The current flow and the voltage difference are proportional while resistance is the proportionality constant of conductor. The ground resistance is obtained as quotient between the voltage and current calculated.

Table 4.1 shows the ground resistance computed by using Finite Element Method (FEM) through COMSOL Multiphysic software. The ground resistance for copper electrode is 191.24Ω and the ground resistance decreases to 33.31% for GI steel electrode without coconut husk. The reduction is due to GI steel electrode used is a hollow rod with bigger diameter compared to copper rod. This contributes to a higher surface contact between GI steel electrode and soil. High surface contact will lower the ground resistance as current will be dissipated easier to soil. Meanwhile, ground resistance for GI steel electrode added with 1kg coconut husk, GI steel electrode added with 1.5kg coconut husk and GI steel electrode added with 2 kg coconut husk is further decreases to 85.87%, 89.86% and 92.1%. The ground resistance decreases as the quantity of coconut husk increases. This proves the effectiveness of coconut husk in lowering the ground resistance. However, ground resistance between GI steel electrode added with 2kg coconut husk and GI steel electrode added with coconut husk layer-by-layer with soil is almost the same with small difference of 0.036%. This shows that different configuration of coconut husk layer does not affect the ground resistance computed as long as the quantity of coconut husk is still the same. Through this simulation, it can be seen that ground resistance decreases when coconut husk is applied to GI electrode. This shows the capability of coconut husk in lowering the ground resistance and thus, leading to grounding system improvement.

Table 4. 1 Ground resistance from simulation

Rod	Ground Resistance (Ω)
Copper electrode	191.24
GI steel electrode without added coconut husk	127.53
GI steel electrode added with 1kg coconut husk	27.03
GI steel electrode added with 1.5 kg coconut husk	19.39
GI steel electrode added with 2kg coconut husk	15.11
GI steel electrode added with coconut husk layer-by-layer with soil.	15.1

4.3.2 Electrical Field Distribution

In a conductor, current density is proportional to electric field. When current flows through grounding electrode to ground, a voltage is induced. The potential distribution will occur between the grounding electrode and ground. As a result, electrical field distribution will be created as result from electric charges. When the grounding electrode is grounded, its potential will become the same as the potential of the ground which is zero. The charges from the electrode will flow to ground to make the electrode's potential zero.

4.3.3 Electric field for different type of ground electrode

Different type of ground electrode will have different magnitude of electric field. Based on Figure 4.5, the electric field for copper electrode is 3732 V/m. The electric field for galvanized (GI) steel electrode is reduced to 58.41% compared to electric field for copper electrode as shown in Figure 4.6. This is because electric field is influenced by ground resistance. Ground resistance for GI steel electrode is lower compared to ground resistance for copper electrode. The GI steel electrode used is a hollow rod with bigger diameter thus, the surface contact of GI steel electrode with soil is greater. Low ground resistance contributes to low magnitude of electric field distribution in soil. When ground resistance is lower, more current flows into soil and leave lower magnitude of electric field at GI steel electrode. Low electric field shows that current density in GI steel electrode is lesser compared to copper electrode.

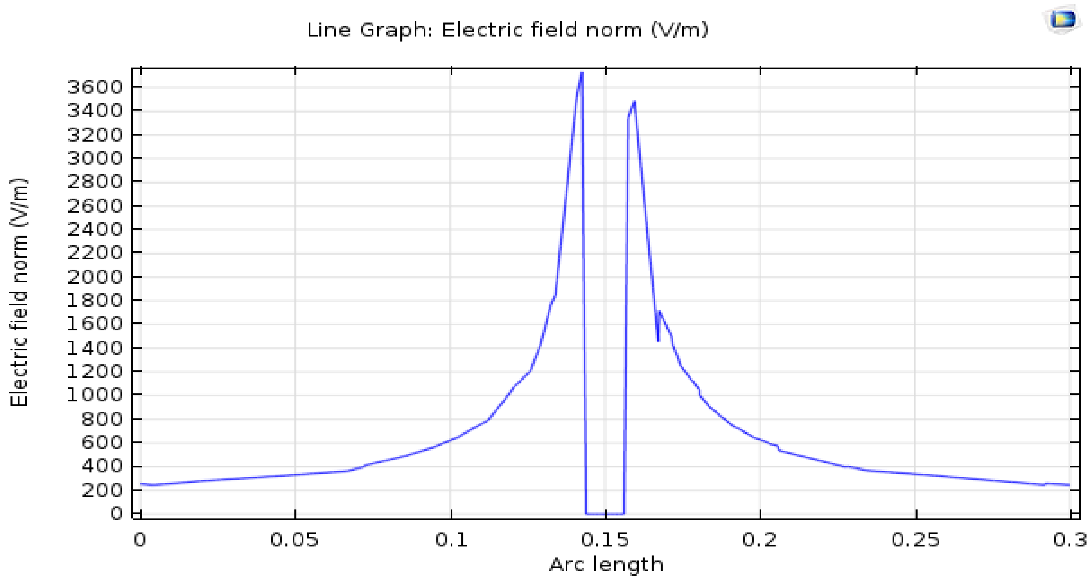


Figure 4. 5 Electric fields for copper electrode

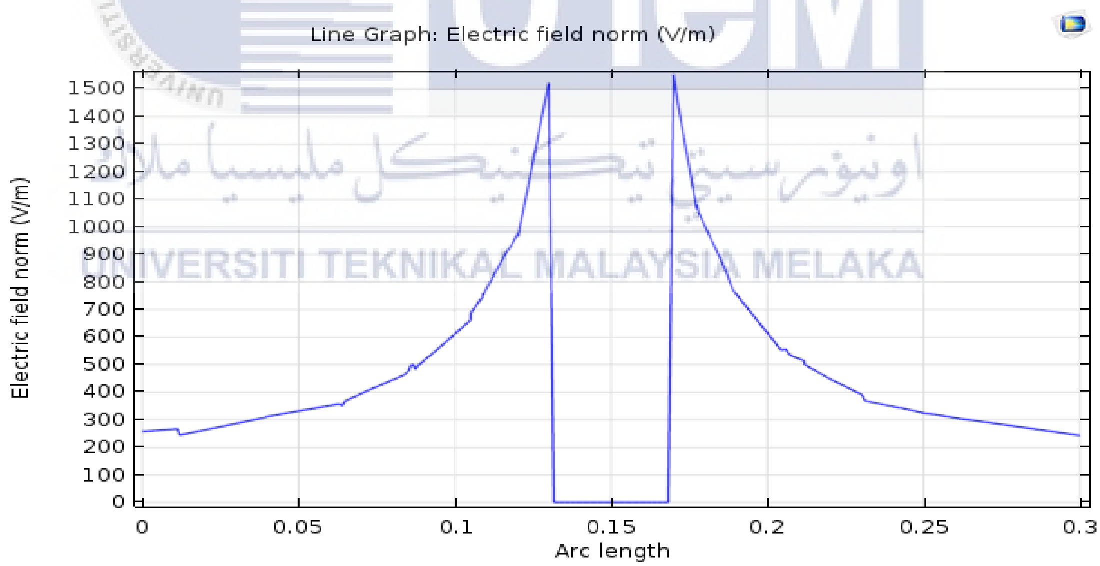


Figure 4. 6 Electric fields for GI steel electrode

4.3.4 Electric field for GI steel electrode added with different coconut husk weight.

In this project, coconut husk is used as soil treatment material in lowering soil resistivity. Lower soil resistivity will lead to lower ground resistance value. Based on Figure 4.7, the electric field for GI steel electrode added with 1kg coconut husk is 322.4 V/m. The magnitude of electric field for GI steel electrode added with 1.5kg coconut husk and magnitude of electric field for GI steel electrode added with 2kg coconut husk is reduced to 33.34% and 43.18% compared to magnitude of electric field for GI steel electrode added with 1kg coconut husk. Water content in soil increases when coconut husk used increases and this will lead to soil resistivity and ground resistance reduction. Electric field is influenced by ground resistance. When quantity of coconut husk used increases, the ground resistance is lower while magnitude of electric field decreases. Electric charges will be distributed more into ground since the ground resistance is low and leave low magnitude of electric field at GI steel electrode. Lower magnitude of electric field will result in lower current density at the electrode. Magnitude of electric field for GI steel electrode added with 2kg coconut husk is lower compared to magnitude of electric field for GI steel electrode added with 1kg coconut husk. Therefore, current density at GI steel electrode added with 2kg coconut husk also will be lower compared to current density at GI steel electrode added with 1kg coconut husk.

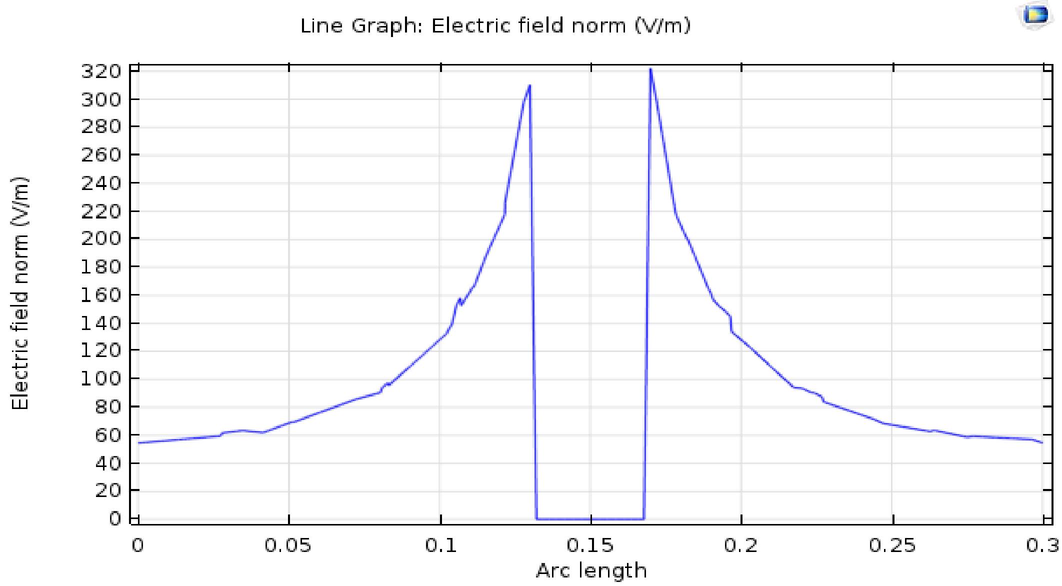


Figure 4. 7 Electric fields for GI steel electrode added with 1kg coconut husk

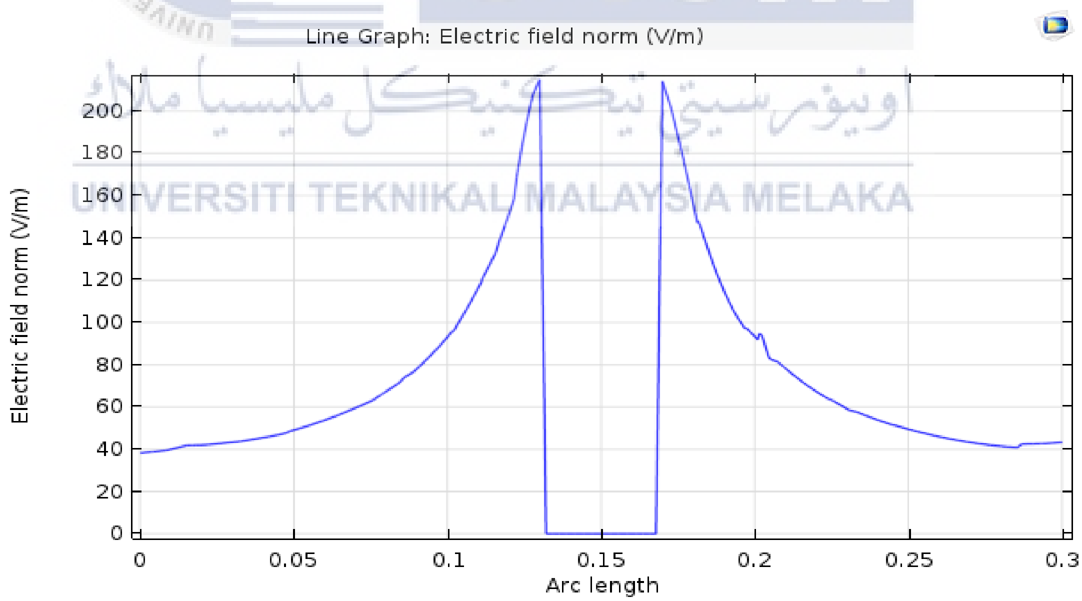


Figure 4. 8 Electric fields for GI steel electrode added with 1.5kg coconut husk

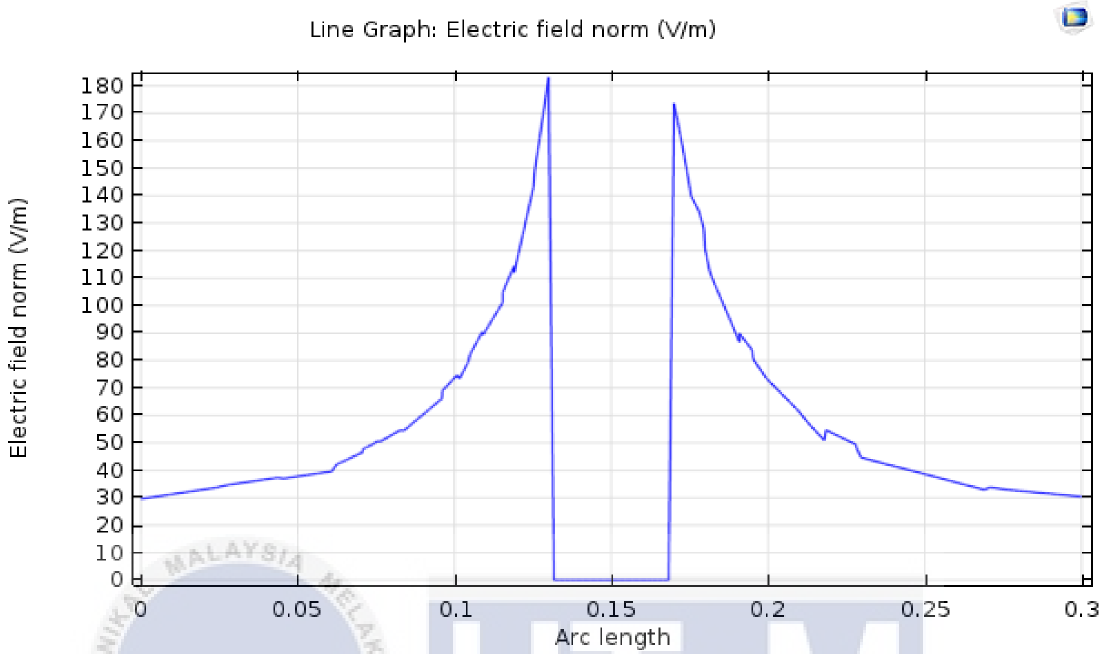


Figure 4. 9 Electric fields for GI steel electrode added with 2kg coconut husk.

4.3.5 Electric field for GI steel added with different coconut husk configuration of layer.

Galvanized (GI) steel electrode added with 2kg coconut husk and galvanized steel (GI) electrode added with coconut husk layer-by-layer with local soil is modeled and simulated. Magnitude of electric field for GI steel electrode added with 2kg coconut husk is higher about 2.18% compared to magnitude of electric field for GI steel electrode added with coconut husk layer-by-layer with soil. From simulation, the ground resistance for both configurations has small deviation to each other. Ground resistance for GI steel electrode added with 2kg coconut husk is higher about 0.06% compared to ground resistance for GI steel electrode added with coconut husk layer-by-layer with soil. Higher ground resistance will result in higher magnitude of electric field. Higher ground resistance will allow less current to be distributed into soil and higher magnitude of electric field will be leave at electrode. When higher magnitude of electric field present at the electrode, the current density also will be higher. The electric field and current density for GI steel electrode added with 2kg coconut husk is higher compared to GI steel electrode added with coconut husk layer-by-layer.

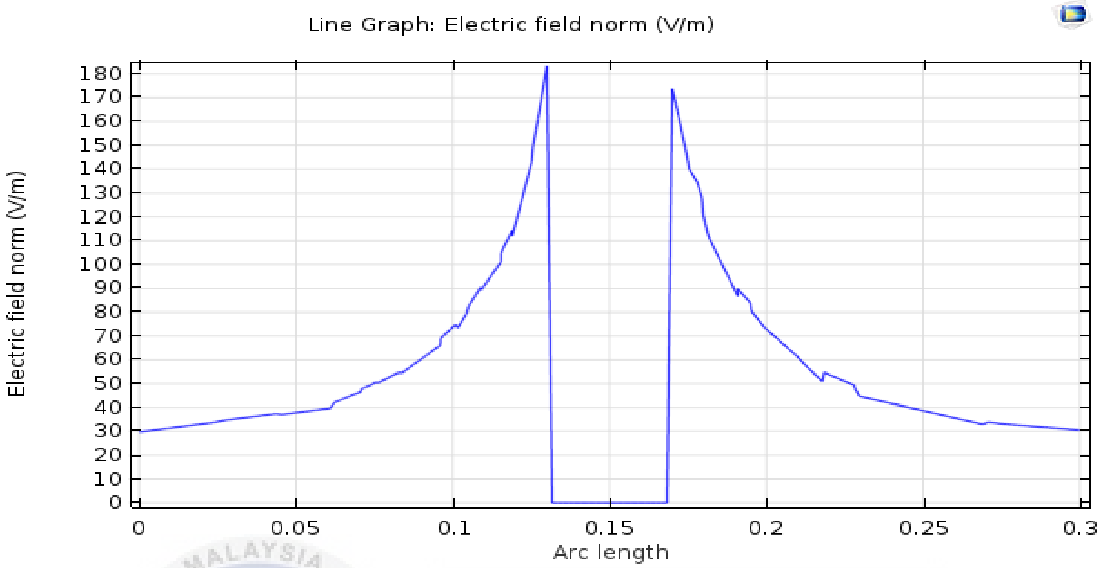


Figure 4. 10 Electrical fields for GI steel electrode added with 2kg coconut husk

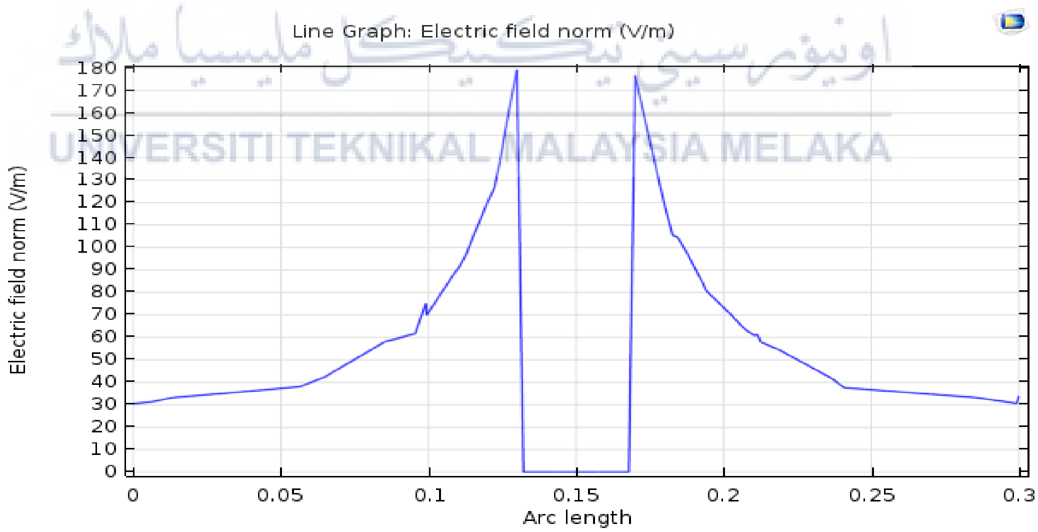


Figure 4. 11 Electrical fields for GI steel electrode added with coconut husk layer-by-layer with soil

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Low ground resistance value is important to ensure performance of grounding system. Soil treatment method is used to improve soil resistivity by implementing additive material. Coconut husk is an additive material that has capability to absorb and store water into its structure. When water content increases, soil resistivity will be lower hence lowering the ground resistance. Besides that, the performance for galvanized steel electrode added with coconut husk is compared with copper electrode in term of their ground resistance. The average ground resistance for galvanized steel electrode added with 2 kg coconut husk is lower by 66.98% compared to average ground resistance for copper electrode. This is because the presence of coconut husk has lowered the soil resistivity thus lead to lower ground resistance value. The magnitude of electric field for galvanized steel electrode added with 2kg coconut husk is lower compared to magnitude of electric field for copper electrode. The current is distributed more into soil due to low ground resistance and leave lower magnitude of electric field at the GI steel electrode. Furthermore, galvanized steel electrode added with 2 kg coconut husk has lower average ground resistance by 43.44% when compared to galvanized steel electrode added with 1kg coconut husk. The current density at GI steel electrode added with 2kg coconut husk is lower compared to current density at GI steel electrode added with 1kg coconut husk as more current is distributed into soil with lower ground resistance value. Therefore, the magnitude of electric field at the galvanized steel electrode added with 2kg coconut husk is lower compared to galvanized steel electrode added with 1kg coconut husk. The average ground resistance for GI steel electrode added with 2kg coconut husk is lower compared to average ground resistance for GI steel electrode added with coconut husk layer-by-layer. This is because 2kg coconut husk at upper hole of GI steel electrode is more affected in lowering ground resistance compared to 500g coconut husk. Besides that, ground resistance for galvanized steel electrode added with coconut husk measured after 2 months of installation is lower compared to ground resistance for galvanized steel electrode added with coconut husk measured after 10 months of installation. The coconut husk might undergo leaching and decay process. This will reduce the efficiency of coconut husk as additive material in soil treatment. From both measurement and simulation, it shows that coconut husk can be used as enhancement material to soil in lowering ground resistance. Therefore, galvanized steel electrode added with additive material has the potential to replace copper electrode in grounding system.

5.2 Recommendation

From this research, continuous study needs to be done in order to investigate the long term effect of coconut husk towards local soil composition. The corrosion rate for galvanized steel electrode also needs to be considered. Copper electrode can last for about 20 years due to its high resistance and corrosion properties. The galvanized steel electrode only can be last for about 2 to 3 years only. Additive material or chemical can be used with coconut husk in order to enhance the performance of coconut husk. This will maximize the performance of coconut husk and ensure its reliability in grounding system.

REFERENCES

NO TITLE

[1] Mohamad Nassereddine; Jamal Rizk; Ali Hellany; Mahmood Nagrial "Estimation of novel position for the current and potential probe for the fall of potential method." Published in IET Generation, Transmission & Distribution, ISSN 1751-8687, 2013.

[2] Mohamed Nayel, Boyang Lu, Yu Tian, Yingzhen Zhao "Study of Soil Resistivity Measurements in Vertical Two-Layer Soil Model." Department of Electric and Electronic Engineering, Xi'an Jiaotong-Liverpool University Suzhou, China, 2012.

[3] Marina Kizhlo, Arvids Kanbergs "Research of the Parameter Changes of the Grounding System" Department of Electrical Machines and Apparatus Riga Technical University, Institute of Power Engineering, Riga, Latvia 2009.

[4] Z.R.Radakovic and M.B.Kostic "Behaviour of grounding loop with bentonite during a ground fault at an overhead line tower." IEE Proc.-Gener. Transin. Distrib. Vol. 148, No. 4, July 2001.

[5] S.Tenaga, "Guidelines For Electrical Wiring In Residential Buildings," pp 1-55, 2008.

[6] Teo Cheng Yu "Principle and Design for Low Voltage System," ISBN 981-00-6041-6 Second Edition.

[7] Getting Down to Earth MeterCenter - 2046 W. Peninsula Circle, Chandler, AZ 85248.

[8] BS 7430:2011, "BS Standard Publication Code of practice for protective earthing of electrical installations," no.1. pp.1-98, 2011.

[9] Warren R. Jones "Bentonite Rods Assure Ground Rod Installation in problem soils," IEEE Transactions On Power Apparatus And Systems, vol. pas-99, No. 4 July/Aug 1980.

[10] M. Nassereddine, J. Rizk, A. Hellany, M. Nagrial, "Transmission Lines Design to Meet Community Requirements during constructions," 17th IEEE Mediterranean Electrotechnical Conference, Beirut, Lebanon, 31-16 April 2014.

[11] Huina Yang, Jiansheng Yuan,Wei Zong "Determination of Three-Layer Earth Model From Wenner Four-Probe Test Data." IEEE Transactions On Magnetics, Vol. 37, NO. 5, September 2001.

[12] Glenn Barton1 and Cynthia Furse2 "Calculating Grounding-Electrode Impedance Using Fall-of-Potential and Impedance Methods," IEEE Antennas and Propagation Magazine, Vol. 52, No.4, August 2010.

[13] N.H Shuhada "Grounding Enhancement Material using Bentonite," Bachelor of Engineering (Electrical) Universiti Teknologi Malaysia, Skudai, Johor, Malaysia, June 2016.

[14] A.N Ikhwan "Grounding Rod Design Evaluation fro Residential Usage," Bachelor of Electrical Engineering (Industrial Power), Universiti Teknikal Malaysia Melaka, Malaysia, 2017.

[15] Arfah Ahmad, and Suziana Ahmad " A Case Study on Ground Resistance Based on Copper Electrode vs. Galvanized Steel Electrode," Faculty of Electrical Engineering, Universiti Teknikal Malaysia Melaka, Malaysia, 2014.

[16] Adee Zhafree Bin Ismail "New Waste Material To Enhance The Performance Of Grounding System," Bachelor Of Engineering (Electrical) Universiti Teknologi Malaysia, Skudai, Johor, Malaysia, June 2011.

[17] Sajad Samadinasab, Farhad Namdari, Mohammad Bakhshipour "A Novel Approach for Earthing System Design Using Finite Element Method," IEEE Journal of Intelligent Procedures in Electrical Technology, 2016.

[18] Fluke Corporation "1623 Earth/Ground Tester Users Manual", USA, January 2006

APPENDIX

A. Result of Ground Resistance for Ground Electrodes System

Table 1: Ground resistance for copper electrode at testing site

Date	Temperature (°C)	Time	Ground Resistance value (Ω)		
			PP 50%	PP 61.8%	PP 70%
13/11/2017	30	10.30am	539	544	549
21/11/2017	28	11.45am	509	514	519
15/12/2017	29	10.00am	525	530	535
31/1/2018	27	10.30am	536	543	549
28/2/2018	32	2.30pm	849	857	863
7/3/2018	29	10.00am	536	540	545
27/4/2018	27	8.30am	589	599	596

Table 2: Ground resistance for galvanized steel electrode without added with coconut husk at testing site.

Date	Temperature (°C)	Time	Ground Resistance value (Ω)		
			PP 50%	PP 61.8%	PP 70%
13/11/2017	30	10.30am	410	415	420
21/11/2017	28	11.45am	382	387	392
15/12/2017	29	10.00am	403	408	413
31/1/2018	27	10.30am	397	404	409
28/2/2018	32	2.30pm	613	618	625
7/3/2018	29	10.00am	402	405	408
27/4/2018	27	8.30am	473	480	487

Table 3: Ground resistance for galvanized steel electrodes added with 1kg coconut husk at testing site

Date	Temperature (°C)	Time	Ground Resistance value (Ω)		
			PP 50%	PP 61.8%	PP 70%
13/11/2017	30	10.30am	318	323	328
21/11/2017	28	11.45am	302	307	311
15/12/2017	29	10.00am	307	312	317
31/1/2018	27	10.30am	329	335	339
28/2/2018	32	2.30pm	425	430	435
7/3/2018	29	10.00am	343	346	349
27/4/2018	27	8.30am	349	354	359

Table 4: Ground resistance for galvanized steel electrode added with 1.5kg coconut husk at testing site

Date	Temperature (℃)	Time	Ground Resistance value (Ω)		
			PP 50%	PP 61.8%	PP 70%
13/11/2017	30	10.30am	417	422	425
21/11/2017	28	11.45am	397	401	404
15/12/2017	29	10.00am	393	398	403
31/1/2018	27	10.30am	441	444	448
28/2/2018	32	2.30pm	636	638	644
7/3/2018	29	10.00am	456	458	461
27/4/2018	27	8.30am	473	478	481

Table 5: Ground resistance for galvanized steel electrode added with 2kg coconut husk at testing site

Date	Temperature (℃)	Time	Ground Resistance value (Ω)		
			PP 50%	PP 61.8%	PP 70%
13/11/2017	30	10.30am	184.1	186	187.4
21/11/2017	28	11.45am	168	170	170
15/12/2017	29	10.00am	169	174	179
31/1/2018	27	10.30am	188.9	191.4	192.8
28/2/2018	32	2.30pm	228	230	231
7/3/2018	29	10.00am	176	179	183
27/4/2018	27	8.30am	231	231	233

Table 6: Ground resistance for galvanized steel electrode added with coconut husk layer-by-layer with local soil at testing site

Date	Temperature (℃)	Time	Ground Resistance value (Ω)		
			PP 50%	PP 61.8%	PP 70%
13/11/2017	30	10.30am	253	255	258
21/11/2017	28	11.45am	228	231	233
15/12/2017	29	10.00am	239	244	249
31/1/2018	27	10.30am	267	270	272
28/2/2018	32	2.30pm	340	342	345
7/3/2018	29	10.00am	242	245	249
27/4/2018	27	8.30am	342	345	348

B. Ground Resistance Value for Ground Electrode System from Simulation

Table 7: Ground resistance value obtained from measurement and simulation

Rod	Measurement at site (Ω)	Simulation (Ω)
Copper electrode	588.85	191.24
GI steel electrode without added coconut husk	445.29	127.53
GI steel electrode added with 1kg coconut husk	343.71	45.54
GI steel electrode added with 1.5 kg coconut husk	462.76	34.46
GI steel electrode added with 2kg coconut husk	194.41	27.71
GI steel electrode added with coconut husk layer-by-layer with soil.	276.04	27.7

C. Electric Field Distribution for Copper Electrode

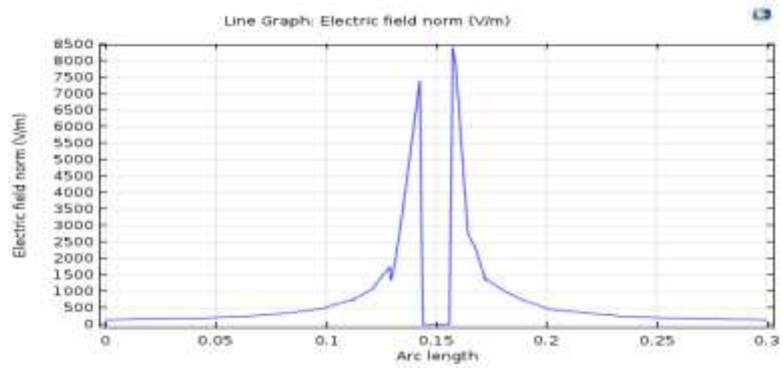


Figure 1: Electric field distribution at lower part

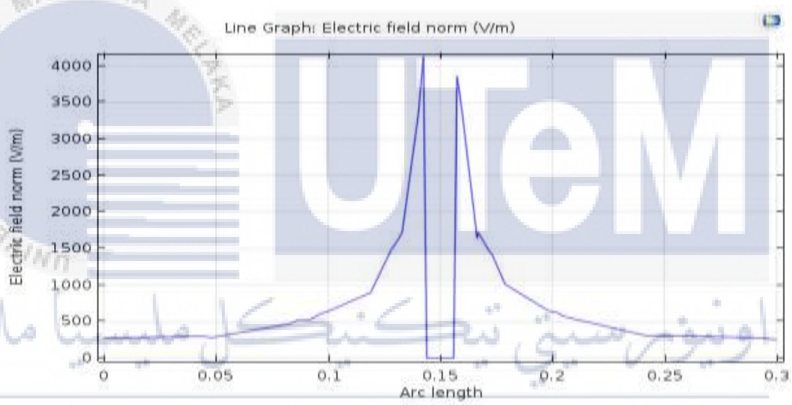


Figure 2: Electric field distribution at upper part

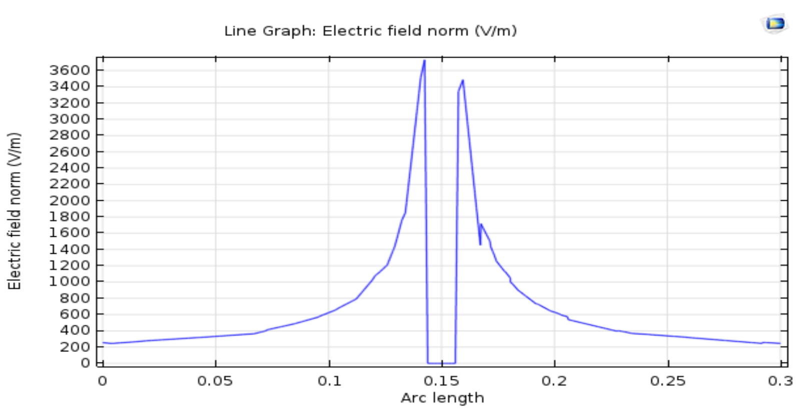


Figure 3: Electric field distribution at middle part

D. Electric Field Distribution for Galvanized Steel Without Addition of Coconut Husk

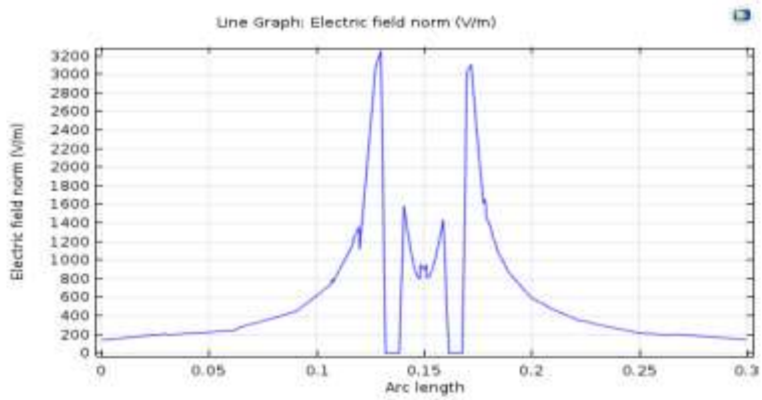


Figure 4: Electric field distribution at lower part

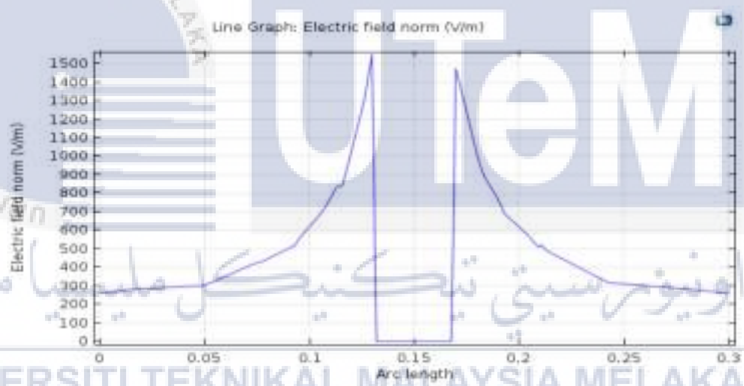


Figure 5: Electric field distribution at upper part

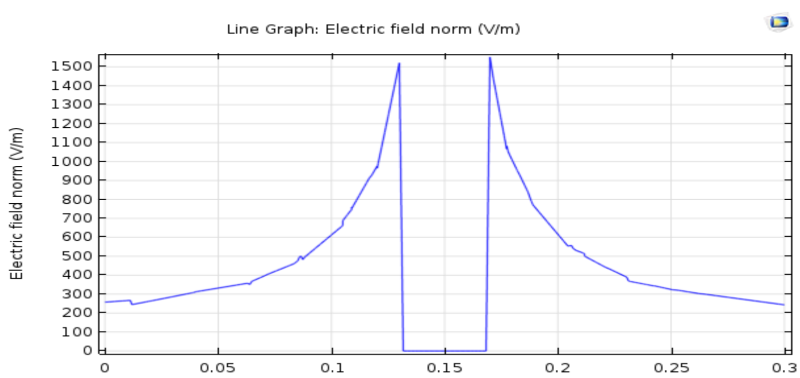


Figure 6: Electric field distribution at middle part

E. Electric Field Distribution for Galvanized Steel Electrode with Addition of 1kg Coconut Husk

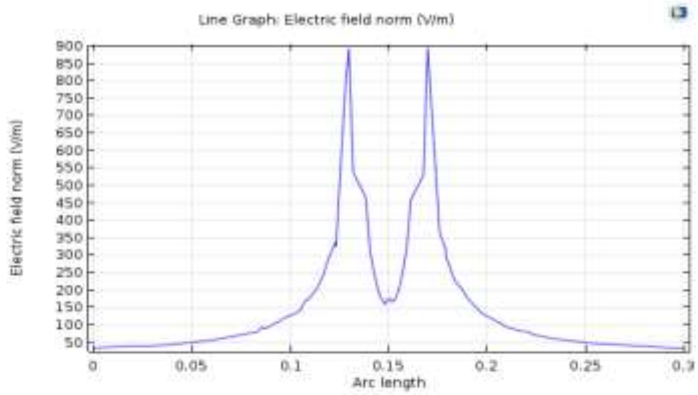


Figure 7: Electric field distribution at lower part

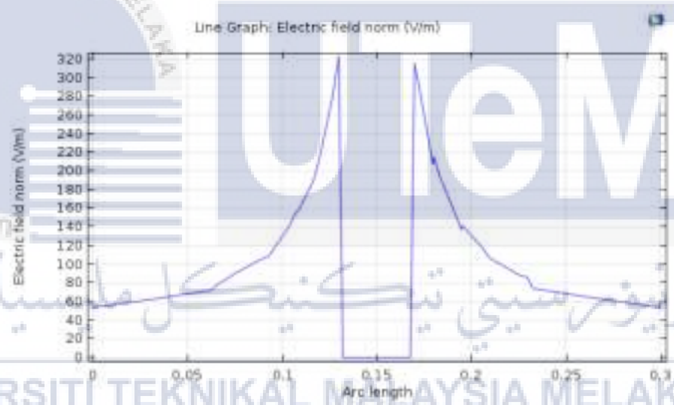


Figure 8: Electric field distribution at upper part

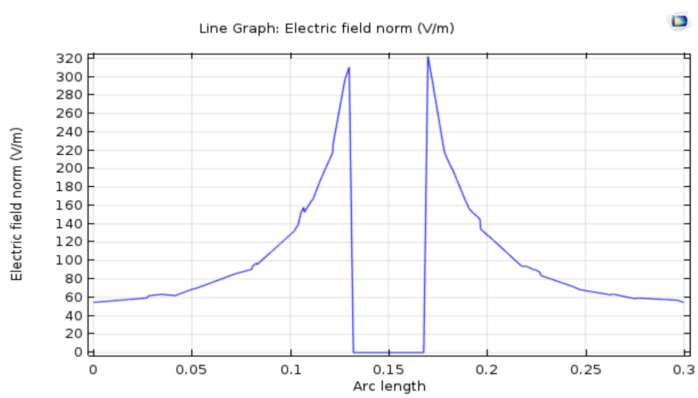


Figure 9: Electric field distribution at middle part

F. Electric Field Distribution for Galvanized Steel with Addition of 1.5kg Coconut Husk

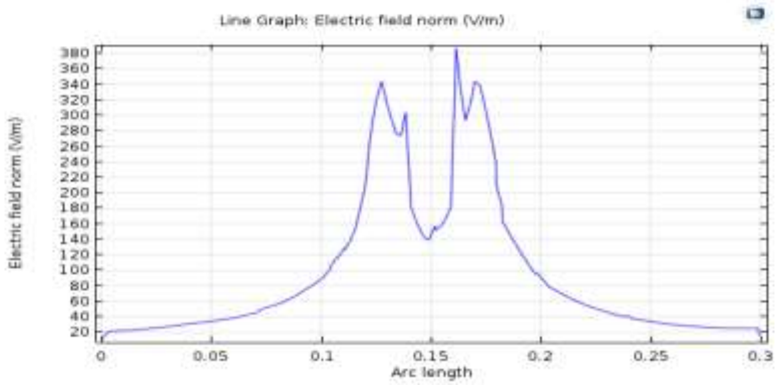


Figure 14: Electric field distribution at lower part

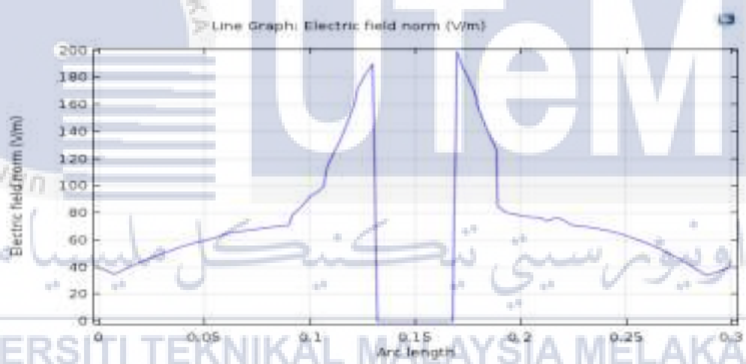


Figure 15: Electric field distribution at upper part

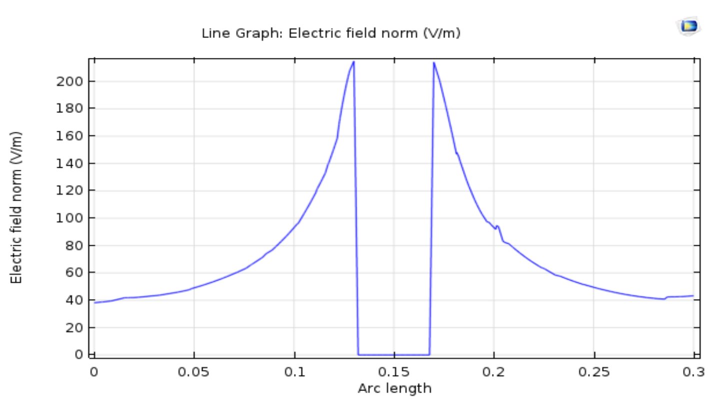


Figure 16: Electric field distribution at middle part

G. Electric Field Distribution of Galvanized Steel Electrode With Addition of 2kg coconut husk

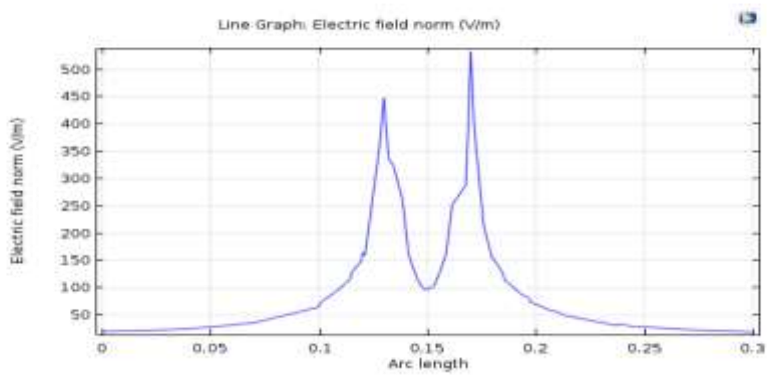


Figure 13: Electric field distribution at lower part

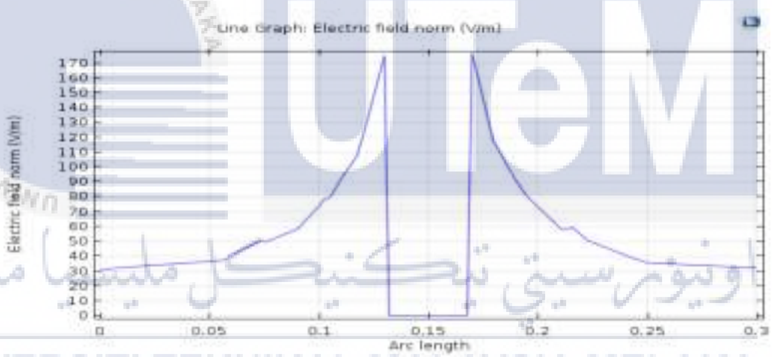


Figure 14: Electric field distribution at upper part

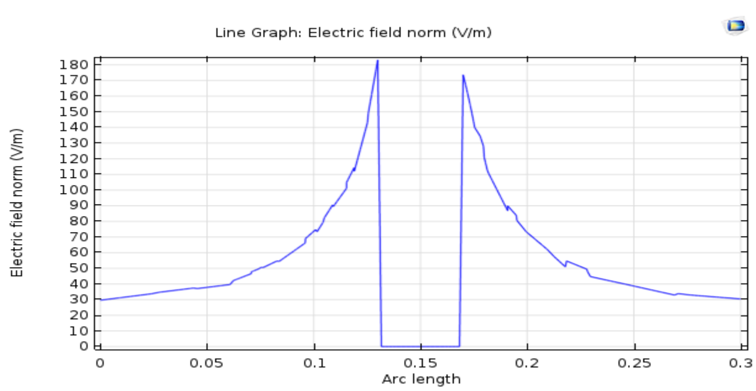


Figure 15: Electric field distribution at middle part

H. Electric Field Distribution for Galvanized Steel Electrode Added with Coconut Husk Layer-By-Layer

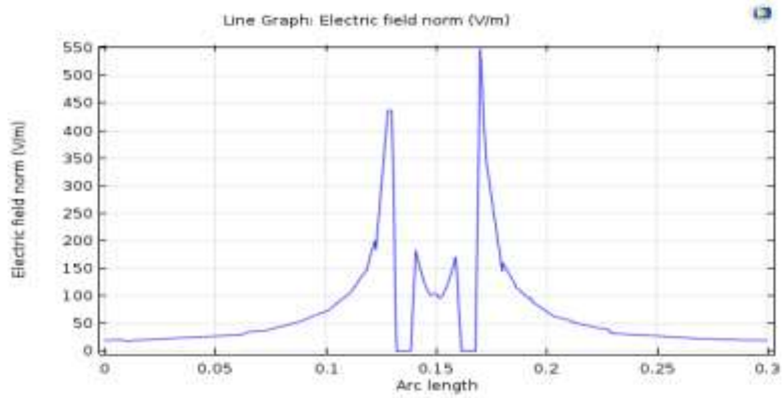


Figure 13: Electric field distribution at lower part

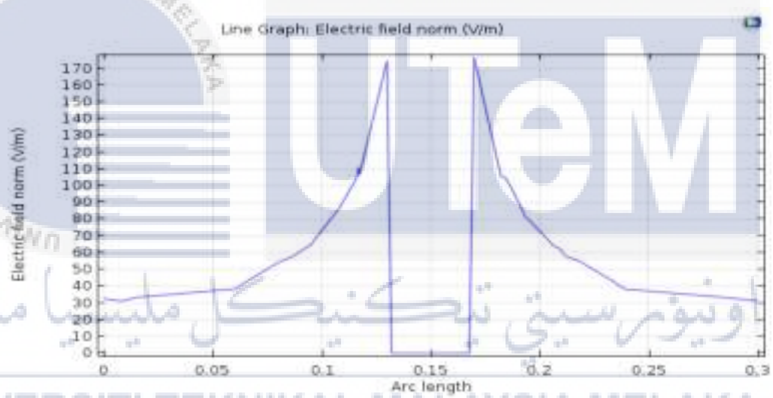


Figure 13: Electric field distribution at upper part

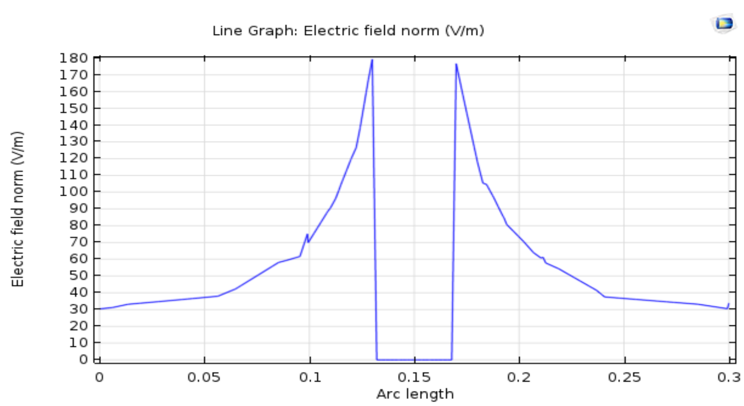


Figure 13: Electric field distribution at middle part