



**ANALYSIS OF TFR BASED ON HIGH-LOW SOIL STRUCTURE
CONFIGURATION**

Mohamad Hazrul Effendi B Mohd Zuki

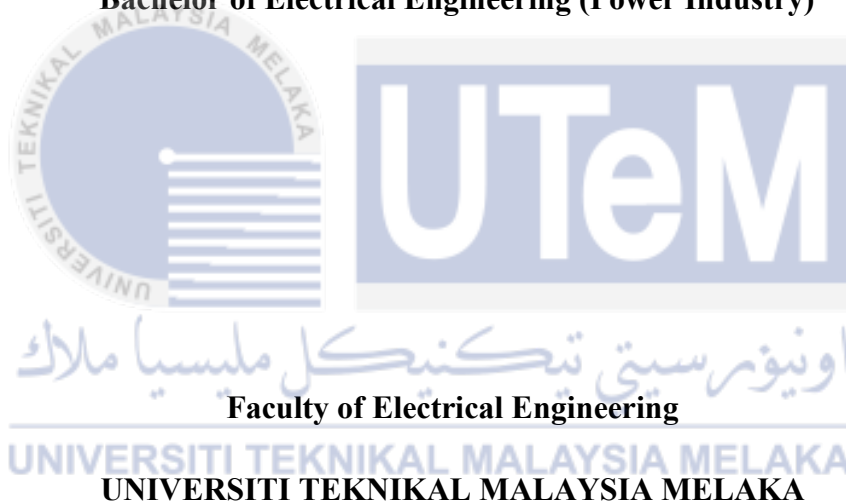
Bachelor of Electrical Engineering (Industrial Power)

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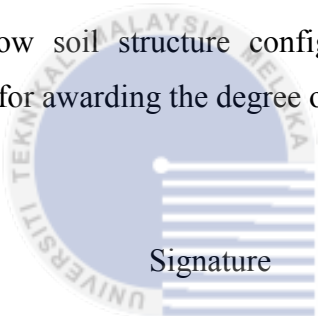
MOHAMAD HAZRUL EFFENDI B MOHD ZUKI

**A report submitted in partial fulfilment of the requirement for the degree of
Bachelor of Electrical Engineering (Power Industry)**



2015

“I hereby declared that I have read through this report entitle “Analysis of TFR based on the high-low soil structure configuration” and found that it has comply the partial fulfilment for awarding the degree of Bachelor of Electrical Engineering.”



Signature : _____

Supervisor's Name : _____
اونيورسيتي تيكنيكل مليسيا ملاك

Date : _____

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To my beloved mother and father



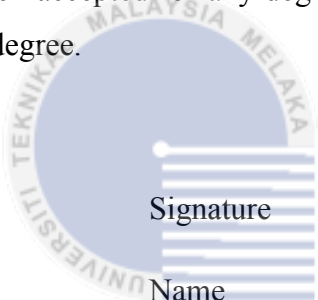
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Other than that, thanks to my beloved friends because always give a moral support and share their knowledge to me. Some of reference material gets from my friend and library. Therefore, I realised the benefit of teamwork and working together.

Finally, I would like to apologize to other unnamed people that directly or indirectly help me in various ways. I am grateful to all my family members. I very appreciate the assistance of all of you.

I declare that this report entitle “Analysis of TFR based on the high-low soil structure configuration” is the result of my own project 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.

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ABSTRACT

This project analysed of tower footing resistance (TFR) on high-low soil structure configuration. Soil is the mixture of many natural resources in earth crust. There are many type of soil and every type of soil has different properties. Therefore, different soil properties give a difference earth resistance. The aim of the project is determine the TFR analysis based on the soil structure, study the effect of chemical contain in the soil and identify the relationship between soil resistivity with the dissolved salt solution. This project only determines the analysis of the high-low soil structure configuration for tower footing resistance. There are some method use for determine the tower footing resistance and soil resistance. Wenner Arrangement and Fall-of-Potential Method are used in measurement in this project. MR and dissolved salt are used in this project to analyse TFR values. The result in this project is to improve transmission tower footing resistance for better grounding system. As known, good earthing can save equipment and human life.

ABSTRAK

Projek ini menganalisa rintangan kaki menara atau tower-footing-resistance (TFR) kepada konfigurasi struktur tanah yang berjenis tinggi-rendah (High-low). Tanah merupakan campuran pelbagai sumber semulajadi yang berada di atas bumi kerak. Terdapat banyak jenis tanah di atas kerak bumi dan setiap jenis tanah mempunyai ciri-ciri yang berbeza. Oleh itu, ciri-ciri tanah yang berbeza memberikan nilai rintangan yang berbeza pada TFR. Tujuan Projek ini adalah menganalisa TFR berdasarkan struktur tanah, mengkaji kesan bahan kimia yang terkandung di dalam tanah kepada TFR dan mengenalpasti hubungan antara kerintangan tanah dengan larutan garam. Projek ini hanya terhad kepada analisa konfigurasi struktur tanah tinggi-rendah untuk TFR. Terdapat beberapa kaedah yang digunakan untuk menentukan nilai TFR dan rintangan tanah. Wenner Arrangement dan Fall-of-Potential Method adalah teknik yang digunakan untuk pengukuran dalam projek ini. Micro-Reservoir (MR) dan garam terlarut adalah bahan yang digunakan dalam projek ini untuk menganalisa nilai-nilai TFR. Hasil projek ini adalah untuk menambahbaik nilai TFR untuk reka bentuk sebuah sistem pembumian yang lebih baik. Seperti yang diketahui, pembumian yang baik boleh menyelamatkan peralatan dan juga dapat menyelamatkan nyawa.

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LIST OF SYMBOL

A	-	Ampere
a	-	Distance between two Electrode
°C	-	Celsius
CaCl ₂	-	Calcium Chloride
CuSO ₄	-	Copper(II) Sulphate
d, D	-	Diameter
FOP	-	Fall-of-Potential
FYP	-	Final Year Project
I	-	Current
l	-	Length
LRM	-	Low Resistance Material
m	-	Meter
MgSO ₄	-	Magnesium Sulphate
MR	-	Moisture Reservoir
NaCl	-	Sodium Chloride
Pcs	-	Pieces
R	-	Resistance
SV	-	Supervisor



TFR	- Tower Footing Resistance
V	- Volt
π	- Pi
ρ	- Soil Resistivity
Ω	- Ohm



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CHAPTER 1

INTRODUCTION

1.1 Motivation

Soil is the mixture of many natural resources like mineral, organic matter, gases and organism in earth crust. These soils have been mapped on swampy terrain, level, undulating, rolling, hilly and mountainous. It is occurring depend at high and low attitudes. Other than that, every place has a different value of soil structure and properties. Nowadays, grounding system or known as earthing system is very importance to protect the equipment and prevent electrical shock. Especially during lightning or fault occurs. Soil structure configuration has relationship with the grounding system in electrical. The soil structure configuration and soil resistivity affects the grounding system efficiency. Lower ground resistance give higher grounding protection. High chemical contain in the soil effect the ground resistance. Adding more chemical contain such as NaCl to the soil will decrease ground resistance. Good grounding system can be achieved when soil resistance value are lower.

1.2 Problem Statement

As known, every place has a difference type of soil configuration. Malaysia has variety type of soils. Every soil configuration have they own properties. In electrical system, grounding system need to be connected into the circuit for safety precaution. There are some specifications that must be fulfilled to design good grounding system. Soil structure configuration indirectly involved to design good grounding system. From the previous research, the TFR value quite higher. TFR must achieve below $10\ \Omega$ for tower grounding resistance. Therefore, this project will help to analysed Tower Footing Resistance (TFR) based on the high-low soil structure configuration. Other than that, this project will help to identify the effect of salt to the soil resistivity.

1.3 Objective

The main objective of this project is:

- i. To determine the analysis of Tower Footing Resistance (TFR) based on the analysis based on the high- low soil structure configuration.
- ii. To study the effect of moisture to the soil resistivity.
- iii. To study the relationship of soil resistivity to salt dissolved soil configuration.

1.4 Scope

This project only covers the analysis of TFR based on high-low soil structure configuration only. The other types of soil structure configuration are not involved. Other than that, this project will be carried out nearby Block F, Faculty of Electrical Engineering, Universiti Teknikal Malaysia Melaka. This project will determine the relationship of soil

resistivity to the salt dissolved into soil configuration. Only circular pit salt installation method is used to install the salt. Result of soil configuration model for two set of TFR will be use as result comparison. Both set of TFR will applied with Micro Reservoir but only Set 1 will applied with salt dissolved. For this project, Micro Reservoir is applied to maintain the moisture in the soil to prevent random error caused by rain. The parameter used in this project is Potential Difference, Volt (V), Current, I (Ampere), Resistance, R (Ω), Distance, d (m) and Resistivity (Ωm). Wenner 4 Pin Method is used to measure soil resistivity and Fall-of-Potential Method is used to measure TFR value.

1.5 Thesis Outline

This project has 5 chapters. Introduction is the first chapter which contain motivation, problem statement, project objective and scope of the project. In first chapter describe what the issues of the problem arise; the objective and scope will guide the researcher from off topic. In Chapter 2, Literature Review contains a lot of paper, journal, conference, previous research and technical manual that related to the project. There are several topics that related to this project which are grounding testing method, designing TFR, factors that affect soil resistivity and TFR, differences of high-low and low-high soil structure configuration and standard guidelines. Methodology is in Chapter 3. Methodology describes the flow of the project and analysis parts are proceeding. The list of equipment and project setup procedure is parts of methodology. In this project, there are two testing method to measure parameter. Another part of methodology is discussing the testing procedure, measurement parameter and analysis part. Result and Discussion are in Chapter 4. All of measured data are recorded and data are analysed. The value of soil resistivity and TFR are analysed. Result will be presented in form table, graph, calculation or simulation. The effect of salt dissolved to TFR and soil resistivity will discuss in this chapter. The last chapter is Chapter 5. This chapter is Conclusion and Recommendation. This chapter will state the significant conclusion and give some recommendation to improve the project for further project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Tower footing resistance (TFR) usually measured at TNB transmission tower. Tower footing resistance help to reducing back flashover occurrence. Lower value of earthing resistance is needed for each TNB transmission tower. The value of earthing resistance depends on the value of transmission voltage. For 132 kV and 275 kV transmission towers must be lower than 10 Ω and 500 kV transmission tower must have lower than 5 Ω of tower footing resistance. TNB standard tower design use stranded galvanised-iron conductor rod as the earthing electrode. Four tower footings will connect to this conductor rod together and 1.2 m cooper-clad steel rod installed in the center [1, 2].

2.2 Review of previous related works

Before this project start, there are some previous works that related to this project. One of the project discuss about TFR in a journal titled as A Practical Evaluation of surge Arrester Placement for Transmission Line Lightning Protection [1]. The authors explain briefly about the TFR calculation and the important of TFR in transmission line. Other than that, in other journal titled as Grounding Resistance Measurement using Fall-of-

Potential Probe Located in Opposite Direction to Current Probe discuss about the effect in measurement if some of the probe are located in different angles [2]. In that paper state that some of the angle in measuring using Fall-of-Potential method will give inaccurate value of ground resistance. Besides that, in conference paper titled Effects of Salt Content on Measurement of Soil Resistivity discuss the effect of salt to soil resistance [3]. In that paper also discuss about the chemical reaction in the soil structure between copper rod and salt solution. Other than that, from that project, it proves the salt absolutely suitable used in grounding. Other than that, in journal titled Analysis of Earth Resistance of Electrodes and Soil Resistivity at Different Environments discuss analysed the value of soil resistivity in different type of soil [4]. Therefore, all of this paper related to this project for TFR and soil resistivity analysis.

2.2.1 Previous Work 1: A Practical Evaluation of surge Arrester Placement for Transmission Line Lightning Protection [1]

In this paper, lightning protection design was evaluated. Other than that, 115 kV transmission line is used by researcher. Tower Footing Resistance is very importance equipment for lightning protection. This paper explain briefly how to get the value of changing resistance by analysis of TFR , lightning current and limitation current. This paper explain briefly the effect of soil ionization gradient and soil resistivity to limitation current that can be initiate soil ionization.

2.2.2 Previous Work 2: Grounding Resistance Measurement using Fall-of-Potential Probe Located in Opposite Direction to Current Probe [2]

In this paper, Fall-of-Potential have some error in measure grounding resistance. This paper briefly explained measurement error can be occurred. Based on paper analysis,

the best probe arrangement is in a straight line. However, the potential probe usually could not be located in straight line. This is because the building, roadblock or metallic pipe at that position. Because of that, the potential probe needs to be located at opposite side of earth electrode and current probe. In other ways, potential probe needs to be located in range from 90° to 270° .

2.2.3 Previous Work 3: Effects of Salt Content on Measurement of Soil Resistivity [3]

In this paper, soil resistivity is the important factor that could be considered in choosing suitable grounding area. The experiment was carried out on the grounding zone of the University Technology MARA. Soils that have high moisture and salt content and also exposed to high temperature can influence the soil resistivity. Ground resisting is a technique used to identify the effectivity of the certain ground for building. This paper explains briefly about chemical reactions of NaCl with copper rod in ionization process. As the result, the resistivity value will decreases when salt are added into the soil.

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2.2.4 Previous Work 4: Analysis of Earth Resistance of Electrodes and Soil Resistivity at Different Environments [4]

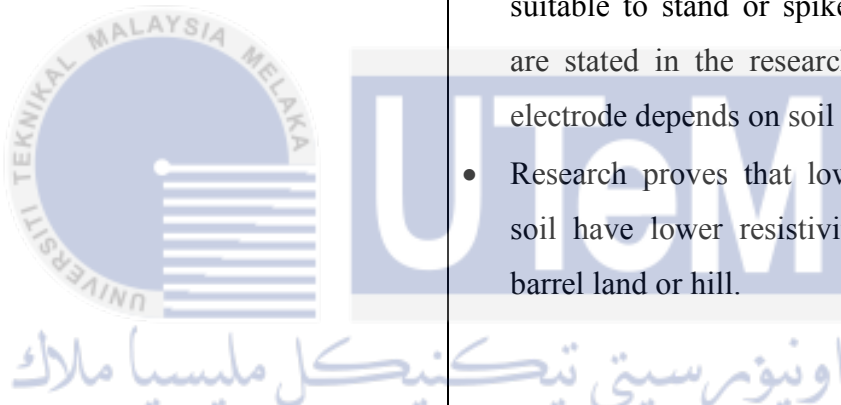
In this paper, the values of soil resistivity are much related to the environment. This project shows the relationship of type of soil and soil resistivity. There are 5 different locations in this project and every location has a different value of soil resistivity. It shows that the lower resistivity happened at lowland and wet soil. The higher soil resistivity is at barrel land and hill. As the result, the type of soil or environment one factor that related that affected the soil resistivity value.

2.2.5 Finding from Previous Work

Referring to previous work, there are some information's that importance to be consider and related to soil resistance and TFR values. Table 2.1 shows the information or finding from the previous work.

Table 2.1: Finding from Previous Work

Previous Work Title	Finding
A Practical Evaluation of surge Arrester Placement for Transmission Line Lightning Protection [1]	- This previous paper briefly explains about TFR analysis and effect of soil ionization. - Standard TFR design is depending on High-low and Low-high soil configuration.
Grounding Resistance Measurement using Fall-of-Potential Probe Located in Opposite Direction to Current Probe [2]	- This previous work proves that the best probe arrangement of Fall-of-Potential Method for TFR measurement is in a straight line. - If the area of measurement using FOP is distriected, the probe must be located in range 90° to 270° opposite to current probe.
Effects of Salt Content on Measurement of Soil Resistivity [3]	In this research paper stated that high moisture, salt content, and high exposed temperature can influence the soil resistivity.

	• Besides that, this previous work explains briefly about salt ionization process. • Salt is the best chemical used in grounding system because salt easier to ionize compare to other LRM.
Analysis of Earth Resistance of Electrodes and Soil Resistivity at Different Environments [4] 	• This previous work shows the relationship of type of soil with soil resistivity. • Other than that, no exact distances that suitable to stand or spike the electrode are stated in the research. Distance of electrode depends on soil resistivity. • Research proves that lowland and wet soil have lower resistivity compare to barrel land or hill.

2.3 Theory and Basic Principle

Before project are carried up or set up, all of theory and basic principles must be understand. There are some theory and basic principle such as design, factor that effected result and some precaution that important to be consider. From this theory and basic principle, method used are selected and project can be set up.

2.3.1 TFR Design

Tower footing resistance design depends on two type of soil model. Two type of soil model is High-low model and Low-high model. Figure 2.1 shows the difference of this two soil model. For Hi-lo soil model, the higher resistivity located at upper layer and the low resistivity located at below layer. For Lo-hi configuration, low resistivity soil layer lay above the high resistivity soil.

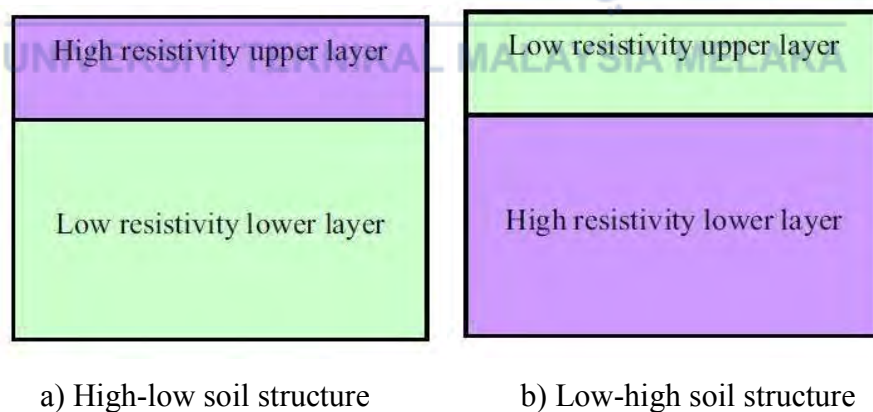


Figure 2.1: Two type of soil structure [1].

The types of earthing design depend on the soil configuration. This project only covers the High-low soil structure configuration. Figure 2.2 shows the High-low soil structure configuration for earthing designed.

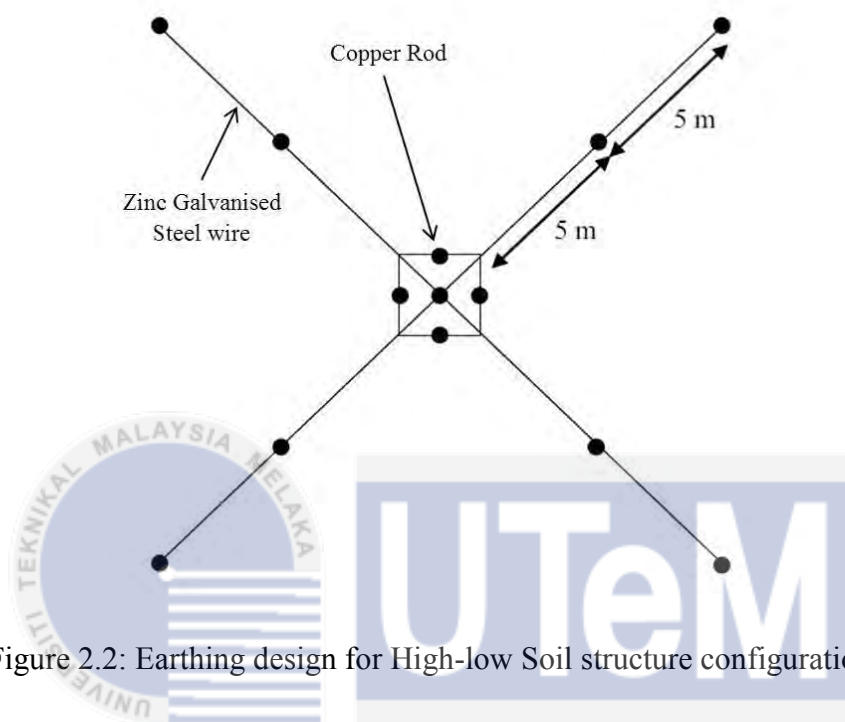


Figure 2.2: Earthing design for High-low Soil structure configuration [1]

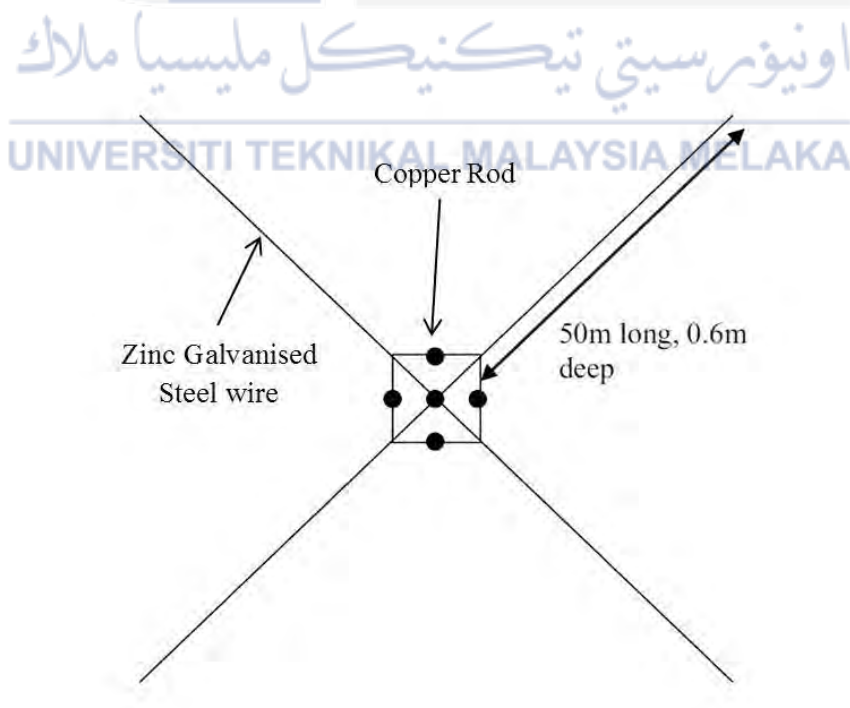


Figure 2.3: Earthing design for Low-high Soil Structure configuration [1]

13 rod in vertical used to achieve the lower resistivity and each rods length is 5.4 meter. The horizontal electrodes planted in the higher resistivity soil layer and the vertical electrodes standing on vertical axis of soil configuration. Zinc galvanised steel wire and copper rod are arrangement as shows in Figure 2.2. The TFR designs for Low-high soil only use 5 copper rods [1]. Figure 2.3 shows the earthing design of Low-high soil configuration.

2.3.2 Effected factor to TFR

There are many factor can influence the soil resistivity and directly influence the TFR values. Moisture, chemical contain, humidity and temperature of the soil are factor that affected the value of soil resistance and TFR values.

2.3.2.1 Moisture

Moisture will influence the soil resistivity value. Water content will affect the ion conductivity of the electrolyte solution. Water can be supplied to the soil naturally by the rain or underground water resources. Water content in natural is correlated to humidity. The higher of water content in the soil structure will reduce the value of soil resistivity. If the water content in the soil is low, the soil resistivity will be higher [5, 6].

Figure 2.4 shows the effect of salt, moisture and temperature to the soil resistivity. Figure 2.4 clearly shows if the salt, moisture and temperature increased, the value of soil resistivity decreased. Therefore, the value of soil resistance is not fixed because it depends to moisture in the soil. If the soils are wet, the soil will have a lower resistivity value and it vice versa if soil is dry.

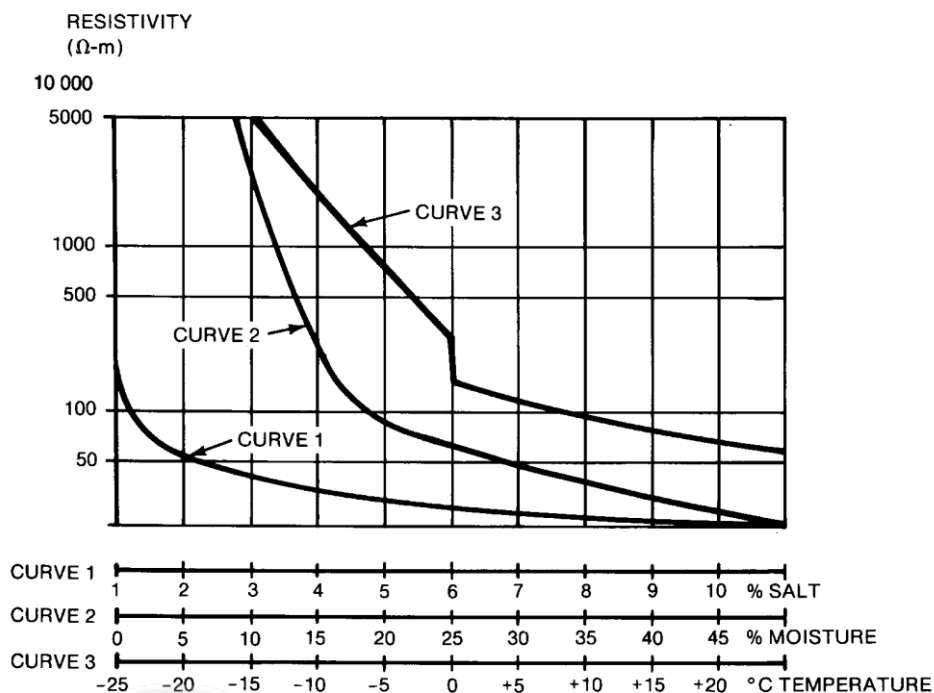


Figure 2.4: Effect of salt, moisture and temperature to the soil resistivity [7]

2.3.2.2 Chemical Contain

Chemical content can affect the value of tower footing resistance. This is because the soil resistivity will decrease when the low resistance material is mixing to the soil structure. Chemicals such as NaCl , MgSO_4 , CuSO_4 and CaCl_2 used to reduce the soil resistivity. Other than that, there are 2 method to adding chemical contain into the rod. First method is cover the rod with low resistance material and the second method is augured hole [8]. Figure 2.5 show LRM installation method into grounding.

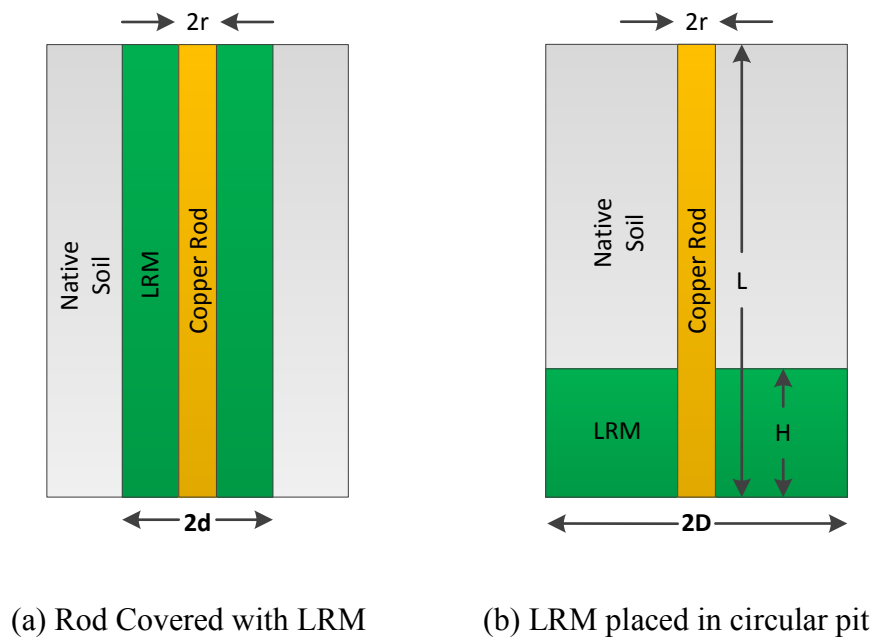


Figure 2.5: LRM installation methods into grounding [8]

When more conducting substances added into soil, the grounding resistance will decrease [9]. Figure 2.4 also shows the relationship between salt and soil resistivity. In real world, there are installation methods to achieve the suitable earthing value. In earthing technique, a cylindrical hole dimension of 200mm x 500mm are dig and 2 kg of salt applied to each rod [10].

Chemical reaction will occur when the back flashover occurred. The electrolysis occurred when the metal electrode get a current flow through it with present of chemical content. Referring the electrolysis theory, salt in chemical term is Sodium Chloride, NaCl and the copper rod in chemical term is Copper, Cu(s). When the NaCl dissolve in water, presence of H₂O will occur. In dissolved salt solution, the dominant ions in solution are Na⁺ (positive ion) and Cl⁻ (negative ions). When the copper electrode gets a current supplied, chemical reaction occur between the electrodes and dissolved salt solution. Chloride ions (anions), Cl⁻ will move on the positive electrode called anode. The Sodium ions (cations), Na⁺ will move on the negative electrode called cathode. Chemical reaction occurs at anode and cathode electrode shows at below.

At copper electrode,



At cathode will accept hydrogen ions from water,



At anode two chloride ions will donate electron to anode,



Salt particles will separate quickly in a short time when the lightning strikes the building [11].

Other than that, IEC 1024-1 (1990) stated that copper is resistance to many material but the corrosion will increased by concentrated chloride, sulphur and organic material. All type of electrodes that usually used in grounding have the weakness against to corrosions type. Table 2.2 shows the corrosion properties in different material follow IEC 1024-1 (1990). Therefore, salt or Sodium Chloride (NaCl) is best chemical used in grounding because it not an agent that increase the corrosion and not electrolytic with the copper rod.

Table 2.2: The corrosion properties of different materials [10]

MATERIAL	CORROSION		
	RESISTANCE	INCREASED	ELECTROLYTIC
Copper	Against many material	Concentration chloride, sulphur and organic material	-
Hot Galvanised Steel	Good even in acid soils	-	Copper
Stainless Steel	Against many material	Water dissolved chloride	-
Aluminium	-	Basic agent	Copper
Lead	High concentration on sulphites	Acid soils	Copper

2.3.2.3 Moisture Control

This project uses a moisture control to maintain the water content in the soil. The suitable method to maintain the soil moisture is using Micro Reservoir (MR). Past research analysed the comparison between the Moistube and Micro Reservoir. The best equipment between this two moisture controls is Micro Reservoir because it can withstand for 3 to 5 day without water supply to it. The 3 litre bag can stand until 15 days without water supply [12].

2.3.3 Measurement Method

There are two type of measurement method. First method that be used for measured soil resistance is Wenner 4-pin Method. Second method is Fall-of-Potential Method. Second method used to determine TFR values.

2.3.3.1 Method 1 (Wenner 4-pin method)

This type of method needs four electrodes. Two electrode will used to current injection and the other two electrode will used for potential measured. Figure 2.6 shows Wenner four pin method.

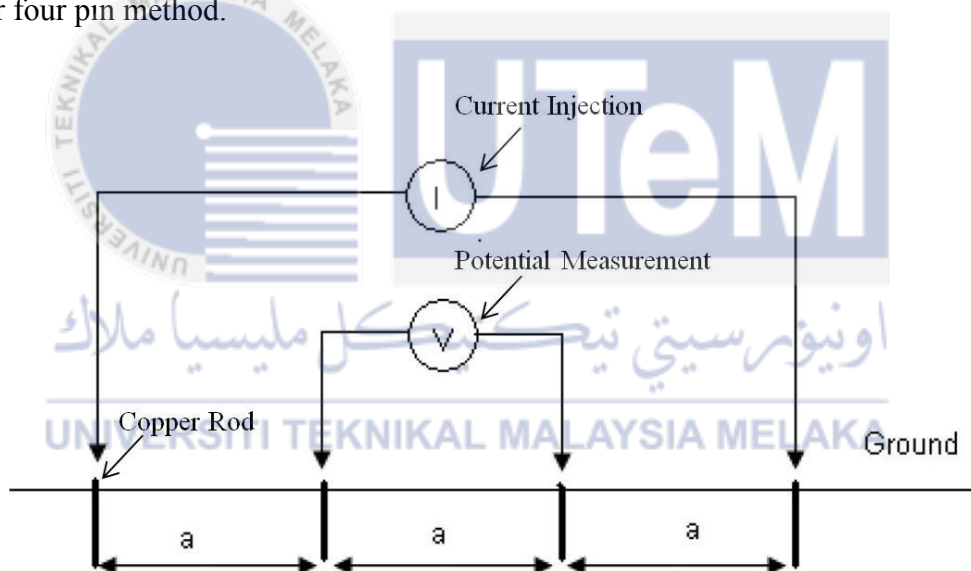


Figure 2.6: Wenner probe arrangement [13]

Soil resistivity, ρ can be calculated by using Wenner method is shown in equation 2.4. The symbol R is for resistance measured by the earth tester. In equation 2.4, “ a ” is the distance between an electrode in meter and π value is 3.124.

$$\rho = 2\pi aR \quad (2.4)$$

Wenner 4-pin method has disadvantage from manpower usage because this method use 4 people to perform the task in short time. However, the benefit of this method is sensitive to detect different stage of soil layer [10].

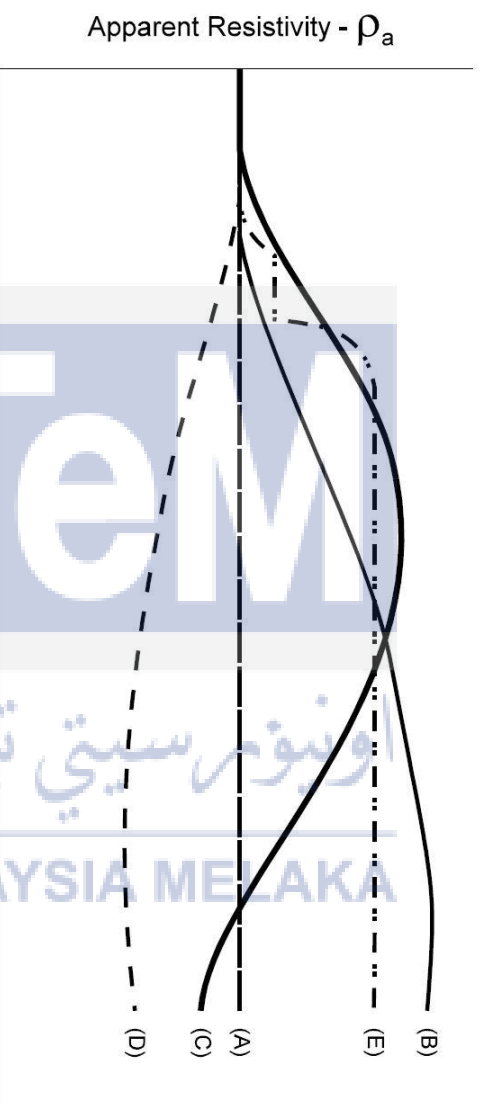


Figure 2.7: Two layers soil structure layout follow IEEE, Volume 4, 2013 [14]

Table 2.3: Type of curve and its two layers soil structure [14]

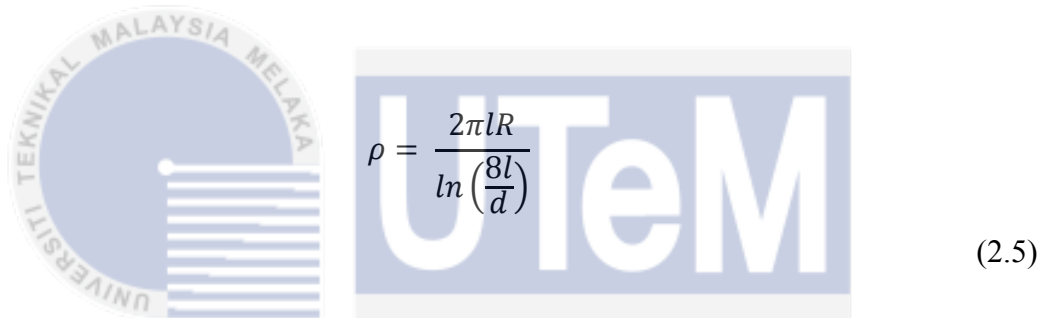
Type of curve	Type of two layers soil structure
A	Homogeneous resistivity
B	Low resistance layer overlaying high resistivity layers.
C	High resistivity between two low resistivity layers.
D	High resistivity layer overlaying a low resistivity layer.
E	Low resistivity layer over high resistivity layer with vertical discontinuity.

The type of soil can be determined using apparent soil resistivity. Figure 2.7 are used to determine three or less layers of soil structure. There are 5 type of two layers soil

structure can be determined using this soil structure layout shows in Table 2.3. Graphical Curve Matching is the easier analysis to identify the type of soil.

2.3.2 Method 2 (3-pin Method)

This method called Driven Rod Method or fall of potential. This method is suitable for transmission line tower earthing test. Figure 2.8 shows the testing arrangement. Other than that, this type of testing method is not accurate on the multiple layers of soil. Soil resistivity can be determined with formula calculation in equation 2.5.



$$\rho = \frac{2\pi l R}{\ln\left(\frac{8l}{d}\right)} \quad (2.5)$$

In equation 2.5, l is the length of driven rod in contact with earth and “d” is the driven rod diameter [13].

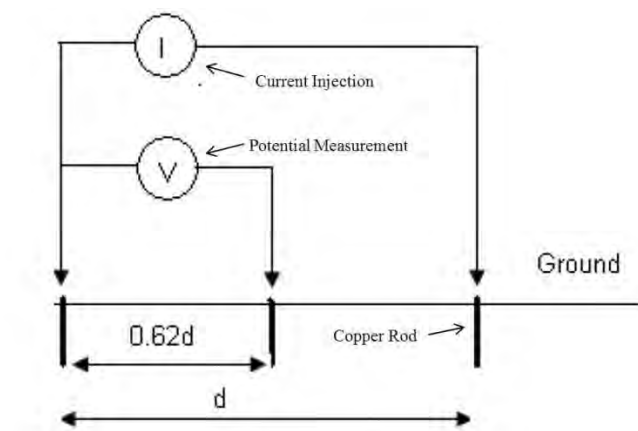


Figure 2.8: Three-pin method arrangement [13]

To get the true value of earth resistance, 62% method is combined to Driven Rod Method. The true value can be determined when 62% of longest length crosses the earth resistance line.

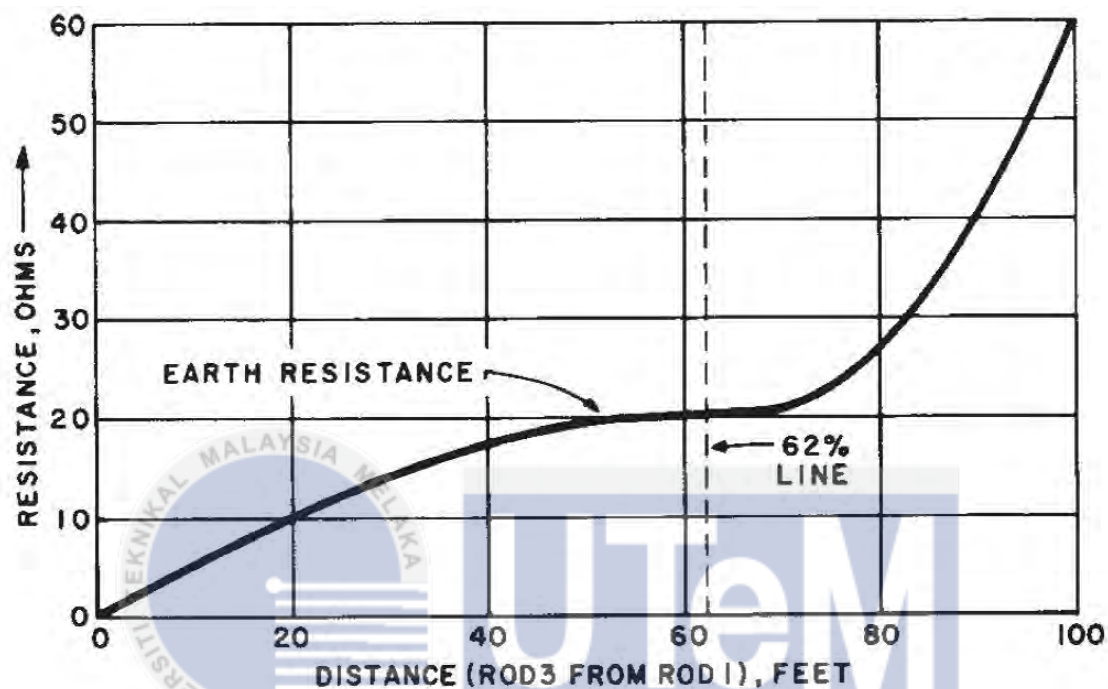


Figure 2.9: 62% Method is combined with Driven Rod Method [7]

From Figure 2.9, 62% Method are combined with Driven Rod Method. In figure, current probe is fixed to 100 feet from earth electrode. True value of earth resistance or earth rod resistance can be found by intersection of the graph with 62% distance of current probe.

2.4 Comparison Testing Method

There are three type of method can be used to measure soil resistance and TFR value. Every method has the advantages and disadvantages. Table 2.4 shows the advantages and disadvantages for Wenner 4 Pole Method, Driven Rod Method and Schlumberger Method.

Table 2.4: Advantage and disadvantage of method.

METHOD	ADVANTAGES	DISADVANTAGES
Wenner 4 Pole Method	• This method more sensitive to different layers of different soil. • Low losses from transmitter to receiver.	• Need more manpower. • Need to reposition all 4 probes for each test. • Need long cable during test.
Driven Rod Method	• Theoretical value or true resistance of rod resistance is simple to calculate. • Suitable to transmission tower. • Suitable in districted area.	• Not accurate on multiple layers of soil.
Schlumberger Method	• Save time and low manpower. • Provides a safer working environment for high current test.	• Not accurate on multiple layers of soil. • Low voltage reading.

2.5 Summary and discussion of the review

In this project, TFR is analysed at High-low soil configuration. The type of TFR must be suitable with the soil configuration.

Micro reservoir is used to control the water content in the soil structure. The benefit using micro reservoir is water can be supplied or migrating continuously until the soil reach the balance point. The use of water is one way to reduce the grounding resistance in the soil resistivity.

For this project, application of dissolved salt solution in the soil structure can improve by previous research [8]. In this project, the soil resistivity depends on the low resistance material (LRM) that contain in the soil structure around the rods. There are two method of application of LRM. First method is cover the rod with low resistance material (LRM) and the second method is augured hole. For this project, augured hole method are use because it more effective to reduced soil resistivity.

Theoretically, the soil resistivity is inversely proportional with the chemical contain in soil structure. The higher value of LRM in the soil structure, the lower soil resistance will be produced. The usually chemical contain that use in the soil structure is NaCl, MgSO₄, CuSO₄ and CaCl₂. For this project, only dissolved NaCl will be used. The another factor choosing the NaCl is more easily to get the material and the properties of salt particles will separate quickly in a short time when the lightning strikes the building. 2 kg of salt is dissolved in water are pour to 200mm x 1000m cylindrical holes follows [10].

The Wenner 4 Pole Method are used to measured soil resistance because it more accurate and suitable on multiple layers of soil structure. For TFR, Driven Rod Method is used to measured earth resistance. Driven road is simplest method to find true resistance or theoretical value and suitable for transmission line testing method.

CHAPTER 3

METHODOLOGY

In this project, the flow chart is used to explain the step by step of the project. In Chapter 2, literature part already review several papers or article, some evaluated from researches, research analysis, and the paper discussion and previous research analysis can help to be motivation to proceed with this project. Other than that, from literature review, the methods of grounding, configuration and requirement equipment are being studied.

3.1 Flow Chart

In this project, two type of measurement will be conducted on the two set of TFR. This two set already setup by previous researcher but the both need to be retest to obtain the current condition. The types of planned measurements are Fall-of-Potential and Soil Resistivity. These measurements are conducted to measure the real resistance of each earthing system. Two set of tower model will installed with Micro Reservoir and only Set 1 will be installing with dissolved salt solution. This result will be used to analyse the efficiency of the dissolved salt solution toward TFR.

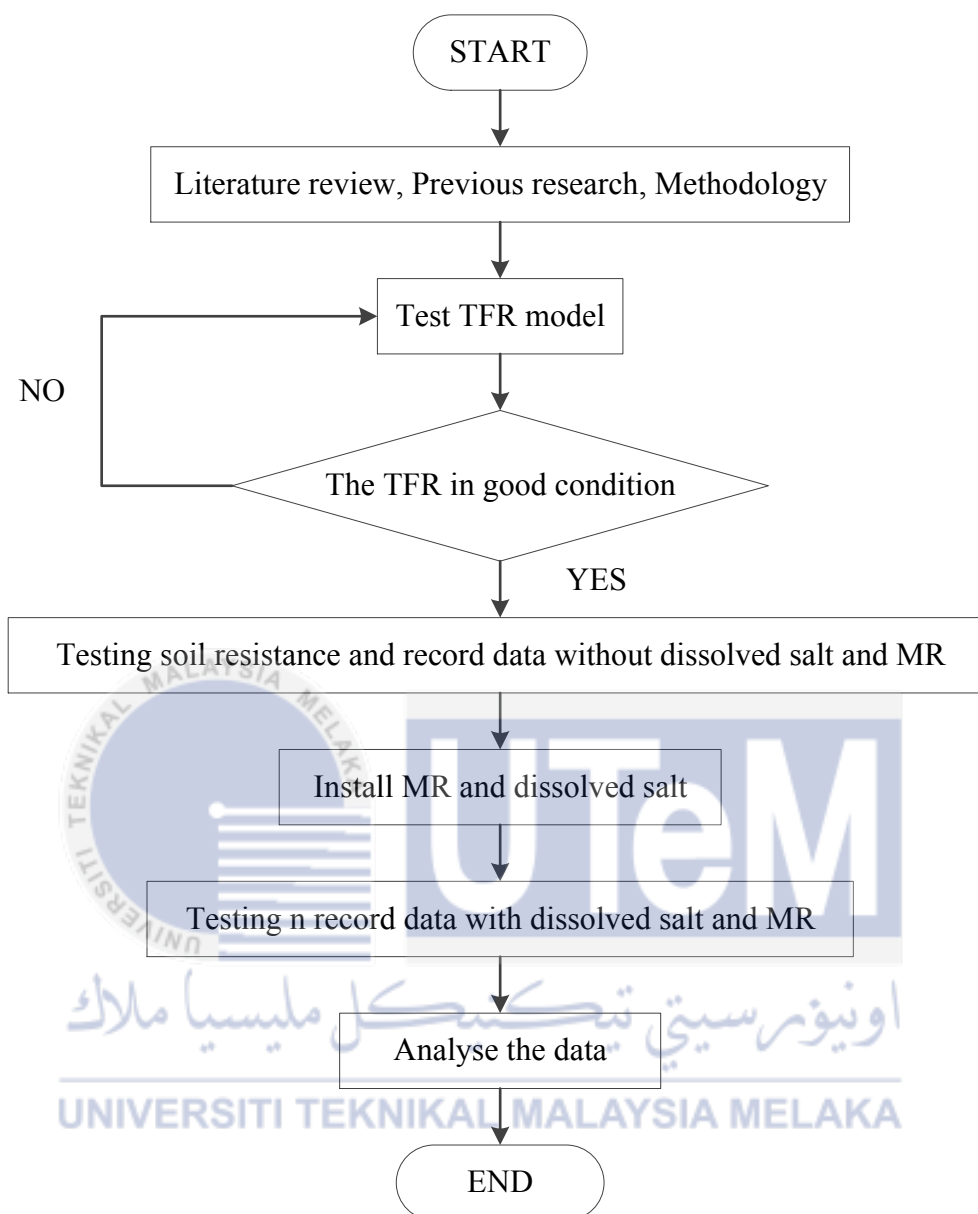


Figure 3.1: Flow Chart of this project.

The flow chart in Figure 3.1 will help the researcher to follow the sequence process. Before start the measurement, the tower must be tested to know the TFR condition. All the equipment that used in the project needs to gather before the project start.

3.2 Location



Figure 3.2: Location of Set 1 and Set 2 of earthing system model by google maps.

The research is implemented near to Block F of Faculty of Electrical Engineering, FKE, UTeM. The research area is a flat open area with grass. Two sets of tower fit in this area if the sets of transmission line grounding tower model are scale down. This two grounding system are installed in near position to get a same soil structure.

The tower footing resistance (TFR) locate near to Block F, FKE, UTeM. The Figure 3.3 below shows the location and the TFR condition.



Figure 3.3: TFR location.



3.3 Setup and Design

For this project, design of TFR is High-low model. Therefore, some of equipment's are needed to setup this project. Earth tester, insulator test and humidity temperature test that used in this project must be borrowed from the laboratories.

3.3.1 List of Equipment

Table 3.1: List of equipment uses in this project.

No	Name of Equipment	Function	Quantity
1	 Fluke 1623 Geo Earth Grounding Tester	To measure the earth resistance.	1
2	 Micro Reservoir (1.5L)	To maintain/control moisture	6

3	 Earth Spike and Alligator Clip *included with Fluke Earth Grounding Tester	Connect the Earth Grounding Tester with the soil.	2
4	 Insulator Test	To test the connectivity between rods.	2

5	 Temperature Humidity Meter	To measure temperature and humidity level	1
6	 Water Container	Refill water into Micro Reservoir	1
7	Zink Steel Wire Bare	Connect the rods together	8m
8	Digging Tools	To implement TFR model	1
9	Salt	Added to the TFR	10kg

3.3.2 Micro Reservoir

The Micro Reservoir is in 1.5L size are places same as previous research. There are three begs of Micro Reservoir of each set of grounding tower model.

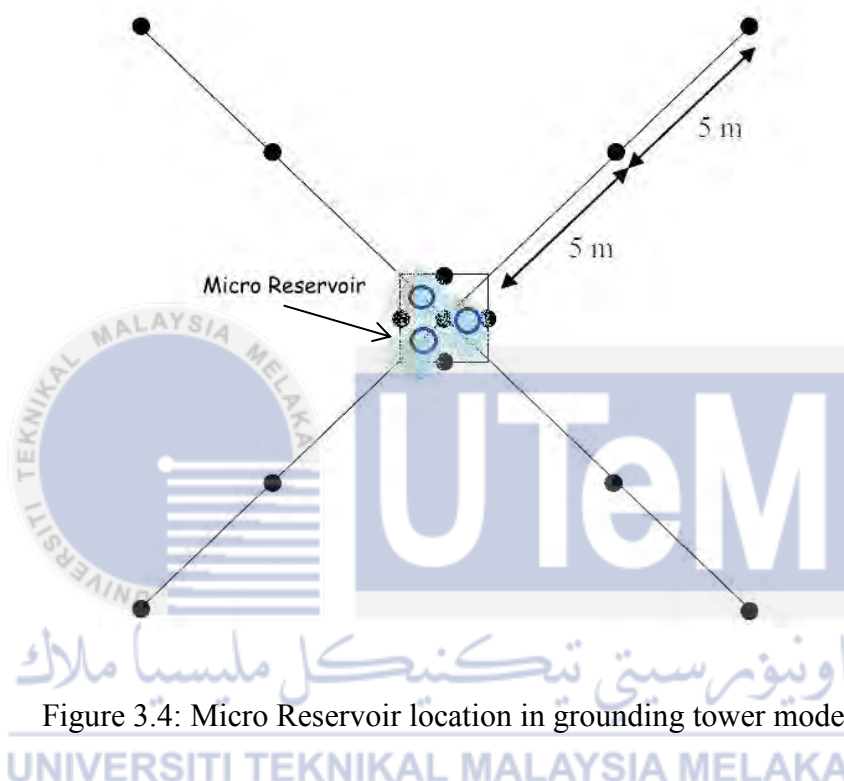
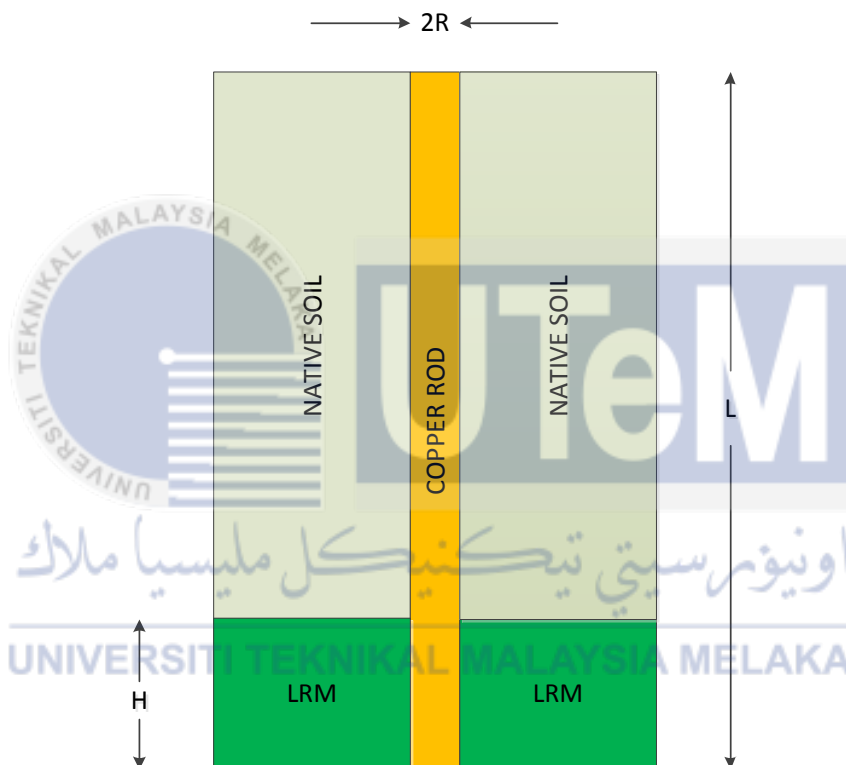


Figure 3.4: Micro Reservoir location in grounding tower model.

From Figure 3.4, the moisture of soil can be seen. The resistivity of the soil can be reduced and the TFR value will low at all time. This configuration will apply into both set of earthing tower model to control the soil moisture. Every set of TFR will be put 3 pieces of MR. Only 3 pieces MR are installed into TFR because of item limitation. MR is refilled with water manually by using water container every day for 30 days.

3.3.3 Dissolved Salt Solution

From literature review, there are two methods to decrease the soil resistivity. First method is copper rod is cover up with Low Resistance Material (LRM) and the second method is copper rod embedded in LRM placed in a circular pit. In this project, rod embedded in LRM placed in a circular pit method will be used.



The Figure 3.5: Rod embedded in LRM placed in a circular pit method [8]

Figure 3.5 will shows the dimension of dissolved salt solution that will cover up the copper rod. “r” is radius of the rod and d is the rod diameter. LRM installed at Set 1 follows Figure 3.5.

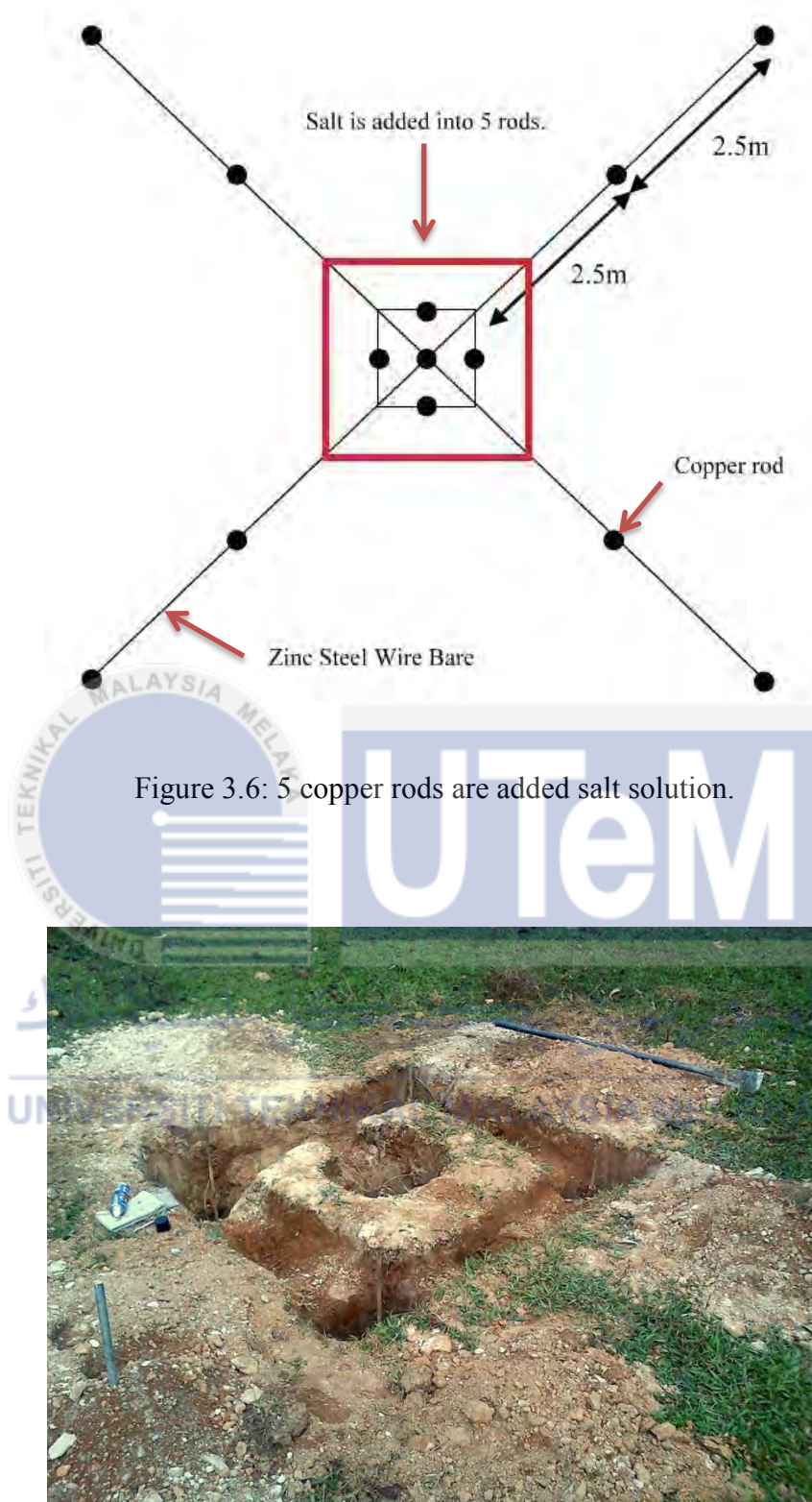


Figure 3.6 shows the position of 5 rod that involve to added salt solution in TFR model. 2 kg of salt solution are added into the each rod. 2kg weight of salt are selected because follow earthing technique in [10]. Figure 3.7 shows the hole around the 5 copper rods. The hole must be dig carefully to avoid the old zinc galvanised steel wire bare from accidently disconnect.



Figure 3.8: 2 kg salt is dissolved in water.

Figure 3.8 shows the dissolved salt in water is installed into the circular pit. In this project, the hole is dig until reach 1m depth. Then 2 kg of salt are dissolved into water and put into the hole. After that, wait around 30 minutes to give time to soil absorb the salt and buried the hole [10].

3.3.4 Scale Configuration.

The High-low TFR model for this project must be scale down. This is because the project area is limited and not enough to build up the actual size of TFR. Referred to actual configuration in Figure 2.2, the length of rod and zinc galvanised steel wire bare are modified. Table 3.2 shows some modification of the TFR model for this project. Figure 3.9 shows the design of the TFR model.

Table 3.2: TFR scale down table

Modification	Actual	Scale Down
Length of rod	16mm x 3m	16mm x 1.5m
Type of wire	4mm Zinc Galvanised Steel Wire	4mm Zinc Steel Wire Bare
Deep of wire buried in soil	0.6m	0.3m
Distance between rod	5m	2.5m

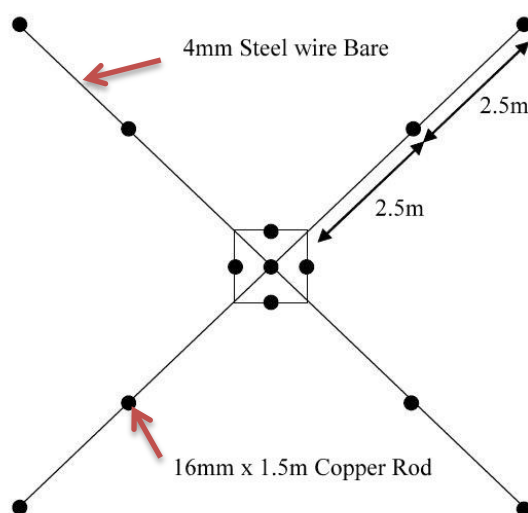


Figure 3.9: Scale down of TFR

3.3.5 Water Container

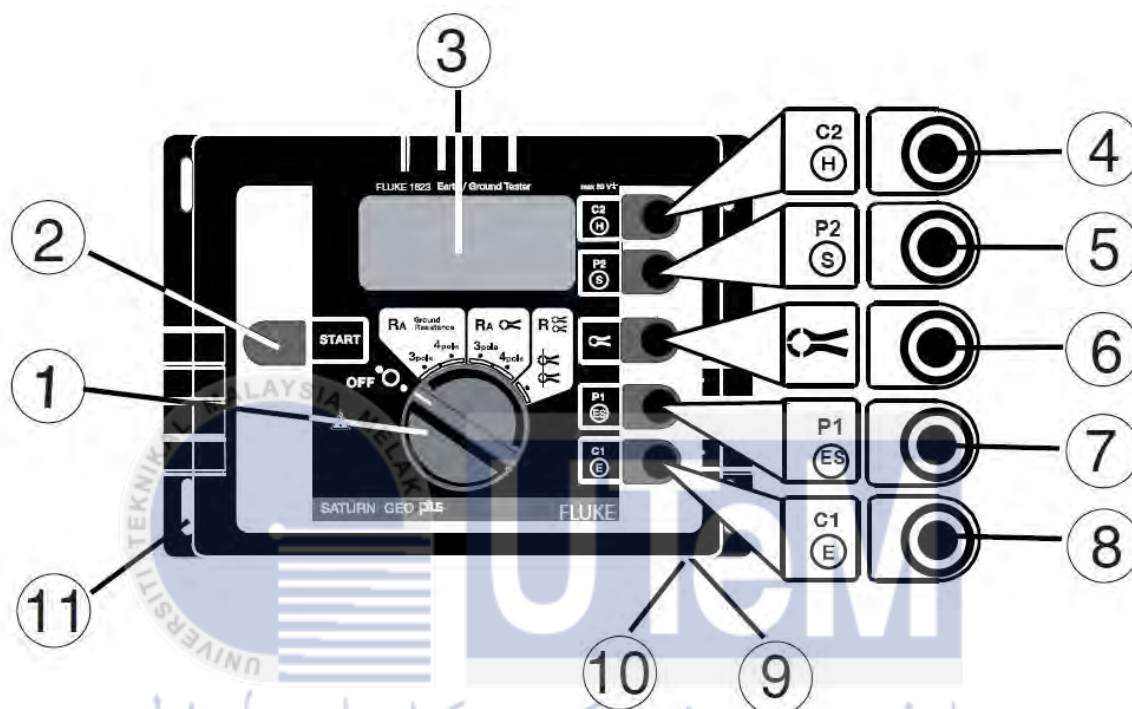
This project needs water to be refill in the Micro Reservoir. Micro Reservoir just needs to be refill around 5 day once or can be continuously supplied. The water container will be modified to be a tank. A tank built near to the tower model for easier water supply to Micro Reservoir. In this project, MR is refill once a day. The MR must be refill to makes sure water are supplied continuously and equally to the soil. Figure 3.10 shows the water container.



Figure 3.10: Water container.

3.4 Testing Measurement Method

3.4.1 Fluke 1623 Geo Earth Grounding Tester



Item	Description
①	Rotary switch for selection of measurement functions and ON/OFF.
②	START button for starting the selected measurement function.
③	Liquid crystal display (LCD).
④	Connection "H" for auxiliary earth 4 mm Ø
⑤	Connection "S" for probe 4 mm Ø
⑥	Connection  for sensing current test clamp
⑦	Connection "ES" for earth electrode probe 4 mm Ø
⑧	Connection "E" for the earth/ground electrode to be measured 4 mm Ø
⑨	Battery compartment for 6 alkaline batteries (type AA, LR6) or NiCd
⑩	batteries (bottom side of instrument)

Figure 3.11: Fluke 1623 Earth Grounding Tester labelling.

Fluke 1623 Geo Earth Grounding Tester will be use in this project. Figure 3.11 shows the labelling of the tester equipment. The method to use this tester can refer to Fluke 16623 Geo Earth Grounding Manual in appendix.

3.4.2 Wenner 4-pin Earthing Test Method

Wenner 4-pin Method test is to identify the value of soil resistivity. Soil resistance must be measured for new installation grounding system to meet all the ground resistance of IEEE requirement. Moisture, depth of electrode, temperature and chemical contain in the soil may change the soil resistivity. Wenner 4 pin method is the excellent method used for testing the soil resistivity. The current will inject to the earth trough the current probe and sensed by potential probe. Soil resistivity can be calculated using a basic Ohm's Law. The earth tester will be the middle between the two potential probes and two current probes. The distance "a" started from 1 meter until 12.5 meter. Distance "a" can be more than 12.5 meter but in this project, there is wire limitation length using Fluke 1623. The procedure for Measurement of Soil Resistance can be done in following steps as shows in Fluke 1623 Geo Earth Grounding Manual in Appendix A.

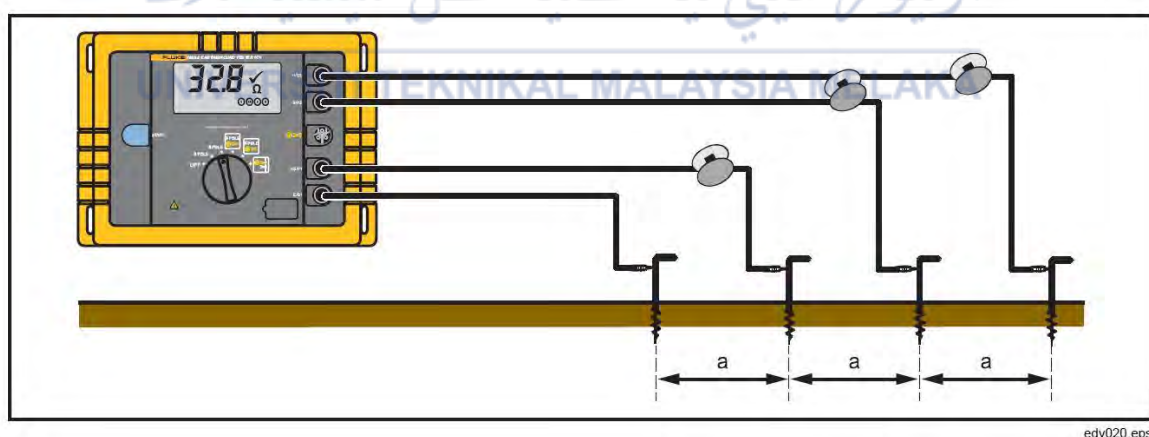


Figure 3.12: Setup of Wenner Method for Soil Resistance measurement [15]

3.4.3 Method 1 (Determine Soil Resistance)

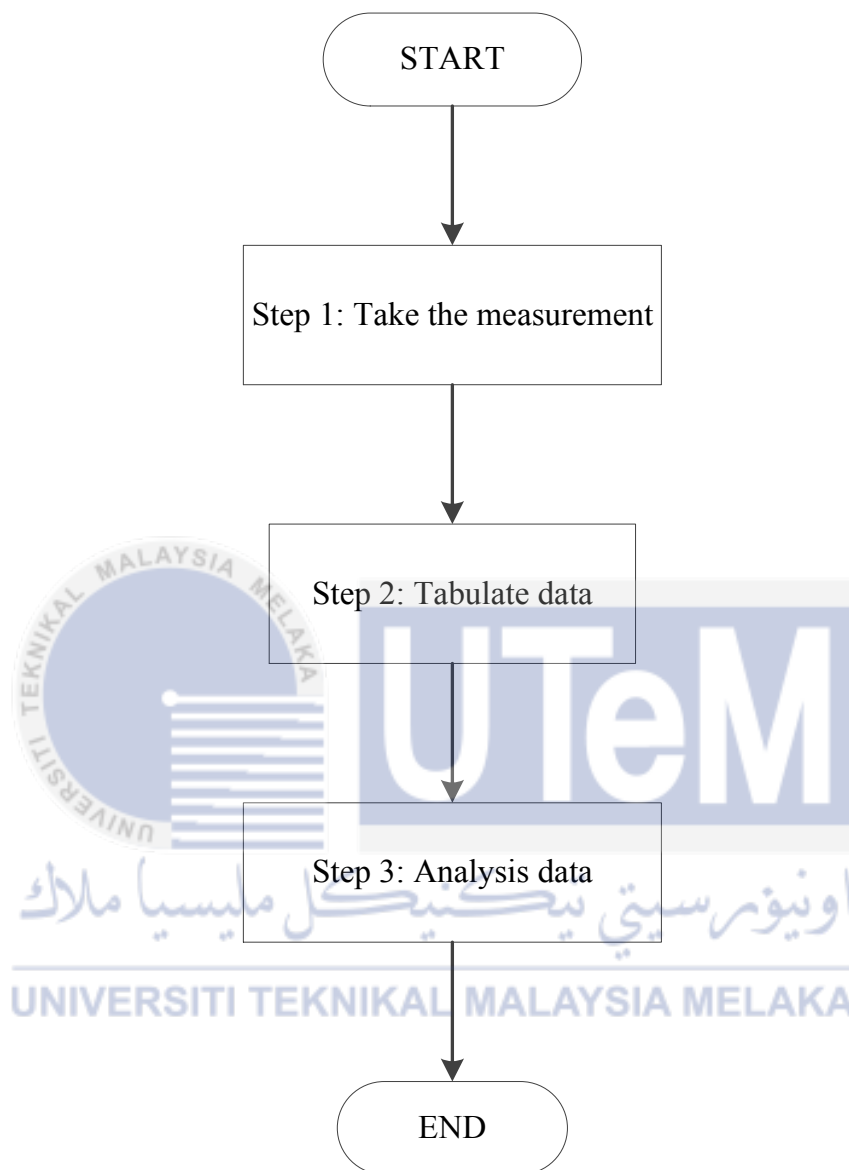


Figure 3.13: Flow chart to determine the soil resistivity.

Step 1 : First step to analyse soil resistivity is take the first measurement using Wenner Arrangement Method. This type of method are selected because this method more accurate and sensitive to multiple layers of soil resistance. Table can be tabulate referred to Table 3.3.

- Step 2 : Data are tabulate with different value of “a”. The distance “a” are distance between four electrode of Fluke 1623 Geo Earth Grounding Tester. Distance of “a” is between 1 meter to 12.5 meter. The distance a can be longer but in Fluke 1623 Tester, there are wire limitation length. The values of earth resistance are displayed on tester screen. The distance chooses are enough to determine the earth resistance pattern. Table 3.3 shows the example for result table to record earth resistance depends to the distance between probes.
- Step 3 : After data are tabulated, the data will be analysed. Other than that, in manual of tester provide the formula to calculate the resistivity value. Resistivity formula can be referred in equation 2.4. The resistivity values will shows the soil characteristic and type of multiples layers characteristic.

Table 3.3: Example of tabulated data for result table for soil resistance.

Distance Probe (m)	Earth Resistance (Ω)	Resistivity (Ωm)
1		
1.5		
2		
3		
4		
4.5		
5		
6		
7		
9		
10		

3.5.4 Driven Rod Testing

The tower footing resistance (TFR) will be measured by using 3-pin earthing test method. This 3-pin test method also called Fall-of-Potential. The two terminals will be connecting to the earth spike and the one terminal will connect to the earth electrode. Two terminals used in this project known as P2 and C2. P2 is the potential probe and C2 is the current injection probe. Distance of P2 probe must be placed in range 20 meter to 50 meter from earth electrode. The C2 probe can be placed 50 meter from the earth spike. For the accurate reading, the earth spike, C2 probe and P2 probe must in a straight line. These measurements are recorded for 30 days. The procedure for Measurement of Driven Rod Test can be done in following steps in Fluke 16623 Geo Earth Grounding Manual.

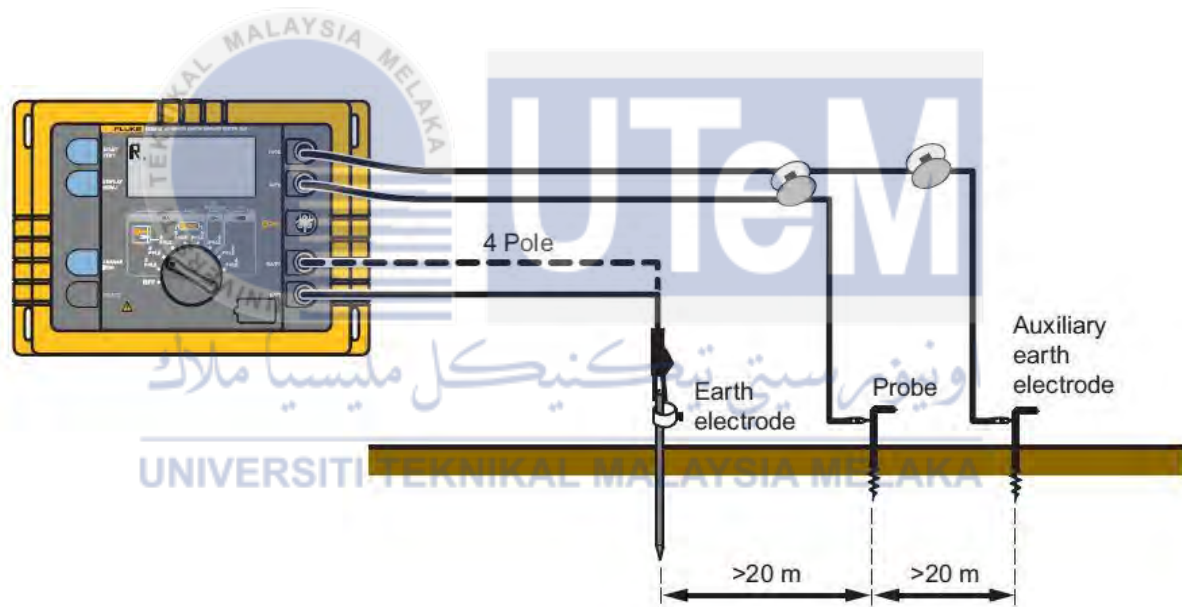


Figure 3.14: Driven Rod testing [14]

3.4.5 Method 2 (Determine TFR Resistance)

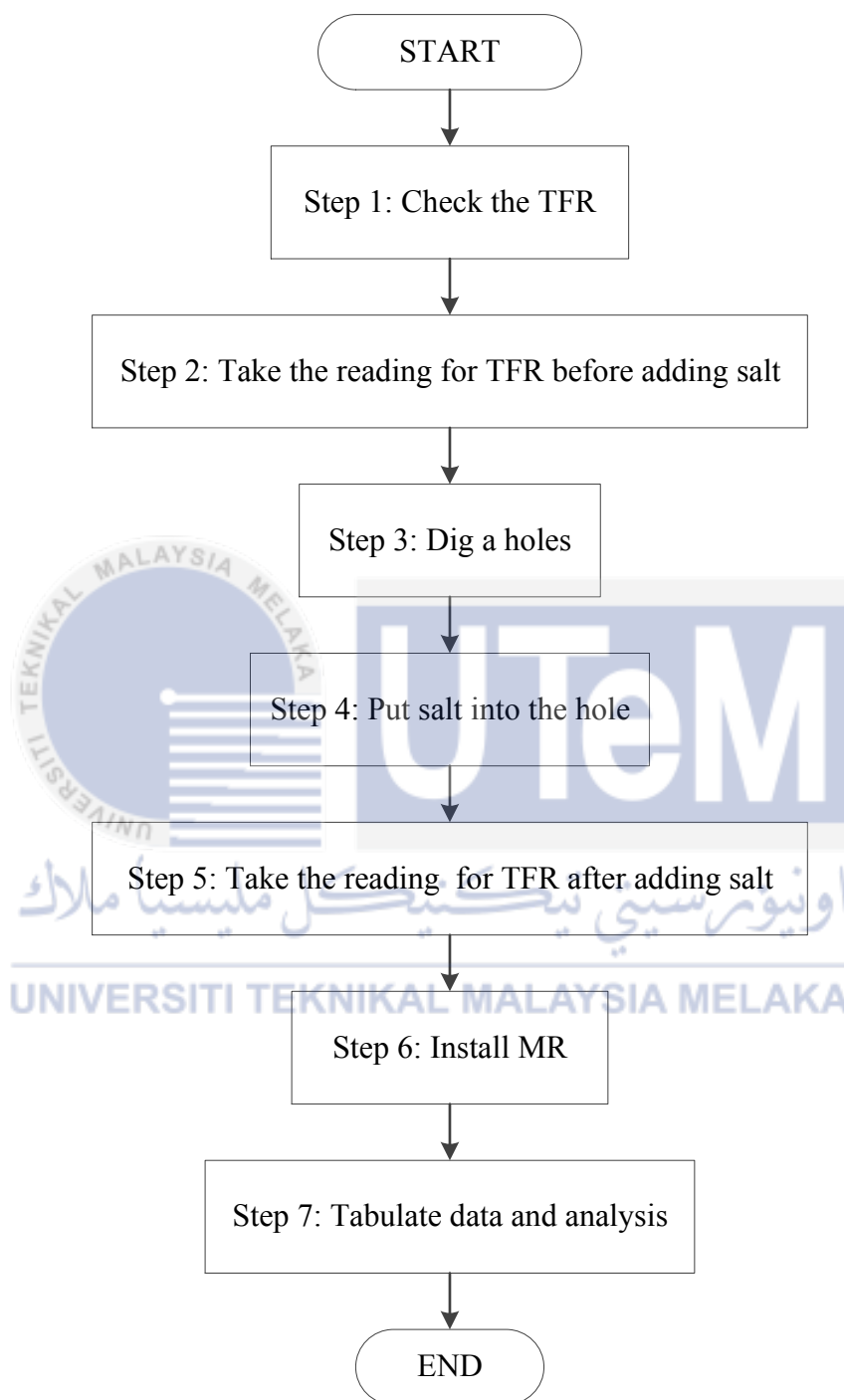


Figure 3.15: Flow chart to determine TFR value.

- Step 1 : Firstly, make sure the TFR are in good condition. Insulation test are the best method to check the continuity of the steel wire bare. The steel wire bare must connected to all rods as shown in Figure 3.6.
- Step 2 : Driven Rod Testing Method are used to measure the TFR value. At this step, the TFR values are not include the effected by dissolved salt or MR. The data is recorded. Table 3.4 shows the example of result recorded table for temperature, humidity, and earth resistance for both set of TFR.
- Step 3 : The holes are dug up around the rods. The cylindrical hole dimension of 200mm x 1000mm.
- Step 4 : In this step, 2kg salt are dissolved into water and put into the hole. Wait approximately 30 minutes before buried back the hole.
- Step 5 : Repeat the Driven Testing Method similar to step 2. Different in this step is the TFR values are included the effect by dissolved salt and MR. The data is recorded.
- Step 6 : MR are installed at Set 1 and Set 2. 3 pieces of MR installed at each set of TFR. Dig 3 holes as shown in Figure 3.4. The hole dimension for MR is 150mm diameter x 300mm deep.
- Step 7 : The data are analysed by using 62% Method to find the “actual resistance” of TFR. 30 days data will be analysed.

Table 3.4: Example table for record result data for TFR.

Date	Time	Temperature	Humidity

Distance (m)		Earth Resistance (Ω)		Resistivity (Ωm)	
Current Probe, C2	Potential Probe, P2	Set 1	Set 2	Set 1	Set 2
50	50				
50	45				
50	40				
50	35				
50	30				
50	25				

CHAPTER 4

RESULT, ANALYSIS AND DISCUSSION

4.1 Soil Resistance Measurement and Analysis

In this project, soil resistance are measured for once a day for 5 days. The temperature and humidity during testing are recorded. The ambient temperatures during reading are approximately same around 30.0 °C until 33.4 °C. Other than that, the percentage of humidity during testing also recorded and the humidity approximately in range. The relative humidity during testing is in range around 60% to 75%. Data are recorded for 5 days started on 20 April until 30 April 2015 with 2 days incrimination. Data are collected for 5 different days because the different temperature and humidity consideration at project location to the soil resistance. Table 4.1 shows the average reading for 5 days for soil resistance. Other than that, by using equation 2.4, the values of resistivity in ohm-meter unit are calculated. Figure 4.2 shows the graph of resistivity against distance of rods.

Table 4.1: Result for soil resistance

Distance Between Probes (m)	Soil Resistance (Ω)	Resistivity (Ωm)
1	122.56	769.68
1.5	74.24	699.34
2	45.02	565.45
3	24.10	454.04
4	15.98	401.42
4.5	14.02	396.21
5	12.42	389.99
6	10.38	391.12
7	8.54	375.42
9	7.96	449.90
10	6.96	437.09
12.5	6.52	511.82

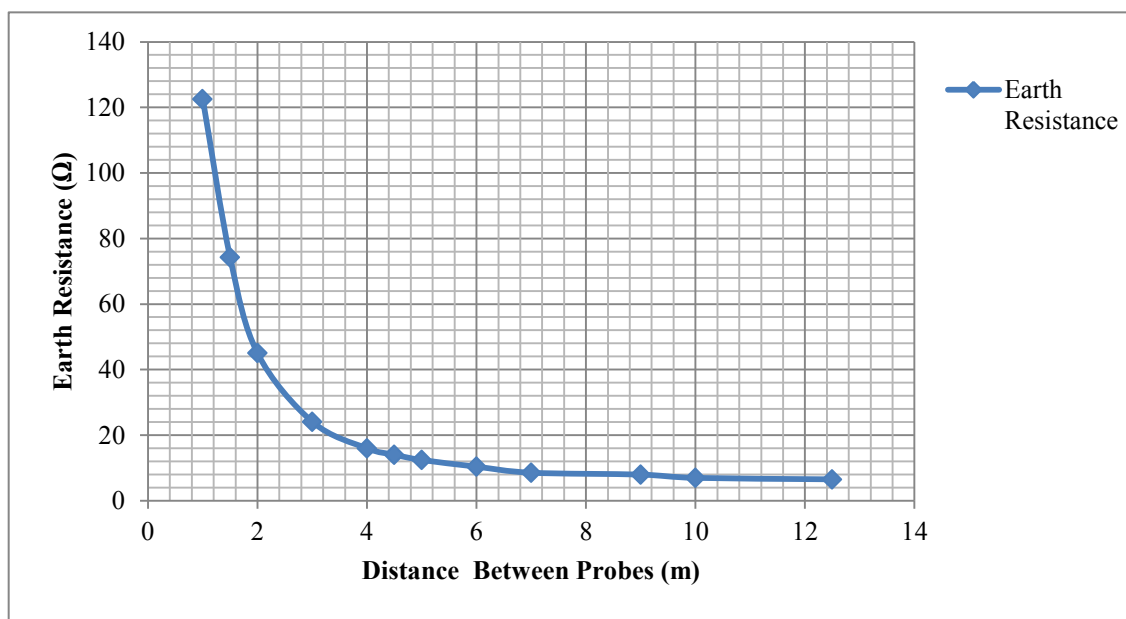


Figure 4.1: Graph of distance between probes against earth resistance value

From the Figure 4.1, the average value of earth resistance decreased if the distance between rods increased. The highest earth resistance is 1 meter and the lowest earth resistance is 12.5 meter.

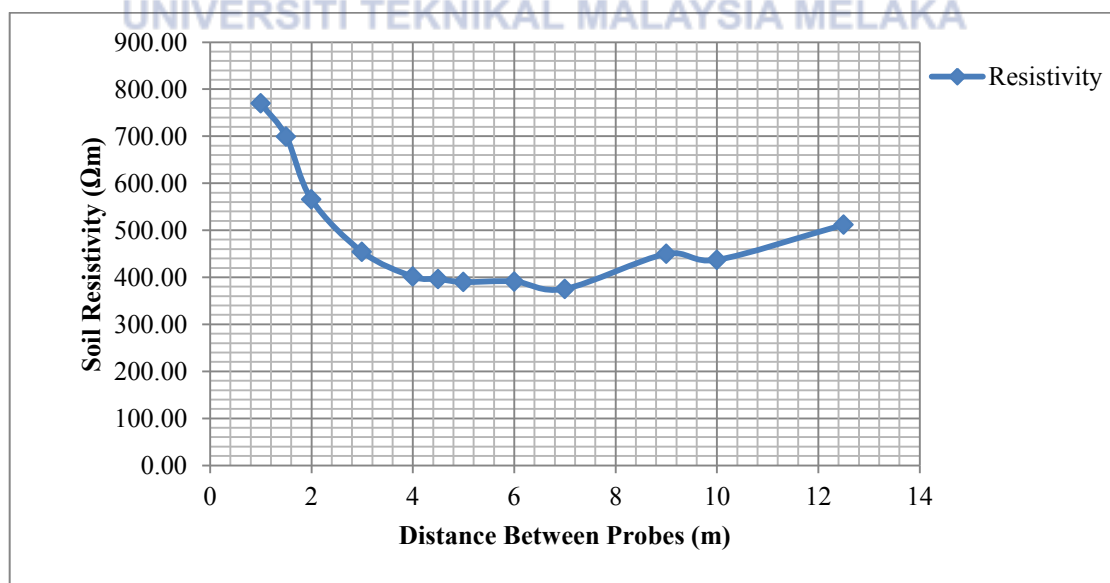


Figure 4.2: Soil resistivity against the distance between probes

The main purpose of this analysis is to determine the type of soil in project location. Graphical Curve Matching is useful analysis to detect anomalies in the soil. Referred to Figure 2.7 in Chapter 2, type of graph in Figure 4.2 shows the High-Low Soil profile. High-Low soil profile means the higher resistivity soil layers overlying the lower resistivity soil layer. The disadvantage of this graphical curve matching analysis is limited to 3 or less layers of soil structure only. The best analysis method is computer based techniques. However, there are constraints to use computer based techniques because the software are very private and only trained or authorised person can use this software. Besides, another consultant company also using a same services to get soil resistance result. Because of that, computer based techniques required longer time to get the result because have to wait to this project turn to process the data. Therefore, graphical curve matching is best analysis method to analysed soil resistivity because this method is simpler.

Other than that, Figure 4.2 also used to determine the best distance to spike the earth electrode in parallel. The suitable distance between the rods can be determined using this analysis. The lowest value is the best soil resistivity. Usually, the lowest soil resistance are used to choose as best distance to spike earth electrode in parallel. The lower soil resistivity can help the fault current to absorb easily to the earth. From the Figure 4.2, the lowest value of soil resistivity is $375.42 \Omega\text{m}$ at 8 meter distance between rods. From the Figure 4.2 also shows the values of resistivity for 4 meter until 8 meter are approximately same. Therefore, the range of suitable rods distance is 4 meter until 8 meter.

4.2 Tower Footing Resistance Measurement

TFR is one of grounding method for high voltage grounding system in electrical system. TFR value must be below $10\ \Omega$ for 132 kV and below $5\ \Omega$ for 500 kV. There are many method can be used to measure TFR referred to Table 2.4. Depend on the location and type of method, the suitable method for measure TFR value is Fall-of-Potential Method. This is because this method used simpler calculation. Other than that, this method usually used to measure transmission tower and suitable to distriected area. For Fall-of-Potential Method, 3 terminals of earth tester are used. The fixed terminal is current injection terminal, C2 and TFR electrode terminal. The distances of potential measurement, P2 terminal are different. This type of method combined with 62% Method to determine the true resistance.

During measurement was collected, the ambient temperature is in range around 30.0°C to 33.5°C same as soil resistivity measurement. The relative humidity during measurement was collected also in range around 60% to 75%. The data measurement are taken once a day on evening around 4 pm to 6 pm. TFR data was recorded for 30 days including the time needed to MR and dissolved salt installation progress. 10 kg of salt are used for this project. 2 kg of salt are put into each of 5 copper rods. The installation of MR can referred to Figure 3.4 and installation of salt can be referred to Figure 3.5 in Chapter 3. Main propose of this measurement is to analysed the TFR relationship with moistures and chemical contain.

There are 2 stage of TFR measurement. First stage measurements are recorded without the MR and dissolved salt. In other words, first stage not considers moistures and chemical contain. The second stage measurements are recorded with MR and dissolved salt.

4.2.1 Tower Footing Resistance Measurement and Analysis (First Stage)

For the first stage measurement, data are collected from 20 April until 27 April 2015. Total data recorded for first stage measurement is 8 days directly. The Table 4.2 shows the result from Fall-of-Potential for TFR value by using earth tester. For show the method calculation, only data on 20 April 2015 are shown in Figure 4.3. Figure 4.3 explain detail the 62% Method to determine true resistance for TFR value.

Table 4.2: TFR values using Fall-of-Potential result at 20 April 2015

Distance (m)		TFR Value (Ω)	
Current Probe, C2	Potential Probe, P2	Set 1	Set 2
50	50	80.8	86.6
50	45	72.1	80.0
50	40	64.7	76.7
50	35	62.3	74.7
50	30	61.1	73.8
50	25	60.4	71.9
0	0	0	0

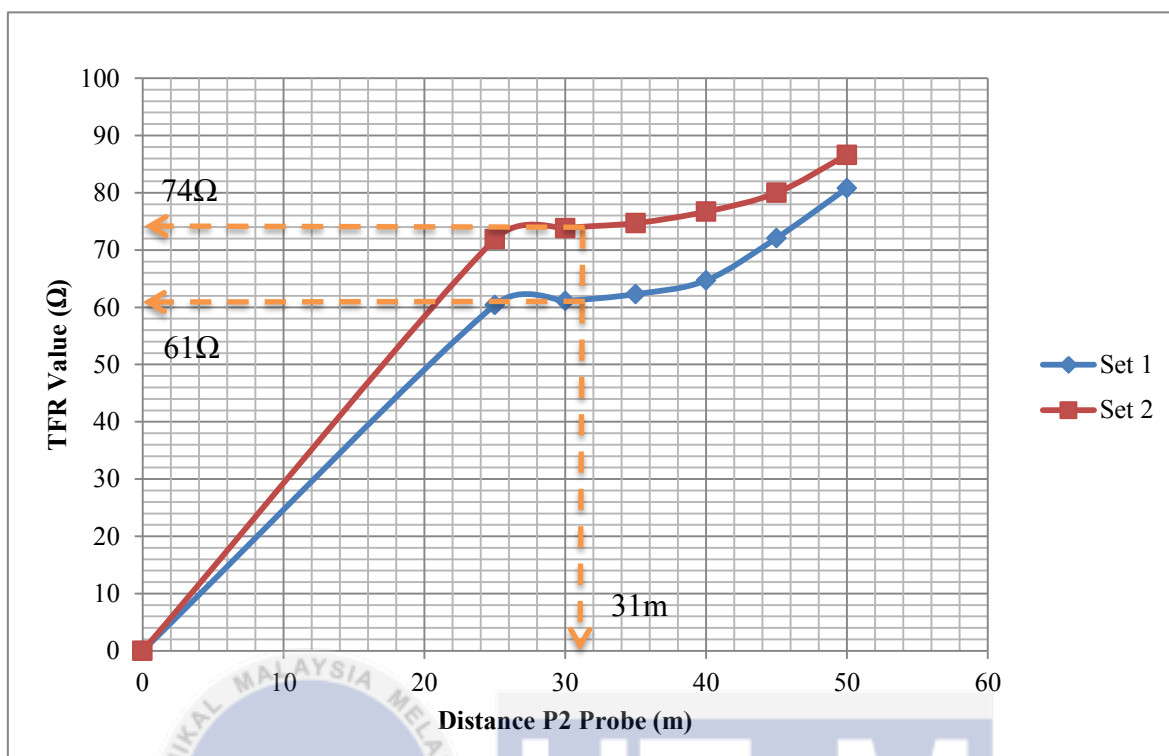


Figure 4.3: Fall-of-Potential Method result on 20 April 2015

Table 4.3: Overall TFR values and TFR resistivity for 8 days

Date	TFR Value (Ω)		TFR Resistivity (Ωm)	
	SET 1	SET 2	SET 1	SET 2
20/4/2015	61	74	102.30	124.10
21/4/2015	67	74	112.36	124.10
22/4/2015	59	72	98.94	120.74
23/4/2015	54	58	90.56	97.26
24/4/2015	47	53	78.82	88.88
25/4/2015	49	52	82.17	87.20
26/4/2015	60	74	100.62	124.10
27/4/2015	58	74	97.26	124.10

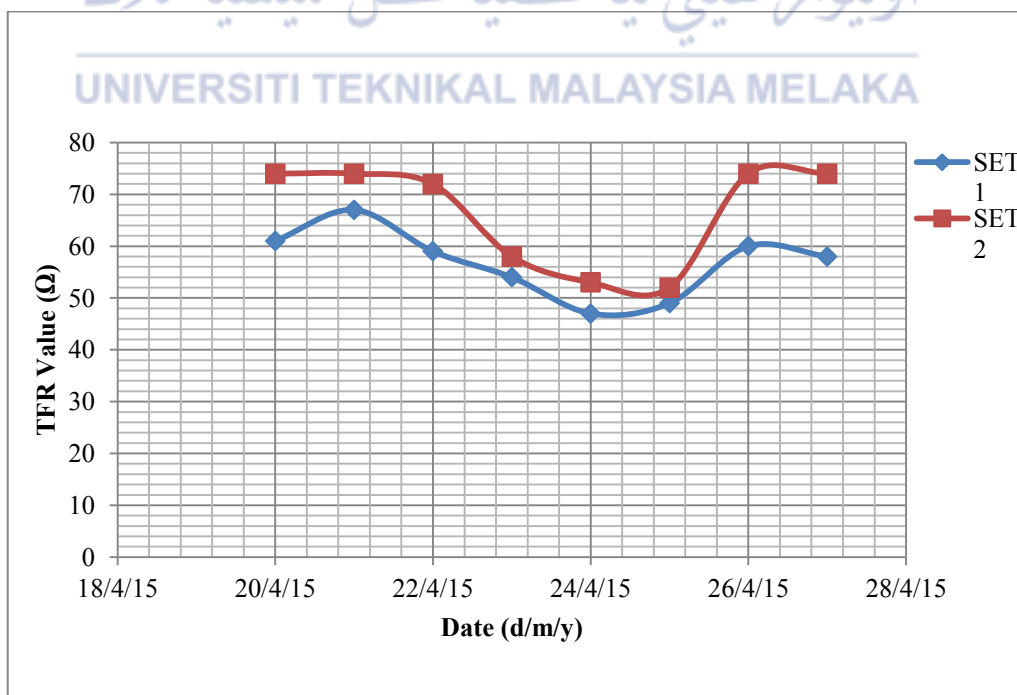


Figure 4.4: TFR value from 20 April until 27 April 2015

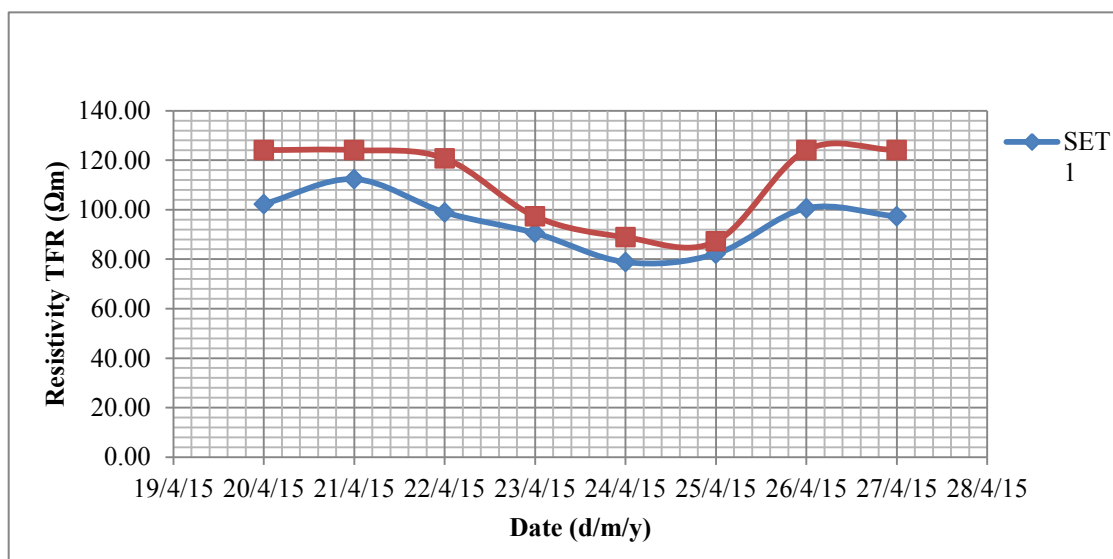


Figure 4.5: TRF resistivity from 20 April until 27 April 2015

From the Table 4.2, the values of TFR will decrease if the potential probes, P2 are decrease. From Figure 4.3, values of TFR are increased if the distances of P2 probe are increased. 62% distance of C2 probe from TFR electrode terminal is 31 meter. Therefore, the true resistance of both set of TFR can be determined at 31 meter. The true resistance for Set 1 is 61 Ω and Set 2 is 74 Ω . The difference between Set 1 and Set 2 is 13 Ω .

Figure 4.3 also clearly shows the pattern of TFR values of both set is same. Even though the pattern is same, the true resistance are different. Set 1 has lower TFR value compare to Set 2. By physical observation, the soil configuration at Set 1 is much softer than Set 2 and Set 2 have a harder and rocky soil structure during digging a hole. The rocky soil configuration of soil structure has higher resistance [7]. Therefore, the values of TFR at Set 1 always lower than Set 2.

Table 4.3 is the result of TFR values and TFR resistivity for all 8 days measurement. Figure 4.4 are build based on Table 4.3. The TFR values are not constant and always be changed. The obvious TFR values change in 8 days at 23 until 25 April 2015. The change caused by the straight heavy rain for 3 days. Therefore, the soil resistance will drop drastically because the moisture in the soil is increased. The TFR values come normally at next day. However, the values of TFR for Set 1 always lower than Set 2. The TFR value very depending to moisture and temperature of the soil. Higher TFR values can be determine during high ambient temperatures and lower moisture of the soil.

Figure 4.5 shows the resistivity of the TFR for 8 days. The pattern of TFR resistivity is same to the TFR value pattern. By referred to equation 2.5, resistivity of the TFR is directly proportional with the TFR values.

4.2.2 Tower Footing Resistance Measurement and Analysis (Second Stage)

For the second stage measurement, data are collected from 1 until 19 May 2015. Total data recorded for first stage measurement is 19 days directly. The Table 4.4 shows the result from Fall-of-Potential for TFR value by using earth tester. For show the method calculation, only data on 1 May 2015 are shown in Figure 4.6. Figure 4.6 explain detail the 62% Method to determine true resistance for TFR value.

Table 4.4: TFR values using Fall-of-Potential result at 1 May 2015

Distance (m)		Earth Resistance (Ω)	
Current Probe	Potential Probe	Set 1	Set 2
50	50	54.4	79.8
50	45	53.8	68.9
50	40	46.3	65.9
50	35	43.9	63.8
50	30	43.7	62.5
50	25	42	61.2
0	0	0	0

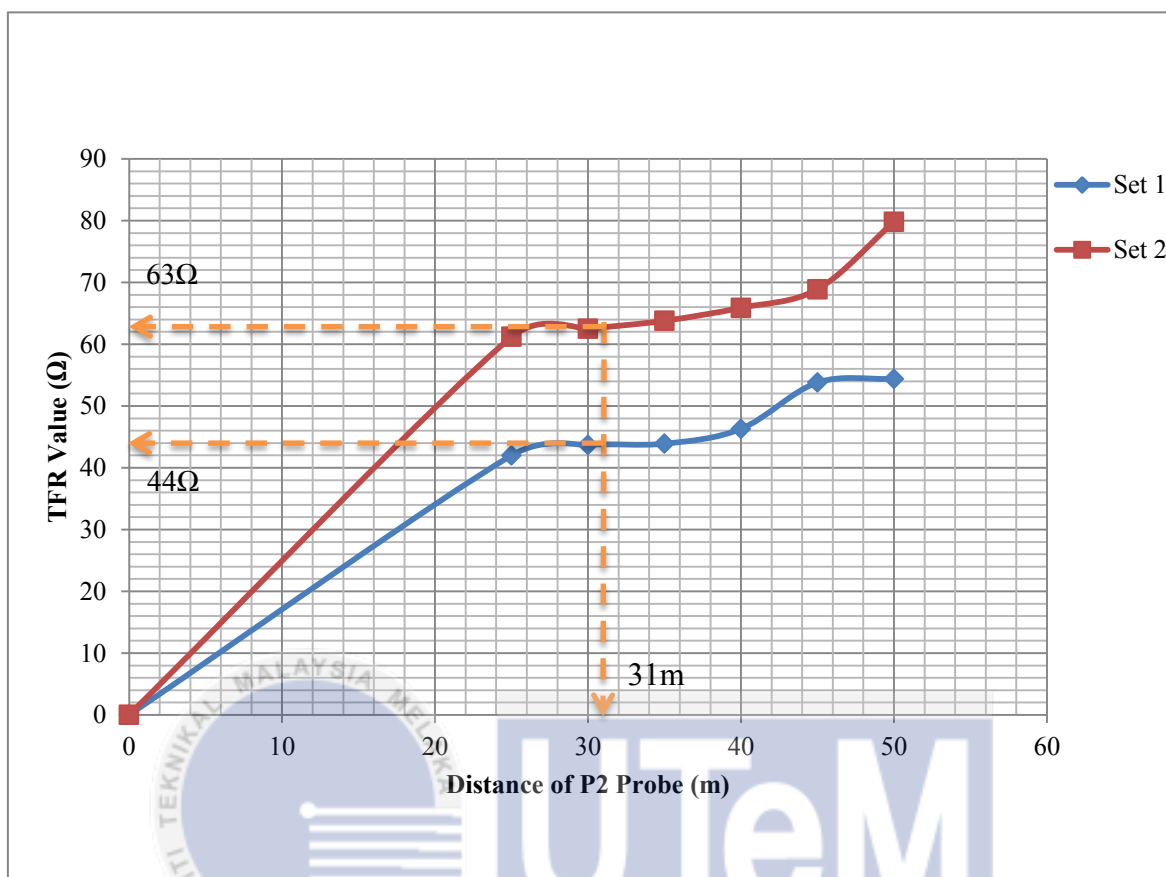


Figure 4.6: Fall-of-Potential Method result on 1 May 2015

Table 4.5: Overall TFR values and TFR resistivity for 19 days

Date	TFR Value (Ω)		TFR Resistivity (Ωm)	
	SET 1	SET 2	SET 1	SET 2
1/5/2015	44	63	73.79	105.65
2/5/2015	33	57	55.34	95.59
3/5/2015	33	57	55.34	95.59
4/5/2015	34	59	57.02	98.94
5/5/2015	32	58	53.66	97.26
6/5/2015	32	59	53.66	98.94
7/5/2015	32	60	53.66	100.62
8/5/2015	33	61	55.34	102.30
9/5/2015	32	61	53.66	102.30
10/5/2015	33	59	55.34	98.94
11/5/2015	34	60	57.02	100.62
12/5/2015	35	62	58.69	103.97
13/5/2015	34	59	57.02	98.94
14/5/2015	35	61	58.69	102.30
15/5/2015	34	60	57.02	100.62
16/5/2015	34	61	57.02	102.30
17/5/2015	32	58	53.66	97.26
18/5/2015	33	59	55.34	98.94
19/5/2015	33	60	55.34	100.62

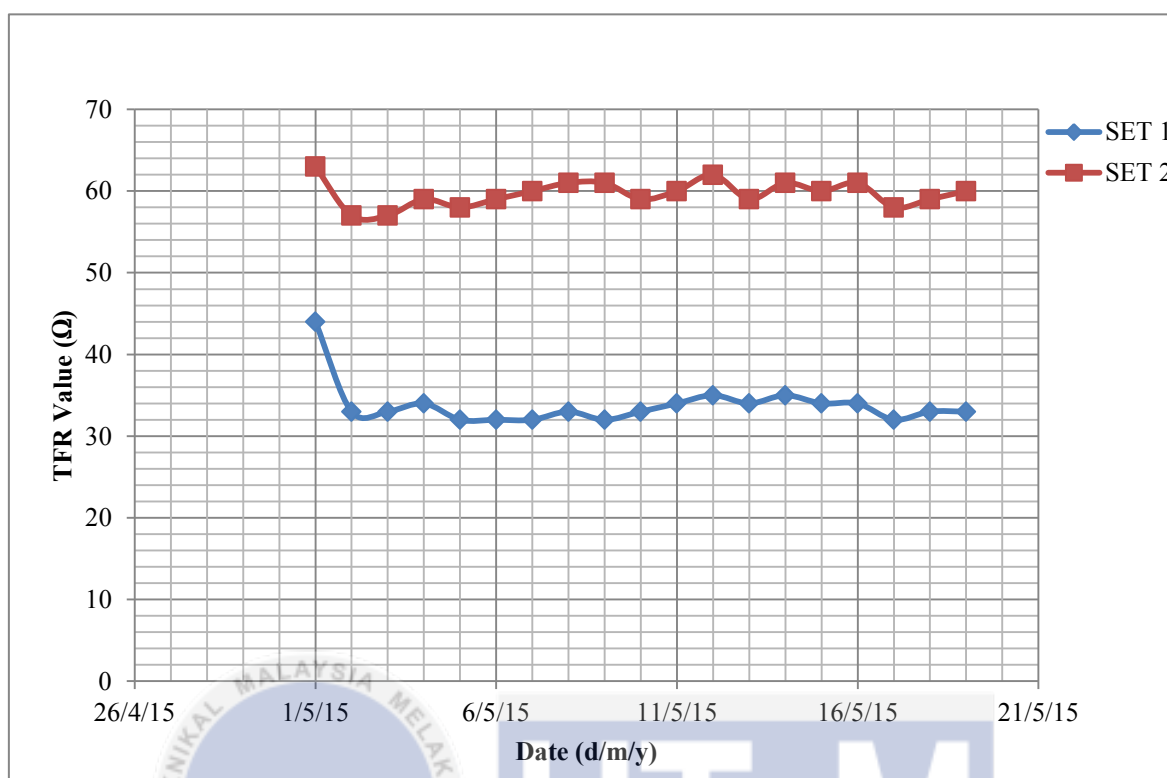


Figure 4.7: TFR value from 1 May until 19 May 2015

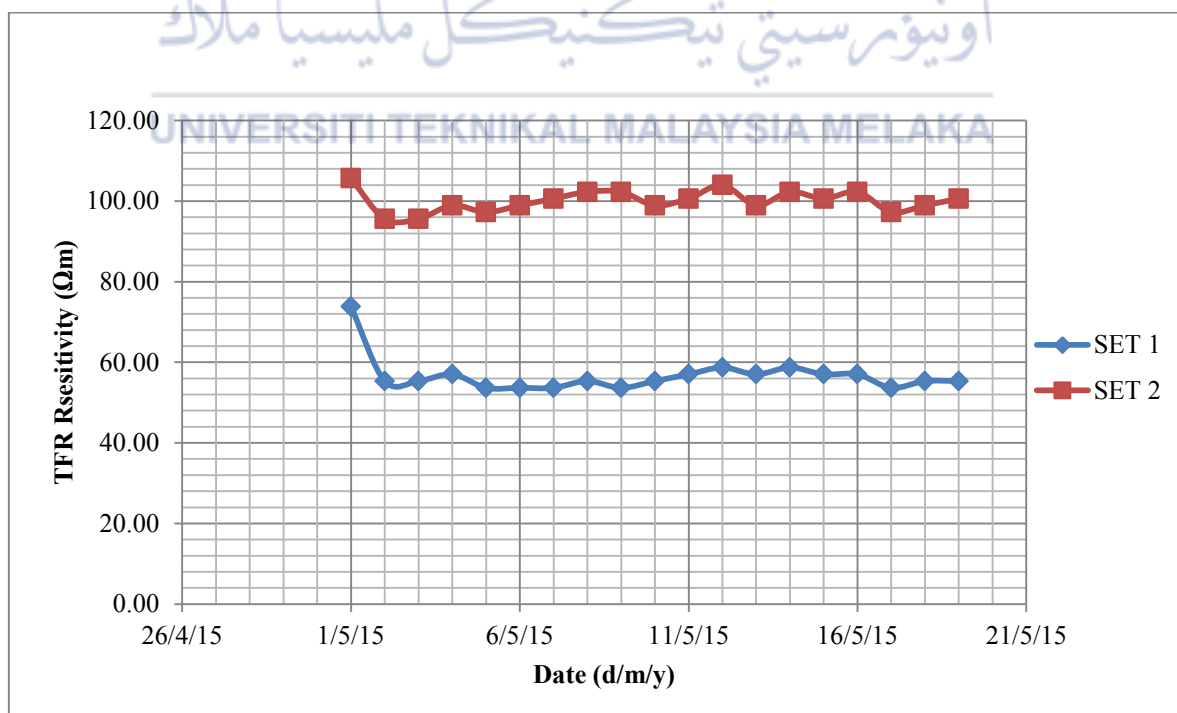


Figure 4.8: TRF resistivity from 1 May until 19 May 2015

In second stage, the measurement methods are same to first stage. Fall-of-Potential Method with 62% Method was used to determine the TFR value. The different between first stages with second stage is water and chemical contain consideration in the TFR. 2 kg of salt are added around the rods. 10 kg of salt is needed to dissolve salt installation in this project.

Figure 4.6 shows the TFR result using earth tester. All measurement method in second stage is same with first stage measurement. Figure 4.6 show the TFR true resistance using 62% Method. The value of Set 1 is 44 Ω and Set 2 is 63 Ω . The difference of TFR value for both set is 19 Ω .

Table 4.5 shows the true resistance for 19 day using 62% Method. Figure 4.7 shows the true resistance for TFR value for 19 days. Values of TFR for 19 days are approximately constant except for first days. Highest TFR values can be seen at earliest measurement at 1 May 2015. This is because the soil is not absorbing dissolved salt fully into the soil. Other than that, the highest values also can be caused by MR installation. There are because MR still releasing water to the soil and not achieve balance point. The balance point of MR achieve when the pressure of water in MR is equivalence with the soil pressure. Started second day and next, the dissolved salt is fully absorbed by the soil and MR achieves the balance point. Therefore, constant readings are recoded starting from second day until days 19.

Figure 4.8 shows TFR resistivity for 19 days. The graph pattern is similar to the TFR value in Figure 4.7. As before, the resistivity of TFR is directly proportional with the TFR values.

4.2.3 First Stage and Second Stage Analysis.

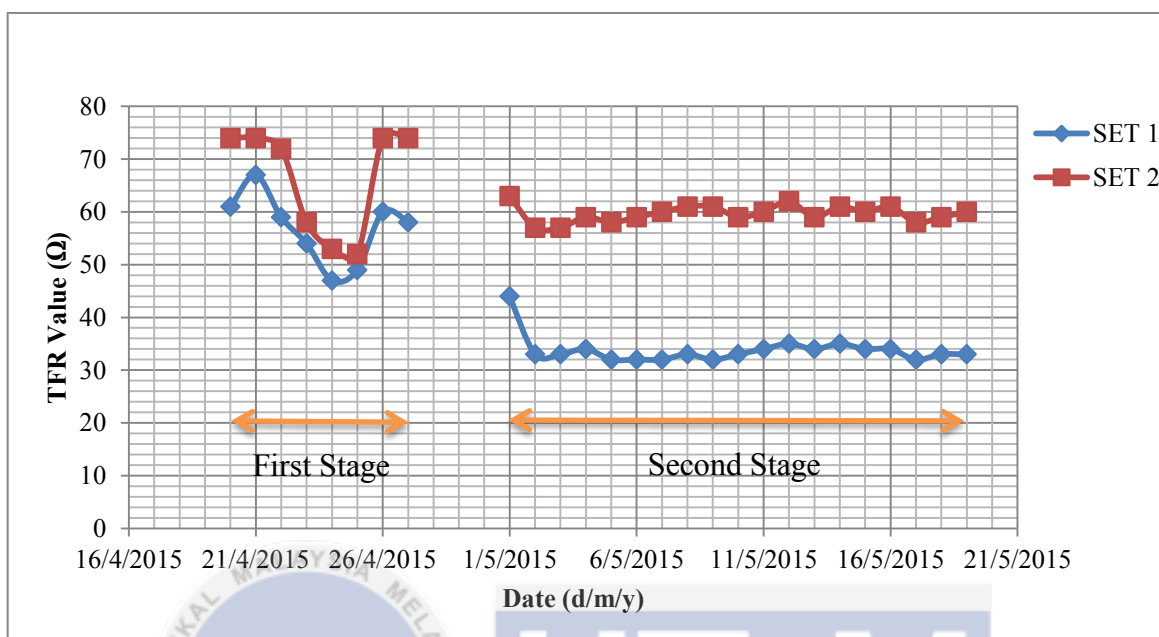


Figure 4.9: Combination of TFR values for both stages in 30 days

Table 4.6: Average reading for First Stage and Second Stage

Condition	Average TFR Value (Ω)		Average Resistivity (Ωm)	
	SET 1	SET 2	SET 1	SET 2
Before MR and Dissolved Salt Installation (FIRST STAGE)	56.9	66.4	95.4	111.3
After MR and Dissolved Salt Installation (SECOND STAGE)	33.8	59.7	56.7	100.1
Percentage of Differences (%)	40.6	10.1	40.6	10.1

Figure 4.9 shows the combination of first stage and second stage of TFR value. TFR measurement and observation are done for 30 days. First Stage duration started from 20 April and ended at 27 April 2015. Second Stage duration started from 1 May and ended at 19 May 2015.

Referring to Figure 4.9, for First Stage, TFR values are very depending to the weather. The TFR value drop drastically when raining days. Comparing to Second Stage, there are raining days on this stage but there are not showing the drastically change in TFR value. This is because MR controls the moistures in the soil. In Figure 4.9 shows the approximately constant value of TFR on Set 2. Set 2 only have MR installation. Therefore, the weather will not give effect the TFR reading because the moisture in the soil is constant. This shows the advantage of MR in this project. From Table 4.6, decreases of average TFR value after MR installation is 10.1%. Although the difference percentage between First Stage and Second Stage are small, MR can help to maintain the moisture in the soil even in hot or raining condition.

For Second Stage, dissolved salt cause a drastic decreases of TFR value. The percentage of difference between First Stage and Second Stage TFR value is 40.6%. The dissolved salt adds the low resistance material into the soil. Low resistance material will decrease the soil resistance. More low resistance material is added, the lower TFR values will produced.

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4.3 TFR Model application for Transmission Line Tower

In this project, the TFR model is not suitable for Transmission Line Tower. This is because the TFR models have higher resistance value. The transmission line tower must have 10 Ω or lower for 275 kV and 5 Ω or lower for 500 kV transmission line tower.

Average TFR value before adding MR and chemical contain is 56.9 Ω for Set 1 and 66.4 Ω for Set 2. Both of TFR model is exceed maximum value of tower resistance. Even though the dimension and items used to build TFR is same, the value of TFR are different. TFR values depends by many factor such as moisture, temperature, chemical

contain and type of soil [7]. During MR and dissolved salt installation, the physical characteristic is observed. The soil configuration at Set 1 is softer than Set 2. Set 2 soil configuration is harder and rocky. Therefore, the value of both of TFR is different.

Besides that, by referring to soil resistivity in Figure 4.2, the suitable distance for parallel electrode is 4 meter to 8 meter. The distance between rods TFR model in this project is 2.5 meter after scale down process. Therefore, the resistivity of the soil is higher. If the project follows the actual scale as shown in Figure 2.2, TFR value will be lower than scaled down model.

Other than that, the value of TFR can be reduced by adding more chemical contain. In this project, 2 kg salt is installed only in 1 meter deep around the rod. The value of TFR can reduce is more salt adding around the rod. In this project, 5 rods are selected. To get lower TFR value, dissolved salt can be added into each of rod in model. Adding more chemical contain such as LRM can reduce TFR values [7].



CHAPTER 5

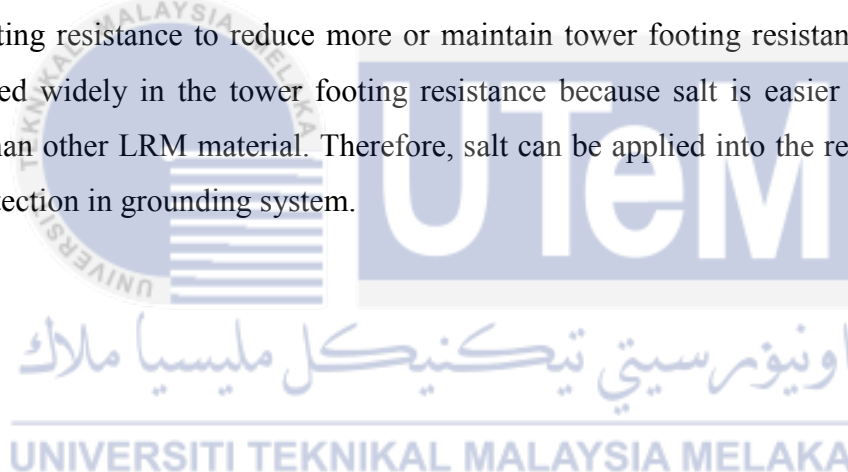
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

From the result of project, combination of MR and dissolved salt into the soil can reduce TFR values. Adding salt into the TFR will change the chemical content in the soil. Lower resistance material installation will reduce TFR value. Installation of MR will maintain the moistures in soil. Fall-of-Potential is one of common method to measure tower resistance for transmission line. Measurements are recorded every day at two different stages. First Stage measurements are recorded before adding dissolved salt and MR installation. The Second Stage is measured after adding dissolved salt and MR installation. A little improvement is done by adding salt and MR installation to TFR resistance. The difference in percentage between before and after adding dissolved and MR installation is 40.6%. The difference in percentage between before and after MR installation is 10.1%. Therefore, TFR values improvement is 40.6% before any modification. As conclusion, moisture and chemical contain is factors that affect TFR value. Reducing soil resistance must be done because the critical value of tower footing resistance is 10 Ω for 275 kV transmission tower and 5 Ω for 500 kV transmission tower.

5.2 Recommendations

Tower footing resistance values can be affected by many factors. Chemical contain in the soil is one of the factors that affect tower footing resistance values. There are many ideas to reduce tower footing resistance values. Other type of LRM such as MgSO_4 , CuSO_4 and CaCl_2 can be combined together with dissolved salt, NaCl to reduced tower footing resistance values. Others than that, the number of rod installed with dissolved salt can be added to reduce more tower footing resistance values. More dissolved salt are added into the soil, the soil resistance can be reduced. Other than that, MR and salt is good combination to reduce tower footing resistance value. Water supplied by MR can help salt to be electrolyte in the soil and salt migrate its charged ion easier into the earth. Salt will ionised easier in high moisture in soil. Therefore, the number of MR can be added into the tower footing resistance to reduce more or maintain tower footing resistance values. Salt can be used widely in the tower footing resistance because salt is easier accessible and cheaper than other LRM material. Therefore, salt can be applied into the real world to get better protection in grounding system.



REFERENCE

- [1] N. A. A. Rahman, A. M. A. Marican, A. M. Davies, M. Z. A. A. Kadir, N. Abdullah, *A Practical Method for Optimised Earth Electrode Designs at Transmission Towers Exposed to Lightning*, (7th Asia-Pacific International Conference on Lightning), Chengdu, China, November 1-4, 2011.
- [2] C.Wang, T. Takasima, T. Sakuta, Y.Tsubota, *Grounding Resistance Measurement Using Fall-of-Potential Method with Potential Probe Located in Opposite Direction to the Current Probe*, (IEEE Transactions on Power Delivery), Vol. 13, No. 4, October 1998.
- [3] A.S. Kusim, N.E. Abdullah, H. Hashim, S. Beeran Kuty, *Effects of Salt Content on Measurement of Soil Resistivity*, (IEEE 7th International Power Engineering and Optimization Conference), Langkawi, Malaysia. 3-4 June 2013.
- [4] L. W. Choun, M. Z. Abidin, C. Gomes, W. Fatinhamamah, *Analysis of Earth Resistance of Electrodes and Soil Resistivity at Different Environments*, (International Conference on Lightning Protection), Vienna, Austria, 2012.
- [5] S.M.T.Islam, Z.Chik, *Simple Equation Guide for Multi-layer Earth Structure with Soil Electrical Properties*, (IEEE Conference on Open System), Langkawi, Malaysia, 2011.
- [6] Y.Yongming, L.Xingmou, Y.Fan, *Soil Structure Effect on Transformer DC Bias*, (IEEE International Conference on Industrial Technology), 2014.
- [7] Substations Committee, *IEEE Guide for Safety in AC Substation Grounding*, (IEEE Standard 80-2000), 30 January 2000.

- [8] A.A.Al-Arainy, Y.Khan, M.I.Qureshi, N.H. Malik, F.R.Pazheri, *Optimized Pit Configuration for Efficient Grounding of the Power System in High Resistivity Soils using Low Resistivity Materials*, (IEEE International Conference), 2011.
- [9] A.Habjanic, M.Trlep, J.Pihler, *The Influence of an Additional Substance in the Trenches Surrounding the Grounding Grid's Conductors on the Grounding Grid's Performance*, (IEEE Transactions on Magnetics), Vol. 43, No 4, April 2007.
- [10] *Lightning & Surge Technologies*, Earthing Techniques.
- [11] A. S. Kusim, N. E. Abdullah, H. Hashim, S. b. Kutty, *Effect of Salt Content on Measurement of Soil Resistivity*, (IEEE 7th International Power Engineering and Optimization Conference), Langkawi, Malaysia, 3-4 June 2013.
- [12] Envirogrower, Moistube, Micro Reservoir and Smart Irrigator, Available at: <http://www.envirogrower.com.au/products-and-services/moistube/> [accessed 23 April 2015]
- [13] National Electrical Engineering Consultancy, *Soil Resistivity Tests*, ACN: 132586675
- [14] M. Nassereddine, J. Rizk, M. Nagrial, A. Hellany, *Estimation of apparent soil resistivity for two-layer soil Structure*, International Journal of Energy and Environment, Volume 4, Issue 4, page 573-580, 2013.
- [15] *1623-2 Earth/Ground Tester User Manual*, FLUKE, January 2014.

APPENDIX



APPENDIX A

Project Gantt Chart



Appendix A: Project Gantt Chart

No	Project Activities	MONTH									
		2014				2015					
		SEP	OCT	NOV	DIS	JAN	FEB	MAR	APR	MAY	JUN
1.0	Read Article & Write Literature Review	X	X								
	1.1 – Identify Objective, Scope, Problem Statement	X	X								
	1.2 – Literature Review : Idea and Past Project	X	X								
2.0	Progress Report Writing & Report Improvement			X							
3.0	Find equipment for project and learn to get preliminary result			X							
4.0	FYP 1 Seminar			X							
5.0	FYP 1 Report Submission				X						
6.0	Setup Project, Record Result, Analysis Result & Discussion					X	X	X	X	X	
	6.1 – Measurement and Installation of MR & Salt Dissolved into TFR								X	X	
7.0	Final Report Submission to Panel and Supervisor										X
8.0	Seminar FYP 2										X

APPENDIX B

Project Milestone



Appendix B: Project Milestones

TASK	DATE
Project Title and SV Approval	25 August 2014
Do the Literature Review	8 August 2014
Progress Report Evaluation	17 November 2014
FYP 1 Seminar	27 November 2014
Report Submission	17 December 2014
Borrow Equipment from Laboratory	22 January 2015
Setup Project	23 February 2015
Start Data Recorded	20 April – 19 May 2015
Final Report Submission to Panel and Supervisor	1 Jun 2015
Seminar FYP 2	8 Jun 2015
Final Report Submission to FYP Committee	24 Jun 2015

APPENDIX C

Fluke 1623 Earth Grounding Tester Manual



APPENDIX D

Turn-It-In Result

