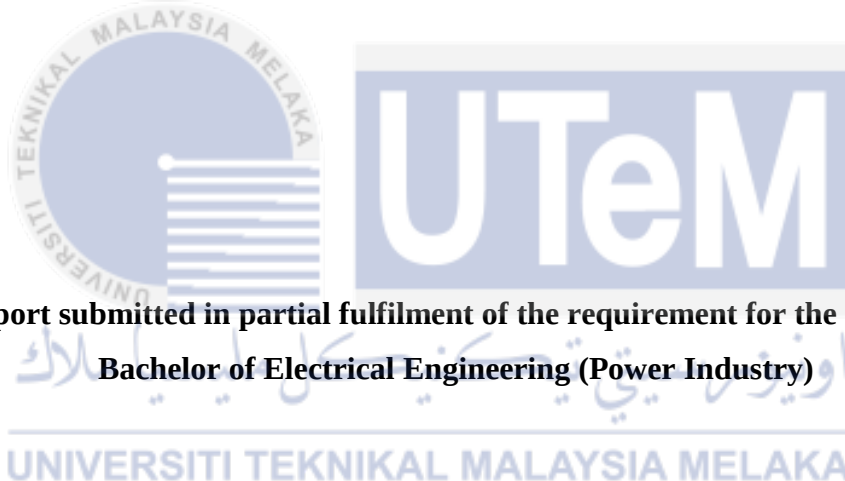


**FEASIBILITY STUDY ON EFFECTIVENESS LARGE SURFACE AREA OF
ELECTRODE FOR EARTH BATTERY**

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

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2015

“I hereby declared that I have read through this report entitle “*Feasibility Study on Effectiveness Large Surface Area of Electrode for Earth Battery*” and found that it has comply he partial fulfilment for awarding the degree of *Bachelor of Electrical Engineering (Industrial Power)*.”

Signature

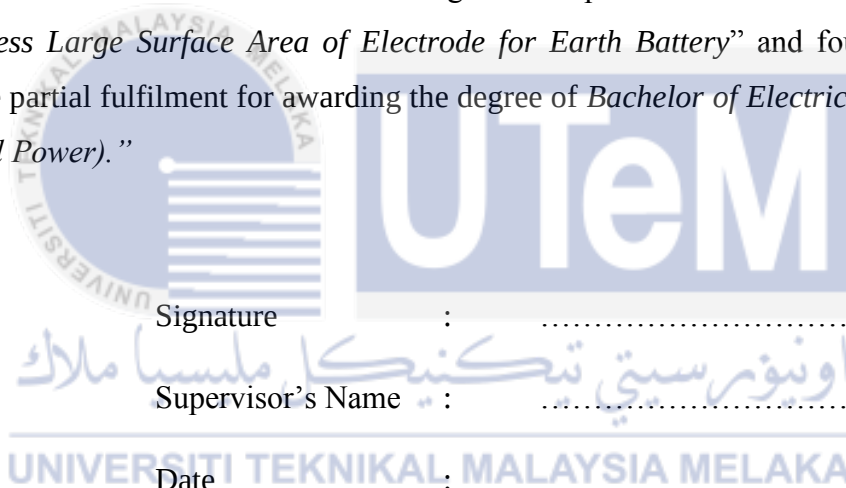
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Supervisor's Name

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Date

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ACKNOWLEDMENT

In the name of Allah, The Most Beneficent, The Most Merciful.

Praise be to Allah for His bless and kindness for giving me strength to me to complete this report. I would like to give thank you to those who have helped me a lot in completing this report the title is "*Feasibility Study on Effectiveness Large Surface Area of Electrode for Earth Battery*". I have put a lot of effort in completing this report. I also would like to recommend a say thank you to my supervisor Madam Anis Niza Binti Ramani whom supervised me to complete my case study and completing the report. I would like to grateful to my panel Miss Arfah Binti Ahmad and Mr. Mohamad Faizal Bin Baharom because give some advice and knowledge to complete my report.

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I declare that this report entitle “*Feasibility Study on Effectiveness Large Surface Area of Electrode for Earth Battery*” 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.

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ABSTRACT

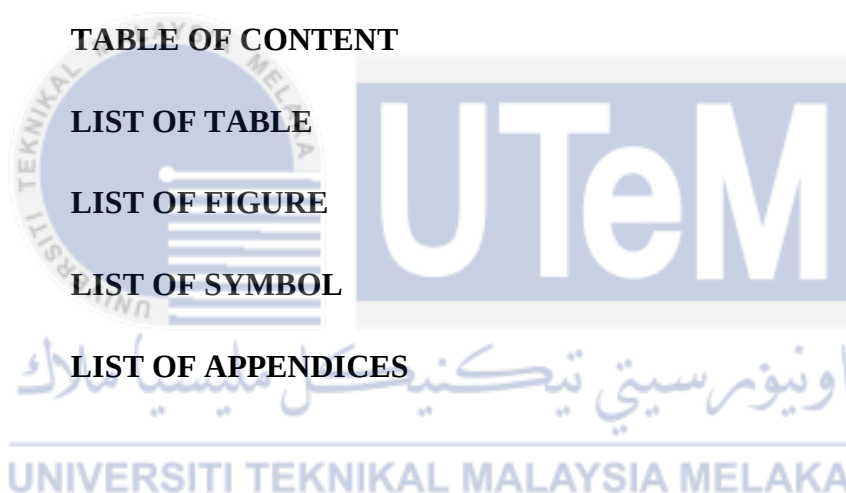
Earth battery is one of the alternative energy that produces the electricity. Basically the operation of the earth battery is the production of electrical energy from chemical reaction between two type of material of the electrode and the organic soil as the electrolyte medium. The objectives of this project are to determine the best distance between two electrodes and to investigate the effect of depth of the electrode in soil. Besides that, this project investigates the effect of moisture content on the soil and the duration of the wet soil battery. The type of material of electrode that used in this experiment are aluminium (Al) and copper (Cu). Other than that, the type of soil that used in this earth battery is organic soil. The arrangement of the battery cell is in cascade connection and the total cells in this experiment are 25 cells. The consideration of the distance between two electrode, the depth of electrode in the soil, the condition of the soil whether dry or wet and the measurement output value for every 12 hours for wet soil battery must take and controllable in order to get the output voltage and current. It can be concluded that the voltage value and current produced form earth battery are related with distance between two electrodes and depth of electrode in the soil.

ABSTRAK

Bateri tanah adalah salah satu tenaga alternatif yang boleh menghasilkan tenaga elektrik. Pada asasnya operasi bateri tanah adalah penghasilan tenaga elektrik daripada tindak balas kimia antara dua jenis bahan elektrod dan tanah organik sebagai medium elektrolit. Objektif projek ini adalah untuk menentukan jarak yang terbaik di antara dua elektrod dan untuk mengkaji kesan kedalaman elektrod di dalam tanah. Selain itu, projek ini mengkaji kesan kandungan kelembapan di dalam tanah dan tempoh bateri tanah yang basah. Jenis bahan elektrod yang digunakan dalam eksperimen ini ialah aluminium (Al) dan tembaga (Cu). Selain daripada itu, jenis tanah yang digunakan dalam bateri tanah ini adalah tanah organik. Susunan sel-sel bateri adalah selari dan jumlah sel-sel dalam eksperimen ini adalah 25 sel bateri. Jarak di antara dua elektrod, kedalaman elektrod di dalam tanah, keadaan tanah sama ada kering atau basah dan nilai output pengukuran untuk setiap 12 jam untuk bateri tanah yang basah mesti diambil kira dan dikawal untuk mendapatkan voltan keluaran dan arus. Dapat disimpulkan bahawa nilai voltan dan arus bateri tanah adalah berkaitan dengan jarak di antara dua elektrod dan kedalaman elektrod di dalam tanah.

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LIST OF SYMBOL

A	-	Ampere
C	-	Celsius
Cu	-	Copper
d, D	-	Diameter
r	-	Radius
Al	-	Aluminium
K	-	Potassium
s	-	Cross sectional area
FYP	-	Final Year Project
I	-	Current
ℓ	-	Length
m	-	Meter
RH	-	Relative Humidity
R	-	Resistance
SV	-	Supervisor
σ	-	Electrical conductivity
V	-	Potential difference/ voltage



π	-	Pi
ρ	-	Soil Resistivity
Ω	-	Ohm
W	-	Power (Watt)
cm	-	Centimetre
mm	-	Millimetre
h	-	Height
DC	-	Direct Current



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CHAPTER 1

INTRODUCTION

1.1 Research background

Earth battery is one of the alternative energy that can be used to produce the electricity. The meaning of the earth battery is the combination of clay soil and electrode such as copper electrode (Cu) with zinc electrode (Zn) or other metal that can produce potential difference (V) and current (A). The high value of the conductivity and electricity can affect output voltage [17].

Soil resistivity is defined as the resistivity of the soil in the flow of electricity. The SI unit is Ohm-Meter (Ω/m). Each type of soil has different value of the resistivity. The soil resistivity value is depending on moisture, temperature, and chemical content in the soil. The characteristic of the soil that used in this project is low resistivity and high moisture. If the soil resistivity is low, the easier the electricity can flow through the system.

Metal is an element, compound or material that has a conductor of electricity and heat. Metal are usually shiny, hard, malleable and ductile. The high value of conductivity and electricity can affect output voltage and current of the design system. The combination of soil and electrode can produce potential difference and this called earth battery.

The arrangement of the earth battery is divided into three parts. The arrangement is in series, parallel, and cascade. For the general knowledge, the voltage of the series connection is increase while the current is same. But for the parallel connection is reverse than series, which are the current is increase while the voltage is same. Meanwhile for cascade connection can control both output voltage and output current.

1.2 Problem Statement

The use of the normal battery or dry cell leads to the greenhouse effect. The environment will contaminated because of the mercury, silver, lithium, cadmium, lead and acid in dry cell or normal battery. If these batteries are burned or land filled, the heavy metals in prototype can affect the environment. Although the value of the output voltage of this battery is higher compared to soil battery or earth battery but the effect face in the long term is harmful. Therefore, by using earth battery will be reducing the greenhouse effect and give benefit to the green technology. However, earth battery produce low voltage compared to the dry cell battery. Therefore earth battery is only use for small load.

1.3 Objectives

The main objectives of this research are:

- i. To determine the best distance between two electrode.
- ii. To investigate the effect of depth of electrode in the soil on the output current and voltage.
- iii. To investigate the effect of moisture content on the soil to the output current and voltage.
- iv. To investigate the performance of wet soil battery.

1.4 Scope

This project only involve in determining the effect of distance between two electrode and depth of electrode in the organic soil. The distances between two electrodes and the depth of the electrode in the soil that use in this project are 1 cm, 2 cm, 3 cm and 4 cm. The material of the electrode that be used in this project are copper (Cu) and aluminium (Al). The size of the width and the length of electrode that used in this project are 2.5 cm and 5 cm respectively. Total amount of batteries cell that used in this experiment is 25 cells batteries. For one battery cell contained 117.8 cm^3 of organic soil. The equipment that be used in this project are digital multimeter and temperature humidity meter. Besides that, the experiment also used to study on moisture content that affecting the performance of earth battery in term of current and voltage. The amount of water that use for each cell is 6 ml for wet soil condition. The measurement of output value will recorded for every 12 hours in 4 days to investigate the performance of wet soil battery.

1.5 Thesis Outline

This research has 5 chapters. Introduction is the first chapter which contain motivation, problem statement, research objective and scope of the research. 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 research which are soil resistivity testing, material of electrode, type of soil and reactivity of the electrode. Methodology is in Chapter 3. Methodology describes the flow of the research and analysis parts are proceeding. The list of equipment and research setup procedure is parts of methodology. 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 will be recorded and data are analysed. 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 for further research.



CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will present the past article that related with this project. This case study review about the type of soil used for earth battery, potential difference or voltage output of two metal electrode that have been choose, the depth of the electrode in soil and the distance between two electrode. Basically literature review will expose the previous work to understand this project. Literature review also helps to find overall information about earth battery to make sure the objective of this project is fulfilled.

Basically the operation of the earth battery is the production of electrical energy from chemical reaction between two type of material of the electrode and the organic soil as the electrolyte medium. The effect for this reaction will change the chemical reaction to electrical energy.

2.2 Soil resistivity

Soil resistivity is a measure of how much the soil resists the flow of electricity. It is a critical factor in design of systems that rely on passing current through the Earth's surface. The soil resistivity is a basic parameter necessary for design of effective grounding and lighting protection system. The characteristic of soil also include as the different layers in the substance, the function of their porosity, permeability, ionic content and mineral. Soil resistivity is consisting of the moisture of soil. The moisture of the soil is the greatest impact on resistivity [8]. Figure 2.1 show one of the type soil resistivity testing.

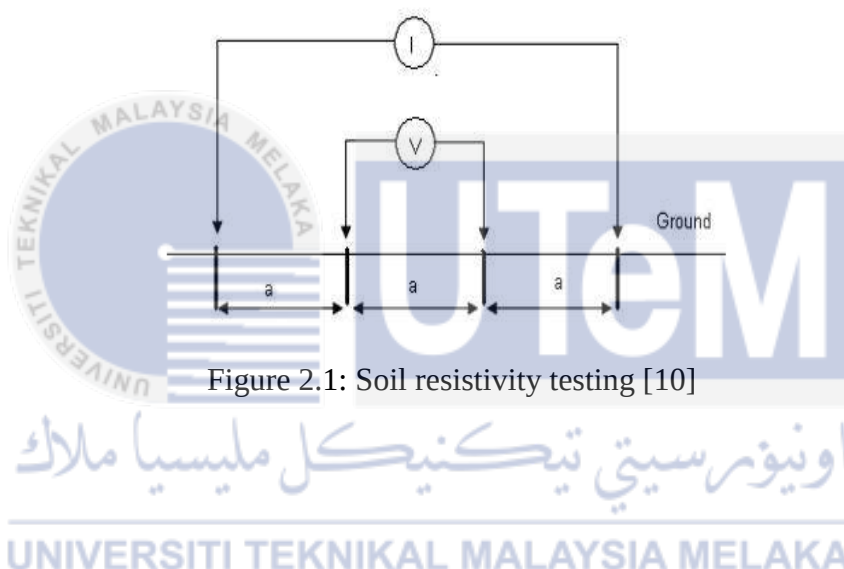


Figure 2.1: Soil resistivity testing [10]

2.3 Material of the electrode

The next parameter to be considered is the type of electrode. Generally, materials have characteristics behaviour of resisting the flow of electrical charge. The ability to resist current is one of the physical properties that used to conduct electricity. Metal is used because it has high conductivity and electricity value. Different type of electrode gives different value of potential difference. Electrode selection is based on the conductivity value of a material. In this part, to increase the voltage, the electrode used must have features such as low resistivity, high conductivity, and high melting point and durable [5]. There are four metal used to investigate the electrical conductivity of the DC supply from organic soil which are copper, aluminium, brass and gold as shown in Figure 2.2.



(a) Copper electrode



(b) Aluminium electrode



(c) Brass electrode



(d) Gold electrode

Figure 2.2: Types of electrodes [5-7]

Copper is a metal which has an excellent electrical conductivity because copper is in group 11 of the periodic table where copper has high ductility and electrical conductivity. The colour of copper is red brown. Copper also is a ductile metal. It can be easily shaped for example in cable wire which has many types of size. In the market, copper metal is very high compared to aluminium and brass [6].

Aluminium is soft, durable, lightweight, ductile and malleable metal with appearance ranging from silvery to dull grey, depending on the surface roughness. It is nonmagnetic and does not easily ignite. Aluminium has about one-third the density and stiffness of steel. It is easily machined, cast, drawn and extruded. Aluminium is a good thermal and electrical conductor, having 59% the conductivity of copper, both thermal and electrical conductivity, while having only 30% of copper's density. Corrosion resistance can be excellent due to a thin surface layer of aluminium oxide that forms when the metal is exposed to air, effectively preventing further oxidation. The strongest aluminium alloys are less corrosion resistant due to galvanic reactions with alloyed copper [7].

Brass is alloy of combination between copper and zinc. The physical of brass are malleable and ductile, with alloys that contain less than 35% zinc able to be cold rolled. The conductivity of brass is only between 23% and 44% of the conductivity of copper, which is still fairly high. The uses of brass vary depending on the percentage of zinc and copper, and which other metals have been added to alloy to bring out specific properties [20]. It conducts heat very well. Brass material with more zinc is stronger and harder. The colour of brass is light yellow colour close to that of gold. Brasses with less zinc are more of a red brown colour [21].

Electric resistivity of the soil can be considered as the variability of soil physical properties. The line distribution of the current flow normally depends on the subject or medium under investigation. This is because they are physically concentrated in volumes. For a simple body or medium, resistivity, ρ can be expressed as follows:

$$\rho = R \left(\frac{S}{L} \right) \quad (2.1)$$

Where,

R= electrical resistance (Ω)

L= length of the cylinder (m)

S = cross sectional area (cm^2)

The formula resistance of the electrical of the cylinder body R (Ω) is defined by the ohms law which is:

$$R = \left(\frac{V}{I} \right) \quad (2.2)$$

Where,

V= Potential difference (V)

I= current (A)

Another characteristic that commonly uses in electrical study are described by the electrical conductivity value is equal to the reciprocal of the soil resistivity. Thus:

$$\sigma = \frac{1}{\rho} \quad (2.3)$$

Where,

$$\rho = \text{Resistivity } (\Omega/\text{m})$$

Based on Table 2.1, the highest electrical conductivity material is copper while the lowest electrical conductivity is brass. Copper materials have the lowest resistivity which is $1.7(\Omega/\text{m})$ compare to the brass is $6.3(\Omega/\text{m})$ which is the highest electrical resistivity. The value of electrical resistivity and conductivity of aluminium is $2.7(\Omega/\text{m})$ and $36.9(\text{s}/\text{m})$ respectively. The good conductivity has a low resistivity value, thus it will produce the higher output voltage compare to the other materials. The appropriate types of metals that can be used are brass and aluminium. This is due to the low cost of these materials compared to copper and gold.

Table 2.1: Comparison of resistivity, conductivity and thermal conductivity of each type of material [3]

Material	Electrical resistivity, $\rho(10.E-8(\Omega/\text{m}))$	Electrical conductivity, $\sigma(10.E6 \text{ Siemens}/\text{m})$	Thermal conductivity (W/m.k)
Gold	2.3	44.2	317
Brass	6.3	15.9	150
Copper	1.7	58.5	401
Aluminium	2.7	36.9	237

2.4 Type of Soil

Generally, soil resistivity is a measure of how much the soil resists the flow of electricity. In the meantime, soil conductivity is a measure of how much the electricity being produced by the soil. The conductivity of the soil is related to the electric charge and the ions concentration in the soil [1]. The ion flow or move through the conducting channel with the different ratio according to the type of soil [1]. The investigation of each type of soil is to determine which one is the best medium in the flow of electricity. These soils have its own value of resistivity and conductivity.

The factors that contribute to the selection of soil are such as low resistivity per meter(Ω/m), high of moisture contain and low pH value. The moisture contain of soils need to maintain, in order to give the stability output voltage. The higher the moisture of the soil thus will increase the output voltage. The meaning of pH is measure of the activity of the (solvated) of hydrogen ion (H), which measures the hydrogen ion concentration [2]. Pure water has a pH very close to 7 at 25 °C. Solutions with a pH less than 7 are said to be acidic and solution with a pH greater 7 are basic or alkaline. The pH scale is traceable to a set of standard solution whose pH is established by international agreement [3]. Based on the Table 2.2, the typical average resistivity of sandstone is higher compare to clay and slate. Type of clay soil has the lowest typical and average resistivity which is 40(Ω/m). The average of resistivity of sandstone and slate are higher compare to clay. Figure 2.3 shows the type of soil. Besides that, Table 2.3 shows another type of earth with their average resistivity [18].

Organic soils are naturally rich in organic matter principally for climatic reasons. Soil organic matter is any material produced originally by living organisms (plant or animal) that is returned to the soil and goes through the decomposition process. Organic soils are topsoil, which contains decomposed vegetable matter or humus materials from the decomposition of animal and plant matter. Most soil organic matter originates from plant tissues. Plant residues contain 60% to 90% moisture. Organic matter existing on the soil surface as war plant residues helps protect the soil from the effect of rainfall, wind and sun. Higher organic matter levels tend to reduce loss of soil by erosion because of better water infiltration through a more stable soil structure [24]. Based on Table 2.3, the average resistivity of wet organic soil is 10 Ω/m .



(a) Sandstone soil



(b) Slate soil



(c) Clay soil



(d) Organic soil

Figure 2.3: Type of soil [1-3]

Table 2.2: Types of soil with average resistivity and typical resistivity value [4]

Types of soil	Typical resistivity (Ω/m)	Average resistivity (Ω/m)
Clay	40	8 ~ 70
Sandstone	2000	200 ~ 3000
Slate	120	10 ~ 100

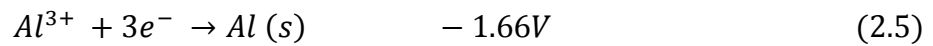
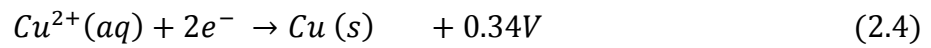
Table 2.3: Average of resistivity of soil [18]

Type of earth	Average resistivity (Ω/m)
Wet organic soil	10
Moist soil	10^2
Dry soil	10^3
bedrock	10^4

2.5 Reactivity of the metal of the electrode

The potassium, K is the most reactive metal while platinum, Pt is the least reactive metal. Then this reactivity of metal based on theory is using electrolysis method [12]. Figure 2.4 show the reactivity series of metal from least to most reactive. The higher the metal in reactivity series, the greater tendency it has to form its positive ion. Therefore the oxidation reaction will occur at metal which is higher in reactivity series. The two solid metals that are connected by the external circuit are called electrodes. The electrode at which oxidation occurs is called the anode while the electrode at which reduction occurs is called the cathode [17].

Equation 2.4 for chemical reaction at cathode because copper is lower in reactivity series in Figure 2.4. While Equation 2.5 is a chemical reaction at anode because of aluminium is higher than copper in reactivity series. This chemical reaction is the Standard Reduction Potential in water at 25°C. Equation 2.6 shows the cell potential. Cell potential is the difference between two electrode potentials, one associated with the cathode and the other associated with the anode [17].



$$E^{\circ}_{\text{cell}} = E^{\circ}(\text{cathode}) - E^{\circ}(\text{anode}) \quad (2.6)$$



Li	Lithium
K	Potassium
Ba	Barium
Ca	Calcium
Na	Sodium
Mg	Magnesium
Al	Aluminum
C	Carbon
Zn	Zinc
Fe	Iron
Ni	Nickel
Sn	Tin
Pb	Lead
H	Hydrogen
Cu	Copper
Hg	Mercury
Ag	Silver
Au	Gold
Pt	Platinum

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Figure 2.4: The reactivity series [12]

2.6 Effect of the moisture of the soil

Temperature also can affect the moisture content of soil. It also can be related to the texture and structure of the different soil types, which can give impact to the soil content moisture. When the soil on the surface becomes dry, the contribution of deeper soil layer will increase so that it will going closer to the soil temperature depth [11]. This is because when the soil in dry condition, the resistance between electrodes getting high [19].

2.7 Configuration of cells connection

The next parameter involved is the arrangement of soil clay battery. The arrangement means the type of connection. The arrangement that will be review and investigate in this project is series, parallel and cascade (series and parallel). For the general knowledge, the voltage of the series connection is increase while the current is same. But for the parallel connection is reverse then series, which are the current is increase while the voltage is same. Meanwhile for cascade connection can control both output voltage and output current.

2.7.1 Series Connection

A series connection is a circuit composed entirely of components connected in series. In a series circuit, the current flowing through each of the components is the same by referring to Equation 2.7, and the voltage across the circuit is the sum of the voltages across each component by referring Equation 2.8. To increase the output voltage in a circuit, series connection will be used as shown in Figure 2.5. However, disadvantage of this circuit is that if one of the components of the series circuit is faulty such as overloaded or short circuit, the whole circuit will then is damaged [15].

$$\text{Current, } I_1 = I_2 = I_3 = I_n \quad (2.7)$$

$$\text{Voltage, } V_t = V_1 + V_2 + V_3 \quad (2.8)$$

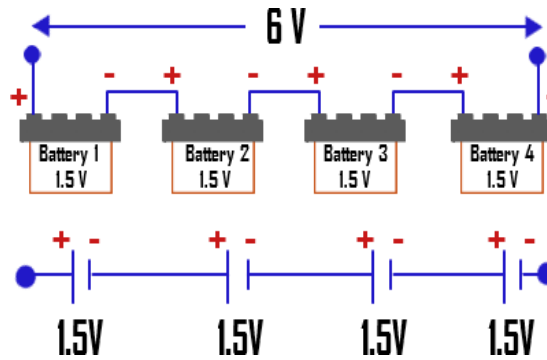


Figure 2.5: Series connection [16]

2.7.2 Parallel Connection

In a parallel connection, the voltage across each of the components is the same by referring Equation 2.9, and the total current is the sum of the currents through each component as stated in Kirchhoff's Current Law by referring Equation 2.10 [15]. If two or more components are connected in parallel, they have the same voltage across their ends as shown in Figure 2.6. The same voltage means the average of the output voltage of the connection. The advantage of parallel connection is increases the current at constant voltage at the supply end, and if there is a short circuit or overload, only the overloaded or short-circuited device will be damage. This makes it easier to isolate faults and perform repairing to the faulty branches. In other words, if one branch fails, the other branches can still keep on working. However, the disadvantage is the output voltage of parallel battery connection is less that the output voltage of series battery connection [16].

$$\text{Voltage, } V_t = V_1 = V_2 = V_3 \quad (2.9)$$

$$\text{Current, } I_t = V_t \frac{1}{R_t} \quad (2.10)$$

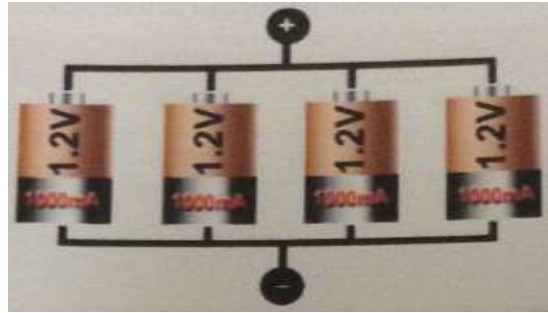


Figure 2.6: Parallel connection [16]

2.7.3 Cascade Connection

This type of connection is the combination of series and parallel connection in one circuit as shown in Figure 2.7. This connection can control both output voltage and output current. If the batteries need to increase voltage, the method is by connecting several of earth batteries in series connection, so it will help to achieve the higher voltage. Besides that, parallel connection may increase the capacity of current produce. The combination of series and parallel connection can increase or decrease both of voltage output and current output [16].

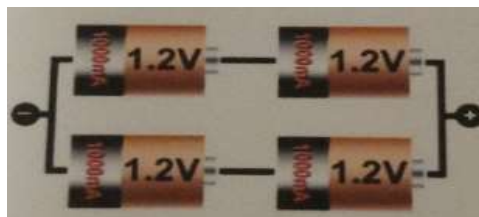


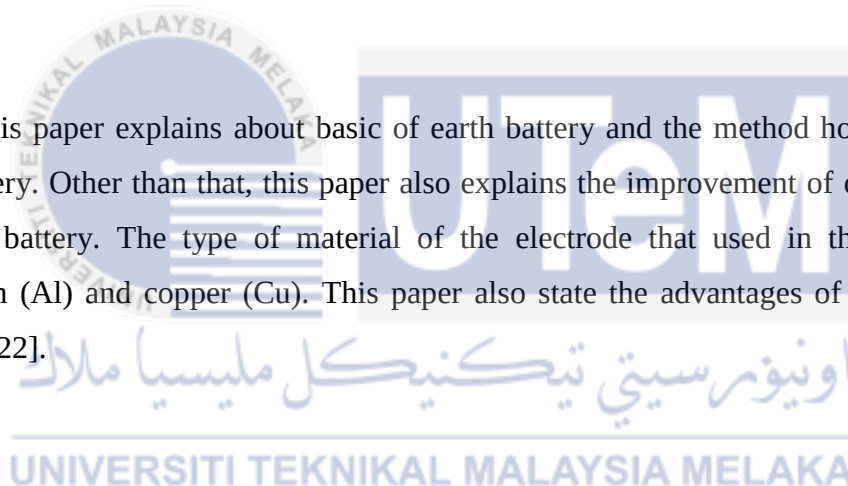
Figure 2.7: Cascade connection [16]

2.8 Review of previous related work

Paper of previous work is one of the main sources to get information about this project. These papers were explained about the effect of the moisture to the output value. Besides that, the distance between two electrodes and the depth of the electrode in the soil also can affect the output value. Table 2.4 show the findings from the previous related work.

2.8.1 Previous work 1: Free Energy from the Earth

This paper explains about basic of earth battery and the method how to assemble earth battery. Other than that, this paper also explains the improvement of output value of the earth battery. The type of material of the electrode that used in this paper were aluminium (Al) and copper (Cu). This paper also state the advantages of earth powered batteries [22].



2.8.2 Previous work 2: Uninterruptable Power Supply Using Earth Battery and Solar Panel

This paper explained the operation of the earth battery. The metal electrodes are collecting free ions in the soil and the soil is acting as a medium of transfer of ions. Each electrode has their own potential difference by referring the reactivity series. Thus both of anode and cathode inserted in the soil kept in an insulating casing. Earth battery can only supply a small load [23].

2.8.3 Previous work 3: Experimental Study of Earth Batteries

This paper investigated the maximum potential difference by the different combination of metallic and non-metallic solid, liquid and gas electrode. This paper was studies the most suitable combination of the commonly available metals. The voltage value that produced can be increased by connecting multiple earth battery cells in series. Meanwhile the output current can be increased by connecting multiple of cells in parallel [19].

2.8.4 Finding from the previous work

Referring to the previous work, some information based on their experiment and theories can be use in this project. Table 2.4 show the findings from the previous work that related to this project.

Table 2.4: List of findings from previous work

Titles	Findings
Free Energy from the Earth [22].	- The distance between two electrodes will affect to the output current. The closer the distance between two electrodes, the more current value are produced. - The reading of the current value that produce will increase when the depth of electrode in the soil increase. - More amount of electrode in a connection can increase output value.

	This paper state the more current output will produced when the electrode deeper in the earth.
Uninterruptable Power Supply Using Earth Battery and Solar Panel [23].	- The voltage value can be increased by connecting multiple cells in series and the current value can be increased by connecting cells in parallel. - This paper using the moist soil as an electrolyte with two electrodes in the soil. This is because dry soil is much lower in conductivity than moist soil. - The voltage that produced by earth battery is depend on the difference of the potential of electrodes used as cathode and anode.
Experimental Study of Earth Batteries [19].	- Previous work state the current values that produced from earth battery can be increase by increasing surface area of electrodes. - Besides that, the voltage and current that produced from earth battery are higher at smaller distance between anode and cathode. - This review found the voltage and current value are depend upon moisture content of the soil. When the soil in dry condition, the current value reduces near to zero due to high resistance between two electrodes.

2.9 Summary and discussion of the review

The type of soil that suitable to use in this project is organic soil because this soil has the lowest typical and average resistivity which is $10(\Omega/\text{m})$ based on Table 2.3. The type of the material of two electrodes that used in this project are aluminium (Al) and copper (Cu) because these metals are excellent in electrical conductivity. For this project, the distance between two electrodes and the depth of the two electrodes in the soil will be consider to determine the potential difference and current that will produce. The moisture of soil whether in dry or wet condition must be consider.



CHAPTER 3

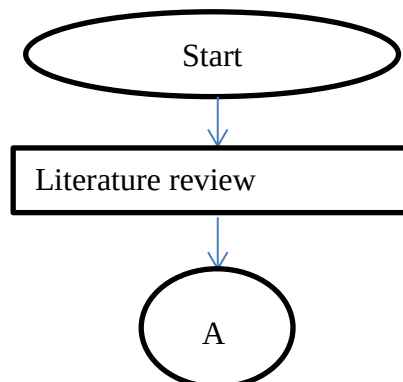
METHODOLOGY

3.1 Introduction

In this chapter explain about flow of methodology and explanation of the method to complete this project. Basically this project is to take measurement of the current and voltage output of the earth battery by using copper electrode and aluminium electrode. Then, all of the experimental research was based on flow chart of methodology.

3.2 Flow chart of methodology

The Figure 3.1 below, display the flow chart of the method of this project.



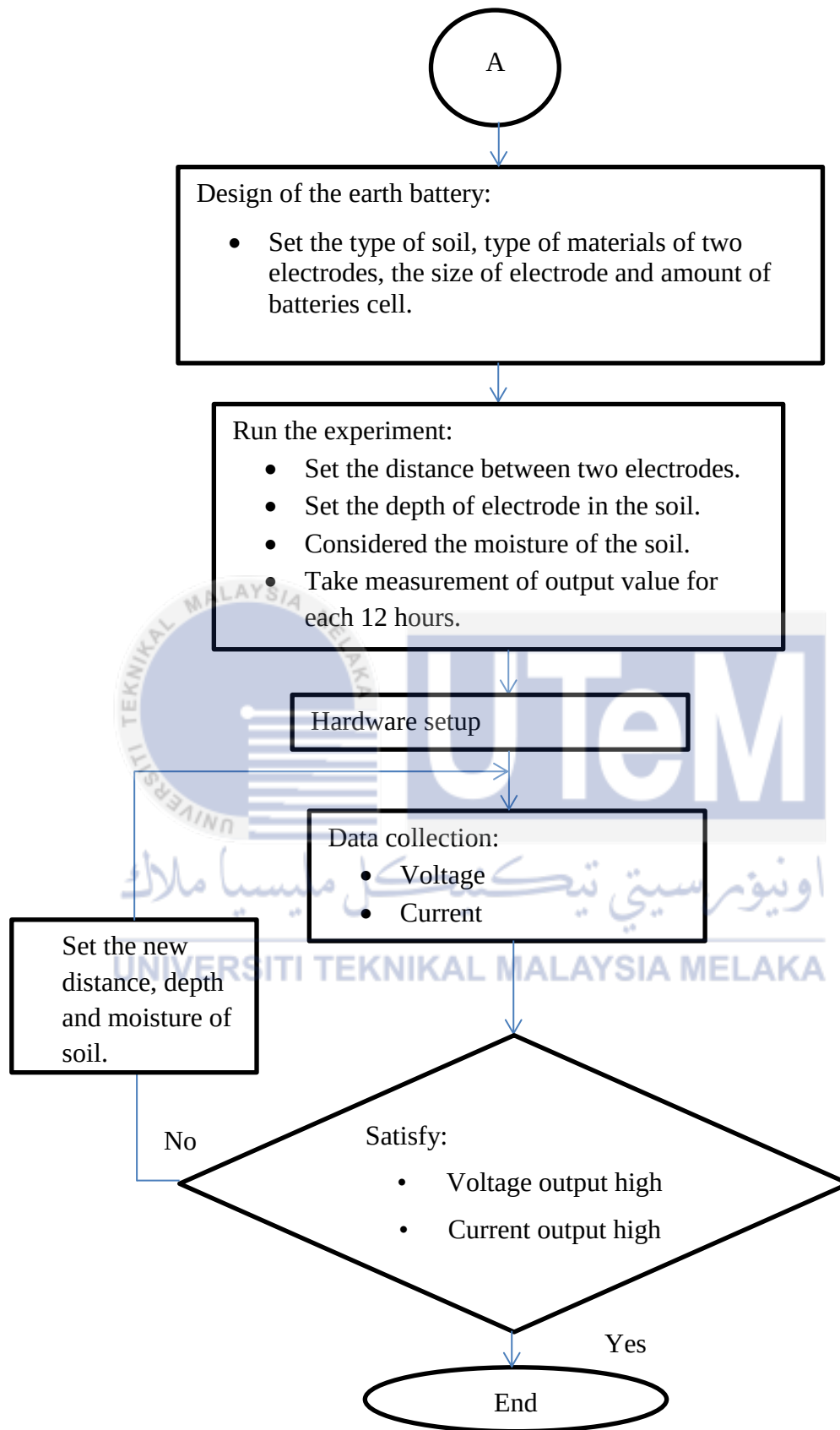


Figure 3.1: Flow chart of this project

3.2.1 Design of the earth battery

3.2.1.1 Type of soil

The medium of this electrolyte system is organic soil. The condition of the soil whether the soil is wet or dry will be considered. By using the syringe, the water is slightly inserted 6 ml to an each cell to maintain its moisture for wet condition and without water for dry condition. The moisture of the soil need to be maintained in order to make sure the resistance is not too high. Then take the reading of the measurement of the current and voltage for both condition moistures.

Then the organic soil placed into the PVC pipe with 6 cm of height and 2.5 cm of radius as shown in Figure 3.2. By using the Equation 3.1, the volume of the soil in PVC pipe is 117.81 cm^3 .

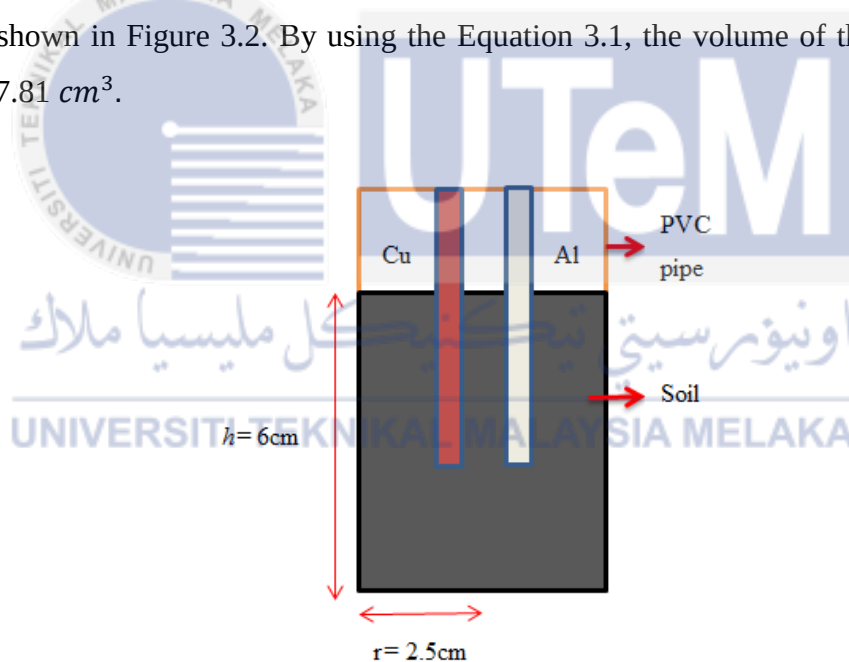


Figure 3.2: Side view of PVC pipes

$$V = \pi r^2 h \quad (3.1)$$

Where,

r = Radius (cm)

h= Height (cm)

V = Volume (cm^3)

3.2.1.2 Type of the material of two electrodes

The material of the two electrodes that used in this project are copper electrode (Cu) and aluminium electrode (Al). This is because these materials are excellent in electrical conductivity. By referring the reactivity series in Figure 2.4, these two types of material has more electronegative and electropositive.

The size of the electrode that used in this project is 5 cm length and 2.5 cm width. Figure 3.3 below show the aluminium electrode that used in this project. While Figure 3.4 show the copper electrode that used in this project. The rod must be clean up first to remove the corrosion on the rod. Both metals polish are applied before cutting the rod. Cutter is used to cut off the rod and maintain it size which is 5 cm length.



Figure 3.3: Aluminium electrode



Figure 3.4: Copper electrode

3.2.2 Run the experiment

3.2.2.1 Distance between two electrodes

This project will be considering the distance between two electrodes. The different distance between two electrodes will be use in this project and take the reading of the measurement of voltage and current that will produce.

The distances between two electrodes were set up with 4 different distances which are 1 cm, 2 cm, 3 cm, and 4 cm. Therefore the reading of the output current and voltage are tabulated. Figure 3.5 show the distance between two electrodes in PVC pipe.

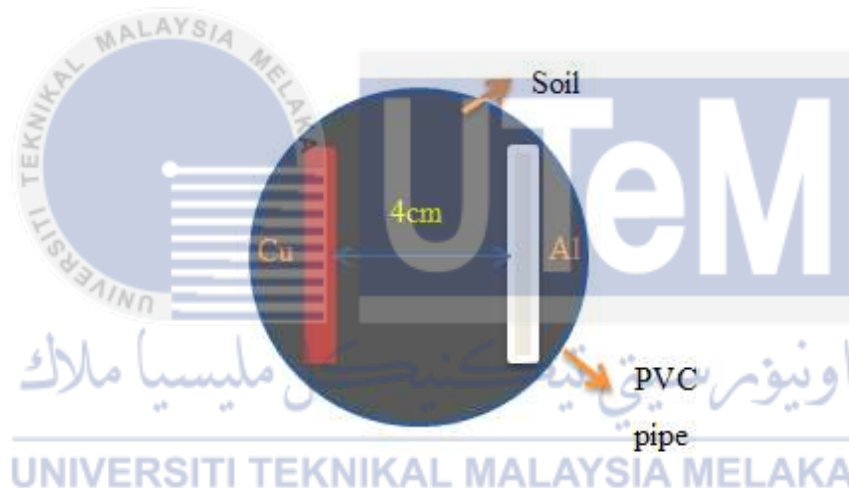


Figure 3.5: Top view of one cell battery

3.2.2.2 Depth of the electrode in the soil

This project also will be considering the depth of the electrode in the soil. The different depth of the electrode in the soil will be use in this project and take the reading of the measurement of voltage and current that produced. Figure 3.6 show the different depth of the electrode with 1 cm each mark.

The reading of the output voltage and output current of the earth battery will tabulate after setup with 4 different depth of the electrode in the organic soil. The depths of the electrode in the soil were setup with 1 cm, 2 cm, 3 cm, and 4 cm because the maximum length of the electrode is 5 cm. This method is to investigate the relation between depth of the electrode in the soil and the output current and voltage.



Figure 3.6: Electrodes with 1cm each mark

3.2.2.3 Duration of the wet soil battery

The output voltage and current are 3.01 V and 0.14 mA respectively when the soil in dry condition as a reference reading. To determine how long the duration of the wet soil battery, 6 ml of water were filled for each cell battery. Every 12 hours, the output readings were taken to see the changes of the output reading. The humidity of the surrounding will be considered by the temperature humidity meter. The duration of this analysis can be determined after output reading of the soil was filled 6 ml of water same as the reference reading.

3.2.2.4 Arrangement of the soil

The connection of the earth battery that applies in this project is series-parallel (cascade connection) by referring Figure 3.7. This is because this connection can control both output voltage and current. If the earth batteries need to increase voltage, the method is by connecting several of earth batteries in series connection. Besides that, parallel connection may increase the output current. The combination of series and parallel can increase both of voltage and current. But this connection needs more earth battery to increase voltage and current.

The experiment based on metal electrode includes anode and cathode electrode, organic soil as electrolyte medium of the earth battery. Both of electrodes are installed into each organic soil cells with cascade connection. After install the electrode, the digital multi meter is used to check the output voltage and current.

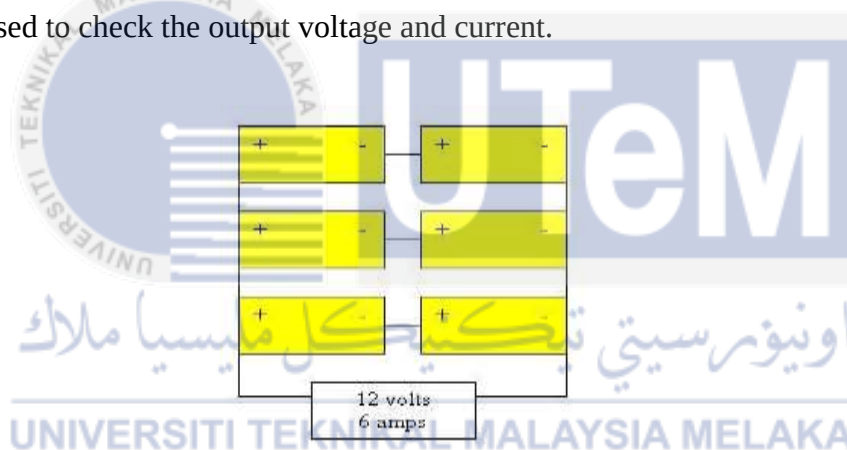


Figure 3.7: Cascade connection of the batteries [16]

3.3 Hardware setup

The parameter that will be consider for hardware testing are, distance between two electrodes, depth of the electrode in the soil and condition of the soil which is in dry or wet condition. While the constant variables are, volume of the soil in each cell, type of electrode at anode and cathode, amount water that use for wet condition, type of connection of cell battery and amount of the cell battery.

Firstly determine the best distance between two electrodes with both condition of soil whether dry or wet. Once the best distance between two electrodes is determined, then investigate the effect of depth of electrode in the soil. The conditions of the soil whether dry or wet, temperature and the humidity will be considered for every testing to investigate the effect of moisture. Figure 3.8 and Figure 3.9 show the example reading of voltage output and current output respectively. Figure 3.10 show the 3 V LED lamp was light up.



Figure 3.8: Voltage output measurement

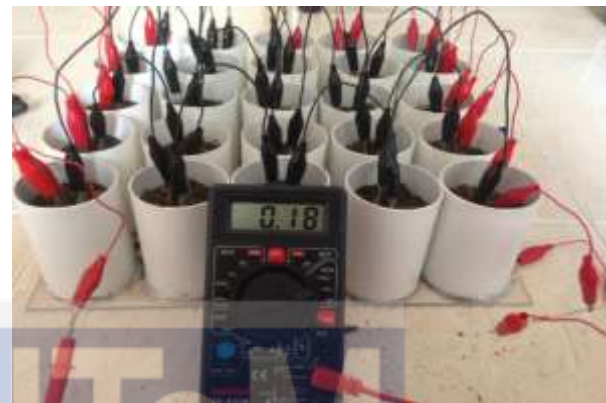


Figure 3.9: Current output measurement



Figure 3.10: 3 volt LED lamp was light up

3.3.1 Setup casing

For this stage, the procedure was design and conduct the experiment base on metal electrode include anode and cathode electrode, acrylic, and organic soil as electrolyte medium for earth battery. The size of the acrylic is 30 cm width and 30 cm length. Then the width and the length of electrode that used in this project are 2.5 cm and 5 cm respectively. Table 3.1 show the other parameter and value used in this project.

The length and width of acrylic both are 30cm as base of the casing earth battery. The height and diameter of PVC pipe as a container of soil are 8cm and 5cm respectively. Figure 3.11 show the total cell battery is 25 pieces with series and parallel connection.

Table 3.1: The parameter and the value used in this project

Parameter	Quantity
• Perspex (30cm x 30cm)	• 1 piece.
• PVC pipe ($h=8\text{cm}$; $d=5\text{cm}$)	• 25 units.
• Organic soil	• 117.81cm^3 Each battery cell.
• Cable.	• 10 metres.
• Crocodile clip	• 60 units.
• Copper electrode (2.5cm width, 5cm length)	• 25 pieces.
• Aluminium electrode (2.5cm width, 5cm length)	• 25 pieces.
• Temperature humidity metre	• 1 unit.



Figure 3.11: Setup casing of earth battery

3.4 Data collection

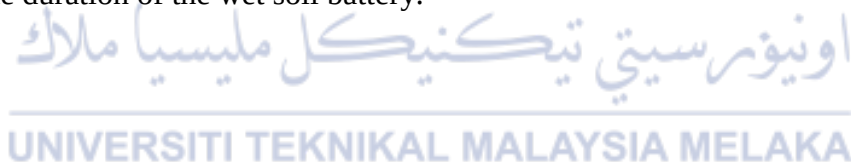
All the data was collected from hardware design until hardware testing. During run the experiment, output current and voltage was collected for each measurement when the distance between two electrodes was changed with 4 different distances to determine the best distance. After got the best distance between two electrodes that can produce high current, the depth of electrode in the soil was changed with 4 different depths to investigate the effect of depth of electrode in the soil on the output reading. All the reading of the output, the moisture of the soil is different whether dry or wet to investigate the effect of moisture of the soil on the output. All the measurement of the output voltage and current were tabulated in a table in Chapter 4.

CHAPTER 4

RESULT, ANALYSIS, AND DISCUSSION

4.1 Introduction

This chapter will presents the result, analysis and discussion of effectiveness large surface area of electrode for earth battery. This project will consider the distance between two types of electrodes, the depth of the electrode in the soil, the moisture content in the soil and the duration of the wet soil battery.



4.2 Distance between two electrodes

The constant variable to get the best distance between two electrodes is depth of the electrode in the soil which is 4 cm. The moisture of the soil will be considered whether dry or wet. This is because the moisture condition will affect the output measurement [9]. Total batteries that used to do this analysis are 25 batteries with cascade connection.

4.2.1 Dry condition

The range of the humidity for dry soil condition is between 65% RH to 74% RH. While the range of temperature when doing this analysis is between 30.5 °C to 33 °C. When the reading of the output voltage and current were determined, the power of the battery can be calculated by using Equation 4.1 for each distance. The output voltage and current was recorded in Table 4.1 where the distance between two electrodes was changing for each reading to determine the best distance.

$$P = I.V \quad (4.1)$$

Where,

P = Power (W)

I = Current (A)

V = Voltage (V)

Table 4.1: Output value when dry condition

Distance between two electrodes (cm)	1	2	3	4
Voltage (V)	2.93	2.98	3.0	3.10
Current (mA)	0.1	0.09	0.08	0.05
Power (W)	0.293	0.268	0.24	0.155
Humidity (% RH)	74	73.1	73	65
Temperature (°C)	30.8	30.5	30.7	33

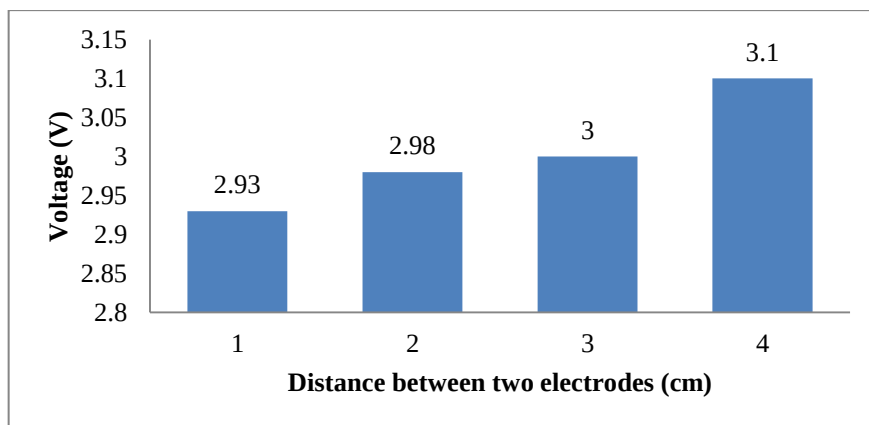


Figure 4.1: Voltage value for dry soil against distance between two electrodes

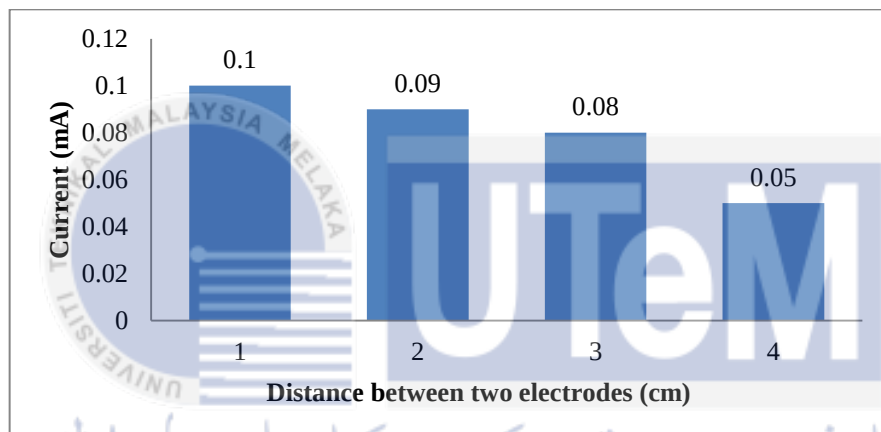


Figure 4.2: Current value for dry soil against distance between two electrodes

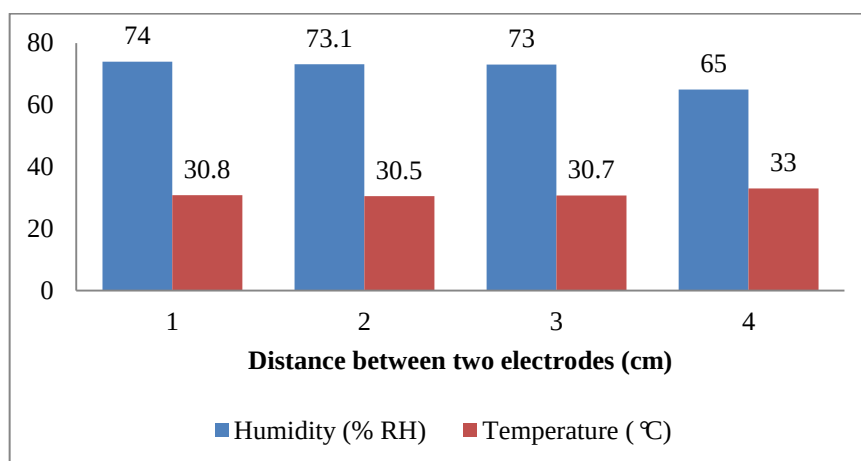


Figure 4.3: Humidity and temperature against distance between two electrodes

From the result in Table 4.1 was taken, the value of output current were depends on the humidity, temperature and distance between two electrodes. From Figure 4.1, the value of the voltage for each reading was unstable but the difference is not too much. The difference of voltage output is only ± 0.17 V. This is because; the type of electrode in this research is constant for each reading. The voltage output is depending on the electrode material and their standard reduction potential [17]. Therefore, selecting material of the electrode will be effect the output voltage. So, the value of positive and negative material of standard reduction potential must higher to get higher voltage output [19].

By referring to Figure 4.2, the output current for each reading were not same. The output current will increase by decreasing the distance between two electrodes. Means that, the nearest distance between two electrodes was produced higher output current than longest distance between two electrodes in a cell. This is because increases of distance between two electrodes will increase the resistance in electrolyte [17]. From the Figure 4.2, the current value for 1cm of distance between two electrodes is 0.1 mA which is the highest current value for this analysis. Other than that, the difference between current reading of 4 cm and 3 cm of distance between two electrodes are too high, while the difference between current reading of 3 cm, 2 cm and 1 cm are only ± 0.01 mA. This is because by referring to Figure 4.3, the difference of relative humidity and the temperature when taking current output for 4 cm and 3 cm of distance between two electrodes is too high. Its show that, the relative humidity and the temperature will affect to the output current. To get a better result, the relative humidity and temperature cannot have too high differences when measuring the output.

4.2.2 Wet condition

The range of the humidity for wet soil condition is between 74.6% RH to 76.1% RH. While the range of temperature when doing this analysis is between 30.4 °C to 32.4 °C. The output voltage and current was recorded in Table 4.2 where the distance between two electrodes was changing for each reading to determine the best distance. In a cell battery, the amount of water that filled is 6 ml. This is because to control the moisture content of the soil for each battery cell is the same.

Table 4.2: Output value when wet condition

Distance between two electrodes (cm)	1	2	3	4
Voltage (V)	2.94	2.95	2.98	3.10
Current (mA)	0.22	0.18	0.15	0.13
Power (W)	0.646	0.531	0.447	0.403
Humidity (% RH)	76.1	74.6	74.7	74.7
Temperature (°C)	30.4	32.4	32.2	32.3

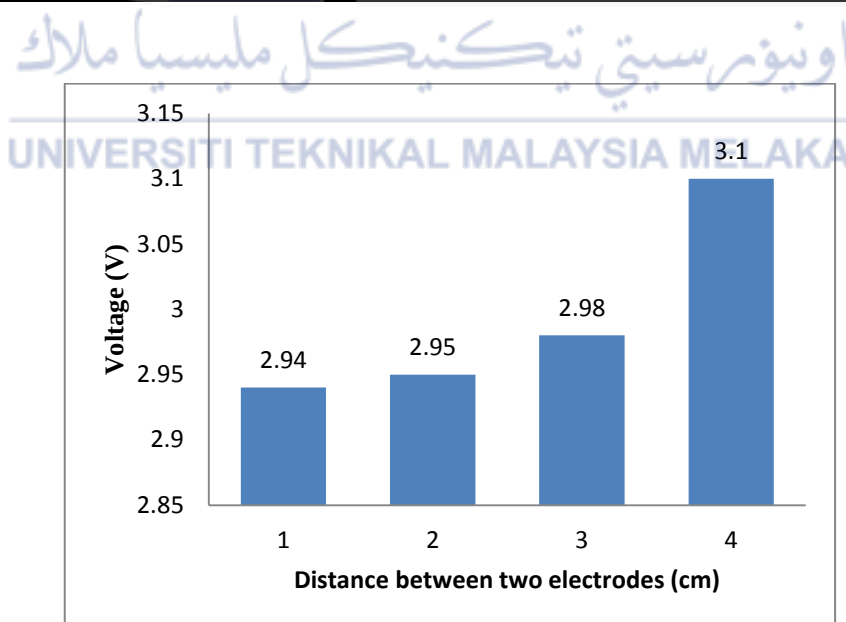


Figure 4.4: Voltage value for wet soil against distance between two electrodes

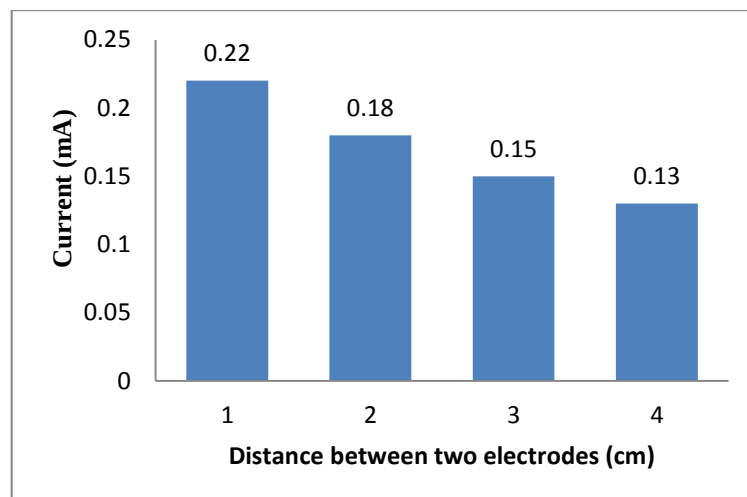


Figure 4.5: Current value for wet soil against distance between two electrodes

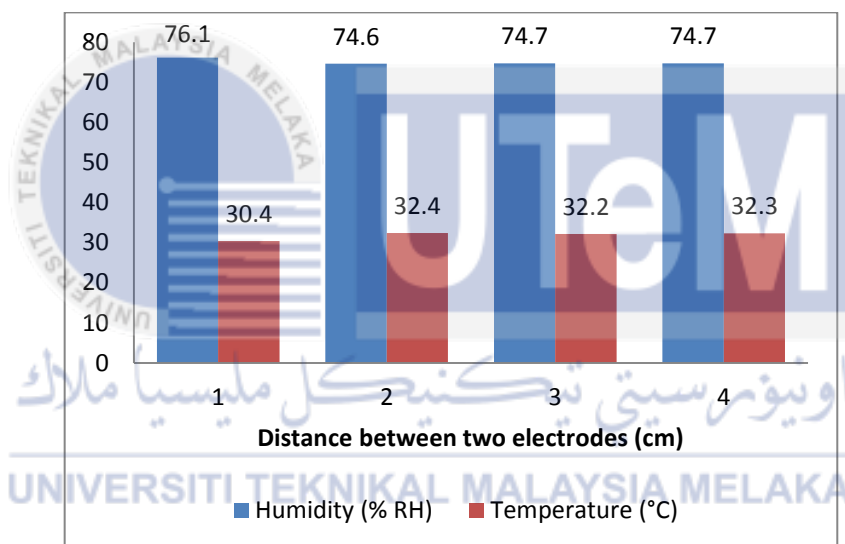


Figure 4.6: Humidity and temperature against distance between two electrodes

When 6 ml of water were filled in every battery cell, the output current in Table 4.2 are increase. From the Figure 4.5, the highest current value for the analysis is 0.22 mA which is nearest distance between two electrodes. By referring to the Figure 4.4, the voltage output for each reading is approximately same. This is because the material of the electrode that used in this experiment project is the same. The voltage output is depending on the electrode material and their standard reduction potential [17].

From the Figure 4.5, the current value for 2 cm of distance between two electrodes is increasing rapidly from 0.18 mA to 0.22 mA. This is because by referring to Figure 4.6, the difference of relative humidity and the temperature are too high compared to another reading. To get a better result, the relative humidity and the temperature must approximately same for each output measurement. The result in Figure 4.5 shows that the nearest distance between two electrodes is the highest current output when in wet condition.

When comparing the result in Table 4.1 and Table 4.2, the best distance of the two electrodes in both conditions is 1 cm. Therefore, the best distance will be used to investigate the effect of depth of electrode in the soil to the output current and voltage.

4.3 Depth of electrode in the soil

Since the best distance was achieved, use that distance to proceed to determine the effect of the depth of electrode in the soil to the output voltage and current. Both condition of soil whether dry or wet will be considered. Actually the concept of the depth of the electrode in the soil is the same with surface area of the electrode in the soil. But a depth of the electrode in the soil is only considering the length of the electrode in the soil. Meanwhile surface area of the electrode in the soil will consider the length and width of the electrode that sink in the soil.

4.3.1 Dry condition

The range of humidity and temperature while doing this analysis are between 74% to 74.5% and 30.4 °C to 31.3 °C respectively. The output voltage and current was recorded in Table 4.3 where the depth of the electrode in the soil was changing with 1cm increment for each measurement to investigate the effect of depth of electrode in the soil.

Table 4.3: Output value with different depth when dry condition

Depth of the electrode in the soil (cm)	1	2	3	4
Voltage (V)	2.53	2.72	2.86	2.98
Current (mA)	0.01	0.04	0.07	0.1
Power (W)	0.025	0.108	0.2	0.298
Humidity (% RH)	65.5	74.4	74	74
Temperature (°C)	31.8	30.4	31.3	30.8

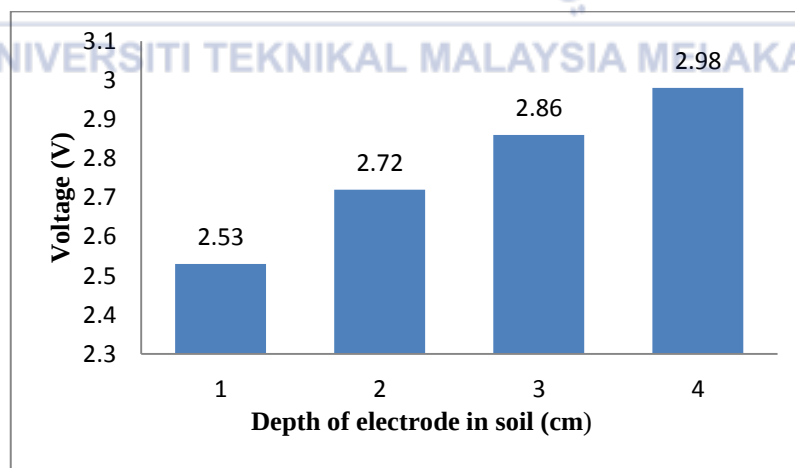


Figure 4.7: Voltage value for dry soil against depth of electrode in soil

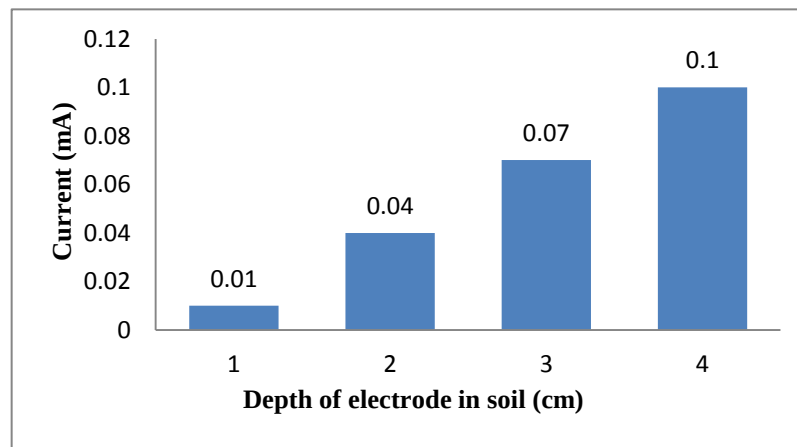


Figure 4.8: Current value for dry soil against depth of electrode in soil

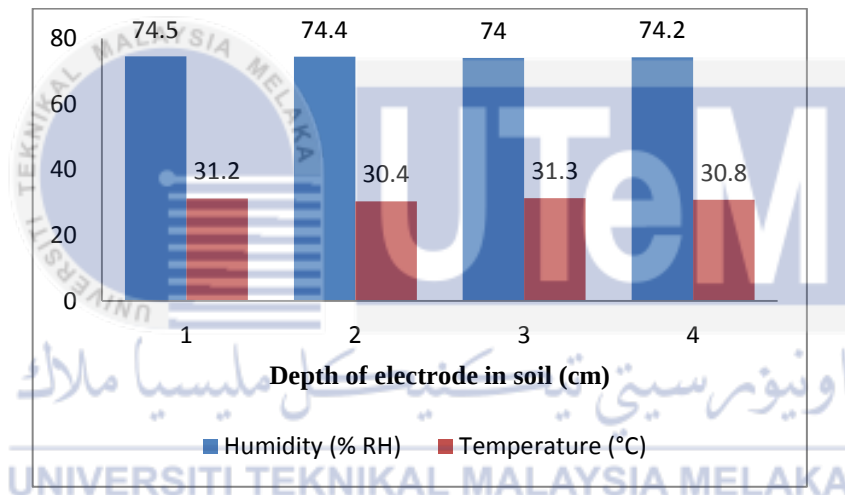


Figure 4.9: Humidity and temperature against depth of electrode in soil

From the result in Table 4.3, the depth of the electrode in the soil will affect the output voltage and current. When higher the surface area of electrode sinks in the soil, higher the output value of current and the voltage. This is because when the surface of area of electrode is increases, the chances of collision of atom at electrode will increase. Therefore the amount of free electrons in this system will increase that causes the output voltage and current will also increase [17]. When the measurements were recorded, the temperature of the surrounding and the relative humidity are approximately same. By referring to Figure 4.9, the difference of relative humidity and the temperature surrounding are too small.

The output value that can measure is only voltage and current. Power value was determined by refereeing Equation 4.1. The output current and voltage were not same for each measurement. This is because the surface areas of electrode sink in the soil are different. From the Figure 4.8 and Figure 4.7, the current value and voltage for 4 cm of depth of electrode in the soil is 0.1 mA and 2.98 V respectively which is the highest output value compared to another reading. Therefore, the deeper the electrode sink in the soil will produce higher output value. Besides that the lowest of the output value in this analysis is 0.01 mA and 2.53 V that have less depth of the electrode in the soil. This is because the chance of collision of atom at electrode is low. Therefore the amount of free electrons in this system will decrease and will produce a low output value [17].

4.3.2 Wet condition

The range of the relative humidity for wet soil condition is between 62.6% RH to 65.6% RH. While the range of temperature surrounding when doing this analysis is between 31.6 °C to 32.4 °C. The output voltage and current was recorded in Table 4.4 where the depth of the electrode in the soil was changing with 1cm increment for each measurement to investigate the effect of depth of electrode in the soil. In a cell battery, the amount of water that filled is 6 ml. This is because to control the moisture content of the soil for each battery cell is the same.

Table 4.4: Output value with different depth when wet condition

Depth of the electrode in the soil (cm)	1	2	3	4
Voltage (V)	2.84	2.9	2.92	3.05
Current (mA)	0.13	0.16	0.19	0.22
Power (W)	0.369	0.464	0.555	0.671
Humidity (% RH)	63.5	65.6	63.1	62.6
Temperature (°C)	31.6	32.1	32.4	32

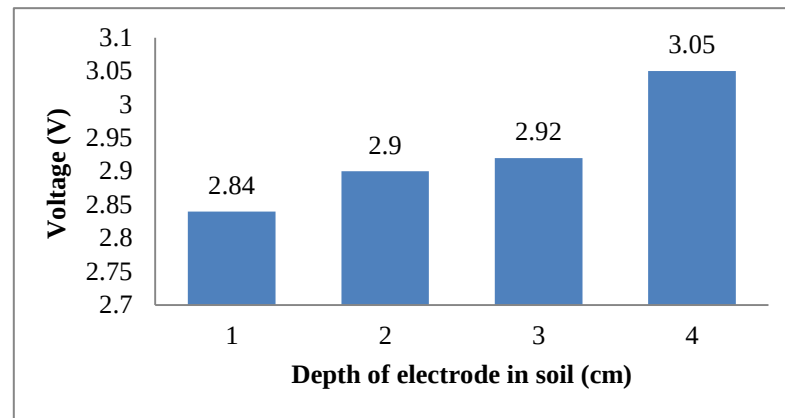


Figure 4.10: Voltage value for wet soil against depth of electrode in soil

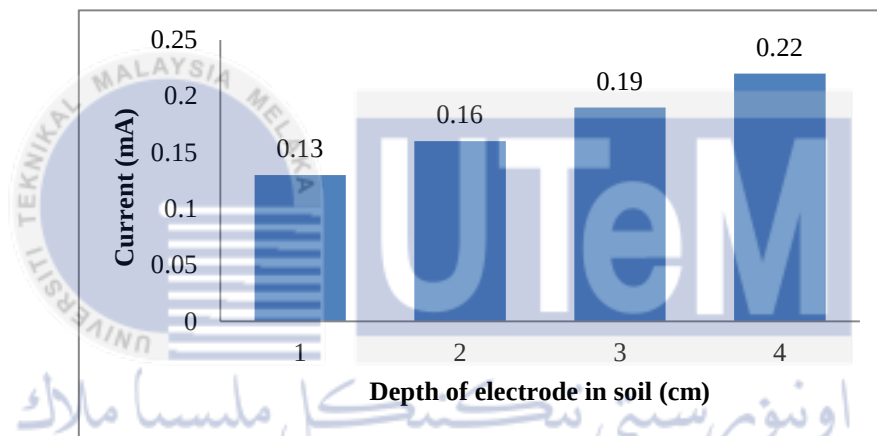


Figure 4.11: Current value for wet soil against depth of electrode in soil

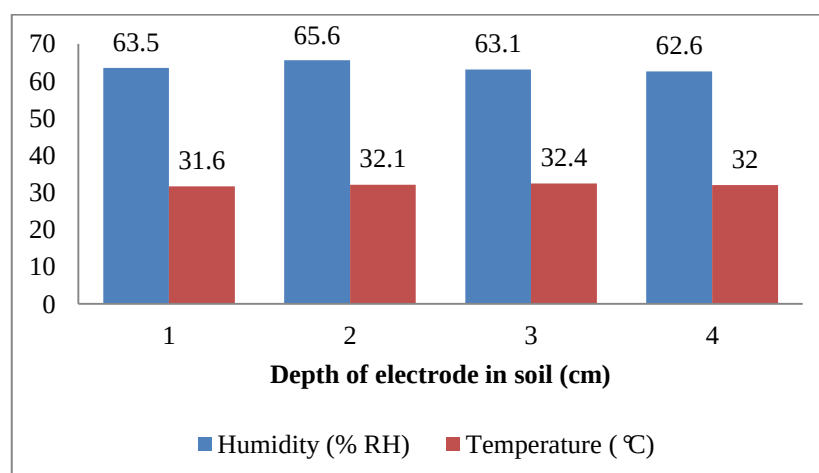


Figure 4.12: Humidity and temperature against depth of electrode in soil

The amount of water that filled for each battery cell is 6 ml. This is because to maintain the moisture content in the soil. From the Figure 4.12, the differences of relative humidity and the temperature surrounding when recorded the measurement are approximately same. Their differences are too small. Therefore the output voltage and current not have high difference. The increment of the output value is remained stable when changing depth of electrode in the soil.

The data in Figure 4.11 shows the highest current value when the depth of electrode in the soil is 4 cm. This is because in chemical reaction between two electrodes, the increases of chance of collision of atom will make increases of free electron. Therefore the output measurement will increase when surface area of electrode sink in the soil is increases. By referring to the Figure 4.11 and Figure 4.10, the highest of current value and voltage are 0.22 mA and 3.05 V respectively. Meanwhile the lowest of current value and voltage are 0.13 mA and 2.84 V respectively. This analysis does not differ significantly because of the relative humidity and the temperatures of surrounding are approximately same due to the small range difference.

When the result in Table 4.3 and Table 4.4 is compared, the highest of output value that measured is when the soil in wet condition and the deepest of the electrode in the soil is 4 cm. Therefore, the electrode of the earth battery must be installed at deeper in the soil and the distance between two electrodes must be nearest to each other to get high output value.

4.4 Duration of the wet soil battery.

This experiment was done in 4 days. Table 4.5 show the result for dry soil battery. Firstly the battery cell was filled with 6ml of water, then every 12 hours the output values were recorded in Table 4.6 to observe how long the duration of the wet soil battery can withstand. Data collecting will stop when the current output of wet soil battery same as current output in Table 4.5. The range of relative humidity and the temperature of surrounding in 4 days when doing this experiment are between 75.8% to 82.5% and 27.6 °C to 30.6 °C respectively.

Table 4.5: Output reading in dry condition as a reference reading

Condition soil	Voltage (V)	Current (mA)
Dry	3.01	0.14

Table 4.6: Output reading for every 12 hours

Time (Hour)	Voltage (V)	Current (mA)	Humidity (% RH)	Temperature (°C)
0	3.03	0.22	82.5	27.6
12	3.04	0.20	78.4	30.3
24	3.05	0.18	79.7	30.2
36	3.04	0.17	77.1	30.6
48	3.05	0.16	82.5	30.2
60	3.04	0.15	78.2	30.3
72	3.07	0.14	75.8	29.2

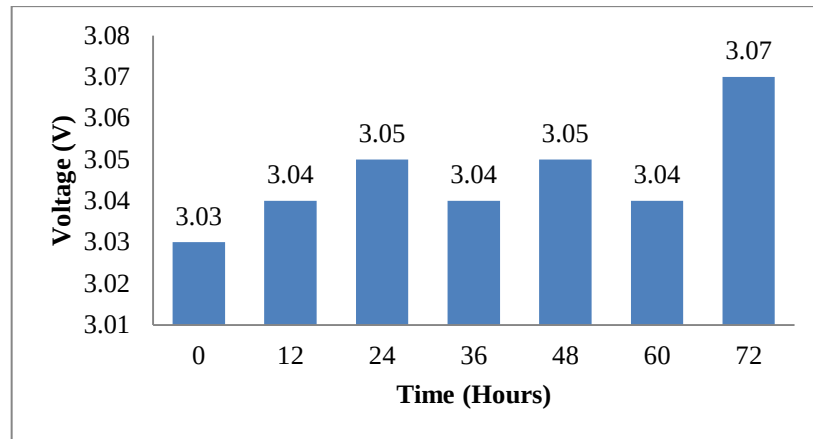


Figure 4.13: Voltage value against time

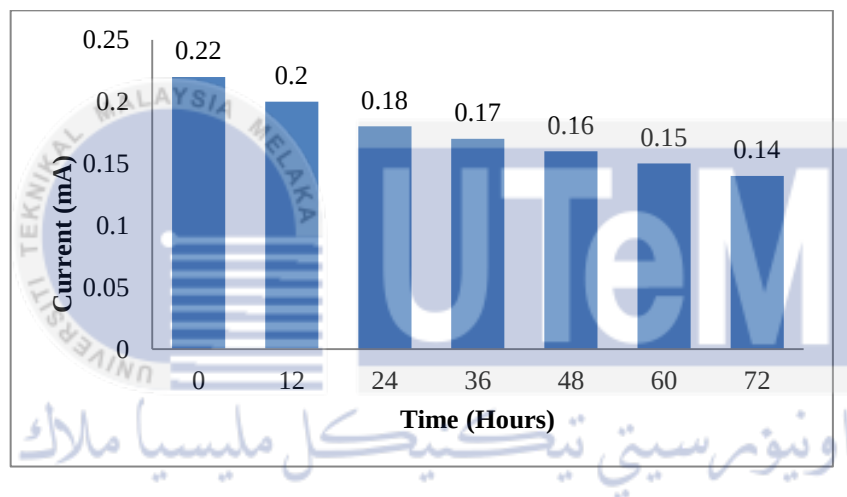


Figure 4.14: Current value against time

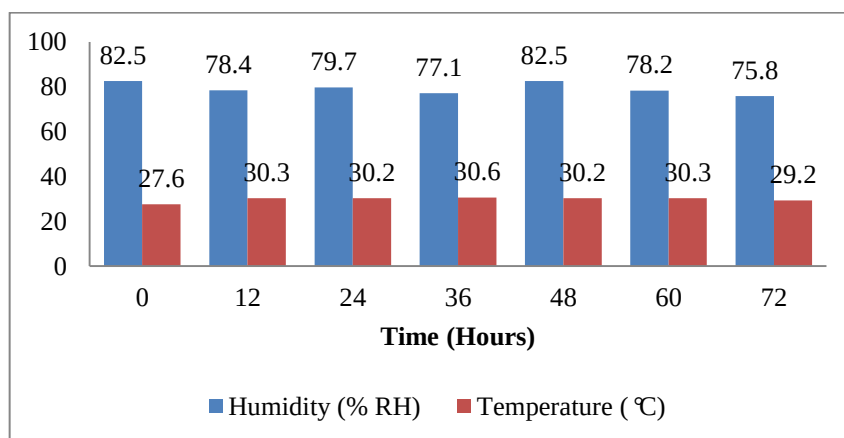
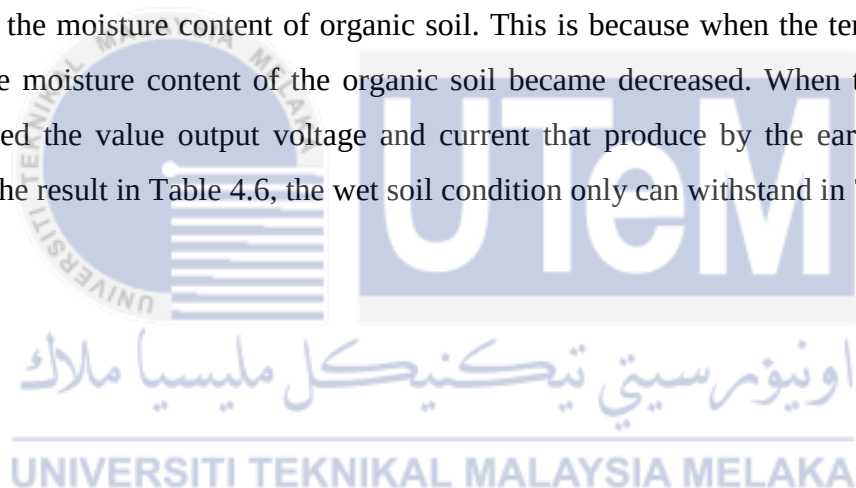


Figure 4.15: Humidity and temperature against time

The measurement of output voltage and current were recorded in 4 days. During this period, referring to the Figure 4.15 the humidity and temperature are not stable. The experiment was done with 7 times measurement because the output current was same as reference reading. From the Figure 4.13, the voltage value is approximately same because the experiment using the same type of material of electrode. The voltage output is depending on the electrode material and their standard reduction potential [17].

Before the battery cell was filled with 6ml of water, the voltage value and current were 3.01 V and 0.14 mA respectively. By referring Figure 4.13 and Figure 4.14, the measurement of output voltage and current rapidly increase to 3.03 V and 0.22 mA respectively when battery cell was filled with 6ml of water. Figure 4.13 and Figure 4.14 show the changes of the voltage value and current for every 12 hours. From the Figure 4.14, the current value was decreased from 0.22 mA to 0.14 mA in 72 hours. The temperature can affect the moisture content of organic soil. This is because when the temperature was higher, the moisture content of the organic soil became decreased. When this happen, it can affected the value output voltage and current that produce by the earth battery. By referring the result in Table 4.6, the wet soil condition only can withstand in 72 hours.



CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

As a conclusion, this earth battery can produce output current and voltage up to 0.22 mA and 3.05 V respectively. The best distance between two electrodes in this experiment is 1cm. The nearest the distance between two electrodes can produce high output current compared to the farthest the distance between two electrodes. Other than that, the depth of electrode in the soil will affect the output voltage and current. This experiment shows that, the deepest the electrode in the soil, the output voltage and current will increase. The deepest of the electrode in the soil is 4 cm. Besides that, moisture content on the soil will affect output current. The organic soil in wet condition can produce high output current compared with dry condition. Furthermore, the wet soil battery can withstand in 4 days. Based on the overall result, it can be concluded that the voltage value and current produced from the earth battery are related with distance between two electrode and depth of electrode in the soil.

5.2 Recommendation

After completing this experiment, there are some suggestions or recommendation in order to improve the whole system of earth battery. The using of the concentrated acidic medium that poured in the organic soil can improve output voltage and current. This is because acidic medium can increase the magnitude of current and voltage [19]. So that the acidic medium in one of the solution to improve output voltage and current.

Furthermore to improve the output voltage of the earth battery, by using the material of electrode that high value of electrical conductivity. Type of metals that used in earth battery is very important to the voltage output. Besides that, the hardware design of the earth battery must minimize the battery size so that the earth battery can easy to carry everywhere and marketable.



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APPENDIX



APPENDIX A

Gantt Chart



APPENDIX A: Gantt Chart

TASK	MONTH									
	2014				2015					
	9	10	11	12	1	2	3	4	5	6
Read Article & Write Article Review	X	X								
Progress Report Evaluation & Report Improvement			X							
Find equipment for project and learn to get preliminary result			X							
FYP 1 Seminar			X							
FYP 1 Report Submission				X						
Setup Project					X	X	X	X	X	
Final Report Submission to Panel and Supervisor										X
Seminar FYP 2										X
Final Report Submission to FYP Committee										X

APPENDIX B

Project Milestone



APPENDIX B: Project Milestone

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 supervisor	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