ABSTRACT

Soil naturally contains energy conductive of microbial fuel cells that capable of generating dc supply voltage. Soil is used as the medium of conducting the small output voltage. The types of soil contain different rate of electrical resistivity and conductivity value. The selection of the clay soil is due to the low resistivity and high moisture content. Electrode made of metal is used to check the potential difference of the soil. The design of clay soil with electrode of anode and cathode which made from copper and aluminium respectively can produce low output voltage. The higher of electrical conductivity of metal may influence the choosing of electrode. The arrangements which are series, parallel and series-parallel (cascade) are implementing in this project. The arrangement of dc supply of clay soil will help to optimize the output voltage. The optimization of the DC supply form clay soil will be check and test by connect small load of LED. The consideration of arrangement of cell, effect of clay soil in temperature, the pH value of clay soil, and arrangement of circuit of the cell must take in order to get the value of output voltage. The output voltage should be increase based on the value of earth battery cell can be constructing in this case study.

(Keywords: earth battery, clay soil, metal electrode, arrangement of circuit)

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LIST OF ABBREVIATION

DC	- Direct Current
LED	- Lighting Emitting Diode
PMMA	- Polymethyl Methacrylate
pH	- Power of Hiydrogen
H	- Hydrogen ion

LIST OF SYMBOL

R	- Resistance
I	- Current
V	- Voltage
L,l	- Length of cylinder rod
S	- Cross sectional area
J	- Current density
K	- Thermal conductivity
ρ	- Electrical resistivity
σ	- Electrical conductivity
Ω	- Ohm
S	- Siemen
A	- Amp
W	- Watt
k	- Kelvin
^{0}C	- Celcius

CHAPTER 1

INTRODUCTION

1.1 Project Background

Soil resistivity is defined as the resistivity of the soil in the flow of electricity. The SI unit value is Ohm-meter (Ω/m). Each type of soil has different value of the resistivity. Soil resistivity value depends on moisture, temperature, humidity, pH and chemical content itself. Clay soil is choosing and will be use due to the low resistivity of and high moisture. Soil resistivity can be determined how the electricity can flow through the soil and if the value of soil resistivity low, the easier the electricity can flow through it.

The arrangement of the DC supply from clay soil or earth battery is divided into three parts. The arrangement is series, parallel and cascade (series and parallel). Basically, the voltage of the series connection is increase while the current is same. The parallel connection is reverse then series, which are the current increase while the voltage is same. The cascade arrangement is the combination of the series and parallel.

Metal is an element, compound, or material that has a conductor of electricity and heat. Metals are usually shiny, hard, malleable and ductile. Copper, brass and aluminium is one of the metals that used in this project. The high value of the conductivity and electricity can affect output voltage of the design system. The combination of clay soil and electrode such as copper electrode with other metal electrode can produce potential difference and this combination is called earth battery. The design of the casing is made of acrylic. The acrylic is material is hard and light. The compatibility of the design is important to make sure the connection can flow. If the design has a leakage, the system probably will have short circuit.

1.2 Problem Statement

The use of dry cells leads to the greenhouse effect. The environmental impacts of mercury, silver, lithium, cadmium, lead and acid have the potential to be hazardous wastes. If the batteries are burned or land filled, the heavy metals in prototype can affect the environment [1]. Although the value of the output voltage of the battery is higher compare to soil battery but the effect faced in the long term is harmful. By using soil as battery, it can reduce the greenhouse effect [2]. Soil is an alternative source of energy that can produce electricity. Using soil as source of electricity can benefit to the green technology, for example earth battery. However, the disadvantage of earth battery is the voltage resulting from the earth battery is low compared to dry cell battery, and it is suitable for small load. To solve this problem, the voltage resulting from the earth soil should be optimizing to enable it to meet the suitable load rate as small 3V LED. To enhance the value of voltage at the battery earth, a detailed study of the arrangement of DC supply of clay soil will be implemented.

1.3 Objectives

1. To design the arrangement of DC supply from clay soil.
2. To identify the optimization of voltage with arrangement of clay soil cell.
3. To evaluate performance of DC supply with arrangement of clay soil.

1.4 Project Scope

This project is focus on the arrangement of dc soil battery design. The arrangement includes series, and series-parallel (cascade) connection. By placing pair of metal electrode of anode and cathode into clay soil, it will produce small output of potential difference. The desired of total output voltage of the DC supply of clay soil produce from the arrangement is need to optimize in order to accommodate a small load such as 3V LED. The effectiveness of the arrangement of soil battery will be investigate and analyzed in this project.

1.5 Report Outline

Report consist and divided into five chapters which have been done and organize in order to understand and easier to read about this whole project. The description of each will be chapter shown below.

In first chapter, it consist introduction, project background, problem statement, objectives, and project scopes. The introduction generally tells about the background of the project. The problem that faces are tells in problem statement. The objective and project scope will be focus and included in this chapter.

For the second chapter, it tells about the literature review that covers the whole of design project. The literature review included and taken in journal, book and internet. The literature review embraces type of soil, design earth battery, type of electrode, arrangement of DC supply of clay soil. The arrangement divided into series, parallel, and cascade connection.

The third chapter is about the project methodology. The method to design project are discussed in this chapter. It consists of hardware setup and hardware testing. For hardware setup, it covers casing of earth soil battery, assemble of electrode, installation of clay soil, and arrangement of clay soil.

The fourth chapter is about the result, analysis and discussion. The data are shown in the chapter will be analyze and discuss. The data it divided into several portions which are, the output voltage of series and cascade connection of each cells and total output voltage of series and cascade connection for the whole battery.

The last chapter covers the recommendation and conclusion of the design of DC supply form clay soil. The recommendation tells about the recommendation for the future study work from this project.

CHAPTER 2

LITERATURE REVIEW

2.1 Type of Soil

There are many parameters involved and need to be considered in designing a DC supply from soil or an earth battery. The parameters are type of soil, design casing material, metal electrode and the arrangement of the soil. This paper will focus on how far the type arrangement of DC soils battery will help to optimize the voltage. First parameter that needs to be surveyed is the type of soil. Generally, soil resistivity is a measure of how much the soil resists the flow of electricity. It is a critical factor in designing of systems relying on passing current through the Earth's surface [3]. 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 [3]. The ions flow or move through the conducting channel with the different ratio according to the type of soil [3]. There are three types of soil that will be chosen which are clay, sandstone and slate. 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.

Factors that contribute to the selection of soil are such as low resistivity per meter (Ω/m), high humidity or 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 will increase slightly 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 [4]. 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 solutions with a pH greater than 7 are basic or alkaline. The pH scale is traceable to a set of standard solution whose pH is established by international agreement [5]. The soil’s layer also needs to be considered as one of the factors, for example one layer and multilayer soils. Another point that corresponds also is the thicknesses and the area of the soil [6]. The large areas can help in terms of endurance time, which means the rate of voltage produce will last longer than the narrow area. All these significant factors may affect to increase the output DC supplies voltage. Based on the Table 2.1, 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.

Table 2.1: Types of Soil with Average Resistivity and Typical Resistivity Value [7]

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

(a) (b) (c)

Figure 2.1: Type of soil

(a) Clay Soil ; (b) Sandy Stone ; (c) Slate Soil [8-10]

2.2 Design Earth Battery

Another point that needs to be considered is the size of the earth battery itself. The size is the most important to design a small and good earth battery. The size will affect the value of the resistivity of the soil. It because the lager space or the distance spacing between electrode, the lower the resistivity [11]. In order to achieve the objective, the design must compatibility to the arrangement. The casing of the earth battery also needs to be considering in order designing a durable and quality product. Polymethyl Methacrylate (PMMA) or Acrylic glass or acrylic plastic is choosing because it durable and hard and light weight compare to glass. PMMA is a tough, highly transparent material with excellent resistance to ultraviolet radiation and weathering [12]. The advantage of acrylic glass is stronger than glass, making it much more impact resistant and therefore safer. Acrylic glass is also very clear, allowing 92% of visible light to pass through it. The thickness of the acrylic is important according to the design. It also weathers well, keeping its clarity over the years without turning yellow or breaking down when exposed to sunlight over a long period of time. Acrylic glass weight is half as heavy as glass. This makes this acrylic easier to use, and makes it a better choice for projects where weight is an issue [12].

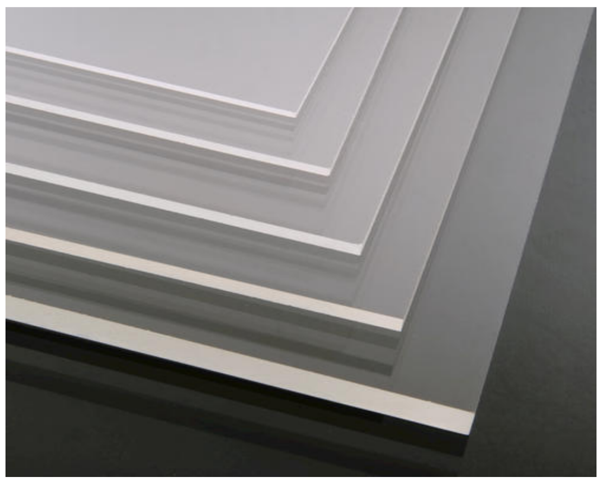


Figure 2.2: Acrylic Material [12]

2.3 Type of Electrode

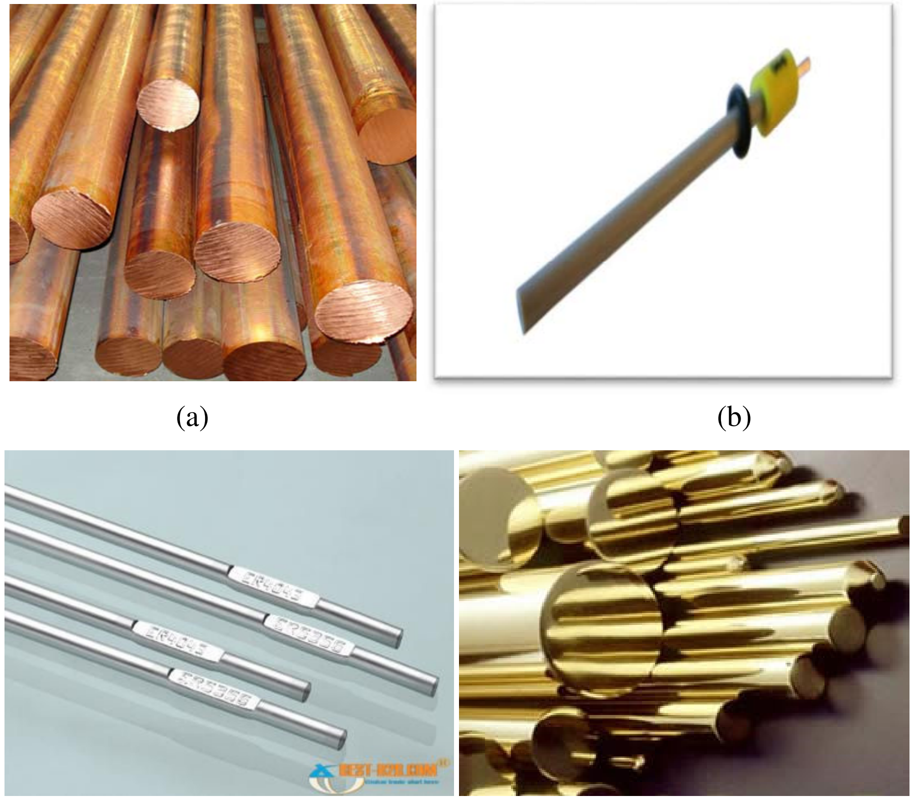
The next parameter to be considered is the type of electrode. Generally, materials have characteristics behaviour of resisting the flow of electrical charge. The ability to resist current is one of the physical properties that used to conduct electricity. Metal is used because it has high conductivity 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, high melting point and durable [13].

There are four metal used to investigate the electrical conductivity of the DC supply from clay soil which are copper, gold, aluminium and brass as shown in Figure 2.3.

Copper is a metal which an excellent electrical conductivity because copper are in group 11 of the periodic table where Copper have high ductility and electrical conductivity. The color of copper is red brown. Copper also is a ductile metal. It can be easily being shape for example in cable wire which has many type of size. In market, copper metal is very high compared to the aluminium and brass [14].

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 [15] 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 [15].

Brass is alloy of combination between copper and zinc. The physical properties 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 percentages of zinc and copper, and which other metals have been added to alloy to bring out specific properties [16]. It conducts heat very well. Brass material with more zinc is stronger and harder. The color of brass is light yellow color close to that of gold. Brasses with less zinc are more of a red brown color [17].



(a) (b)

(c) (d)

Figure 2.3: Type of Electrode

(a) Copper Electrode; (b) Gold Electrode; (c) Aluminium Electrode; (d) Brass Electrode [18-21]

Electrical resistivity of the soil can be considered as the variability of soil physical properties (Banton et al., 1997). The line distributions of the current flow normally depend 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:

$$\rho = \mathrm{R}\ (\frac{\mathrm{S}}{\mathrm{L}}) \tag{2.1}$$

Where,

R = electrical resistance (Ω)

L = length of the cylinder (m)

S = cross sectional area ($cm2$)

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

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

Where,

V= potential different (V)

I = current (A)

Another characteristic that commonly uses in electrical study is described by the electrical conductivity value σ (Sm−1), equal to the mutual or reciprocal of the soil resistivity. Thus:

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

Where,

ρ = Resistivity (Ω/m)

In a homogeneous and isotropic half-space, electrical equipotential are hemispherical when the current electrodes are located at the soil surface as shown in Figure 2.4. Then, a calculation on current density J (A/m2) for the entire radial can be determined by the equation 2.5 is stand for the surface of a hemispherical sphere of radius *r*. Then the potential different which is voltage (*V*) can be defined as

$$J = \frac{1}{2\pi r^2} \quad (2.4)$$

$$V = \frac{\rho l}{2\pi r} \quad (2.5)$$

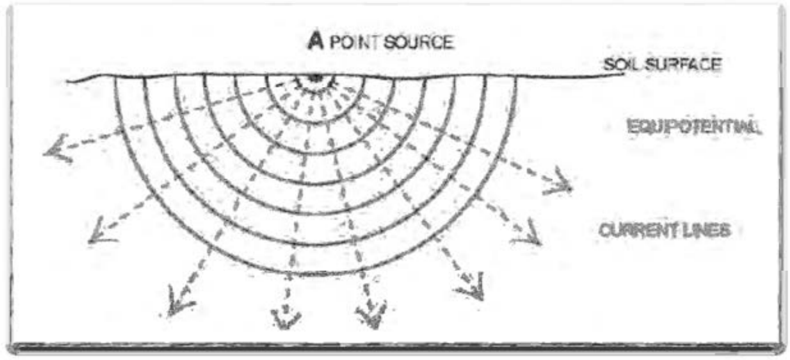


Figure 2.4: Distribution of Current in a Homogenous Soil [22]

Based on the Table 2.2, the highest electrical conductivity material is copper while the lowest electrical conductivity is brass. Copper materials have the lowest resistivity which is 1.7 (Ω/m) compare to the brass is 6.3 (Ω/m) which the highest electrical resistivity. The value of electrical resistivity and conductivity of aluminum is 2.7(Ω/m) and 36.9 (s/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 aluminum. This is due to the low cost of these materials compared to copper and gold.

Table 2.2: Comparison of Resistivity, Conductivity and Thermal conductivity of Each Type of Material [23]

Material	Electrical resistivity, ρ (10.E-8(Ω/m))	Electrical conductivity, σ (10.E6 Siemens/m)	Thermal Conductivity (W/m.k)
Copper	1.7	58.5	401
Brass	6.3	15.9	150
Aluminium	2.7	36.9	237
Gold	2.3	44.2	317

2.4 Arrangement of DC Supply of Clay Soil

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). Method of arrangement of position or type of connection that will be applies in order to optimize the output voltage from the DC supply of clay soil battery.

2.4.1 Series Connection

A series circuit 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, and the voltage across the circuit is the sum of the voltages across each component. 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 [24].

Current

$$I_1 = I_2 = I_3 = I_n \tag{2.6}$$

Voltage

$$V_t = V_1 + V_2 + V_3 \tag{2.7}$$

Resistance

$$\mathrm{R_t} = \mathrm{R_1} + \mathrm{R_2} + \mathrm{R_3} \tag{2.8}$$

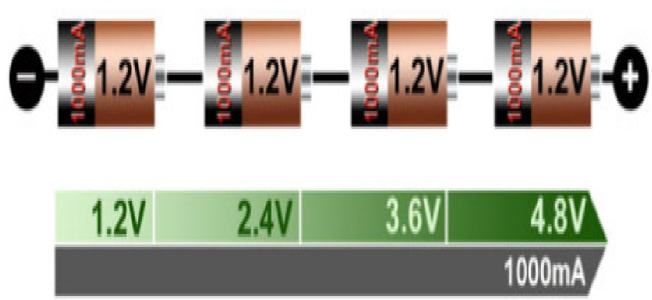


Figure 2.5: Series Connection [25]

2.4.2 Parallel Connection

The second method is parallel connection. In a parallel circuit, the voltage across each of the components is the same, and the total current is the sum of the currents through each component as stated in Kirchhoff's current law [24]. 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 that it 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 damaged. 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 is less than the output voltage of series battery connection [26].

Voltage

$$V_t = V_1 = V_2 = V_3 \tag{2.10}$$

Current

$$I_t = V_t\left(\frac{1}{R_t}\right) \tag{2.11}$$

Resistance

$$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_n} \tag{2.12}$$

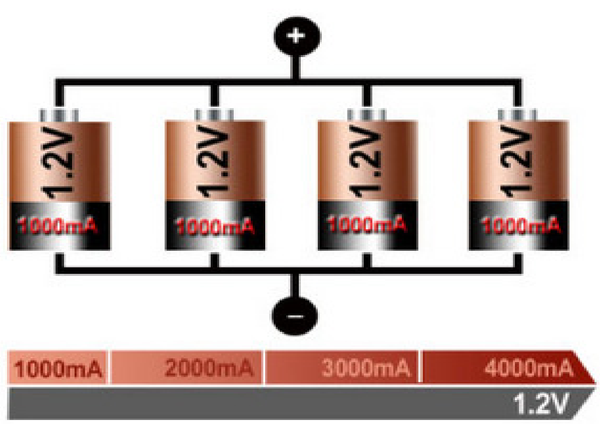


Figure 2.6: Parallel Connection [25]

2.4.3 Cascade Connection

This method is the combination of series-parallel connection in one circuit as shown in Figure 2.7. To calculate the output of the voltage and current of this circuit, the theory of series and parallel is applied. The series-parallel combination has same advantage as series and parallel, but this type of connection needs more battery to increase the voltage.

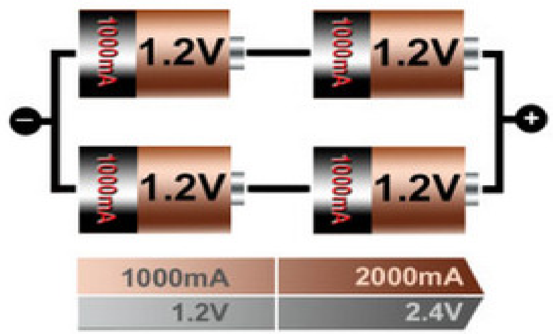


Figure 2.7: Series-Parallel Connection [25]

Table 2.3: Comparison of Connection between Series, Parallel, Cascade.

Connection	Series	Parallel	Cascade
Voltage	High	Low	Medium
Current	Low	High	Medium

Based on Table 2.3, in term of voltage and current produce the good connection is cascade. The advantage of cascade connection is both output voltage and current is it can be control. If the earth batteries need to increase voltage, the method is by connecting several of earth battery 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 can increase both of voltage and current. But the cascade connection needs more battery to increase voltage and current. Other than that, when fault occurs in series connection, It will affect the whole system because the connection is in series. The output voltage of this connection more stable compare to series connection. As conclusion, the best arrangement method of DC supply of clay soil is series-parallel connection [24, 26].

CHAPTER 3

PROJECT METHODOLOGY

3.1 Hardware setup

The following procedure describes on how to design DC supply of clay soil. The constant variables are clay soil and metal electrode. The metal electrode made from brass and aluminium has high value of conductivity is chose. The combination of clay soil and these electrodes with series-parallel arrangement may have a high output voltage and suitable with a small load such as 3V LED lamp. As the distance between the electrode and the interface between the two soils increases, the apparent resistivity decreases.

3.1.1 Casing of Earth Soil

To design the hardware, cost factor need to be consider. Cost of the design includes soil, metal electrode, wire and container. The overall design must be portable and harsh. The equipment required to design the hardware of the DC supply from clay soil are metal electrode including anode and cathode electrode, and acrylic glass container with clay soil as electrolyte medium. The soil battery container is made of acrylic material. The scientific name of acrylic is Poly methyl methacrylate (PMMA). Acrylic is use because of durability and light.