INVESTIGATION of SOIL RESISTIVITY BASE on DESIGN

of an EXPERIMENT APPROACH

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Bachelor of Electrical Engineering (Power Electronic and Drives)

July 2012

" I hereby declare that I have read through this report entitle *"Investigation of Soil Resistivity Base on Design of an Experiment Approach*" and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Power Electronics and Drive)"

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A report submitted in partial fulfillment of the requirements for the Bachelor Of Electrical Engineering (Power Electronics and Drive)

Faculty of Electrical Engineering
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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I declare that this report entitle *"Investigation of Soil Resistivity Base on Design of an Experiment Approach*" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : ABADI BIN MESIRAN

Date : 29th JUNE 2012

To my beloved Mother and father

ACKNOWLEDGEMENT

"In the name of ALLAH the Most Gracious, the Compassionate Merciful"

Praise to Allah S.W.T. the Lord of the universe, for his wisdom, strength and blessing. Without His Grace and Mercifulness, this report may not be completed on time. Peace and blessings of Allah be upon His Messenger, Muhammad S.W.T.

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ABSTRACT

According to National Electric Code (NEC), ground can be defined as a conduction connection, whether intentional or accidental between an electrical circuit or equipment, and the earth, or to some conducting body that serves in place of the earth. The purpose of an earthing system is to provide a safe path for the dissipation of Fault Current (FC), lightning strike, static discharge, EMI and RFI signals and interference; this is in additional to the safety of the personnel and machinery. Generally, in electrical engineering field, grounding is a vital action. Any fault implicates or involving the ground, large current and raised potential occur which is can be considered as out of normal operating conditions. Soil resistivity testing is a crucial technique or action that must be taken before committing the grounding system. It will determine the impedance of the soil and identify the factors that can affect the resistivity of the soil. The properties or the characteristics of the soil will determine the level or the degree of the soil resistivity. Soil resistivity normally varies according to the conditions of the environment. In this research, two types of soil will be taken as a test subject. The aim of this study is to determine the factors that affect the soil resistivity, to identify the best soil between clay and peat moss for grounding purpose and finally, to analyze the effects of each factor to soil resistivity by using factorial design. Clay, laterite and peat moss with control amount of several materials that represent as natural factors that affecting the soil resistivity will undergo a periodic testing. The tool use for measurement is BS 1377-3. The resistivity values obtain from the test exhibit the relative capability electric currents from which the corrosiveness of the soil can be inferred. Final part of this research is compare the result and analyzed the data by using statistical method.

ABSTRAK

Menurut National Electric Code (NEC), tanah boleh ditakrifkan sebagai sambungan konduksi, sama ada sengaja atau tidak sengaja antara litar elektrik atau peralatan, dan bumi, atau beberapa badan menjalankan yang berkhidmat di tempat bumi. Tujuan sistem pembumian adalah untuk menyediakan satu laluan yang selamat bagi mengelakkan daripada Kerosakan Semasa (FC), panahan petir, pelepasan statik, EMI dan RFI isyarat dan gangguan; ini adalah tambahan kepada keselamatan kakitangan dan jentera. Secara umumnya, dalam bidang kejuruteraan elektrik, pembumian adalah satu tindakan yang penting. Kerosakan mana-mana bahagian yang melibatkan tanah,berpotensi berlakunya keadaan yang boleh dianggap sebagai keadaan operasi biasa. Ujian kerintangan tanah adalah satu teknik penting atau tindakan yang mesti diambil sebelum melakukan sistem pembumian. Ia akan menentukan galangan tanah dan mengenalpasti faktor-faktor yang boleh menjejaskan kerintangan tanah. Sifat-sifat atau ciri-ciri tanah akan menentukan tahap kerintangan tanah. Kerintangan tanah biasanya berbeza-beza mengikut keadaan persekitaran. Dalam kajian ini, tiga jenis tanah akan diambil sebagai subjek ujian. Tujuan kajian ini adalah untuk menentukan faktor-faktor yang memberi kesan kerintangan tanah, untuk mengenal pasti tanah yang terbaik di antara tanah liat, gambut dan merah untuk tujuan pembumian dan juga untuk menganalisis kesan setiap faktor kerintangan tanah dengan menggunakan reka bentuk faktorial. Tanah liat, merah dan gambut dengan jumlah yang tertentu berserta beberapa faktor alam yang mempengaruhi kerintangan tanah akan menjalani ujian berkala dengan menggunakan alat BS 1377-3. Nilai-nilai kerintangan yang diperolehi daripada ujian arus keupayaan relatif elektrik dari mana kekakisan tanah boleh disimpulkan di bahagian akhir kajian ini. Bahagian akhir kajian ini membandingkan keputusan dan menganalisis data dengan menggunakan kaedah statistik.

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CHAPTER 1

INTRODUCTION

1.0 Overview

The earth is actually covered with four different types of layer. The outermost layer of the earth is called earth crust and this is where the entire living things live and build up their lives. The earth's crust is actually the thinnest layer among all the layers that build up the earth. One of the important materials in the earth's crust is soil. Physically, the soil looks like just a soil and not more than that. However, there are thousand even million other materials that concentrated in it and that's what makes a soil is a soil. Scientifically, soil can be described as a natural body consisting of layers of mineral with various thicknesses and because of that, soil can be characterized to various types [5]. In conjunction with the characteristics of the soil, one term in electrical field has been automatically strongly connected with the various soils in this world. The term is „resistivity". Resistivity is a term in an electric field to indicate a barrier or obstacle in a material [6]. It is inversely proportional with another electrical term which is conductivity. The higher the resistivity, the lower the conductivity will be and otherwise if the resistivity is less, then the conductivity will become better. In electrical engineering field, soil resistivity study is crucial because, any current in this world will be grounded or ended to earth. So, if the resistivity of a soil is not properly study, there is a possibility that bad things occur. Several common factors such as type of soil, temperature, humidity or moisture and acidity that affect the soil resistivity have been listed for further investigation.

1.1 Research Background

Voltage can be defined through Ohm‟s law stated as:

$$V=IR \quad (1)$$

Ohm‟s Law is one of the basic laws in electrical engineering field. This law was made up by three important terms which are voltage (V), current (I) and resistance (R). According to Alexander Sadiku in his books entitle, Third Edition of Fundamental of Electric Circuit, Ohm‟s Law can be defined as the voltage (V) across a resistor that is directly proportional to the current (I) flowing through the resistor [1] . The creator of this law defined the constant of proportionality for a resistor to be a resistance, R. Thus, that is how the law being created.

Generally, materials have characteristics behaviour of resisting the flow of electrical charge. The ability to resist current is one of the physical properties that posses by any materials in this whole world. This physical property also known as resistance and represented by the symbol, R. Resistivity varies according to the different material. Certain material posses‟ low resistivity which can be categorized as a good conductor while some materials have high resistivity which is widely used for insulation process. In addition, there is a research on producing a material that posse‟s free resistivity and done by a genius scientist from Europe. This phenomenon is known as superconductivity and the material produce known as superconductor [11]. While the research is still in progress, the world of technology today has kept increasing in terms of the quality or the standard in order to meet the modernization demand. However, behind all these intelligence technologies, only one term has been highlighted which is the resistivity.

Electrical resistivity of the soil can be considered as a proxy for 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, resistivity, R can be expressed as follows:

$$\rho = R(\frac{S}{L}) \quad (2)$$

Where, R = electrical resistance (Ω)

L = length of the cylinder (m)

S = cross sectional area (m^2)

The resistance of the electrical of the cylindrical body R (Ω) is defined by the ohm‟s law which is:

$$R = \frac{V}{I} \tag{3}$$

V= potential different (V)

I = current (A)

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

$$\sigma = \frac{1}{\rho} \tag{4}$$

In a homogeneous and isotropic half-space, electrical equipotential are hemispherical when the current electrodes are located at the soil surface as shown in Fig. 1 (Scollar et al., 1990; Kearey et al., 2002; Sharma, 1997; Reynolds, 1997). Then, a calculation on current density J (A/m^2) for the entire radial can be determined via the given formulae:

$2\pi r^2$ is stand for the surface of a hemispherical sphere of radius r. Then the potential different which is voltage (V) can be defined as:

$$J = \frac{I}{2\pi r^2} \tag{5}$$

$$V = \frac{\rho l}{2\pi r} \tag{6}$$

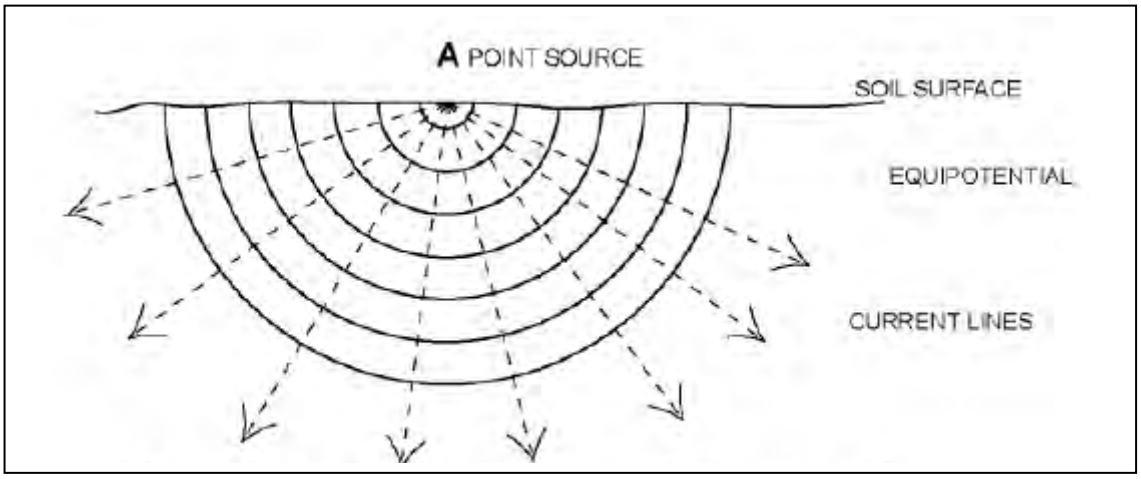

Figure 1.0: distribution of current flow in homogenous soil

Soil resistivity normally related to the several factors that affect the degree of the resistivity. Whether the resistivity is high or low, it will be determined by all the factors. Normally, factors such as chemical content, water control, temperature, humidity and type of the soil itself has a strong connection with the degree of the resistivity. Among these factors there will be specific factors that affect the resistivity of the soil [2].

1.2 Problem Statement

The earth's crust was made by various types of soil. Each soil has their own characteristics and different utilities. Normally, the characteristics of the soil will be determined by the location where the soil was found. In other words, current condition of the location will affect the properties of the soil.

This research is done in order to determine the factors that influence the soil resistivity. Soil resistivity normally varies according to several factors. Besides that, this research also intends to identify the best soil among the three soil use in this research which is clay, laterite and peat moss for grounding purpose. Different type of soil has different characteristics. So, this research is done in order to determine the best soil for grounding system. Usually, soil with low resistivity value is the best soil for grounding purposes because it can let the fault current passing through.

This research is important because it has a direct relation with an electrical field. In this modern civilization, electrical field has played a big role for bring up the live into the level in which our standing at. Nowadays, everything in this world is tending to use electric as the main power and grounding system for electrical is important because it is one of the ways to protect the consumers. So, if the soil resistivity is not properly studied, a lot of problems will occur and it will lead to the worst case scenario which is death.

Result from this research will be helpful because the outcomes of this research will make the grounding procedure easier and effective. Clay, laterite and peat moss are the most common type of soil in Malaysia. All these three soil certainly posses certain factors that may affect the resistivity itself. So, it is important that before attempting any grounding system, soil in the current place need to be identified first and the person who in charge in attempting grounding system need to be clear about the factors that may affect

the resistivity of the soil and how to overcome it. The outcomes of this research will certainly give a guideline to everybody who required to do the grounding system.

1.3 Objectives

i. To determine the factors that affects the soil resistivity.
ii. To identify the best soil between clay, laterite and peat moss for grounding purpose.
iii. To analyze the effects of each factors to soil resistivity by using factorial design.

1.4 Project Scope

This experiment will be stressed on the factors that affecting the soil resistivity. All the factors will be mingled with the chosen soil. Factors that have been chosen as manipulated variables are temperature, moisture and acidity. Three types of soil will be used in this experiment which is clay, laterite and peat moss. All these three soils have been taken as a test subject because these soils are readily available and have a clear distinction on its physical properties. One of the factors in affecting the soil resistivity is acidity. In order to personify the acidity in the soil, sodium chloride will be used.

BS 1377-3 is a soil resistivity tester. The equipment will be used throughout the study. The test subject will undergo periodic testing and by the time the result obtains all the data will be analyzed for further discussion. The design of this experiment will be based on factorial design and the data obtain will be analyzed using statistical method.
To make the project scope clear, the point below will make the project scope clearer:

I. This project is a study on determining and analysis the factors that affect the soil resistivity.
II. The tool use for measurement is BS 1377-3 which is based on disc electrode method.

III. Disc electrodes are fitted to the end of cylindrical with or without testing subjects in order to be measured in the laboratory. Voltage will be applied across the electrodes. Then, the current flowing between them will be measured and Ohm‟s law will be applied in this situation in order to derive the resistivity from the test subject.

IV. Apparatus use for measurement of the resistivity are:

- Cylindrical container
- Two metal disc
- DC power source

V. The statistical method will be used to analysis the data.

CHAPTER 2

LITERATURE SURVEY AND THEORY

2.1 Introduction

K-Chart is a tool for organizing the research systematically. The content of the K-Chart will be focused on the importance of this research need to be done. It will be presented through a tree diagram and the highlighted points are points that will be stressed in this research.

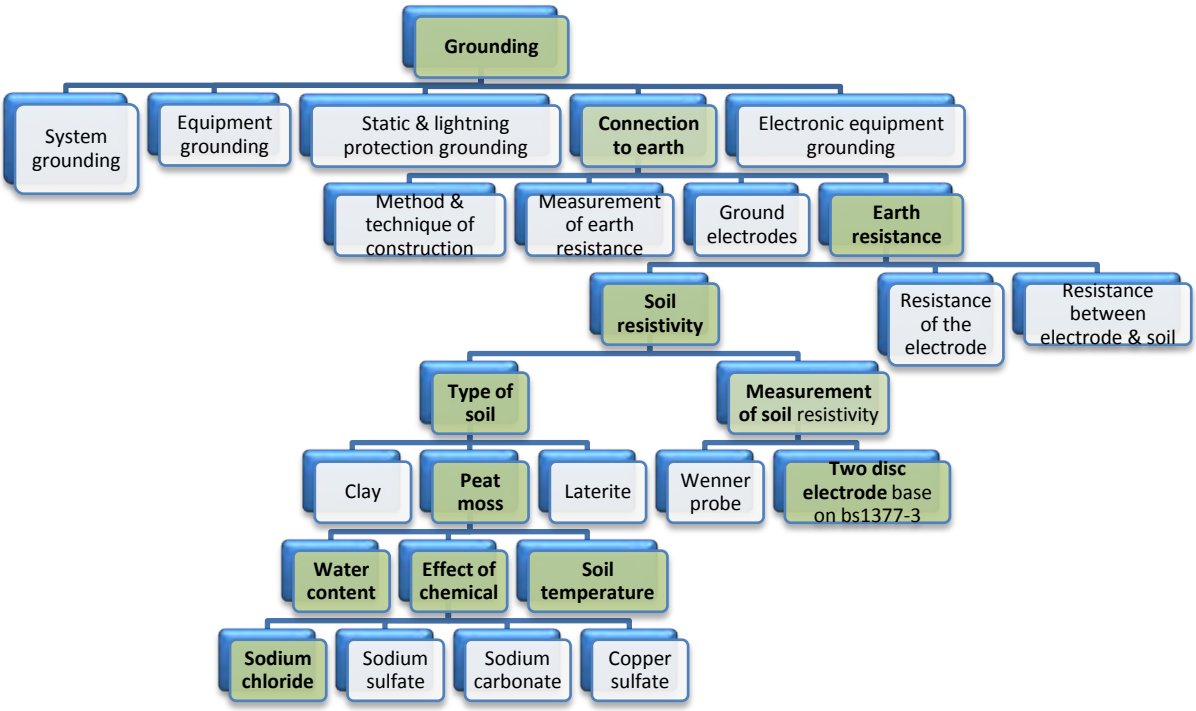

Figure 2.0: Flows of K-Chart

K-Chart in figure 2.0 shows the importance of soil resistivity in grounding system. The purpose of grounding is to provide safety to the consumer. The grounding must be done properly and in order to get the proper grounding system, several procedures must be followed. Measuring the earth resistance is the first procedure before connecting the

grounding system. Then, followed by the construction method used for temp the grounding system and the application of the grounding system. Earth resistance is composed of three elements which is the resistance of the electrode, the resistance between electrode and soil and finally soil resistivity. Soil resistivity is the main topic for this research and more details about that will be discussed.

2.2 Soil Resistivity

Practically, the layer structure of the soil and the depth of each layer will determine the average resistivity of the soil. When it comes to grounding or earthing system, soil resistivity is the most important factors that need to be concerned before attempting any grounding system. This is because earth resistance is directly proportional to the earth electrode that install into the earth.

According to Landviser.com, electrical soil resistivity was first measured at the end of the 19th century. Whitney et al. (18970, Gardner (1898) and Briggs (1899) developed relationship between soil resistivity with the factors of water content, temperature and salt content [7]. Factors that include in the experiment is the factors that most affect the soil resistivity.

Theoretically, resistance is a term to describe the behavior of opposing the electric current flow when a voltage is applied across the two ends. In terms of soil resistivity, sometimes resistivity is referred as specific resistance because resistivity is the resistance between the opposite faces of cube of material with side dimension of one meter [8]. Normally, factors that have a big effect in soil resistivity are the type of soil, moisturecontent, temperature and chemical composition. The resistivity of the soil may decrease rapidly when the moisture of the soil is increase. However, after 20% of moisture, the resistivity decrease is much less. Soil with moisture content greater than 40% is rarely occurring. When the soil temperature is beyond the freezing point, soil resistivity will become negilible. Soil resistivity also affected by the chemical content of the soil. Normally, dissolved salt is a substance that oftenly give the variation to the soil resistivity value[8].

2.3 Type of Soil

The figure 2.1 below is showing the reason why depth and type of soil layer play a big role in determining the soil resistivity.

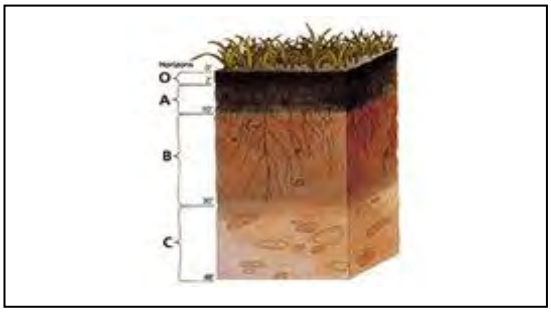

Figure 2.1: Soil layer

As soil develops, it forms layers. Soil profile is the name given to the layered structure and each layer is called the soil horizon. The top layer of the soil structure is called the „O" horizon. „O" horizon is a thin layer and mostly made of dead things such as dead plant. The combination of „A" and „O" horizon is also called top soil.

Beneath the top soil, there is a zone of leaching. As rainwater struggling through the soil, it washes down the material from the above layers such as dissolved calcite, iron oxide which is an agent that will determine the colour of the soil, clay minerals and other products of humus decay. Sandy material is not dissolved by rain water. So, it will leave behind.

The „B" horizon is the final destination for all the stuff that dissolved from the above layer. This zone is also called as accumulation zone. This zone tends to be clayey and stained with iron oxides. It is a place where clay will be compact and creating a layer that impermeable to the water and it is called hardpan. In this layer, calcium carbonate can percipitate back out to glue soil particles together in a form of hardpaan which is called caliche. Beside that, acid and salt also accumulate in this layer.

The „C" horizon is a zone full with chunks of big rock and stone. This zone is above the „R" horizon. „R" horizon is a zone that filled with bedrock. So, each depth of soil contains different type of soil. Different type of soil will give the variation of soil resistivity because it is clear that the characteristics of each soil is different. For example, some of the soil contains water or moisture and some of it does not contain any kind of

moisture. So, soil that contains more moisture normally posses low resistivity because water or moisture is a good electrical conductor.

Soil resistivity has a direct effect on the grounding system. The most influential factor that infect the soil resistivity is the type of soil. According to AEMC Instruments in his article dry soil has higher resistivity compared to others. This will be significant when the soil does not contain any soluble salt [5].

Table 1.0: Resistivity range of different type of soil

Soil	**Min. Resistivity (Ω-cm)**	**Average Resisitivity (Ω-cm)**	**Max. Resistivity (Ω-cm)**
Ashes, cinders, brine, waste	590	2370	7000
Clay, shale gumbo, loam	340	4060	16300
Same with varying proportions of sand and gravel	1020	15800	135000
Gravel, sand, stone with little clay or loam	59000	94000	458000

2.4 Water content

Moisture has a great influence on the resistivity value of the soil. Quantity of water held by the soil will determine the resistivity of the soil itself. 15% percent of moisture is enough to quickly drop the resistivity value of the soil. Soil resistivity normally behaves inversely proportional to the depth. The deeper the ground the less resistivity value will obtain. In many locations water table goes down in dry weather conditions. Water from the above layer of the soil will seep into the ground until it reaches the limit where the soil itself will become a waterproof. There will be no water will passing through the waterproof soil and it will accumulate in there until it saturated. So, it is clear that the amount of water in the deeper ground or layer of soil is greater than in the top soil.