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EXPERIMENTAL STUDY ON THE EFFECT OF SOIL RESISTIVITY WHEN TREATED WITH WATER, SALT AND CARBON

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"I hereby declare that I have read through this report entitle "Experimental Study On The Effect Of Soil Resistivity When Treated With Water, Salt And Carbon" and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)"

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EXPERIMENTAL STUDY ON THE EFFECT OF SOIL RESISTIVITY WHEN TREATED WITH WATER, SALT AND CARBON

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A report submitted in partial fulfillment of the requirements for the degree of Bachelor of Electrical Engineering (Industrial Power)

Faculty of Electrical Engineering
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2015

"I declare this report entitle "Experimental Study On The Effect Of Soil Resistivity When Treated With Water, Salt And Carbon" 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 the candidature of any other degree"

Signature :.....……..

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ABSTRACT

Grounding is a very important aspect in any modern electrical protection system design. Improper grounding may expose the personnel as well as the equipments to unsafe condition. Generally, there are two ways can be used to reduce the earth resistance of a system. The first method is adding more ground rod and the second method is doping on the soil medium. However, the first method is not economically viable when compared to second method which is more effective and cheaper way in reducing the grounding resistance and thereby improve the system performance. Before implementing the grounding system in certain location, the soil characteristic and resistivity in the proposed location must be determined first. This laboratory research aims to test on five different types of soil which includes clay, loam, sandy soil, laterite and top soil at uniform room temperature in order to determine which type of soil will exhibit the lowest resistivity and suitable to be used in grounding system. All five types of soil with the mass of 1 kilogram are treated by water content, salt solution, charcoal and salted charcoal with percentage variation from 2.5% to 30% and 200V DC voltage being applied to BS 1377-3 cylindrical soil resistivity tester. The recorded current is used to obtain resistivity values by applying resistivity equation. Then, the resistivity data is analyzed by using statistical methods which include scatter plot, correlation coefficient analysis and regression analysis. From the scatter plot, the relationships appear to be curvilinear trend and the clay soil is the best soil to be used for grounding installation as it has strongest correlation coefficient. The observations have shown that the resistivity values for all soils will decrease as the water, salt and salted charcoal treatment are increased. However, the relationship between charcoal content and soil resistivity do not show any decrease in resistivity but it appears to increase the resistivity value.

ABSTRAK

Pembumian adalah aspek terpenting dalam mana-mana reka bentuk sistem perlindungan elektrik moden. Asas yang tidak sempurna boleh mendatangkan risiko kepada pekerja serta peralatan. Secara umumnya, terdapat dua cara boleh diguna bagi mengurangkan rintangan bumi dalam sesuatu sistem. Kaedah pertama adalah dengan menambah lebih banyak rod bumi dan kaedah kedua pula dengan menambahkan bahan asing dalam tanah. Walau bagaimanapun, kaedah yang pertama adalah tidak ekonomi manakala kaedah kedua adalah lebih berkesan di mana ia ialah satu cara yang murah untuk mengurangkan rintangan pembumian serta akan meningkatkan prestasi sesuatu sistem. Kerintangan dan ciri-ciri tanah harus ditentukan sebelum melakukan sistem pembumian di sesuatu lokasi. Kajian makmal telah dilaksanakan untuk menguji lima jenis tanah iaitu tanah liat, tanah gembur, tanah berpasir, tanah laterit dan tanah hitam pada suhu bilik yang seragam bagi menentukan jenis tanah yang tersesuai digunakan dalam sistem pembumian. Lima jenis tanah dengan jisim 1 kilogram telah ditambah dengan kandungan air, larutan garam, arang dan campuran larutan arang dengan garam dengan peratusan yang berbeza yang bermula daripada 2.5% sehingga 30% dengan penggunaan 200V DC pada BS 1377-3 penguji kerintangan tanah jenis silinder. Nilai arus yang dicatat telah diguna untuk mengira kerintangan dengan menggunakan persamaan kerintangan. Kemudian, data kerintangan dianalisis dengan menggunakan kaedah statistik iaitu gambar rajah berselerak, analisis korelasi dan analisis regresi. Trend berbentuk garis lengkung telah dilihat pada gambar rajah berselerak dan juga didapati bahawa tanah liat adalah tanah tersesuai digunakan untuk pemasangan sistem pembumian kerana ia mempunyai korelasi yang kuat. Pemerhatian menunjukkan bahawa nilai kerintangan bagi semua tanah akan berkurangan apabila kandungan air, garam dan campuran larutan arang dengan garam meningkat. Namun, penambahan kandungan arang dalam tanah tidak menunjukkan pengurangan kerintangan disebaliknya ia telah meningkatkan kerintangan tanah.

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LIST OF ABBREVIATIONS

AC	-	Alternating Current
DC	-	Direct Current
OSHA	-	Occupational Safety and Health Administration
NIOSH	-	National Institute Occupational Safety and Health
BS	-	British Standard
EMI	-	Electromagnetic Interference
RFI	-	Radio Frequency Interference
IEEE	-	Institute Of Electrical And Electronics Engineers
Z	-	Impedance
∅	-	Phase Angle
PSD	-	Particle Size Distribution
K	-	Conductivity
FYP	-	Final Year Project
UTeM	-	University Technical Malaysia Malacca
R	-	Resistance
ρ	-	Soil Resistivity

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CHAPTER 1

INTRODUCTION

1.1 Project Background

The earth's interior is composed of four layers, namely crust, mantle, liquid outer core and solid inner core. The crust is the outermost layer. It is made up of loose material, like rocks, soil and seabed. Soil has covered out much of the land on earth's surface. The soil is an important resource that is used in people's daily lives and other living things. There are different types of soil on the earth and each type of the soil has its own unique characteristics [1]. These unique characteristics must be determined in order to decide what the soil will be used for as there are many different materials composition exists in the soil. In electrical engineering field, precise determination of engineering properties of soil is essential for proper design and successful construction of any electrical system [2].

In conjunction with the characteristics of the soil, one term in electrical field has been automatically connected with different kinds of soil in this world is the resistivity. Resistivity is the measure of how much a material resists flowing of an electrical current. Soil resistivity is directly affected the design of a grounding (earthing) electrode system. It is the vital factor that determines the resistance to earth of a grounding electrode system. Therefore, prior to the design and installation of a new grounding electrode system, the proposed location should be tested to determine the soil resistivity.

Soil electrical resistivity depends on the physical and chemical properties of the soil, water content, fluid composition, seasonal variation and current magnitude [3]. Since the

soils all around the world have different characteristics, the difference values of soil resistivity will be observed under the application of electric field.Seasonal variations will also affect soil resistivity, primarily due to change in soil moisture content. These dynamic variations may impact significantly on earthing measurement, depending on both the nature of the soil and underlying rock and the type of earthing system [4].

It is a statutory obligation in most countries, as well as a technical requirement, that all parts of an electric power system should have an effective connection to earth. This implies that each electrically separate part of a system which is magnetically coupled to other parts at the transformation points must be separately earthed. In the words of the definition contained in the 1937 Electricity Supply Regulations which still remain relevant today, “A connection to earth means connected with the general mass of earth in such a manner as to ensure at all times an immediate and safe discharge of energy”[5].

The earthing of electrical installation is primarily concerned with safety; in particular, the prevention of electrical shock risks to life. Others are to help in providing protection of the plants and equipment from unintentional contact with the live conductor besides providing a safe path to efficiently dissipate lightning energy, static discharge, EMI (electromagnetic interference) and RFI signals and interference into the ground. As such, an earthing system must be designed, tested and maintained to satisfy this primary aim [4]. A ground system that provides adequate current-carrying capacity and a low resistance path to an earthing connection will dissipate, isolate or disconnect overpotential areas resulting from overcurrent or surge overvoltage. Equipment grounding conductors under normal conditions carry no current. The only time they carry current is under abnormal conditions when an electrical appliance or piece of electrical equipment is faulty and has become a potential shock or fire hazard. Under fault conditions, the grounding conductor that is connected to the outer shell of the equipment must be able to provide a very low resistance path back to the source of the power so that sufficient current will flow, causing a breaker or fuse to open the circuit and automatically disconnect the hazard from the system[5].

1.2 Research Motivation

Soil resistivity is an important parameter in power system; it plays a key role in designing an effective grounding system. At the present day, the electric power is becoming an important part of human life. Constant supply of electricity is essential for mankind because it may affect human activities or cause life-threatening. However, the electrical power system from all over the world is subjected to disturbances such as faults and lightning strikes. The component in power system that will protect the human being from electrical shock or deaths is the grounding system. A system without a proper grounding may cause harming to the surrounding living things or damage to the equipments. There are many accidents due to electric shock can be seen at the newspaper or via Occupational Safety and Health Administration (OSHA) website throughout the years. On the other hand, based on the statistical data from National Institute Occupational Safety and Health (NIOSH) there are 5348 deaths caused by electrocutions accounted for 7% of all fatalities and an average of 411 deaths per year [6]. Hence, the study of soil resistivity should be continued as it has a clear correlation of having a well calculated and planned for grounding system. Although there is impossible of having a grounding resistance equal to zero, as an electrical power engineer must continuously improve the earthing system in order to achieve a more reliable, secure, efficient and effective system besides meeting the electrical system requirements.

1.3 Problem Statement

In this new era, the technologies have grown rapidly which is then caused the demand of the electricity for the loads to increase. Most of the technologies are required the supply of electricity to function. As the demand of the electricity is increasing, the mankind needs to construct more low, medium and high voltage systems in order to fulfill the demand for the loads besides ensuring the continuity supply of electric. When constructing an electrical power system, the grounding system is the main concerned. This is because when lightning or ground fault has occurred, the high intensity of current will tend to flow through the path which has the lowest resistance. Normally, the fault current

flows to the earth which is then caused the ground surface potential to increase to a high level. If a system without a proper grounding, it may cause harming to the surrounding living things.

As grounding is an integral part of any modern electrical protection system design, the understanding on what factors will affect the earthing system is crucial. Normally, the ground resistance is dependent on the electrode arrangement and the soil resistivity. Thus, there are two ways can be used to reduce the earth resistance of a system. The first method is adding more ground rod and the second method is doping on the soil medium. However, the first method is not economically in which it will be needed to expense a lot of money on doing the grounding system. The second method is more effective and it is an inexpensive way to reduce the grounding resistance which will then improve the system performance.

Soil resistivity is one of the vital factors that must be taken into account when designing a grounding system in order to avoid constructing less effective earthing system. An accurate assessment of the soil condition is required as each type of soil has different characteristics and properties which will affect the soil resistivity. Basically, the soil at different location will exhibit different characteristics because there are many different materials composition exists in the soil. The soil resistivity is varied according to the soil types. The soil with high resistivity will resist the flow of electricity and vice versa. If based on the ideal condition the ground resistance should be zero ohm. However, in the real situation it is impossible to achieve the zero ohm earth resistance. Practically the ground resistance should be 5 ohms or less [7]. Therefore, when planning for installation of grounding system it is recommended to locate to a place where the soil resistivity is low. Otherwise, it will be very costly and need a lot of effort in maintenance if it locates at the place where the soil resistivity is high.

This research experiment is conducted to evaluate the variation of soil resistivity with several parameters such as moisture content and chemical content. Other than that, this research experiment will identify a soil with the lowest soil resistivity among five different types of soil to be used in grounding installation system. Generally, soil with lowest resistivity or high conductivity value is chosen. This is because when lightning or power system fault has occurred, the huge intensity of current will tend to flow through the path which has the lowest resistance.

It is therefore, the knowledge of factors affecting the soil resistivity is essential in designing for the grounding purpose. A system with excellent grounding should be able to provide personnel safety as well as reliable protection for equipments and to minimize the interruptions of service which will result in costly downtime. The outcomes from this research experiment will definitely provide some guidelines for those who in charge in implementing grounding installation system and consequently will help lessen future issues with grounding.

1.4 Objectives

The aims of this research project are:

i. To determine the best type of soil between clay, loam, sandy soil, laterite and top soil that give the lowest resistivity for grounding installation.
ii. To investigate the effect of moisture content on soil resistivity.
iii. To investigate the effect of chemical content, which are sodium chloride, charcoal and salted charcoal on soil resistivity.
iv. To analyze the effect of soil resistivity when treated with water, salt, charcoal and salted charcoal by using statistical analysis techniques.

1.5 Scope of Project

This research is focused primarily on examining the effect of soil resistivity when treated with water, salt, charcoal and salted charcoal. A vivid scopes is required in order to ensure that the development of this research project in the right path so that all the objectives are achieved at the end of the research. The scopes of this project are:

(a) Focus on five types of soil only which are:
    i. Clay
    ii. Loam
    iii. Sandy soil
    iv. Laterite

v. Top soil

(b) Types of statistical analysis technique will be used are:

i. Scatter plot diagram

ii. Regression Analysis

iii. Correlation Coefficient

(c) Locations of the experiment will be carried out are:

i. The experiment will be conducted at power system protection laboratory, UTeM, Melaka

(d) Apparatus will be used are:

i. Electric Oven

ii. Cylindrical type soil container

iii. BS 1377-3 soil resistivity tester based on disc electrode method

iv. ECS820C Digital multimeter

v. 200Volt DC power supply

vi. Two disc electrodes

vii. Weighing machine

(e) Additives materials will be applied on the soil are:

i. Distilled water

ii. Common salt solution

iii. Carbon (charcoal)

iv. Salted charcoal

(f) This experiment is to study on the two factors affecting the soil resistivity which are moisture content and chemical content.

(g) The resistivity of each type of soil will be calculated based on the derivation of formula from the Ohm's Law.

(h) The experiment will be carried out at constant room temperature due to soil resistivity varies with temperature.

1.6 Report Outline

The report is organized into five chapters as follows:

Chapter 1 introduces the background of electrical resistivity measurement in soil and the importance of grounding connection, research motivation, the statement of problem, specific objectives, scopes of the research and report organization. Basically this chapter is used to give an overview of what have been motivated to carry out this project and the significance of this project to the society. The project limitation and boundary is described in the objectives and scope section.

Chapter 2 presents literature review about the soil profile on the earth and the basic terms that are related to the soil resistivity of the grounding system. Then, the previous related works are being discussed and summarized. The comparison of this research with others related research is done in table form.

Following that, the chapter 3 will provide the different methodologies that will be used to complete this research. The flowchart diagram is used to describe the research methodology and experiment procedure. Various techniques that will be used to analyze the data are also presented in this chapter.

In chapter 4 of this report will present the result of this project. The scatter plot diagram, correlation coefficient and regression analysis is used to show the relation between soil resistivity and the parameters that affect the soil resistivity such as water content, sodium chloride solution and charcoal content. After that the detailed explanation on the results that have obtained is directed.

At the end, the chapter 5 is for doing a conclusion and recommendation for this research. The outcome from this project will be compared with the early specified objectives or hypotheses to see whether the objectives are achieved or not. Then, the suggestion for improving of the future project is included in this section.