DESIGN AND ANALYSE THE CONFIGURATION OF EARTHING SYSTEM BASED ON HIGH-LOW AND LOW-HIGH SOIL STRUCTURE

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Bachelor of Electrical Engineering (Industrial Power)
June 2013

“I hereby declare that I have read through this report entitle “Design and Analyse the Configuration of Earthing System Based on High-Low and Low-High Soil Structure” and found that it has comply the partial fulfilment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)”

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A report submitted in partial fulfilment of the requirement for the degree

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2013

I declare that this report entitle "Design and Analyse the Configuration of Earthing System Based on High-Low and Low-High Soil Structure" 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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To my beloved mother and father

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ABSTRACT

Each TNB transmission tower requires a tower footing resistance (TFR) with a lower grounding resistance value that depend on the transmission line voltage. For 132kV and 275kV tower, the TFR must less than 10Ω and 500kV tower must less than 5Ω. The TFR is changeable with variable factors such as soil resistivity. Low TFR provides essential protection to the fault such as lightning strike that may occur at any time. The fault current flow to the lowest resistance path and easily disperses to earth. Back flashover voltage across the insulator of transmission lines may occur when the TFR is high. The TFR is influenced by soil resistivity. There are three parameters affecting the soil resistivity; moisture content, salt content and temperature of the soil. High moisture content in soil will reduce the soil resistivity and resultant low TFR. Small scale moisture control by using Micro Reservoir (MR) irrigation with semi-permeable membranes have the power to offer the stable moisture in soil. By using osmosis concept, it is the process of net movement of water molecules from high potential water to lower potential water though a semi permeable membrane. The MR can withstand for 3 to 5 days without continuous water supply. The MR installed in the centre of the tower that contains a multiple parallel of electrode rods. The concentrated of electrode rods grounding configuration with a combination of MR will improve the TFR even at multilayer soil. As a result, MR gives a little improvement to TFR. The MR in area of concentrated electrode rod configuration to ensure the soil always wet and moist at all times. The changes in soil affect the tower-footing-resistance. The tower-footing-resistance measurement at afternoon is higher than at evening because of the temperature and moisture content in soil is change due to sun radiation.

ABSTRAK

Setiap menara talian penghantaran kuasa TNB memerlukan perlu mempunyai rintangan-kaki-menara atau *tower-footing-resistance* (TFR) yang rendah dan nilai tersebut bergantung kepada sistem voltan talian penghantaran tersebut. Untuk 132kV dan 275kV menara, TFR mestilah kurang daripada 10Ω manakala untuk 500kV menara mesti kurang daripada 5Ω. TFR berubah dengan faktor-faktor seperti rintangan tanah (SR). TFR yang rendah memberi perlindungan yang penting untuk kerosakan dan kemalangan seperti arus kilat boleh berlaku pada bila-bila masa. Aliran arus tersebut akan mengalir ke rintangan yang paling rendah dan dikebumikan. Kejadian voltan *back flashover* mungkin berlaku akibat TFR yang tinggi. TFR dipengaruhi oleh kerintangan tanah. Terdapat tiga parameter yang mempengaruhi kerintangan tanah; kandungan kelembapan, kandungan garam dan suhu tanah tersebut. Kandungan kelembapan yang tinggi di dalam tanah akan mengurangkan kerintangan tanah dan hasilnya TFR yang rendah. Pengawalan kelembapan yang kecil, takungan air micro atau *Micro Reservoir*(MR) merupakan membran separa telap yang mampu mengawal kelembapan tanah. Dengan menggunakan konsep osmosis, proses pergerakan molekul air keluar dari keupayaan yang tinggi ke keupayaanyang lebih rendah melalui membran separa telap. MR boleh bertahan selama 3 hingga 5 hari tanpa bekalan air yang berterusan. MR dipasang di tengah-tengah menara bersama rod elektrod. Penumpuan bilangan rod elektrod yang banyak di tengah-tengah dengan gabungan MR menurunkan TFR walaupun pada tanah yang mempunyai lapisan yang berbeza. Hasilnya, MR memberikan sedikit pembaikkan untuk TFR dengan pengunaannya di kawasan penumpuan bilangan rod elektrod dengan memastikan tanah sentiasa lembap pada setiap masa. Perubahan dalam tanah memberi kesan kepada TFR. TFR pada petang adalah lebih tinggi daripada berbanding waktu petang kerana suhu dan kandungan kelembapan dalam tanah berubah disebabkan sinaran matahari.

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LIST OF ABBREVIATIONS

MR	-	Moisture Reservoir
TFR	-	Tower Footing Resistance
SR	-	Soil Resistivity
Qty	-	quantity
pcs	-	pieces
mm	-	milimeter
m	-	meter

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CHAPTER 1

INTRODUCTION

The introduction consists of problem statements, motivations, objectives and project scopes of Design and Analyse the Configuration of Grounding System Based on High-Low and Low-High Soil Structure.

1.1 Problem statements

1. The tower footing resistance (TFR) of Tenaga Nasional Berhad (TNB)'s transmission lines for 132kV and 275kV must be lower than 10Ω. For 500kV transmission towers, the TFR must below than 5Ω [1]. Unfortunately, the TFR is changeable with variable factors such as soil resistivity, weather, aging and etc.
2. When the TFR failed to achieve a low resistance, an extra material such as counterpoises, copper rods or Earth Additive Fillers (EAF) are needed to install. Extra materials are also costly.
3. The reliable TFR must not exceed the safety requirement at all time to ensure better protection due to the fault. By controlling the soil resistivity, the TFR is also can be controlled. One of the variables is moisture content.

The motivation of the project is to maintain the moisture content of soil by using Micro Reservoir (MR) with concentrated electrode rod configuration in order to achieve a consistent low tower footing resistance at all time. High moisture in the soil reduces the soil resistivity and then affects the tower footing resistance to have low resistance grounding. When fault occurs, the current flow to the lowest resistance path and easily disperses to earth.

1.2 Objectives

1. To perform the tower footing resistance and soil resistivity measurement based on high-low and low high grounding configuration.
2. To evaluate the performance and reliability of the micro reservoir grounding system based on soil structure to tower footing resistance.
3. To study the relationship between the soil resistivity to micro reservoir grounding configuration.

1.3 Project Scope

1. The scale down model of the transmission tower grounding system are build based on configuration practice [1] with counterpoises and the copper rod. There are two set of model at different location which is in the same area near with Block F, Faculty of Electrical Engineering. In order to install the counterpoises, the soil needs to be dig as 0.3meter deep. The installed copper rod must be interconnected with counterpoises by rod clamper. Both set of grounding system must have a same configuration in size, material and the depth of counterpoises and chopper rod. The concentrate electrode rod configuration is selected and be setup for each set of model.

2. The Micro Reservoir grounding system is applied in the grounding system with external water sources. In the first stage, the Micro Reservoir was installed in Set 2. After the measurement of tower-footing-resistance in each set had done, the Micro Reservoir will be removed and installed in Set 1. Then, the same measurement will be conducted.

3. The measurement of tower footing resistance and soil resistivity are using Fluke 1623 GEO Earth Ground Testers in FKE, UTeM. The Fluke GEO Earth Ground Testers is a suitable device to do the measurement. The measurement is carryout by a procedure in method 61.8% Method and Wenner Method. These methods are a regular method used in measurement to determine the grounding resistance of tower which is tower-footing-

resistance and soil resistivity. The soil resistivity affects the tower-footing-resistance. Generally, the soil resistivity has a multilayer resistance based on the depth of soil. The measurement data of soil resistivity by Wenner method is analyse using CDEGS (Current Distribution, Electromagnetic Fields, Grounding and Soil Structure Analysis) software by collaboration with TNB Research Sdn. Bhd. RESAP is the tool in CDEGS software that can construct the corresponding soil model in simulation based on measured soil resistivity data.

1.4 Thesis Outline

The thesis contains 5 chapters. The first chapter is Introduction which contains a problem statements, motivations, objectives and project scopes. The Chapter 2 is Literature Review which contains a lot of paper studies that related to the project. There are 5 topics related information which are the parameter affect the tower-footing-resistance and soil resistivity, the comparison of testing method, comparison between Micro Reservoir and Moistube, and soil profile. The Chapter 3 is Methodology. In this chapter, it will cover the flow of the project until analysis part. The flow chart is important to understand in brief about the project. The location, list of equipments, setup and design is the first part of methodology. The second part of methodology discuss on testing, measurement and analysis part. The Chapter 4 is Result and Discussion. All the measured data from measurement part are analysed to obtain the resistance value of tower model which are tower-footing resistance and also the soil resistivity. The analysis can be done by using graph, simple calculation and simulation. The reasons and effect about grounding modelling and Micro Reservoir are also discussed in this chapter. The Chapter 5 is Conclusion and Recommendation which is the last chapter in the thesis. The finding and significance of the project is state in the conclusion part and the recommendation is the part whereas any suggestion to improve the project for further research.

CHAPTER 2

LITERATURE REVIEW

The literature review is a past studies related of grounding system which is about configuration of the grounding system, the affect of moisture content in soil and the affect of soil resistivity to tower-footing-resistance. The comparison of the Micro Reservoir and Moistube are also be reviewed to compared their advantages and disadvantages. The detail function of Micro Reservoir and how it work is discussed in this part. There are lot measurements methods of soil resistivity and tower-footing-resistance can take into account and the best method is by using Wenner Method for soil resistivity and 3 point measurement for tower-footing-resistance.

2.1 Introduction

Each TNB transmission tower requires a tower footing resistance (TFR) with a lower earthing resistance value that depend on the transmission line voltage. For 132kV and 275kV tower, the TFR must less than 10Ω and 500kV tower must less than 5Ω [1]. Grounding configuration and design depends on many factors such as soil resistivity and soil structure in order to achieve low impedance grounding in order to provide essential protection to the electrical facilities

2.2 Parameters that affect the TFR

a) Moisture Content

The soil resistivity varies by many parameters. The deep-ground-well is the method for controlling the soil moisture with a well around the substation that cover 90×90m2 area produces a low grounding resistance compared popular vertical grounding electrode. The water to act as a medium to filled the pores of dry soil and reduces the current dispersing resistance. Hence, the current disperse directly to low soil resistivity. The low soil resistivity has a high content of moisture and water in the soil. The dry clay soil resistivity has an extremely high resistivity compared to wet clay soil [2]. Unfortunately, it is not suitable to install this method along the transmission tower that has a small area along the line.

b) Configuration

The discharging current to earth is not uniform based on different configuration of electrodes by varying the distance and layout of the electrodes. Each electrode carries current and disperse to earth have a different initial magnitude current until it is fully discharged to zero [3]. The arrangement of the electrode can be determined by soil resistivity measurement to identifying the resistive layer of soil. Low resistivity at first layer provides a good discharging but on high resistivity at first layer provides a small level of current discharging. Thus, the deep rod is compulsory in order to disperse the current through a deep layer [4]. Earth Additive Filler (EAF) material for grounding provide a low impedance grounding at high soil resistivity produce a low resistance that sustains beyond 25 weeks for both galvanized iron and copper tape [5]. The soil must be burrowed and filled with new EAF material are required when the electrode arrangement failed to achieve required grounding resistance. Basically, the soil resistivity measurement must be carried out before deciding the arrangement of electrode. It is not practical for testing each tower before installing the grounding electrode. Yet, the soil resistivity is not constantly low at all the time. On the other hand, the grounding measurement for vertical-layered soil has a huge error depend on the arrangement of earth spike. The measurement on the high resistivity soil side produce higher value than actual grounding resistance but measurement on the low resistivity soil side produces a lower value than the actual grounding resistance. Uniquely, the measurement of the vertical boundary between both soils produces an approximate value to actual grounding resistance [6]. The measurement using 61.8% method which is practically used is inaccurate on vertical layered soil if the earth spike is not at the vertical boundary of soil.

2.3 Parameter that affect the Soil Resistivity (SR)

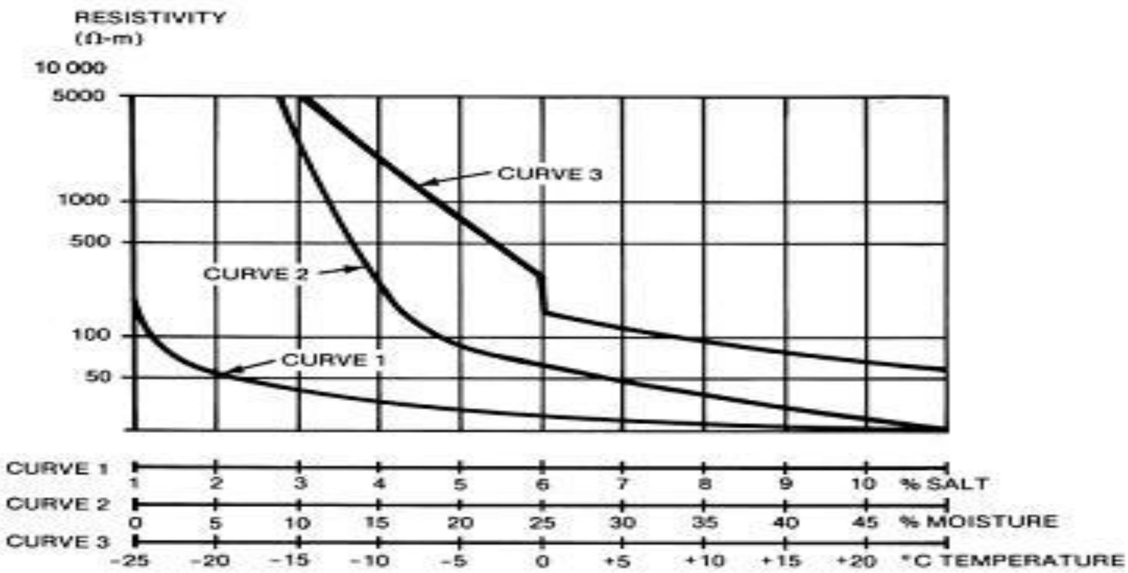


Figure 2.1: The three parameters that affect soil resistivity graph [7]

The soil resistivity is varied by three parameters; salt, moisture, and temperature [7]. The increases of salt, moisture and temperature of the soil will reduce the soil resistivity. Thus, the low resistive soils act as a good conductor. In contrast, high soil resistivity happens when; the salt content is soil is low, the temperature is cold such as during winter and the moisture content is soil is low. High soil resistivity acts as bad conductor. Conductivity of soil is on the subject of how hardly the current flow through it.

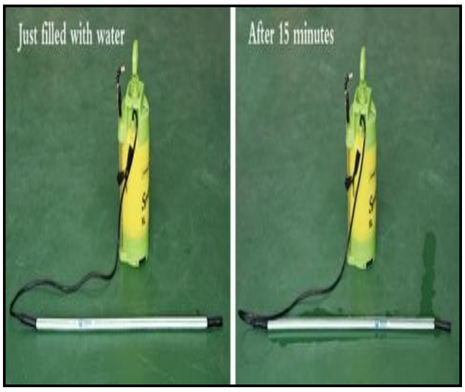
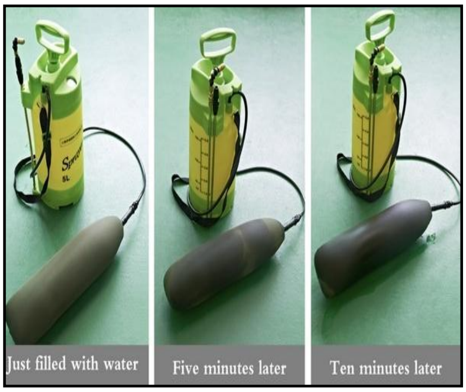
The low moisture content happen when the water dry from the soil. It may caused by the dry season and the area will have a low rainfall. Therefore, the tower footing resistance is affected by the soil resistivity. The low soil resistivity will give a low resistance of tower footing resistance. This has happened because the low soil resistivity act as good conductor that let the current easily disperses to the earth. In reality, when a fault occurs on the transmission line, the grounding of transmission tower will provide a low resistance path that lets the current flow and disperse to earth. Unfortunately, if the tower footing resistance is high, the back flashover voltage across the insulator of transmission lines may occur [8].

2.4 Moisture Control – Comparison between Moistube and Micro Reservoir.

The comparison between Moistube and Micro Reservoir is show in Table 2.1 whereas the Micro Reservoir is selected in the project. The MR is the irrigation system used in desert plantation whereas the full capacity of water by a single MR can withstand for 3 days to 5 days without continuous water supply to it. The system used in irrigates desert plantation area to provide uninterrupted water to soil without any operating of electricity and people. The MR is compatible at any type of soil and not affected by the altitude. So, the irrigation is uniformity and it distributes the water at all spots with the same amount of the water.

It is an artificial semi permeable membrane bag that has a similar characteristic of plant membrane cells. By using osmosis concept, it is the process of net movement of water molecules from high potential water to lower potential water though a semi permeable membrane. The Micro Reservoir is filled with the water. The energy differences make the water flow through the semi permeable membrane continuously until it reaches a balance point. High energy differences make the water penetrate faster from membrane than the low energy differences. Thus, affect the capacity of water out of the membrane [9].

Table 2.1: Comparison between Moistube and Micro Reservoir

	Moistube	**Micro Reservoir (MR)**
Picture of Equipment		
Size	The Moistube is available in 10m to 200m in tubes.	Micro Reservoir (MR) is a 1.5 litre bag
Water Supply	The tubes connected with water supply such as a water tank and main water	External water (1.5litre)
Method Supply	Continuous water supply	Need to refill every 3-5 days. *Depend on soil and weather
Location	Moistube working on flat Low slope contours	Can be located at type of land such as high slope and steep area.
Application	Lawn, Crop, Fruit, Vegetable and Landscape Irrigation.	Any trees that located on slopes and steep area. Desert Forestation

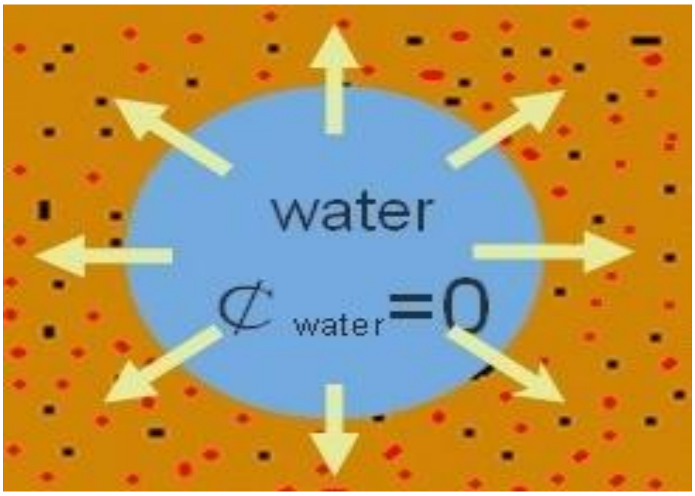


Figure 2.2: The osmosis process of semi permeable membrane of Micro Reservoir [9]