INVESTIGATION ON THE EARTHING SYSTEM INSTALLATION FOR BUILDINGS AND STRUCTURES IN SARAWAK

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DEDICATION

This thesis is wholeheartedly dedicated to my beloved parents, who have been my source of inspiration and gave me strength when I thought of giving up, who continually provide their moral, spiritual, emotional, and financial support.

To Nadia and my lovely son, your sacrifice through the hard time is always the reason I continue this journey.

To my brothers, sisters, relatives, mentor, friends, and classmates who shared their words of advice and encouragement to finish this study.

And lastly, I dedicated this book to the Almighty Allah, thank you for the guidance, strength, power of mind, protection and skills and for giving us a healthy life. My great teacher and messenger, Muhammad S.A.W (May Allah bless and grant him), who taught us the purpose of life. All of these, I offer to you.

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ABSTRACT

In electrical engineering, grounding or earthing may be defined as the act of connecting general mass of earth with electrically conducting materials of an installation which under normal conditions do not carry a voltage or charge. Flash protection and earthing systems around the world are now governed by national and international standards that emphasize comprehensive solution requirements. In other words, the structure of lightning protection system cannot and will not protect electronics systems over lightning and transient over voltages. For this reason, a good earthing system is required to provide effective life security and reliable long-term protection and electronics systems. In this study, the safety aspect, type of protection and functionality of earthing system for selected buildings and structures in Sarawak especially in Kuching was identified and discussed. It covers a wide range of earthing system requirements for at home residences, commercial buildings, power systems and telecommunications structures, datacentres, healthcare centres and others. Earthing resistance value of selected buildings and structures was measured, validate and analysed. The analysis of the earthing resistance system was done using AutoGroundandDesign software by Safe Engineering Services & technologies ltd. (SES). The simulation-based result was compared with the measurement-based value. From the result, the conditions of the soil that have a low earth resistivity had a good earthing system and high safety protection for the electrical equipment and the human life eventhough the design is just one earthing copper rod being installed vertically into the soil. The implications to buildings and structures in Kuching, Sarawak from the measurement-based result and simulation-based result are the venue of sites for development of buildings and structures need to consider also the soils condition as long as the sites is still having a huge area to develop. If not, needs to design the earthing system with the design that have the lowest earthing resistance value that is Hemispherical Electrode design.

ABSTRAK

Dalam bidang kejuruteraan elektrik, pembumian atau pembumian boleh ditakrifkan sebagai menyambung jisim umum bumi dengan bahan elektrik yang menjalankan suatu pemasangan yang di bawah keadaan biasa tidak membawa voltan atau caj. Perlindungan ‘flash’ dan sistem pembumian di seluruh dunia kini dikawal oleh piawaian kebangsaan dan antarabangsa yang menekankan keperluan penyelesaian yang komprehensif. Struktur sistem perlindungan kilat tidak boleh dan tidak akan melindungi sistem elektronik daripada kilat dan transien ke atas voltan. Atas sebab ini, sistem pembumian yang baik diperlukan untuk menyediakan keselamatan hayat yang berkesan dan perlindungan jangka panjang dan sistem elektronik yang boleh dipercayai. Dalam kajian ini, aspek keselamatan, jenis perlindungan dan fungsi sistem pembumian untuk bangunan dan struktur terpilih di Sarawak khususnya di Kuching telah dikenalpasti dan dibincangkan. Ia merangkumi pelbagai keperluan sistem pembumian untuk kediaman di rumah, bangunan komersial, sistem kuasa dan struktur telekomunikasi, ‘datacenters’, pusat penjagaan kesihatan dan lain-lain. Nilai rintangan bumi bagi bangunan dan struktur yang dipilih diukur, disahkan dan dianalisis. Analisis sistem rintangan bumi dilakukan menggunakan perisian AutoGroundandDesign oleh Safe Engineering Services & technologies ltd. (SES). Hasil simulasi dibandingkan dengan nilai pengukuran. Hasilnya, keadaan tanah yang mempunyai kerintangan tanah rendah mempunyai sistem pembumian yang baik dan perlindungan keselamatan yang tinggi untuk peralatan elektrik dan kehidupan manusia walaupun reka bentuknya hanya satu ‘earthing rod’yang dipasang secara menegak ke dalam tanah. Implikasi terhadap bangunan dan struktur di Kuching, Sarawak dari hasil pengukuran dan simulasi adalah tapak untuk pembangunan bangunan dan struktur yang perlu dipertimbangkan juga keadaan tanah selagi tapak masih mempunyai kawasan besar untuk pembinaan. Jika tidak, mereka perlu merekabentuk sistem pembumian dengan reka bentuk yang mempunyai nilai rintangan bumi yang paling rendah iaitu Reka bentuk Elektro Hemispherikal.

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LIST OF ABBREVIATIONS

LRM	-	Low Resistivity Material
NEM	-	Natural Enhancement Material
NEC	-	National Electrical Code
GI	-	Galvanised Iron
PVC	-	Polyvinyl Chloride
AT	-	Authorised Tester
GFI	-	Ground Fault Interrupter
MWH	-	Mega Watt Per Hour
kWH	-	Kilo Watt Per Hour
V	-	Volt
UTM	-	Universiti Teknologi Malaysia
CDEGS	-	Current Distribution, Electromagnetic Fields, Grounding and Soil Structure Analysis

LIST OF SYMBOLS

δ	-	Minimal Error
D, d	-	Rod Diameter
h	-	Upper Layer Depth
ρ_1	-	Upper Layer Soil Resistivity
φEE	-	Earth- Electrode Potential Caused by The Current in The Earth- Electrode
φEC	-	Earth Electrode Potential Caused by The Current Flowing from The Current Probe
φPE	-	Potential of The Potential Probe Caused by The Current in The Soil Electrode
φPC	-	Potential of The Potential Sample Caused by The Current from The Current Probe.
k	-	Reflection Factor
l	-	Rod Length
C	-	Distance Between Potential Samples
R	-	Measured Instrument Resistance Value.
ρ	-	Ground Resistance
I	-	Current Flowing Through the Rod
a	-	Distance Between the Samples

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CHAPTER 1

INTRODUCTION

1.1 Background of Problem

The words ground, shield, isolation, and earth are one of semantic difficulties. The word ground is used to describe the framework of an aircraft, spaceship, or building. It is also a connection to mother earth. Words such as loam, sod, or soil are available to help, but they are rarely used in an electrical sense. The National Electrical Code (NEC) is generally accepted as a guideline for the safe installation of power and power equipment in facilities. Section 69 of this code provides with a set of definitions for unique terms and words used two or more times in the text of the Code [8][9]. The definition for "ground" is:

'A conducting connection, whether intentional or accidental between an electrical circuit or equipment and the earth or some conducting body that serves in place of the earth'

The word earth is a fundamental part of this definition as the NEC (National Electrical Code) is primarily concerned with electrical in structures and buildings that rest on earth. As shown in Figure 1.1, to ground the electrical system, it is connected to earth by a grounding electrode [9]. Man walks on the earth, buildings are set in earth, and lightning discharges to earth sometimes by way of the building. It is therefore desirable to use the earth as part of a security system to prevent electrical harm. When a power engineer uses the word ground there is usually little ambiguity. The electronics engineer uses the word in a much different manner.

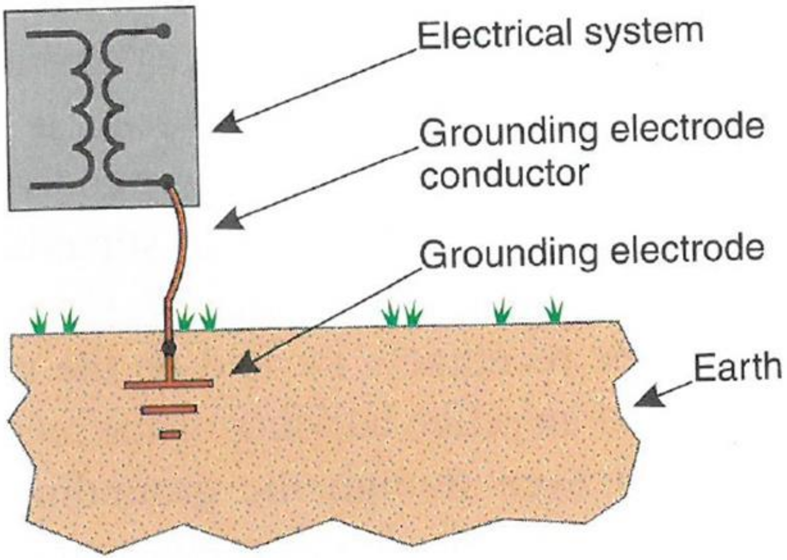

Figure 1.1: A grounded electrical system [45]

Appropriate presentation of electrical systems is essential for the safety of technical personnel, civilians and animals. The functional function of a suitable protective device depends on the grounding system. NEC (NFPA-70 Standard) sets the basic method for all installations in or in public or private buildings or other structures. As in the Figure 1.2, ground faults on circuits supplied by the generator will return to the windings of the generator over the bonding jumper between the frame and neutral [10].

Sarawak, the largest state in Malaysia that covers a varied area land of 124,450km^2 scattering between latitude 0° 50' and 5°N and longitude 109° 36' and 115° 40'E that making up 37.5% of the total area of Malaysia [30]. Same as other part of the world, in Sarawak, multiple connection to the earth are expected and desired in facilities. These connections generally occur via structural steel piping, and grounding electrodes. These conductors carry many signal and power currents. Some of these currents are undesirable and others can be ignored.

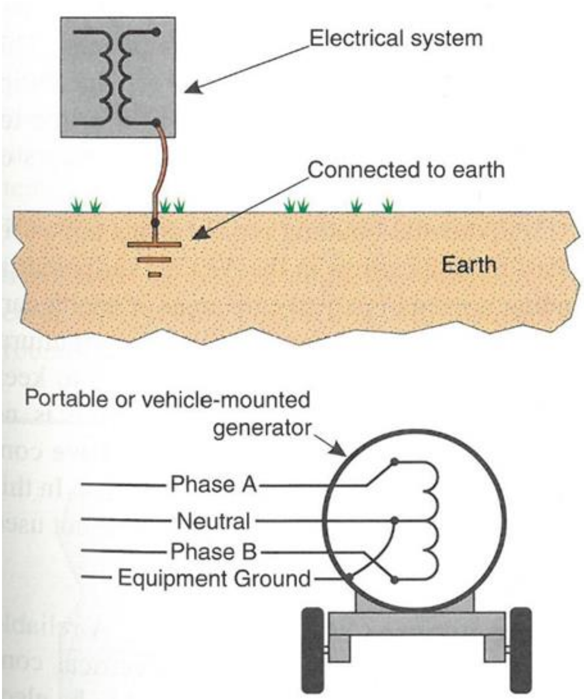

Figure 1.2: A bonding jumper between the frame and neutral of a generator [45]

The idea that the earth is an infinite electric body with zero resistance is not necessarily like this. The idea is popular that the earth is the place to get rid of all the sounds and that it is lost and lost in some way is not necessarily. All currents must flow into the loop, and any current results in possible potential of the earth. The potential differences are a source of trouble for many designers and users of electronic hardware. In some application microvolts of potential difference are a problem and in other cases kilovolts can damage the equipment [9]. A wide range of situations can occur, and the designer must consider every aspect of the problem.

Small potential differences between ground points cause problems for electronic designers. These voltages, often referred to as “noise” and sometimes as “hum”, are present in all facilities and result from normal practices. In desperation designers use unsafe practices to reduce or eliminate these troublesome signals. In other cases, designers may elect to “ground” their circuitry to eliminate noise. The word ground as used here implies a connection to a conductor that eventually connects to the earth. Designers find that different grounding schemes or different grounding points can create an improvement. This starts the each for the “the best ground”, and this is an unending search that is costly and usually unproductive.

It will be puzzled by this search for a better ground. Unfortunately, grounding is not a simple subject (nor it is complex), but it is often poorly treated in design. This lack of understanding forces many technical personnel to view the subject as black magic. Under pressure this search for an answer may force an unsafe practice. Some of these unsafe practices are initiated because lack of knowledge. There is always a technique possible that eliminate noise yet are perfectly safe.

Electronic designers can use word ground to mean normal power supply connection or electronic enclosure. An earth connection is simply incidental. Many devices are earthed because “they seem to work better that way”. The electronic person does not share the power engineer’s definition of ground. It is a communication gap between these two disciplines.

The earth is a complex conductor. The pattern of current flow depends on soil conditions, contact area, and frequency. Resistance diverges depending on dampness content and soil type. In desert areas the surface resistivity can be very high. Rocky areas can be very unpredictable. The frozen tundra presents its own problems. In some areas a good earth connection is impossible and other means must be applied to reduce noise or provide safety. The electrical resistance of the earth is largely determined by the chemical ingredients of the soil and the amount of moisture present [8]. Measurement of ground resistance completed by the Bureau of Standards are summarized in Table 1.1.

Table 1.1: Resistance of Different Types of Soil [43]

Soil	Resistance, ohms		
	Average	Minimum	Maximum
Fills and ground containing more or less refuse such as ashes, cinders, and brine waste	14	3.5	41
Clay, shale, adobe, gumbo, loam, and slightly sandy loam with no stones or gravel	24	2.0	98
Clay, adobe, gumbo, and loam mixed with varying proportions of sand, gravel, and stones	93	6.0	800
Sand, stones, or gravel with little or no clay or loam	554	35	2700

Courtesy of Bureau of Standards Technologic Paper 108.

In the electrical power world, the word ground implies the earth under foot as well as any conductor making connection to this earth. The conductor that connects with Earth is called "the grounding electrode". This might be a buried rod, a buried plate, or the steel in a building. In every facility a grounding electrode is required at the power entrance. This ground connection is critical to human safety. Engineers who argue that this connection should be changed are literally breaking the law. These suggestions occur when there seems to be no alternative to making a noise-free system.

Lightning protection and earth connections are closely related. Low resistance connections to earth do not solve the problem. Lightning may hit take the obvious path to earth. Often it is capricious as shown is Figure 1.3 The areas of concern include human safety, equipment protection, and facility protection. The rules applicable to power safety are not directed specifically toward lightning protection, but there are safeguards embedded in the Code. Lightning protection and power safety should both be considered in a facilities design. The NEC should be used for the electrical system design and the National Lightning Protection Code (ANSI/NFPA-78-1987) should be followed for lightning protection [19 -20].

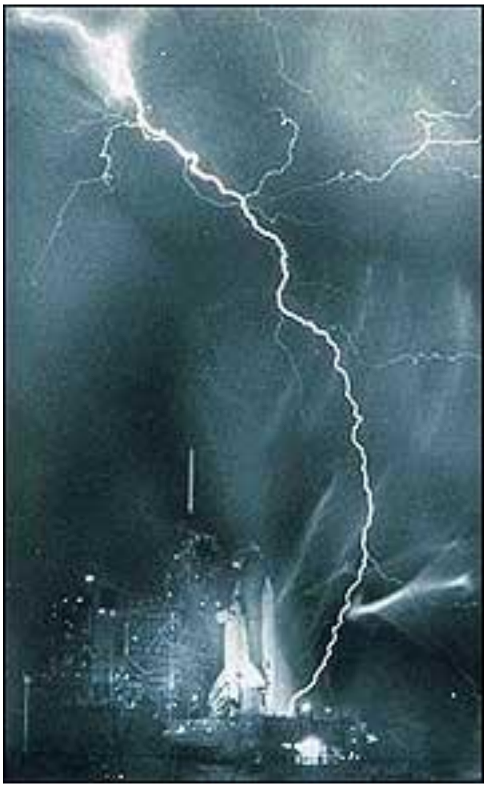

Figure 1.3**:** A lightning strike at the base of a launch vehicle [43]

Electrical connections are made to the earth through building steel, buried utility pipe, special grounding rods, and buried cable. These conductive paths can be improved by using arrays or by burying bare wire in a ring around a facility. The electrical resistance between a conductor and earth is rarely below 1 Ω. For this reason, a fault condition that uses the earth as a conductor may not trip a protecting breaker. The earth must be used for safety reasons, but it cannot be relied on as a low-impedance conductor. If a fault current does use the earth, large potential differences can result. This is particularly true where lighting is concerned. A 50,000 Ampere lightning pulse can cause a 50,000 Volt potential difference between earth points. To avoid this problem low-impedance conductors must interconnect all portions of a facility. These conductors are in the form of equipment grounding conductors, conduit, raceways building steel, and so forth. NEC and National Lightning Protection Code determine the size of the conductor and the nature of the electrical connection. This driver is part of the basics [8] [20].

1.2 Problem Statement

a) The resistance value of the earthing system for different kind of buildings and structures are varies. It depends on the sectors, features and the standard requirement.

b) Different types of soils will have different value of it's resistivity. Thus, the high sensitivity features buildings/structures to be built on the high resistivity soil will be challenging to get the low resistance grounding value.

c) The 'bad earthing system' will make the premises have the Power Quality Issues for its electricity supply and the customer will expose to the danger of High Current Fault and High Lightning Current.

1.3 Research Objectives

a) To investigate the condition of grounding resistance for selected buildings and structures with the different types of soils.

b) To identify and suggest suitable grounding method to improve grounding resistance

1.4 Scope of Work

a) Measurement of grounding resistance will be implemented in Kota Samarahan and Bario, Sarawak.

b) Interview session with the Authorised Tester / Installer and get the info of the earthing system condition in Sarawak.

c) Focus on buildings and structures only.

d) Simulation will be carried out using AutoGroundDesign (CDEGS) and results will be compared to the measurement value.

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