Electric Field and Electric Potential on Different Concrete Grounding System with Fly Ash and Marconite

by

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LIST OF ABBREVIATIONS

GEM	Grounding Enhancement Material
3D	3-Dimention
FEM	Finite Element Method
EMTP/ATP	Bruce and Golde function
BG	Electromagnetic Transients Program/Alternative Transient Program
UTM	Universiti Teknologi Malaysia
UNIKL MSI	Universiti Kuala Lumpur Malaysian Spanish Institute

LIST OF SYMBOLS

α	Alpha
β	Beta
γ	Gamma
δ	Delta
η	Special corrector factor
V	Potential difference
I	Current
R	Resistance
ρ	Resistivity
J	Current density
E	Electric field

Medan elektrik dan Potensi Elektrik pada Sistem Pembumian Konkrit yang berbeza dengan Abu Terbang dan Marconite

ABSTRAK

Sistem pembumian adalah sambungan elektrik ke bumi dengan wayar atau konduktor lain. Tujuan utama sistem pembumian adalah untuk melindungi manusia, peralatan elektrik dan bangunan dari kejutan elektrik akibat kilat atau bentuk elektrik lain yang berbahaya. Oleh itu, untuk mencapai matlamat ini, bahagian asasnya mesti diambil kira. Secara ringkas, dalam kajian ini terdapat beberapa sistem pembumian telah dimodelkan dengan menggunakan perisian FEM,ianya terdiri daripada konkrit penuh, konkrit tiga perempat, separuh konkrit dan konkrit seperempat yang diisi dengan Bahan Peningkatan Pembumian (GEM). GEM yang digunakan adalah abu terbang arang batu dan marconite. Terdapat dua jenis analisis yang dilakukan iaitu analisis medan elektrik dan analisis potensi elektrik. Untuk bahagian analisis medan elektrik, nilai medan elektrik diukur pada kedudukan atas dan kedudukan bawah dari sistem pembumian yang telah dimodelkan iaitu sistem pembumian yang telah di isi denagn kedua-dua GEM (fly ash dan marconite). Keputusan yang diperoleh telah dibandingkan untuk menilai model sistem pembumian yang paling terbaik di kedua-dua kedudukan tersebut. Ini kerana, medan elektrik yang lebih rendah dapat memberikan jalan impedans terendah ke tanah. Namun, hasil keseluruhan analisis medan elektrik yang diperoleh menunjukkan model sistem pembumian dengan marconite adalah lebih baik berbanding model sistem pembumian dengan abu terbang dari segi nilai medan elektrik yang lebih rendah. Untuk medan elektrik yang diukur di kedudukan atas, hasilnya jelas menunjukkan bahawa konkrit penuh dengan marconite memperoleh nilai medan elektrik yang terendah. Sementara itu, untuk medan elektrik yang diukur di kedudukan bawah, konkrit seperempat dengan marconite adalah model sistem pembumian yang paling sesuai dibandingkan dengan model sistem pembumian yang lain. Ini kerana, sistem pembumian konkrit seperempat ditanam ke kedalaman yang tertentu jauh di bawah tanah dan ia mempunyai luas permukaan terbesar yang bersentuhan dengan tanah yang menghadirkan jalan elektrik rintangan rendah ke bumi. Seterusnya, untuk bahagian analisis potensi elektrik, arus impuls kilat menggunakan model Heidler dimasukkan ke dalam perisian ini. Arus impuls kilat Heidler disisipkan pada semua sistem pembumian yang dimodelkan. Hasil kajian menunjukkan bahawa konkrit penuh memperoleh nilai potensi elektrik terendah diikuti oleh konkrit tiga suku, separuh konkrit, konkrit seperempat dan potensi elektrik tertinggi adalah sistem pembumian rujukan. Namun, hasil yang diperoleh untuk model sistem pembumian dengan marconite adalah lebih baik berbanding model sistem pembumian dengan abu terbang dari segi nilai potensi elektrik yang lebih rendah. Hasil ini jelas menunjukkan bahawa konkrit penuh dengan marconite adalah konkrit yang paling sesuai untuk menahan arus desakan kilat Heidler berbanding yang lain. Kesimpulannya, hasil keseluruhan yang diperoleh menunjukkan bahawa prestasi sistem pembumian dengan marconite adalah lebih baik daripada sistem pembumian dengan fly ash dari segi nilai medan elektrik dan nilai potensi elektrik yang lebih rendah. Oleh itu, dapat disimpulkan bahawa konkrit penuh dengan marconite adalah model sistem pembumian terbaik yang akan dipasang di tapak pembumian.

Electric Field and Electric Potential on Different Concrete Grounding System with Fly Ash and Marconite

ABSTRACT

A grounding system is the connection of electrical connection to the earth ground by a wire or other conductor. The main purpose of the grounding system is to protect humans, electrical appliances and buildings from electrical shock due to lightning or another form of electricity that hazardous. Therefore, to achieve this goal, the fundamental part must be taken into account. In brief, few grounding systems were modeled using FEM software, which consists of full concrete, three-quarter concrete, half-concrete and a quarter concrete filled with Grounding Enhancement Material (GEM). The GEM used is coal fly ashes and marconite. There are two types of analyses that were carried out which are electric field analysis and electric potential analysis. For the electric field analysis part, the electric field value obtained from all the grounding systems modeled with both GEM (fly ash and marconite) at position top and position bottom was analyzed and compared to evaluate the best grounding system model at both positions. This is because, a lower electric field can provide the lowest impedance path to the ground. However, the result obtained for the grounding system model with marconite is better than the grounding system model with fly ash in terms of the lower electric field. Therefore, for the measured electric field at position top, the results clearly show that full concrete with marconite obtained the lowest electric field value. Meanwhile, for the measured electric field at position bottom, a quarter concrete with marconite is the most suitable grounding system model compared to the other grounding system model. This is because, a quarter concrete grounding system was buried to a specified depth underground and it has the largest surface area in contact with the soil which presents a low resistance electrical path to the earth. Next, for the electric potential analysis part, lightning impulse current using the Heidler model was injected into this software. The Heidler lightning impulse current was injected on all the grounding systems modeled. The finding shows that full concrete obtained the lowest electric potential value followed by three-quarter concrete, half concrete, a quarter concrete and the highest electric potential is the reference grounding system. However, the result obtained for the grounding system model with marconite is better than the grounding system model with fly ash in terms of lower electric potential. This result clearly shows that full concrete with marconite is the most suitable concrete case to withstand the Heidler lightning impulse current compared to the others. In conclusion, the overall result obtained shows that the performance of the grounding system with marconite is better than the groundings system with fly ash in terms of lowered electric field and electric potential value. Therefore, it can be concluded that full concrete with marconite is the best grounding system model to be installed at the grounding site

CHAPTER 1 : INTRODUCTION

1.1 Research Background

One of the most important functions of a lightning protection system is to prevent property damage caused by lightning strikes. The lightning protection system would reduce the structural damage caused by lightning by directing electrical energy to the ground rather than allowing it to spread freely across the building. The grounding system is one method of the lightning protection system. A grounding system is the connection of electrical equipment or wiring system to the earth ground by a wire or other conductor. The grounding system must function properly at all times, in both normal and abnormal situations. Ground faults and lightning strikes are the two most common abnormal phenomena that can cause property damage, injury, or even death (Ahmad et al., 2018).

The grounding system must be capable of providing the lowest impedance route to the ground to ensure that fault current or lightning strikes diverge mainly through the grounding electrode into the earth. To achieve the lowest impedance path to the ground, soil resistivity must be considered as the main factor in designing any grounding system. This is because the soil resistivity value tends to vary depending on the type and texture of the soil. Therefore, finding an accurate soil resistivity model is crucial for achieving the desired result when designing a grounding system (Lai et al., 2017).

There are several methods to reducing soil resistivity, one of which is modifying soil characteristics with an enhancement filler material, where the soil may be treated with chemical or natural enhancement materials. This technique is one of the methods to enhance the efficiency of a grounding system (Wan Ahmad et al., 2018)

According to (Lim et al., 2015) to improve the performance of the grounding system, enhancement material must have certain characteristics, such as the ability to create a protective layer to prevent grounding electrode corrosion, the ability to change the surrounding soil to be less resistive and the ability to retain soil moisture. Therefore, it is crucial to choose suitable enhancement material, depending on the type and texture of the soil. This research aims to use coal fly ashes and marconite as enhancement filler materials to improves the grounding system.

According to IEE 142-1991, "the intentional connection of a phase or neutral conductor to earth to control the voltage to earth or ground within predictable limits. It also provides for the flow of current that will allow detection of an unwanted connection between system conductors and ground which may instigate the operation of automatic devices to remove the source of voltage. The control of voltage also allows reduction of shock hazard to the person who might come in contact with live conductors." From the statement, the grounding system aims to limit potential differences of neutral for system stability, also for personal safety, and allow for operation of relays and system protection devices (Thottappillil & Rakov, 2007).

This ensures that every individual, electrical appliance, or any building in the vicinity of the grounding system area is not exposed to critical electrical shocks due to lightning or fault. Therefore, to achieve an effective grounding system, the fundamental part of the grounding system design must be considered before installing the grounding system practically. To achieve an excellent grounding system, the fundamental part in designing the grounding system must be taken into account before installing the grounding system practically. This is critical since an improperly installed grounding system will cause more damage than not getting one at all (Pfeiffer, 2001).

In this research, a few analyses using the software were carried out to analyze and evaluate the distribution of electric field and the electric potential of the grounding system. According to (Pfeiffer, 2001) a grounding system with a lower electric field is capable of providing the lowest impedance path to the ground. Modeling of transient phenomena is also an essential part of lightning protection design and analysis. Therefore, this research also analyses the electric potential of the injected impulse using software to evaluate the performance of the grounding system modeled (Mešter, 2004). The results of the analysis on both distribution of electric field and electric potential are expected to assist in the preparation before the actual experiment is carried out.

1.2 Problem Statement

The grounding system plays an important role in ensuring that every individual, electrical appliance, or building in the vicinity of the grounding system area is not exposed to critical electrical shocks due to lightning or fault. Therefore, it is crucial to design the best grounding system model to improve the performance of the grounding system. The use of enhancement materials is one of the effective methods to improve the performance of the grounding system as it helps to reduce soil resistivity. Thus, providing the lowest impedance path to the ground to ensure fault current and lightning strikes to diverge mainly to the grounding electrode into the soil. Recent research shows that researchers tend to use enhancement material as a solution to the high resistivity of soil in the grounding system. Therefore, in this study, coal fly ash and marconite were used as grounding enhancement materials (GEM).

However, all the previous research conducted has not studied the effect of the electrical field and electrical potential distribution which may seem to affect the grounding system. This is because, the distribution of high electric field triggers damaging discharge activities to the grounding system (T. Imakoma Y. Suzuki 0. Fujii I. Nakajima, 1994). High electric fields also can accelerate premature aging of the grounding system which can cause flashover. Therefore, in this research, few grounding systems were modeled using software to recognize the best grounding system design that has the lowest electric field.

Moreover, the analysis of the electrical potential of the grounding system due to the lightning impulse current is also important (Stolzenburg & Marshall, 2009). Lightning is a natural phenomenon that has an incredible appearance and has always had a tremendous impact on humans and their communities due to its threats imposed on life and systems. With the growth of micro-electronics technology and the information industry, the loss caused by lightning increased every year (Stolzenburg & Marshall, 2009)(Sima et al., 2016). As the consequence, a grounding system with lightning research is developed in this research to recognize suited grounding system design that can endure severe lightning better.

The fundamental part of the appropriate grounding system modeled is necessary to assist in the planning before the actual experiment is conducted. Therefore, this research is aimed to analyze the electric field and electric potential to recognize the best grounding system design to be installed at the grounding site.

1.3 Objective

This study embarks on the following objectives:

1) To model and simulate different 3-D cylindrical concrete cases of grounding system with GEM fly ash and marconite using FEM software.

2) To analyze the electric field of the grounding system modeled with GEM fly ash and marconite.

3) To evaluate the electric potential of the injected lightning impulse current of the grounding system modeled with GEM fly ash and marconite.

1.4 Research Scope

The scopes of this study are:

1) Modeling different 3-D cylindrical concrete cases of grounding system with GEM fly ash and marconite using FEM software.

2) The volume and mixture of each concrete in the grounding system model are the same.

3) The grounding system modeled only used copper rod copper rod with a diameter of 0.014m and a length of 2m.

4) Analyze electric field and the electric potential of the grounding system modeled using FEM software.

5) The usage of GEM fly ash and marconite are considered in the grounding system modeled as enhancement material with the vertical type of grounding rod.

CHAPTER 2 : LITERATURE REVIEW

2.1 Introduction

This chapter covered the literature review based on the previous studies for the grounding system. Grounding systems play an important role to allow the transmission and distribution of the fault current or lightning strikes into the soil to provide safety protection in the installation area. Therefore, a lot of researchers and engineers had involved in the research and installation of the grounding system. In this research, the tendency of choosing cylindrical shape grounding filler over rectangular shape grounding filler was discussed. Also, the knowledge of soil resistivity in designing the grounding system had been discussed. Then, the modifying soil characteristic's technique using the Grounding Enhancement Material (GEM) also has been reviewed. Furthermore, the comprehensive selection of the copper grounding electrode is highlighted according to the previous research. Besides, the review of the previous study on the effect of the electric field is evaluated in this research to ensure the performance of the grounding system. Also, the different type of channel base lightning impulse current was discussed in this chapter whereby the Heidler function is highlighted. All of these subtopics would contribute to the improvement of the grounding system in this research.

2.2 Shape in Grounding System

The grounding system is a technology to connect the air termination rod and down conductor to the ground. However, the grounding filler shape used by the researcher in installing the grounding system does not seem to be consistent over the year. This is shown in the previous study. There are two types of shapes had been used in this grounding system field is a rectangular shape and a cylindrical shape. In 2012, an application of rectangular wood ceramics as a grounding system was investigated. H. Shimizu and N. Watanabe manufactured some wood ceramics plates with dimensions 78mm x 64mm x 7mm to act as an electrode. Then, this rectangular wood ceramic electrode was soldered with a grounding wire and was buried in 200mm depth with about 60mm separation between each electrode (Shimizu & Watanabe, 2012). Meanwhile, in 2013, Lim et al. a rectangular shape of steel cages encased in concrete mixed with various proportions of bentonite was designed. In this study, the concrete mixed with the various proportion of bentonite was installed in 8 pits aside (Lim et al., 2013). Based on these, there were no significant explanations or reasons on both rectangular shape wood ceramics and rectangular shape steel cages were chosen for their studies.

Next, as time passed by, a cylindrical shape become dominant compared to a rectangular shape. In 2015, a 2D cylindrical concrete was designed to coat the electrode by using COMSOL Software. This research investigated the grounding system with additive and without additive material using COMSOL software (Memon, 2015). In 2016, Chen et al. used coal fly ash as a reducing agent to reduce the resistivity of soil at Kung Shan University of Technology. In this study, the authors buried five grounding bars in the ground at the Kung Shan University of Technology. The grounding bars were steel-core copper sticks of diameter 2.104cm and length 280cm. Out of five grounding bars, grounding bars No.1 to No.3 were only partially covered with a reduction agent in a cylindrical shape, and grounding bars No.4 and No.5 were not (Chen et al., 2006). Again, there was no solid explanation on the cylindrical shape that was being chosen in their studies.

Three years later (2018), a cylindrical shape concrete filled with additive material once again has been used by N.H. Halim coated the electrodes to investigate the performance of galvanized steel and copper electrode using paddy husk ashes (Halim et al., 2018). Also, in the same year (2018), a cylindrical grounding conductor made up of copper with a length of 1.5m and diameter of 0.013m was used to study bentonite and Kenaf as an additive material in the grounding system (Wan Ahmad et al., 2018).

Therefore, as shown in Table 2.1, it can be seen that a previous study from the year 2012 to 2013 tends to use a rectangular filler shape for the grounding system purposes. However, in recent year's research which is from 2015 up until 2018, the trend of designing the grounding system filler has changed to a cylindrical shape. Also, recent research shows that researchers tend to use enhancement filler material as a solution to the high resistivity of soil in the grounding system.

There was no solid explanation on the tendency of choosing cylindrical shape over the rectangular shape in the recent year research. Therefore, in this study, a cylindrical shape with GEM filler was chosen rather than a rectangular shape following the previous recent year study. Also, the cylindrical shape is the common shape used compared to the rectangular shape.