IMPROVEMENT OF GROUND IMPEDANCE MEASURMENT USING SINGLE ROD METHOD

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DEDICATION

To the dearest figures of my life, my parents Mohammad and Farzaneh. Without whom none of my success would be possible.

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ABSTRACT

In city centers, measurement of ground impedance is found to be crucial to prevent any hazard to the city citizens and equipment due to lightning and short circuits. Although various methods introduced to measure ground impedance but they mostly require a large site area or adoptable only for low frequencies. Therefore, a new approach is needed to accurately measure the ground impedance value. In this study, an innovative method is developed based on one-rod measurement technique to overcome the limitation of site area measurement as well as to consider the frequency influence on ground electrode. In this method, a 5V-AC is injected by a signal generator with a variable frequency (from 5 Hz to 300 kHz) into the driven rod. The measured current is recorded accordingly. The ground resistance is then determined as the ratio of voltage and current. The corresponding resistivity is obtained based on Dwight formula. For the validation of the method in low frequency range, the obtained ground resistance from one-rod method was compared to that value obtained from fall-of-potential (FOP) method. In addition, for the validation of the method in high frequency range, the obtained ground resistances from one-rod method were compared to those values obtained from Visacro-Alipio theoretical model. The results show that the resistivity value obtained from the developed method and FOP were 113.28 Ω.m and 117.36Ω.m, respectively, which shows 3.5% difference. In addition, the resistivity value obtained from the developed method and Visacro-Alipio for the frequency range of 100 Hz to 300 kHz showed a minimum difference of 1.33% only. The simulation results of Single Rod method using CDEGS and EMTP showed the maximum of 1.09 % and 0.08% difference between simulation and experimental results respectively. These results validated the reliability of using one-rod method as an alternative method for measuring ground resistance especially in the congested area.

ABSTRAK

Di kawasan pusat bandar, pengukuran galangan tanah didapati penting untuk mengelakkan sebarang bahaya kepada penduduk bandar dan peralatan disebabkan oleh kilat dan litar pintas. Walaupun pelbagai kaedah diperkenalkan untuk mengukur galangan tanah namun kebanyakannya memerlukan kawasan tapak yang besar atau dilaraskan hanya untuk frekuensi rendah. Oleh itu, pendekatan baru diperlukan untuk mengukur dengan tepat nilai impedans tanah. Dalam kajian ini, kaedah inovatif dibangunkan berdasarkan kepada teknik pengukuran satu rod untuk mengatasi had pengukuran kawasan tapak dan juga mengambil kira pengaruh frekuensi pada elektrod bumi. Dalam kaedah ini, 5V-AC disuntik oleh penjana isyarat dengan frekuensi bolehubah (dari 5 Hz hingga 300 kHz) ke dalam rod yang dipandu. Arus yang diukur direkodkan dengan sewajarnya. Rintangan tanah kemudian ditentukan sebagai nisbah voltan dan arus. Kerintangan sepadan diperolehi berdasarkan formula Dwight. Untuk mengesahkan kaedah dalam julat frekuensi yang rendah, rintangan tanah yang diperolehi dari kaedah satu-rod dibandingkan dengan nilai yang diperolehi daripada kaedah “fall-of-potential” (FOP). Manakala, untuk mengesahkan kaedah dalam julat frekuensi tinggi, ianya dibandingkan dengan nilai yang diperolehi daripada teori model Visacro-Alípio. Keputusan menunjukkan bahawa nilai kerintangan yang diperolehi dari kaedah yang dibangunkan dan FOP adalah 113,28 Ω.m dan 117.36Ω.m, masing-masing, menunjukkan perbezaan 3.5%. Di samping itu, nilai kerintangan yang diperolehi dari kaedah yang dibangunkan dan Visacro-Alípio untuk julat frekuensi 100 Hz hingga 300 kHz menunjukkan perbezaan minimum 1.33% sahaja. Keputusan simulasi kaedah Single Rod menggunakan CDEGS dan EMTP masing-masing menunjukkan perbezaan maksimum 1.09% dan 0.08% antara simulasi dan keputusan eksperimen. Keputusan ini mengesahkan kebolehpercayaan menggunakan kaedah satu-rod sebagai kaedah alternatif untuk mengukur rintangan tanah terutama di kawasan yang sesak.

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LIST OF SYMBOLS

a	–	Physical electrode radius
a_{eq}	–	Equivalent electrode radius
L	–	Electrode inductance
q	–	Electric charge
Q	–	Total electric charge
R	–	Low current and low frequency grounding electrode resistance
C_g	–	Soil capacitance of non–ionized region
E_a	–	Electric field in air void
E_s	–	Electric field in soil particle
J_a	–	Current density in air void
J_s	–	Current density in soil particle
R_g	–	Soil resistance of non–ionized region
$R_G(t)$	–	Dynamic grounding electrode resistance
T_f	–	Current front time
U_a	–	Voltage across the air void
U_s	–	Voltage across the soil particle
$v(t)$	–	Grounding electrode voltage at current injection point
Z_g	–	Equivalent impedance of the parallel elements R_g and C_g
ε	–	Permittivity
σ	–	Conductivity
ρ	–	Soil resistivity
τ	–	Time constant
ε_s	–	Soil permittivity

ε_a	–	Air permittivity
σ_s	–	Soil particle conductivity
σ_a	–	Air conductivity
v_d	–	Electron drift velocity

LIST OF ABBREVIATIONS

CDEGS	–	Current Distribution, Electromagnetic Fields, Grounding, and Soil Structure Analysis
EM	–	Electromagnetic Approach
EM–MoM	–	Electromagnetic Approach with Method of Moment
EMTP	–	Electromagnetic Transient Program
FFT	–	Fast Fourier Transform
IEC	–	The International Electrotechnical Commission
IEEE	–	The Institute of Electrical and Electronics Engineers
IFFT	–	Inverse Fast Fourier Transform

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Grounding basically began as the safety measure to help prevent people from accidently coming in contact with electrical Hazards. In the electrical system the grounding system or earthing system are the circuits used to connect electrical devices to the ground. Grounding of electrical installation is primarily concerned when safety aspect of equipment and user are concern. In the electrical system grounding is important to provide a reference voltage (zero potential ground potential) against which all other voltages in a system. An effective ground connection also minimize the susceptibility of equipment to interface and to reduce the risk of equipment damage due to lightning.

Grounding electrodes are important components in lightning protection systems (LPS). The main goal of any grounding system is to provide low impedance path for fault and/or transient currents to the ground in order to avoid any hazard or danger cussed to human or equipment nearby. The performance of this insulation scaled by the ground impedance of the system that leads to improvement of safety and optimization of the system [1], [2].

Usually, in the analysis of grounding systems subject to lightning current, the electrical parameters (permittivity and conductivity) of the soil are considered to be constant as a function of frequency. Only very recently, the frequency dependence of the soil electrical parameters was taken into account in the analysis of grounding systems [3-6]. Extensive experimental characterization of the frequency dependence of soil electric conductivity and permittivity are available in the literature. There are six different models which have been proposed for the representation of soil electrical parameters, such as Scott (S) [7], Smith and Longmire (SL) [8], and Visacro and Alipio (VA) [3].

According to IEEE Standard [9], ground impedance can be resistive, inductive, and capacitive and is highly dependent on the frequency. This characterization is a significant factor in determining the overall ground impedance behavior. Solutions based on either circuit theory [10]–[12] or electromagnetic theory[13], [14] can be used to model the ground impedance characteristic under transient conditions. In the circuit-based model, the ground impedance is represented either as a lumped or as a distributed circuit[14].The elements of the circuits and their values are computed by using relevant formulas proposed by Sunde [15]. In the lumped circuit model, the elements are combined together into one section to give only a single resistance, inductance, and capacitance to represent the whole electrode. On the other hand, in the distributed model, the elements are uniformly distribute.

In this project for frequency dependent models Visacro-Alipio (VA) have been adopted and the effects are simulated using CDEGS. For Electromagnetic point of view, lumped circuit based model has been used and the effects are simulated using EMTP software.

1.2 Research Problem Statement

Most of the conventional methods such as Fall of Potential (FOP) [16] as an accurate reference in ground measurement are despicable of measuring impedances for high frequency. Even though if the method is accurate or is not bounded to low frequency measurement, it requires a large site area for measurement. Other conventional methods that might measure high frequencies do not have adequate accuracy. Therefore, another approach is required to fulfill all three factors at the same time.

1.3 Research Objectives

The objectives of the study are as follows:

(i) To improve the drawbacks of conventional methods (Fall of Potential) using a new application of Single Rod method.

(ii) To conduct a study on the performance of single rod method in ground impedance measurement.

(iii) To validate the new application of the method for both low frequency and high frequency cases in CDEGS and EMTP software meanwhile maintain accuracy of measurements.

(iv) To compare the performance of the improved measurement using Single rod method with fall-of-potential method to verify lack of space issue.

1.4 Research Scope

The soil in this project assumed as uniform and ionization of ground neglected due to low amplitude of current and voltage. For simulation and validity of the results CDEGS and EMTP software has been adopted. The methodology carried out by lab experiments and validated further by comparison with conventional methods.

1.5 Research Significance

The main superiority of the proposed application of single rod method is the implementation of the method for the grounding impedance measurement is capable of removing limitation of the test site area as an obstacle since it uses only one rod for ground impedance measurements. Moreover, it provides the measurement with higher accuracy compared to conventional FOP method. Using proposed application of the method, facilitates the ground impedance measurement for a wide range of frequency.

1.6 Thesis Outline

Chapter 1 mainly emphasis to the objectives of the study and the methodology used to solve the stated problems. Chapter 2 presents a critical review on related works conducted to measure ground impedance. Chapter 3 presents a methodology used to develop a new application of single rod and Fall of Potential

method. Chapter 4 is assigned to validate and evaluate the accuracy and the performance of the single rod method by comparing the results obtained from the Single Rod model with those obtained from the FOP and Visacro-Alipio model. Finally, Chapter 5 presents the conclusions and future recommendations.

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