SIMULATION AND ANALYSIS OF VOLTAGE AND ELECTRIC FIELD DISTRIBUTION ALONG HIGH VOLTAGE INSULATOR

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A project report submitted in fulfilment of
the requirements for the award of the
degree of Master of Engineering
(Electrical Power)

School of Electrical Engineering
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FEBRUARY 2022

DEDICATION

This thesis is dedicated to my father, who taught me that the best kind of knowledge to have been that which is learned for its own sake. It is also dedicated to my mother, who taught me that even the largest task can be accomplished if it is done one step at a time.

ACKNOWLEDGEMENT

First of all, I am grateful towards Universiti Teknologi Malaysia for providing a great opportunity of learning and development by undertaking and completing this Final Year Project.

I would also like to express my sincere and greatest gratitude to my supervisor Dr Norjulia binti Mohamad Nordin from the Faculty of Engineering, Universiti Teknologi Malaysia for her guidance and advices throughout the whole Final Year Project. Despite her busy schedule, she would still allocate some time for providing me her assistance, teachings and keeping me on the correct path by using her knowledge, expertise and experience so that I could deliver this project successfully.

I would also like to thank and appreciate my family and friends who have given me continuous encouragements and supports throughout my years of studies especially during the time of undergoing this project. They have provided so much support and guidance during the research work and thesis writing.

My fellow postgraduate student should also be recognised for their support. My sincere appreciation also extends to all my colleagues and others who have provided assistance at various occasions. Their views and tips are useful indeed. Unfortunately, it is not possible to list all of them in this limited space.

ABSTRACT

High voltage insulators play a major rule in energy transmission systems. The main role of these insulators is to ensure and maintain high level of line-tower insulation. However, the voltage distribution of insulator string is uneven which may easily lead to corona, insulators' surface deterioration and even flashover. Although there is various research for this topic, but there still have some limitations regarding on the performance of insulator in terms of voltage and electric field distributions. In this project, high voltage insulator strings with will be designed and simulated by using simulation software such as SOLIDWORKS and EMS software and their data (electric field and voltage distributions) will be collected and analysed. The modelling of the insulator will be designed by considering the effect of conductor and transmission tower as well as different material type of high voltage insulator such as porcelain, glass and silicon rubber. In addition, the improvement on the performance of the insulator also will be taken into consideration in this project. The research described in this dissertation is directly applicable to the Voltage and Electric Field distributions along the high voltage insulators design and development.

ABSTRAK

Penebat voltan tinggi memainkan peraturan utama dalam sistem penghantaran tenaga. Peranan utama penebat ini adalah untuk memastikan dan mengekalkan tahap penebat menara talian yang tinggi. Walau bagaimanapun, taburan voltan rentetan penebat adalah tidak sekata yang boleh membawa kepada korona, kemerosotan permukaan penebat dan juga kilatan kilat. Walaupun terdapat pelbagai kajian untuk topik ini, namun, masih terdapat beberapa batasan mengenai prestasi penebat dari segi taburan voltan dan medan elektrik. Dalam projek ini, rentetan penebat voltan tinggi dengan akan direka bentuk dan disimulasikan dengan menggunakan perisian simulasi seperti perisian SOLIDWORKS dan EMS dan datanya (taburan medan elektrik dan voltan) akan dikumpul dan dianalisis. Pemodelan penebat akan direka bentuk dengan mengambil kira kesan konduktor dan menara penghantaran serta jenis bahan yang berbeza bagi penebat voltan tinggi seperti porselin, kaca dan getah silikon. Di samping itu, peningkatan prestasi penebat juga akan diambil kira dalam projek ini. Penyelidikan yang diterangkan dalam disertasi ini terpakai secara langsung kepada taburan Voltan dan Medan Elektrik di sepanjang reka bentuk dan pembangunan penebat voltan tinggi.

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LIST OF SYMBOLS AND ABBREVIATIONS

BEM	Boundary Element Method
CSM	Charge Simulation Method
EMS	Electric and Magnetic Simulation
EPDM	Ethylene Propylene Diene Methylene
EPR	Ethylene Propylene Rubber
FDM	Finite Difference Method
FEM	Finite Element Method
FRP	Fiber Reinforced Rod
IEEE	Institute of Electrical and Electronics Engineering
HV	High Voltage
HVAC	High Voltage Alternative Current
HVDC	High Voltage Direct Current
SiR	Silicon Rubber
2-D	Two Dimension
3-D	Three Dimension
E	Electric Field Vector
D	Electric Flux Density
H	Magnetic Field Vector
J	Magnetic Field Density
F	Force
Q	Charge
ε_r	Relative Permittivity
σ	Conductivity

CHAPTER 1

INTRODUCTION

1.1 Research Background

High voltage transmission line is a connection line of the high voltage transmission tower that along the generating stations and distributions systems. Normally, it can be separated in two types which are transmission line and distribution line. Each of the line consists of four major electrical characteristics which are resistance, inductance, capacitance and conductance. Nowadays, HVDC transmission line is used to replace HVAC transmission line for several long-distance transmission because of lower losses and high transmission capability.

The first power DC transmission line was built by René Thury at Miesbach-Munich Power Transmission in Germany on 1882 as shown as Figure 1.1 below. The distance for the transmission line was 57 km and the capacity was only 2.5 kW for power transmission [1]. However, the DC voltage level could not reach high values enough to reduce the losses during transmission because of power electronic converters technologies were not fully developed at that time and the AC voltage can be easily increased by using transformer. Hence, HVDC transmission at that time was replaced by using HVAC transmission in 1886.

Figure 1.1 Miesbach-Munich Power Transmission Line

As for now, fast development of power electronic devices making the HVDC technology has risen and gained popularity again. For example, a 120km, 300kV HVDC transmission line was implemented and connects the converter stations in Southern Thailand and Northern Malaysia and includes a full-length neutral conductor. HVDC technology is now being considered because of power transmission in long distance will be more sTable, high flexibility and controllability [2]. In addition, power supply in Malaysia is 50Hz while power supply in Thailand is 60Hz which this different frequency issues can be synchronized by using rectifier and inverter.

Along the high voltage transmission line, there is one of the important parts which is known as insulator which is shown as Figure 1.2. The main purpose of the insulator is to provide isolation between the transmission line and the grounded tower. In addition, it is also separate or support the electrical conductor on high voltage electricity supply network. Insulator can be classified into 3 types materials:

Ceramic, Glass and Composite. Ceramic and glass insulator are known for the durability and long life while composite insulator is light weighted and have a better hydrophobicity property [3].

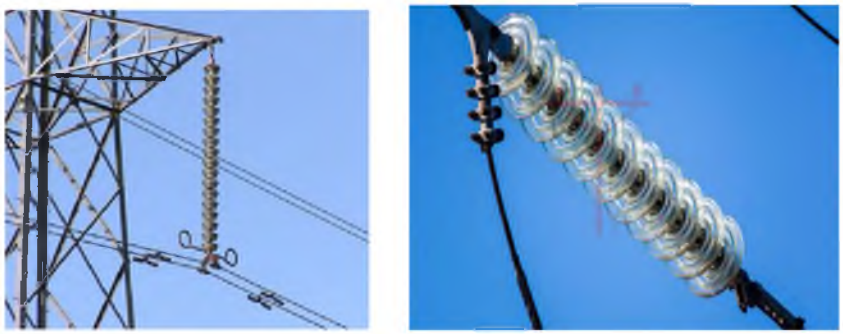

Figure 1.2 Outdoor Insulators

In addition, the function of the insulator also acts as to insulate the electrical part from any charged from the equipment. For better understanding, it also performs as a barrier to prevent from electric shock. In terms of high voltage, insulator can be assumed as it is an earth wire to separate from the conductor and the ground. However, in transmission and distribution system, it is necessary that the insulator need to able to carry very large tensional and compressive load.

In terms of insulator designing, there are many shapes and types of insulators that used in power transmission. Each shape or type of insulator will have different densities, tensile strengths and performance to withstand the worst outdoor environments such as lightning surge and switching surge. Therefore, insulator design

should be compatible with electrical and mechanical strengths as well as outdoor environmental stress such as humidity, temperature and pollution.

1.2 Problem Statement

Voltage and electric field distribution along the insulator sometimes will be uneven greatly because of coupling capacitance between the insulator and conductors. In addition, these insulators are subjected to outdoor environmental stress which also will affect the voltage and electric field distribution of the insulator around 3 – 5 times higher than normal rating, which will have a possible chance the insulator will have a long-term problem where it can result in insulator failure. Mostly reasons from the insulator failure are flashover, surface deterioration, corona discharge, mechanical stresses, porosity of material and etc.

For flashover of the insulator, it is the insulator failure which happened the most and it will cause the insulator overheated and will have an effect on the insulator which can shattering the insulator with big cracks. In addition, the presence of luminosity, audible noise and radio interference on the insulator is known as corona discharge. It is a non-linear phenomenon of electrical discharge and will cause the electrical energy flow the conductor to the ionized medium. The presence of contamination such as fog and raining also will cause flashover along the insulators. Uneven voltage also will cause the surface of the insulator deterioration which also known as cracking of

insulator. This is because there is an unequal expansion of material of the insulators during the varying condition of cold and heat [4].

As nowadays the load penetration on the transmission and distribution lines are increasing rapidly, many research has been done and studied in terms of voltage and electric field distribution on the insulator, however, insulator failure still always happens in all over the world. Furthermore, studies on voltage and electric field distribution along the high voltage insulator still immature and the performance of the insulators have not been well investigated as well. Old technology and methods were being used during the research, and the results and analysis are only approximation and not accurate. Therefore, exquisite researches needed to be done in this area in order to improve the performance and reliability of the high voltage insulators.

1.3 Research Objectives

The main objective of this project is to simulate and analyze the voltage and electric field distribution along the high voltage insulator and further to improve the voltage and electric field performance. There are some objectives that need to be achieved which shown as below:

- Modelling and testing (meshing) the 3-Dimensional High Voltage Insulator.

- Simulate and analyze the voltage and electric field distributions along the high voltage insulator by considering the effects of transmission tower and line conductor.
- Simulate and analyze the voltage and electric field distributions along the high voltage insulator with different types of surface materials such as porcelain, glass and silicon rubber.
- Proposed a optimize design to improve the insulator performance in terms of different number of disc units in the insulator string.

1.4 Research Scope

The scope and focuses of this project are shown as follows:

- High voltage insulator model chosen to develop is used for 230kV (400kV Line to Line Voltage).
- Modelling and simulation work is done by using SOLIDWORKS and EMS according to Finite Element Method (FEM).
- 3-Dimensions modeling and simulation for more realistic and accurate voltage and electric field distributions.
- Suspension Insulator is developed and it is ideal and clean conditions

1.5 Research Contributions and Significances

The main research contributions and significant after this project is done are shown as follows:

- To reduce the possibility of insulator failure as well as cost optimization by propose a optimize design of the high voltage insulator such as reduce the number of disc units in the insulator string.
- To help the high voltage engineers to take care of the regions where the voltage and electric field is expected to be very high under polluted and contaminated conditions.
- In terms of electrical utilities and economical, designers and engineers can choose the suitable devices dimensions and suitable materials that be used for insulators.

1.6 Thesis Organizations/Outline

This thesis for this project consists of 6 chapters which will organized as following:

- Chapter 1 is the introduction for this project which is mainly discussed on the background and the problem/issues for this project. All the objectives, scope and the research contributions had been discussed in this chapter.
- Chapter 2 is the literature review for this project. Some concepts and theory regarding the insulator will be

reviewed and discussed in this chapter. In addition, some of the past works regarding this project also has been literature and discussed in this chapter.

- In Chapter 3 which is the research methodology in this project, the research method to analyze the voltage and electric field distribution along the insulator via simulation software is discussed. Moreover, the used governing equations as well as Finite Element Method (FEM) also will be presented in this chapter. All the procedures will be shown in block diagram for easy to understand. Moreover, the insulator model will be shown as well as the insulator's parameter setting and its configurations. In addition, case study to testing the insulator also shown. Furthermore, research planning for this overall project will be shown in Gantt Chart in this chapter.
- For Chapter 4, all the simulations results will be shown based on the mentioned objectives as well as its analysis, calculations and its justifications. In additions, benchmarking also will be conducted by comparing and verifying the simulation results with other journals and articles.
- Lastly, Chapter 5 presented the overall conclusions for this project. Moreover, some recommendations and suggested for future works also will be discussed and reviewed in this chapter.

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