FAKULTI KEJURUTERAAN ELEKTRIK
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LAPORAN PROJEK
SARJANA MUDA

SURGE ARRESTER MODELING: A COMPARISON BETWEEN DIFFERENT MODELS FOR 500KV TRANSMISSION LINE

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Bachelor of Electrical Engineering (Industrial Power) – BEKP

JUNE 2013

"I hereby declare that I have read through this report entitle "Surge Arrester Modeling: A Comparison between Different Models For 500kV Transmission Line" and found that it has comply the partial fulfillment for awarding the degree of Bachelor of
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TITLE OF PROJECT

SURGE ARRESTER MODELLING: A COMPARISON BETWEEN DIFFERENT MODELS FOR 500KV TRANSMISSION LINE

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A report submitted in partial fulfillment of the requirements for the degree Of Bachelor of Electrical Engineering (Industrial Power) - BEKP

Faculty of Electrical Engineering

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JUNE 2013

I declare that this report entitle “Surge Arrester Modeling: A Comparison between Different Models For 500kV Transmission Line” 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.

Signature: .....

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ABSTRACT

Lightning and switching surge is the factor that leads to overvoltage and unstable system in electrical power system. Metal oxide surge arrester was used to prevent the lightning and switching overvoltage and to protect the system and equipment. Modeling surge arrester was used to determine the residual voltage and percentage of error for a surge arrester through the simulation. Surge arrester modeling starts with the selection of model and also the parameters evaluation for each component. This research is focused on 500kV metal oxide surge arrester. The data and specification of surge arrester have been obtained from the manufactures which are Toshiba and Siemens. Several models are used to represent surge arrester such as IEEE, Fernandez & Diaz, Pinceti & Giannettoni and Proposed. Models are developed using the Power System Computer Aided Design (PSCAD) software. Simulation on the PSCAD software was conducted to the value of residual voltage and compared with the data obtained from by the manufactures. Surge arrester models are injected by the lightning and switching surge current. The residual voltage of each model was implying by the two impulses current which are lightning 8/20μs and switching 30/60μs. The results were discussed based on literature review and previous findings obtained by the other researchers. It shows that all the models function with a satisfactory accuracy and the differences between models by the parameter's estimation. The best model is selected by the two impulses current. Fernandez & Diaz model is the best for lightning impulse current and IEEE model is the best for switching impulse current. Findings from this project can be a significant modeling guideline of surge arrester modeling for insulation studies in power systems. This project also can be as reference and guidance for other researchers to make an improvement of surge arrester model.

ABSTRAK

Ketidak stabilan sesebuah sistem elektrik itu adalah berpunca daripada lebihan voltan ataupun arus. Perkara seperti ini boleh terjadi apabila berlakunya panahan kilat kepada sistem elektrik ataupun semasa proses pensuisan. Bagi mengatasi masalah ini, sistem elektrik telah menggunakan penangkap luaran yang berfungsi menghadkan lebihan voltan ataupun arus daripada masuk menerusi peralatan-peralatan dan mengalirkan lebihan ke bumi. Penangkap luaran yang digunakan sebagai kajian adalah dari jenis logam oksida pada sistem 500kV. Pemodelan penangkap luaran adalah bertujuan untuk menentukan voltan baki dan peratusan ralat bagi penangkap luaran yang diperolehi melalui proses simulasi. Pemodelan penangkap luaran ini bermula dengan pemilihan model dan juga pengiraan parameter bagi setiap komponen. Pemodelan ini dilakukan dengan menggunakan perisian PSCAD (Power System Computer Aided Design). Data dan spesifikasi penangkap luaran telah diperolehi daripada pihak pengeluar seperti Toshiba dan Siemens. Kajian ini memberi tumpuan kepada beberapa model penangkap luaran seperti IEEE model, Fernandez & Diaz model, Pinceti & Giannettoni model dan Proposed model. Simulasi daripada perisian PSCAD telah dibandingkan dengan data daripada pihak pengeluar. Kajian keupayaan penangkap luaran telah dilakukan dengan dua jenis lonjakan iaitu kilat dan pensuisan. Voltan baki bagi setiap model telah diperolehi daripada kedua-dua arus lonjakan iaitu pada masa 8/20μs untuk kilat dan pada masa 30/60μs untuk pensuisan. Keputusan kajian telah dibincangkan berdasarkan kajian literatur daripada penemuan sebelumnya yang diperolehi daripada penyelidik lain. Ia menunjukkan bahawa semua model berfungsi dengan ketepatan yang memuaskan dan perbezaan yang timbul di antara setiap model adalah masalah anggaran parameter ini. Hasil daripada projek ini boleh dijadikan sebagai satu garis panduan bagi pemodelan penangkap luaran untuk kajian penebatan atau perlindungan dalam sistem kuasa. Projek ini juga boleh dijadikan rujukan dan panduan kepada penyelidik lain untuk membuat peningkatan model penangkap luaran.

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CHAPTER 1

INTRODUCTION

1.1 Project background

Surge arrester is a device that used to protect the equipment from damage due to switching and lightning overvoltage in power system. Surge arrester has widely used in electrical system such as for the generation, transmission and distribution system.

In the 18th century, the phenomenon of lightning has become a big problem such as harmless to humans, damaging property and kill wildlife [1]. In this century also, iron rods have been used to the lightning and grounding protection. In the 19th century, it used as a protection to the telephone system. In the 20th century, researches have been study of the materials and also characteristic of lightning tower design for surge arrester.

Surge arrester modeling is importance to select the appropriate parameters for the surge arrester as the better improvement in electrical power systems. Research on modeling of surge arrester was started from 1983 by D.W. Durbak at the IEEE impulse wave protective device committee (W.G.3.4.11) in Memphis Tennesseee [2]. After that, the reforms of the research continue until this day. Various model and method is created to produce the best model to represent surge arrester for every rating of system voltage.

1.2 Motivation

Previous researchers have created several models of surge arrester which are IEEE, Fernandez & Diaz, Pinceti & Giannettoni and Proposed. Many studies or researches have been done to get the best model that can represent surge arrester accurate. As mentioned before, each model was created to obtain the residual voltages from simulation that approaching the actual values of surge arrester.

There are many engineering software that commonly used such as PSCAD, ATP-EMTP and Matlab. From the previous studies or researcher have done the simulation on some voltage rating such as 10kV, 30kVand 132kV. For this project, selection made is for the higher voltage of 500kV. This selection is made because this voltage rating is the highest of voltage rating that used in Malaysia. One of the important things in the selection of surge arrester is the voltage ratings. But, not all manufacturers produced the same voltage rating for surge arrester. Therefore, this project has shown two types of surge arrester manufacturer which are Toshiba and Siemens. Voltage rating that used for both manufacturers is 420kV with the nominal voltage within 500kV.

Previous researchers have done the studies to compare among several models selected such as by IEEE with Pinceti & Giannettoni [3] or the IEEE with Pinceti & Giannettoni and Fernandez & Diaz [1]. Reforms that have made in this project are for the higher voltage of 500kV, the research was made to the four types of model which are IEEE, Fernandez & Diaz, Pinceti & Giannettoni and Proposed. There's also improvement for this research which is the comparison of two different manufacturers against each model of surge arrester. This improvement was done in order to achieve the project objectives and to determine the best choice of surge arrester model by looking at the percentage of error for every rating of current surge.

1.3 Problem Statement

There are some problems caused by the lightning and switching to the electrical system due to the overvoltage. Lightning and switching can cause unstable system and also can cause damage to the electrical equipment. Model selection of surge arrester should be made to meet the standards required for a surge arrester. There are variety models of surge arrester such as IEEE, Fernandez & Diaz, Pinceti & Gianettoni and Proposed. The difficulty in modeling surge arrester is the estimation of its parameters that suit with the manufactures data and specification [1]. Each model of surge arrester has its own circuit and the selection of appropriate parameters can produce a good result for surge arrester model.

The objective of this project is to compare the residual voltage and percentage of error between the models of surge arrester. This comparison method is from simulation and experimental results. To get the accurate result, the hardest part is the procedure of simulation that held by trial and error process. The results from this research can optimize the performance of surge arrester and used as learning materials.

1.4 Objective

Objectives of this project are:-

i. To develop several models of 500kV surge arrester using PSCAD.
ii. To investigate the difference of each surge arrester model through the PSCAD simulation.
iii. To select the best model of surge arrester.

1.5 Scope

The scopes of this project are:-

i. Surge arrester model is developed using PSCAD software and the result is compared with the actual experimental data.
ii. This project only used metal oxide type for surge arrester.
iii. This project only used two manufacturer data.
iv. The models of surge arrester are IEEE, Pinceti & Giannettoni, Fernandez & Diaz and Proposed.

1.6 Report Organization

This projects report consists of 5 chapters. In Chapter 1, a general introduction about the project is given such as the objective of modeling surge arrester. In Chapter 2 is about the literature review that showed the details about this project such as the models of surge arrester. Chapter 3 presents the methodology which is the flow of project development. Chapter 4 is the most important part which is the result from the simulation of modeling surge arrester, analysis process and discussion from the result of simulation. Lastly is Chapter 5 that presents the general conclusions and also recommendation for future analysis of the project.

CHAPTER 2

LITERATURE SURVEY

2.1 Lightning

Lightning comes from many several different sources but the most common is from the clouds that associated with the storm systems. The cloud that able to produce the lightning is the cumulonimbus or thundercloud or thunderhead [4]. Figure 2.1 shows the process of lightning happens. During thunderstorms of lightning phenomenon, positive and negative charges will separated by the heavy air current with ice crystals in the upper part of clouds and rain in the lower parts [5]. The negative charges will acts as lightning because the ground or earth wills neutral it by being the positive charges.

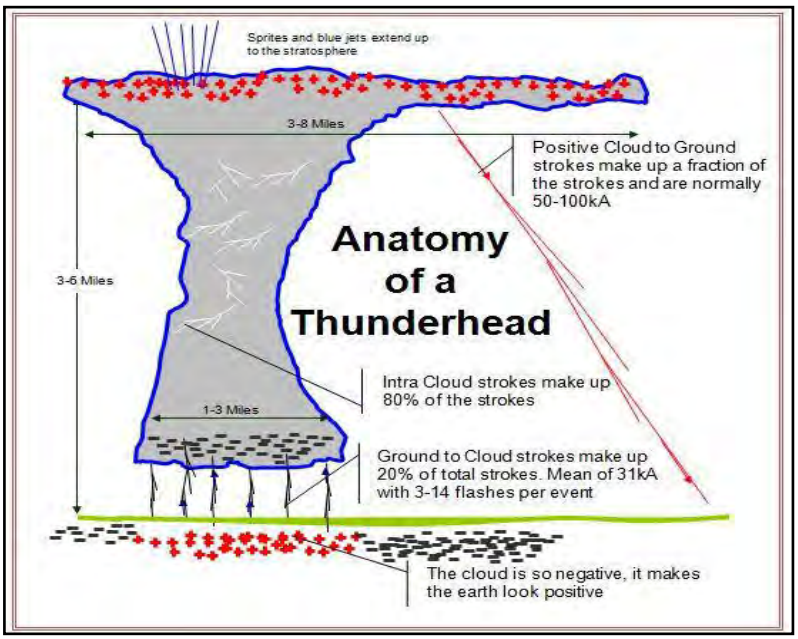

Figure 2.1 : The process of lightning [4]

2.2 Switching

Switching can happen by the making and breaking of electric circuit with switchgear. It's resulted in abnormal overvoltage in power systems [5]. There's characteristic of switching process such as de-energizing of transmission lines, cables and shunt capacitor. This can happen because of the performance of equipment that weakens over the years. The disconnection by the unloaded transformer also can cause the surge. The other process such as the sudden switching off or on of loads, short circuits and faults clearance. The change of a condition of one system can affect the normal waves.

2.3 Surge

The definition for a surge in general is it can increase the current or voltage at least ten percent only a few microseconds. Although the surge duration is short, voltage can rise to as much as few thousand volts. The unstable of sine wave after surge happen to the system is shown in Figure 2.2. Surge can happen by two situations such as lightning and switching. The switching surge is generally happen by the operation of a breaker and switching process. This surge exists because of the inductance and capacitance principle in the power system. Whether this component were added or removed, it caused the unstable on the power system. The lightning surge is the situation when its charged is transferred to a power system. The lightning surge can be determined by two ways on a power system which are from lightning stroke directly strike to the phase and from the nearby strike to the earth where it shows that the lightning surge is much lower in amplitude.

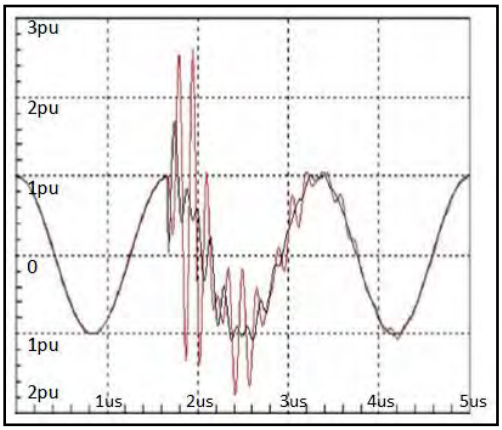

Figure 2.2 : Typical switching surge effect on a power system [2]

2.4 Overvoltage

Generally, there are three type of overvoltage that occurs in power system which is lightning, switching and temporary. Most of overvoltage have a higher magnitude and surely can cause the disruption of the system also equipment. The duration of overvoltage showed how fast the impact of the overvoltage can give impact to the stability of power system.

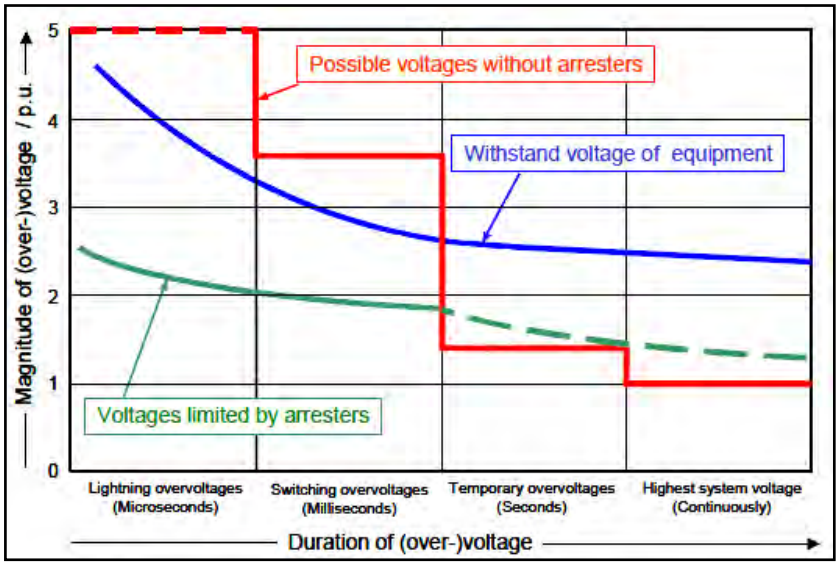

Figure 2.3 : Schematic representation of the magnitude of voltages and overvoltage in a high voltage electrical power system versus duration of their appearance [6]

Figure 2.3 showed there the magnitude of voltages and overvoltage in per unit that may appear in high voltage electrical power system depending on the duration of their appearance. The time axis shows there are divided into the range of lightning overvoltage, switching overvoltage, temporary overvoltage and highest system voltage. The possibility voltage without arrester when lightning and switching overvoltage can damage the equipment because it's higher than the withstand voltage of the equipment. This overvoltage can be secured by used the surge arrester because it's limit the overvoltage to prevent the damage to the equipment.

2.5 Surge Arrester

In the term of overvoltage protection, there have equipments that used such as surge arrester, circuit breaker and fuse. Surge arrester is used for the higher voltage range to protect the system such as at the transmission line. Surge arrester by definition is protection devices that overcome the overvoltage due to the lightning or switching. The function of surge arrester is to provide a protection on power system or for electrical equipment from the damaging effects of electrical surges. It have the ratings of protection depends on the system.

The principle of surge arrester is to protect an electrical system by limiting the voltage that can be applied to the protected circuit when surge occur [2]. It flow the excess energy from the surge to ground. Under normal condition, surge arrester is placed in parallel to the equipment that needs to be protected. To maintain the performance of equipment, the resistance is very high in this condition to allow very small current to earth. When an overvoltage was occur on the system, a surge current will across the non-linear resistor and flow to earth. For this condition, non-linear resistor will offer a very low resistance to diverting the surge current from the equipment. When the overvoltage was disappearing, the surge arrester is back to the normal condition.

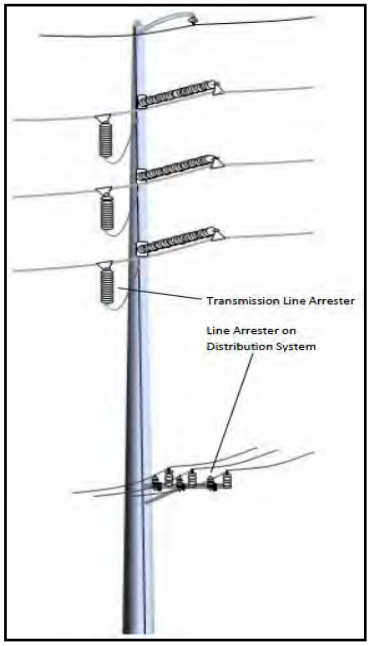

Figure 2.4 : Two forms of line arrester - transmission and distribution arrester [7]

Figure 2.4 above showed the location of surge arrester at the line of transmission and distribution. This arrester was connected to ground or earth wire to overcome the overvoltage whether from lightning or switching phenomena.

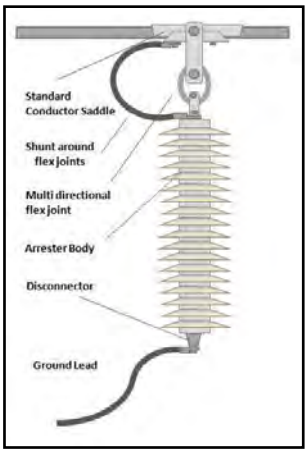

Figure 2.5 : Typical suspension arrester [7]

This Figure 2.5 showed the component for the typical suspension arrester. The Table 2.1 below showed the function of every component of typical suspension arrester.

Table 2.1 : The function of components of typical suspension arrester [7]

Component	Function
Saddle Clamp / Standard Conductor Saddled	This component is used to connect the conductor to the insulators.
Multi directional flex joint	This joint is important for the longevity of arrester and eliminates mechanical stress due to the motion of the conductor.
Shunt around flex joint	This is component used carrying the current from the conductor.
Arrester Body	This component is electrically specified to conduct whether lightning or switching surge or both of it.
Disconnector	This component used if the failure to the arrester. It operates when arrester becomes a short circuit and it isolates the arrester from earth.
Ground Lead	This component is connection between the arrester and the tower ground. Lead function is to insure that the ground lead doesn't make contact with other phase.

2.6 Type of Surge Arrester

There are the usual type of surge arrester such as silicon carbide arrester with the sparks gaps, silicon carbide arresters with the current limiting gaps and the gapless of metal oxide arrester [5]. Electrical characteristic for the silicon carbide arrester are very high resistance to low voltage and very low resistance to high voltage [8]. Its use a nonlinear resistance that made of bonded silicon carbide and placed in series with the gaps. The gaps function is to isolate the resistor from normal voltage and provide a high limiting voltage. If the surge arrester doesn't have a gap, it wills not enough to limit the change of power frequency that follows on current. Furthermore, this arrester with the sparks gaps cannot appropriate to use for the switching surges cases.

Nowadays, mostly surge arrester used the metal oxide type. It doesn't have a gap which is design to eliminate the high heat associated with the arcing discharges. It has two voltage rating such as duty cycle and maximum continuous operating voltage [8]. Duty cycle testing is performed to know the ability of surge arrester due to lightning surge at 1 minute intervals. Maximum continuous operating voltage rating usually is 80 to 90% of the duty cycle rating. The important part of this type is the metal oxide varistor (MOV). This element is sensitive to the voltage. At the normal voltage, it will not conduct current but at higher voltage caused by a lightning, it becomes a conductor. The advantages of this arrester are they are simple in construction and with the gapless it can prevent the steep voltage gradient when sparking occurs.

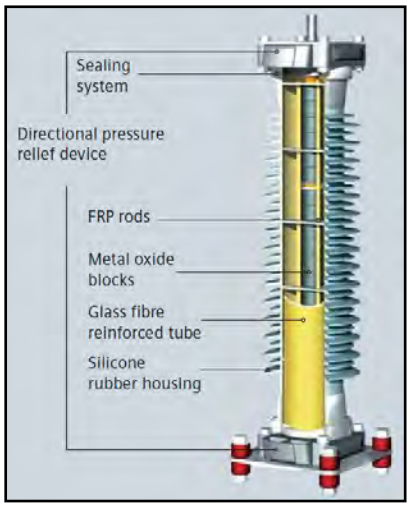

Figure 2.6 : MOV surge arrester cross section [9]