FAST TRANSIENT SIMULATION OF PINCETI SURGE ARRESTER MODEL ON A TRANSMISSION LINE USING ATP SOFTWARE

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Prise to Allah for his guidance and blessing, this project was finally completed

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ABSTRACT

Lightning is one of the main causes of overvoltage on power system. Over voltages problem at the transmission line can cause flashover voltage at the insulator string, power system disturbances and transformer failure. To prevent of insulator string and equipment of the power system from damaging effect by lightning overvoltage, metal oxide surge arrester is installed at overhead line in parallel with insulator string. Due to metal oxide surge arrester have dynamic behaviour, this arrester can be simulated using non-linear resistor. Therefore Pinceti model is proposed to simulate using Alternative Transient Program (ATP) software. Several procedures have been following to calculate Pinceti arrester model parameters so that compatible with 132kV overhead transmission line system. Tested result by simulation is compared with the manufacturer arrester datasheet to evaluate accuracy of Pinceti model before installed arrester at 132kV transmission line model. Pinceti model are installed at several locations on the transmission line model to evaluate the level of effectiveness and capabilities to reduce the level of overvoltage across insulator string and to ensure lightning overcurrent draws to ground totally.

ABSTRAK

Kilat merupakan salah satu punca berlakunya masalah voltan lampau dalam sistem kuasa. Masalah voltan lampau dalam talian penghantaran boleh menyebabkan berlakunya voltan lampau pada penebat, gangguan dalam sistem kuasa dan kebakaran pada alatubah. Untuk mencegah dari berlakunya kerosakan pada penebat dan alatan dalam sistem kuasa kesan dari voltan lampau kilat ini, penangkap kilat jenis *metal oxide* dipasang pada talian penghantaran secara selari dengan penebat. Disebabkan penangkap kilat jenis *metal oxide* ini mempunyai ciri-ciri dinamik, penangkap kilat ini boleh disimulasikan dengan meggunakan perintang bukan linear. Oleh itu, model penangkap kilat Pinceti dicadangkan untuk disimulasikan dengan menggunakan perisian *Alternative Transient Program (ATP).* Beberapa prosedur harus diikut untuk mengira parameter-parameter pada model Pinceti supaya bersesuaian dengan talian penghantaran 132kV. Hasil ujikaji dengan menggunakan simulasi dibandingkan dengan data penangkap kilat yang diperolehi dari pembuat penangkap kilat sebenar bagi menilai ketepatan model Pinceti sebelum ia dipasang pada model talian penghantaran 132kV. Model Pinceti dipasang pada beberapa lokasi talian penghantaran untuk menilai keberkesanan dan keupayaan bagi mengurangkan aras voltan lampau kilat pada penebat dan untuk memastikan arus lampau kilat dapat mengalir ke bumi secara keseluruhannya.

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LIST OF SYMBOLS AND ABBREVIATIONS

MOV	-	Metal Oxide Varistor
ZnO	-	Zinc Oxide
SiC	-	Silicone Carbaid
ATP	-	Alternative Transient Program
MCOV	-	Maximum Continuous Operating Voltage
TLA	-	Transmission Line Surge Arrester
CFO	-	Critical flashover voltage
IEC	-	International Electrotechnical Commission
IEEE	-	Institute of Electrical and Electronics Engineers
AAAC	-	All Aluminium Alloy Conductor
ACSR	-	Aluminium Conductor Steel Reinforced
TNB	-	Tenaga Nasional Berhad
AC	-	Alternating Current
I-V	-	Current – Voltage

CHAPTER 1

INTRODUCTION

1.1 Introduction

Lightning is one of the main causes of the outages on power networks. The lightning surge can produce dangerous overvoltage, causing power supply interruptions that result in costly damage to equipment and also imposing an extra cost to the power utility because of the undelivered energy such in Figure 1.1. The amount of energy contained in a lightning stroke is very high and it can be extremely destructive, even a single stroke to a distribution line can be sufficient to cause a blackout through a feeder.

Figure 1.1: Damage of transformer at TNB substation due to lightning strike

Generally lightning strikes mostly the top of a transmission tower (shied-wire) rather than the phase conductor. When lightning current hits the top of a transmission tower, it flows to the bottom of the tower and out onto ground. If the voltage equals or exceeds the line critical flashover voltage (CFO), flashover will occur across insulator string. This flashover issues are important for evaluating of lightning performance. Therefore, in order to increase the reliability and availability of the power system, the lightning-related outages rates must be reduced.

Nowadays, transmission line surge arresters (TLAs) are vital elements to protect the power systems against the lightning surges by absorbing the energy of surges and limiting their resultant overvoltage below a certain value which is basic impulse insulation level [1]. TLA able to reduce lightning initiated flashovers, maintain high power quality and to avoid damages and disturbances especially in areas with high soil resistivity and lightning ground flash density [2]. TLA is connected in parallel with them at selected towers. A computer program is used to determine the optimum number of locations and to calculate the arrester stresses at each of the chosen locations. Surge arrester as a robust and efficient alternative, could be located at line ends and along the line at selected points.

In Malaysia, lightning overvoltage is concern more for 132kV/275kV transmission line system. Many observations have been done to evaluate about this problem experimentally and by software modelling. One of the famous tools for modelling 132kV transmission line system is by using Alternative Transient Program (ATP) software. This software is most useful for modelling transmission line model and the most famous model design by using this software is multi-storey tower model.

1.2 Problem statement

Electrical power systems have three main parts that transform other types of energy into electrical energy and transmit this energy to consumer. The three main components are generation, transmission and distribution system. However, transmission line have the longest distance compare with generation and distribution system. So transmission line most attracted to the lightning strike due to high structure of transmission line tower.

According to Malaysia Meteorological Services Department, most state of Malaysia has a number of days with thunderstorm more than 100 per day. Malaysia ranks one of the countries with highest lightning activities in the world. Refer to Figure

1.2; average thunders for Kuala Lumpur are 180-300 per annum. Eighty percent of lightning discharges current to ground in Malaysia exceed 20kA, potentially approaching 50-100 million volts. Lightning is classified as a transient event. The amount of energy contained in a lightning stroke is very high. Lightning can cause destruction of equipment, damage to substation or power plant equipment.

Figure 1.2: No of day with lightning strike in Malaysia [3]

Lightning faults have two types which are flash over and back flashovers. Flash over mainly following a screen failure and caused by direct hitting to the phase conductor. Back flash over which can occur when lightning strike hits tower or the ground wire. In this case, the potential at the top of the tower rises in an important way and can exceed the dielectric strength of the insulator string. Therefore, it is very important to propose some idea for improve the lightning protection scheme in electrical power system. This can be done by proposed a new surge arrester [4].

Transmission line surge arresters are installed in an overhead line in parallel to an insulator string to prevent flashover at the insulator string. Line arresters are preferably installed where frequent backlash over occur due to missing or inadequate overhead ground or shield wire protection and or high tower footing impedances. In order to improve the supply quality of an already existing transmission or distribution line, installing line arrester on all or only on same of the tower poles is in many cases a cost saving alternative to improving the shielding of the line or the grounding or towers or poles [5].

However for the economical factor, not all transmission line towers are installed with surge arrester. As far as economy and other factors are concerned, the transmission lines in our country are only installed one or two kilometres lightning conductors in and out of the substations or power factories. Power supply faults and failure caused by detour or back lightning striking happen especially in mountain areas [6]. TNB transmission line department use TFlash Software to determine which tower and which phase should be installed with Transmission Line surge arrester (TLA).

An accurate surge arrester model will increase the lightning protective level of the electric power system. Surge arrester installation removes the superfluous charge from the line. The most common types of surge arrester are open spark gap, Silicon Carbaid (SiC) arrester with spark gap and metal oxide surge arrester without spark gap. Mainly Zink Oxide under metal oxide category is today most common used [4].

Metal oxide arresters are extensively used in power systems due to their good performance in over-voltage protection. Appropriate modelling of their dynamic characteristics is very important for arrester location and insulation coordination studies. For switching surge studies, the MOAs can be represented simply with their nonlinear – characteristics. However, such a practice will not be appropriate for lightning surge studies because the MOA exhibits dynamic characteristics such that the voltage across the arrester increases as the time-to-crest of the arrester current decreases and the arrester voltage reaches a peak before the arrester current peaks [7].

Figure 1.3: Lightning surge arrester

1.3 Objectives

The purpose of the research is to accomplish three objectives as follow:-

a) To develop 132kV high voltage transmission line system using ATP software.
b) To use Pinceti surge arrester model in ATP software.
c) To evaluate the effectiveness of the Pinceti surge arrester model.

1.4 Project scopes

As the research a boundary, several limitations has describes as follow:-

1. This project only concern on Pinceti surge arrester lightning protection model performance.
2. Develop the 132kV overhead transmission line double circuit Bergeron model.
3. Develop the 10kA lightning current impulse 8/20μs wave shape and strike only at top of fourth tower out of seven tower

4. Pinceti model surge arrester are installed at third, fourth and fifth tower
5. Study only metal oxide surge arrester type only.

1.5 Outline of dissertation

This thesis is dividing into five chapters. Basically, some theory and literature review, introduction, methodology, simulation result, comparison of result, analysis and discussion and conclusion were included in these five chapters.

Chapter 1 summarizes project background and elaborates on project objectives, scope and problem statement.

Chapter 2 explains a few literature reviews about surge arrester, description of lightning strike phenomenon and parameter of transmission line tower.

Chapter 3 describes the methodology of project development. This chapter also will explain detail about ATP software, 132kV transmission line tower model parameter, overvoltage cable, Pinceti surge arrester model parameter and AC voltage source. Chapter 4 shows about the result and discussion of simulation to evaluate effectiveness of Pinceti model surge arrester when installed at transmission line after 10kA lightning surge strikes at transmission line tower. This chapter divided to three phases. First phase is to shows the result of testing the effectiveness of Pinceti arrester itself. Second phase is shows the measurement result for the value of voltage and current when lightning strike to tower without Pinceti arrester and for the last phase is to shows the measurement result for the value of voltage and current at transmission line with Pinceti arrester installed parallel with insulator string. All result for those three phases are discussed briefly in this chapter.

Chapter 5 elaborates generally about the conclusion and recommendation for this master project overall.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction of lightning

Lightning is the most frequent cause of overvoltage and is classified as a transient overvoltage event. This is because lightning strikes a power line, it is like closing a big switch between a large current source and the power line circuit and cause abrupt change in the circuit conditions creating transient problem. Lightning spark resulting from the development of millions of volts between clouds or between a cloud and the earth. It is similar to the dielectric breakdown of a huge capacitor [1]. The voltage of a lightning stroke may start at hundreds of millions of volts between the cloud and earth. The study of lightning strokes in power lines is very important because typically, the highest structures located in high incidence lightning regions. Any structure, no matter its size, may be struck by lightning, but the probability of a structure been struck increases with its height [8]. Most lightning strikes terminate on shield wire rather than on phase wire.

Basically, there are four types of lightning, which are cloud-to-ground downward positive, cloud-to-ground downward negative, ground-to-cloud upward positive and ground-to-cloud upward negative as shown in Figure 2.1 respectively. However, only cloud-to-ground lightning has been studied widely due to human and power system safety.

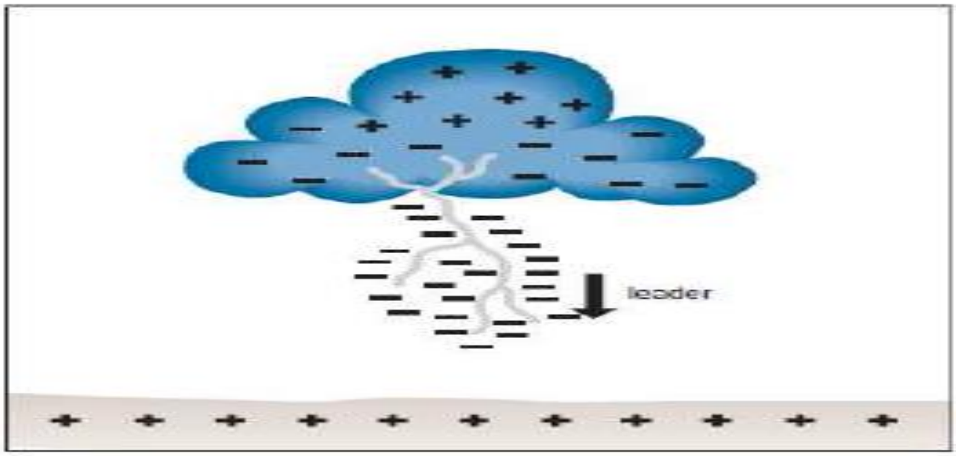

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Figure 2. 1: Cloud to ground downward negative lightning [8]

Lightning occurs when clouds acquire electrical charge. Electric field is considered have strength are created within the cloud and between cloud and earth. When the field become excessive, the dielectric of huge capacitor cannot longer support electrical stress and then lightning flash occurs. According to Martin A. Uman and Rocov (2001), about 90% of cloud-to-ground lightning is downward moving negative charged leader while only 10% of the cloud-to ground lightning is downward moving positive leader. Cloud to ground flashes are composed of a single stroke or a multiple number of component strokes. Multiple stroke flashes have 3 to 4 strokes. Lightning flash between lightning head and earth conductor resulting travelling-wave comes down the tower and acts through its effective impedance, raising potential of tower top to a point where difference in voltage across insulation is sufficient to cause flashover from tower back to conductor. Travelling wave occurs when lightning strikes a transmission line span and a high current surge is injected on to the conductor phase. The impulse voltage and current waves divide and propagate in both directions from the stroke terminal at a velocity of approximately 300 meters per microsecond with magnitudes determined by the stroke current and line surge impedance. This strike type is called back flashover (J. Rohan Lucas, 2001). Back flashover occurs when lightning strike terminates at overhead ground wire or tower. Back flashover occurs across insulator string if the voltage equal or exceed the line's critical flashover voltage (CFO) (Andrew R. Hileman, 1999). Back flashover is most prevalent when tower footing impedance is high.

2.2 Fundamental of surge arrester

Generally, the use of line arrester is to decrease or eliminate lightning flashover on transmission and distribution lines. The purpose of line arrester installation in transmission line system is to improve the performance of overhead lines with poor shielding or with very high tower footing impedance. Arresters avoid lightning flashovers since transmission lines insulation voltage is higher than the residual voltage developed across the arresters, either due to back flashover or shielding failure [9]. The lightning arrester is a non-linear device that acts as an open circuit to low potentials, but conducts electrical current at very high potentials. When lightning strikes a line protected with a lightning arrester, the non-linear resistance draws the current to ground. Surge arresters are the primary protection against atmospheric. There are generally connected parallel with the equipment to be protected to divert the surge current. One of the most common lightning arresters is the MOV (Metal Oxide Varistor). The MOV has a piece of metal oxide that is joined to the power and grounding line by a pair of semiconductors. The semiconductors have a variable resistance dependent on voltage. When the voltage level in the power line is at the rated voltage for the arrester, the electrons in the semiconductors flow in a way that creates a very high resistance. If the voltage level in the power line exceeds the arrester rated voltage, the electrons behave differently and create a low resistance path that conducts the injected lightning current to the ground system [10]. During lightning overvoltage, surge arrester plays an important role in limiting voltage levels and protecting power system components. Surge arresters used for protection of exterior electrical distribution lines will be either of the Metal-Oxide Surge Arrester (MOSA), with resistors made of zinc-oxide (ZnO) blocks, or gapped type with resistors made of Silicon-Carbide (SiC). Silicon carbide arresters are developed in power systems to protect the equipment from lightning over voltages. But this kind of surge arresters has some advantages, such as negligible power losses, low level reliability and low speed response to the over-voltages. So, silicon carbide arresters are replaced by metal oxide surge arresters.

2.2.1 Metal Oxide Surge arrester (Zine oxide)

The substitution of silicon carbide arresters with zine oxide surge arresters has brought benefits to overvoltage protection such as higher energy absorption capacity coupled with most simultaneous action by parallel arresters in the same line branch. Metal Oxide is a ceramal of zinc oxide with admixtures of other metal oxides such as bismuth, cobalt, manganese and aluminium. Metal-oxide (MO) surge arrester is very important protection device in power systems and widely used as protective devices against switching and lightning over-voltages in power systems [11]. Since there are no series gaps in metal-oxide surge arresters, the arresters continuously withstand the operating voltage applied. In order to improve performance and maximize applications of metal-oxide surge arresters, polymer housings have been used to replace porcelain housings. [11].

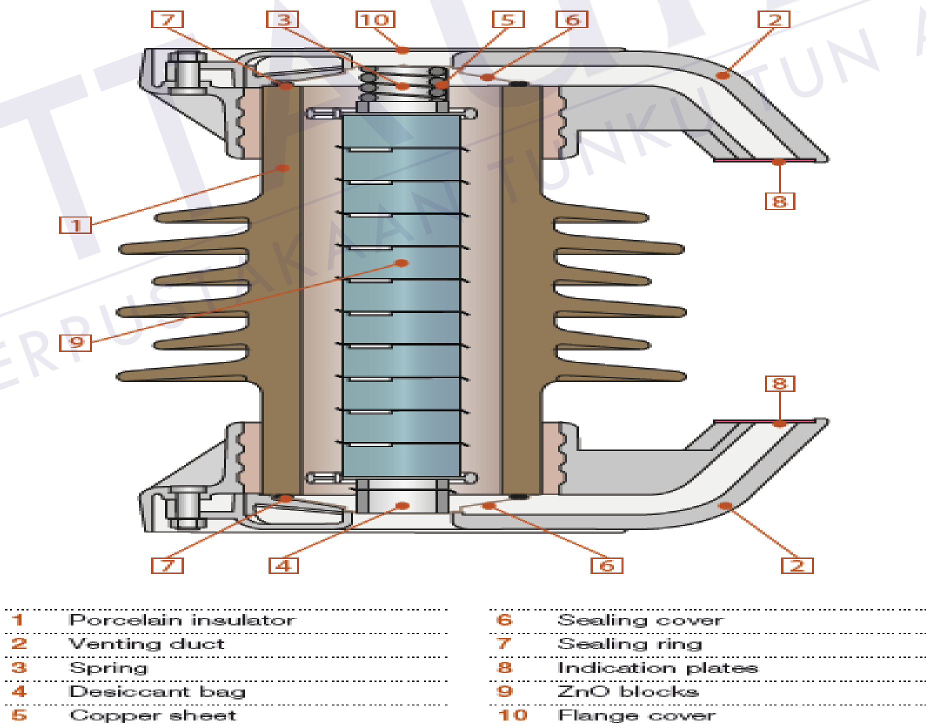

Figure 2.2: Porcelain housing metal oxide surge arrester [12]

Figure 2.2 shows the porcelain housing TLA containing a single column of ZnO blocks, all individually extensively routine-tested during manufacture, dispersed with the necessary spacers as determined by the electrical design for the arrester. Longer arresters often require external grading or sealing ring to maintain a uniform and acceptable voltage stress along their length. Operation of such arrester without this grading ring therefore may lead to failure and invalidates our guarantees/warranties.

2.3 V-I characteristics

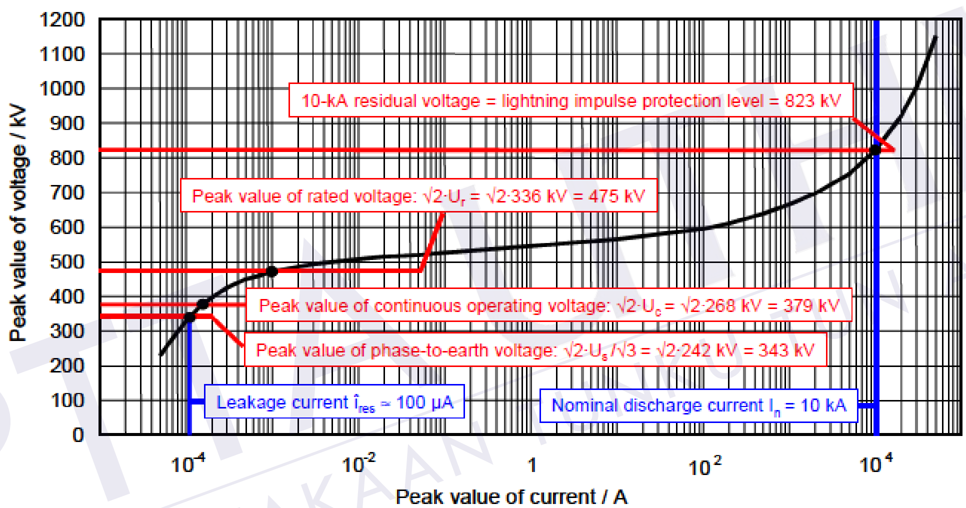

Figure 2.3:V-I characteristics of MO arrester 336kV [12]

Figure 2.3 shows the V-I characteristics of MOV arrester. The distinctive features of the MO arresters are their extremely non-linear voltage-current or V-I characteristic, ignorable power losses, high level reliability in the operation time, high speed response to the overvoltage, simplicity of design, easier for maintenance and long life time. Accurate modelling and simulation of their dynamic characteristics are very important for arrester allocation, systems reliability and insulation coordination studies. For switching over voltages studies, the surge arresters can be represented by their nonlinear V-I characteristics. Metal oxide surge arresters have frequency depended properties such as time-to-crest of the arrester current effect on residual voltage of arresters. Because of these dynamic behaviours, surge arrester nowadays in power systems software is very

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