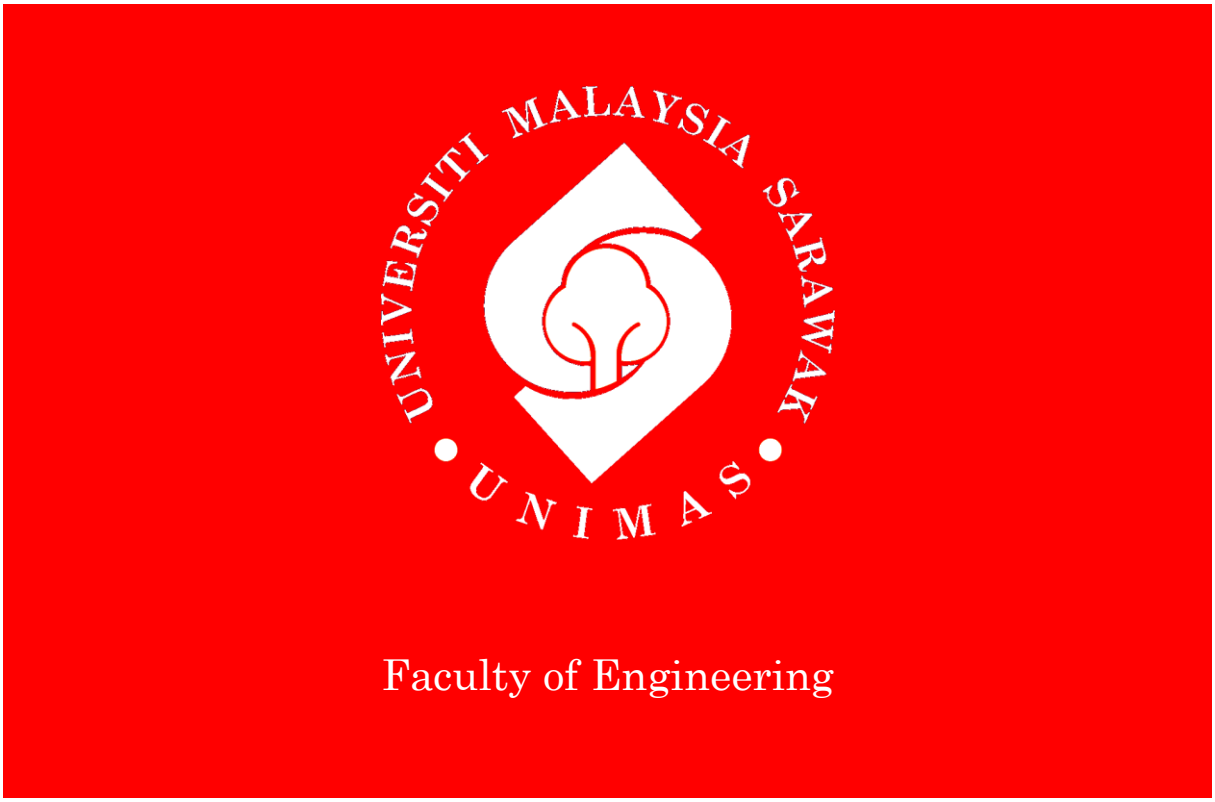

TRANSIENT OVERVOLTAGE ON 500 kV TRANSMISSION LINE PLAN IN SARAWAK USING POWER SYSTEM COMPUTER AIDED DESIGN

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Bachelor of Engineering (Hons) Electronics and Electronic Engineering

2018

UNIVERSITI MALAYSIA SARAWAK

Grade: _____

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Final Year Project Report	√
Masters	
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TRANSIENT OVERVOLTAGE ON 500 KV TRANSMISSION LINE PLAN IN SARAWAK USING POWER SYSTEM COMPUTER AIDED DESIGN

NUR IZZIANI BINTI ROSLAN

A dissertation submitted in partial fulfillment

of the requirement for the degree of

Bachelor of Engineering with Honors

(Electrical and Electronic Engineering)

Faculty of Engineering

Universiti Malaysia Sarawak

2018

This thesis is dedicated to all my family and friends

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ABSTRACT

Transmission system is a crucial system in electrical power since the system transmit the electricity from power generation to consumer's load. The power losses of the transmission line were rapidly changing from year to year at the rate of 3.85% in the year of 2013 to 5.792% in 2014. Losses in transmission system are most likely from power quality problems such as transients. Transients are the high unexpected increment in voltages or currents magnitudes. The peak values of both voltages and current are usually more than twice of that normal voltage and current amplitudes. The surges due to transients can vitally cause power system failure and breakdown of electrical equipment especially at the substations. There were few known transient overcurrent and overvoltage problems which are due to faults, lightning and line energizing. This project is mainly about simulating transients for 500 kV transmission system which use Sarawak as the case study location. Sarawak has main 275 kV Transmission line covering the whole Sarawak from Miri to Kuching known as Sarawak backbone, but due to lots of industries and human population increase in Sarawak, there is planned a 500 kV transmission as a backup if the power failure at the 275 kV transmission line. In Sarawak, the 500 kV was planned to be energized at 275 kV. But, in fact this project was for that transmission line to be operated at 500 kV hence, monitored the highest transient may occur. Overall, lightning and three phase faults of 1.0 s fault time duration cause biggest change in amplitude current of the line up to 9.06 pu and 9.27 pu. Highest lightning amplitude observed when lightning was been simulated at the receiving end of the line which is near to the Tada substation. Substations should be equipped with high performance electrical protection equipment since substation were linked to other transmission lines or consumers load and usually own equipment such as transformer that was costly and hard to maintain once broken.

ABSTRAK

Sistem pengaliran tenaga elektrik adalah sistem yang penting memandangkan sistem ini digunakan untuk memindahkan elektrik dari penjana kuasa kepada beban pengguna. Kerugian tenaga elektrik pada sistem pengaliran kuasa elektrik berubah dari tahun ke tahun sebanyak 3.85% pada tahun 2013 kepada 5.792% pada tahun 2014. Kerugian dalam sistem penghantaran kemungkinan besar daripada *power quality problem* seperti *transients*. *Transien*t adalah kenaikan amplitud yang tidak dijangka dalam magnitud voltan atau arus elektrik. Magnitud biasanya lebih dua kali ganda daripada kebiasaan voltan dan arus elektrik. Lonjakan yang disebabkan oleh *transient* boleh menyebabkan kegagalan sistem kuasa dan kerosakan peralatan elektrik terutama di pencawang. Terdapat beberapa penyebab *overcurrent* dan *overvoltage* iaitu yang disebabkan oleh kerosakan, kilat dan garis tenaga. Projek ini adalah terutamanya mengenai simulasi sistem penghantaran kuasa 500 kV yang menggunakan Sarawak sebagai lokasi kajian kes. Sarawak mempunyai talian penghantaran 275 kV utama yang meliputi seluruh Sarawak dari Miri ke Kuching yang dikenali sebagai tulang belakang Sarawak, tetapi disebabkan oleh banyak industri dan peningkatan populasi manusia di Sarawak, terdapat rancangan transmisi 500 kV sebagai cadangan jika kegagalan kuasa di 275 kV talian penghantaran. Di Sarawak, 500 kV dijangka beroperasi pada 275 kV. Tetapi, sebenarnya projek ini telah dilakukan untuk talian penghantaran yang akan dikendalikan pada 500 kV justeru, memantau kemungkinan transien tertinggi. Keseluruhannya, kilat menyebabkan perubahan terbesar dalam amplitud arus elektrik sehingga 9.06 pu. Amplitud tertinggi didapati apabila kilat disimulasikan pada akhir penerimaan garis yang berhampiran dengan pencawang Tada. Pencawang harus dilengkapi dengan peralatan perlindungan elektrik berprestasi tinggi kerana pencawang dihubungkan dengan saluran penghantaran atau beban pengguna selain pencawang biasanya mempunyai peralatan seperti *transformer* yang mahal dan sukar diselenggara sekiranya rosak.

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LIST OF ABBREVIATION

AC	-	Alternating Current
DC	-	Direct Current
EHV	-	Extra High Voltage
EMTP	-	Electromagnetic Transient Program
HVAC	-	High Voltage Alternating Current
IEC	-	Institute Electrotechnical Commission
IEEE	-	Institute of Electrical and Electronic Engineering
LPTC	-	Lightning Protection Analysis System for Transmission line
PSCAD	-	Power System Computer Aided Design
PQ	-	Power Quality
RMS	-	Root Mean Square
SEB	-	Sarawak Energy Berhad
TNB	-	Tenaga Nasional Berhad
UCAP	-	Ultracapacitor

CHAPTER 1

INTRODUCTION

1.1 Project Background

Generally, this project was conducted in order to observe effects of transient overvoltage and overcurrent in 500kV overhead line power transmission system. The project was simulated based on Sarawak transmission system as a case study.

Transmission lines are used to transmit electricity from power generating plants to consumer's loads of grid network. Usually, the analogy of delivering water through pipes are used to explain the transmission system concept of transmitting electricity. The water flow is the flow of currents while the pipe is the conductor wire. To move water from one point to another point in a given amount of time, there are few given situation. First, the low pressure flow of water with large diameter size of water pipe and the second one is the high pressure water with small diameter size of water pipe. Pressure of water is the amount of voltage being transmitted while the diameter pipe is the size of the cable wire and the thickness of the pipe walls are corresponds to the cable insulation. In order to transmit high pressure of water, there is in need use of low diameter size of the pipe with larger thickness of pipe walls to withstand that high pressure water and vice versa. That also applied to transmitting electricity through transmission lines. The size of the cables and the thickness of insulation need to be accordance to the amount of voltage being transmitted. When transmitting high voltage, small size of cable being used with larger size of the wire insulations to withstand the high pressure capability of transmitted electricity.

These transmission lines has been used for many years since 19th century by using hydraulic transmission to deliver power to factory motor. From the first invention of transmission lines, today, people are inventing a high voltage direct current for the underground cable. The biggest advantage of direct current is that the DC have lower power transmission loss due to unstable power being transmitted. And the DC also have no defect to power quality problems.

The power quality problems is now the prior cause to power losses during power transmission. There are several types of power quality such as transient, harmonic, noise, flicker, voltage swell and voltage sag. For example the transient overvoltage occur due to lightning or switching. When lightning strike the overhead transmission lines, the transients occur and thus affecting the power being delivered through that transmission lines. Therefore, this study is to observe the impact of transient for 500kV transmission system. With the help of the simulation software, the defects can be observed and compared in between faults, line energizing and lightning which caused higher impact on that transmission system.

1.1.1 Power Quality Problems

Based on IEEE Emerald Book, power quality is defined as the concept of grounding and powering electronic equipment in a way that is acceptable to the operation of that equipment and accordant with the wiring system of the premise and other connected equipment [1]. Tenaga Nasional Berhad (TNB) is a private company wholly-owned by the government of Malaysia which is the largest electricity utility in this country. TNB defined power quality as the changing of the perfect sinusoidal waveform to non-sinusoidal or distorted waveform [2]. There are various types of power quality problems such as voltage sag, voltage swell, interruption, transients and waveform distortion. As we know, alternating current (AC) is being used worldwide from power generations to electrical loads. AC is an alternating waveform of currents formed by an AC generator in which causes an interruption if power quality problems occurs.

Institute of Electrical and Electronic Engineering (IEEE) Standard 1159 described voltage swell as an increase in Root Mean Square (RMS) voltage for duration from 0.5 cycles to 1min, with a distinctive magnitude between 1.1 to 1.8 [3]. Voltage sag is an event of either current or voltage magnitudes decreased compared to the nominal voltage and currents. Causes of voltage sag and voltage swells usually are related to the unbalanced on a three phase system or switching of heavy loads.

According to IEEE Standard 1159, a sustained interruption is defined as the decreased to zero of the supply voltage for a time period excess 1 minute. Voltage interruptions longer than 1 minute necessitate manual intervention for restoration which the interruptions are frequently permanent in nature [4]. Interruptions occur normally due to loss of power supply or power outages.

Waveform distortion is a steady-state deviation from an ideal sine wave of power frequency principally characterized by the spectral content of the deviation [4]. There are four known types of waveform distortion which are, direct current (DC) offset, harmonic, notching and noise. DC offset is a presence of DC components in an AC waveform. Harmonic are sinusoidal component of a periodic waveform that have frequencies which can be resolved into approximately multiple of the based frequency [5]. Notching is a periodic voltage disturbances caused by line commutated thyristor circuits [6] and noise is basically significances of discrete and particle nature of energy and matter where electrical charge is not continuous, but is carried in discrete amounts equal to the electron charge [7].

1.1.2 Transients

Transients is defined as voltage or current having impulsive nonrecurring changes in the magnitude. An impulse transients was described by the time to decay to half of its peak value and time to reach peak value usually caused by lightning [8]. The transient is known to be occurred due to some reasons such as faults, lightning and line energizing. An oscillatory transient can cause damage to power line insulators while an impulsive transient can cause equipment damage at its point of inception [9]. Direct stroke to a line conductor causes a very high overvoltage or overcurrent. The theory behind lightning is that lightning current choose the best medium to fast travel to earth. Lightning contain very high current which can cause fatally damage to equipment if got struck. Lightning can lead to an overvoltage of over 500kV that can only be withstood by a line at the highest voltage level even lightning current is small as 5kA [10].

1.1.3 Transmission lines

Transmission lines is a systems that transfer power from generator to consumers load. Transmission lines carried the power from generating stations and make it available for distribution through distribution network. Any electrical transmission line has four major parameters which are important. The parameters were resistance, inductance, capacitance and conductance [11]. Electrical resistance is a measure of degree in which the conductor opposed the currents that flow through that conductor. In transmission system, resistance was responsible for power losses. Power losses of transmission lines increased as distance increased due to increments in resistivity across the conductor lines. Capacitance also existed in transmission lines system in which is the charge of conductors per unit of potential differences between them. Meanwhile the inductance is a ratio

between the induced voltages and a rate of change of the currents. Usually for analysis, the inductance and resistance are assumed to be lumped [11].

Overhead line is one of the type of transmission system that have towers or poles to hold the power cables from one point to another point. The overhead lines of transmission system is much cheaper than underground cable but, the overhead lines are endangered to the faults occurring due to short circuit, lightning and line breakage [11]. For an overhead lines, there will be a construction tower or pole to support the power cable. The tower must support the line under worst case loading with an adequate safety margin, exhibit minimal effect on the transmission line characteristics and economical [12].

According to International Electrotechnical Commission (IEC) 60038, the voltage range for power system are classified as table below:

Table 1.1: Voltage Range according to IEC 60038 [13]

IEC voltage range	AC RMS voltage (V)	DC voltage (V)	Defining risk
High voltage	>1000	>1500	Electrical arcing
Low voltage	50 to 1000	120 to 1500	Electrical shock
Extra-low voltage	<50	<120	Low risk

In Malaysia, there are six main voltage range in which are 415 V or 400 V, 11 kV, 33 kV, 132 kV, 275 kV and 500 kV. The maximum voltage for power transmission in Malaysia is 500 kV which according to IEC as high voltage range. The 500 kV transmission line was the main transmission for some places in Peninsular Malaysia while as a future plan for Sarawak, to be covered from Similajau to Tondong with approximate 505 km in total. The predominant reason for a higher voltage transmission line is to reduce power losses especially for transmitting long distance of electricity.

1.2 Problem Statements

The increased in electricity consumption demands by customer caused the power generation and transmission to enhance the capability of delivering power to customer. In fact the demand was getting higher everyday with country development cannot handle this losses. Transient is one of the top power quality problem that can interrupt power transmission and at some point can cause electrical breakdown. Other than that, there is not much transient study on 500 kV transmission line for Sarawak system plan. Moreover, the power quality problems mainly

transient are difficult to conduct in practice unless using simulation. Therefore, the study of transient overvoltage and overcurrent on 500 kV transmission line plan in Sarawak can help to increase power transmission efficiency and electrical protection designing.

1.3 Objectives

1. To conduct a transient study using faults, line energizing and lightning on 500 kV Sarawak Transmission line plan.
2. To simulate and observe the effect of transient overvoltage and overcurrent on 500kV overhead transmission line plan of Sarawak system.
3. To compare cases which causes the highest peak current or voltage on 500 kV transmission system.

1.4 Project Scope

The project scope is by simulating transient study for 500 kV planned transmission line in Sarawak using power system computer aided design (PSCAD) software. The data of Sarawak system, the distances between substations and 500 kV overhead line is acquired accordance to journals that conducted in Malaysia particularly in Sarawak and Google Maps. There are some data obtained officially from Sarawak Energy Berhad (SEB) and the SEB annual reports. The voltage level is 500 kV while the distance around 313 km based on the distance simulated from Tondong substation to Tada substation. The type of transient being simulated is transient overvoltage and transient overcurrent which three cases were 30kA and 120kA lightning current injection, four types of faults on transmission line and the line energizing at the end of the transmission line either receiving or sending end. The four types of faults in transmission line were single line to ground fault, double line to ground fault, line to line fault and three phase fault.

1.5 Project Outlines

Chapter one of this report was basically an introduction for this project. This part consist of the project background, problem statement, objectives, project scopes and project outlines. Chapter one have the brief idea on 500kV transmission line plan in Sarawak system also the power quality simulated which is transient overvoltage and overcurrent.

Chapter two consist of the literature review of the past research. The literature review is corresponds to the project title which are transient overvoltage on 500 kV transmission line plan in Sarawak by using Power System Computer Aided Design (PSCAD). There were an overview of power quality existed such as voltage sag, voltage swells, noise and many more. Other than that, in this part also consisted of few understanding of transient and the uses of PSCAD software.

Besides that, there were chapter three which described method been used in this project. The process of how the project was done are shown and predicted. This chapter contained flowchart of the project, the simulation design flowchart, simulation tools, regional of study and any other related information.

In chapter four of results and discussion part, there were results obtained from the simulations and the discussion of the results obtained. The analysis of the simulation also included in this chapter.

Lastly, chapter five consisted of the conclusion of this project. There were some recommendation and improvement provided for future uses.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Electricity contributed widely in many fields such as commercial, industrial and residential field. The usage of electricity has increased from day to day depending on the innovation of technology. Electricity was generated from energy resources which are renewable and non-renewable energy. The renewable energy is the energy that were able to regenerate while non-renewable energy will be replenished since the energy cannot be reproduced. From power generation part, the activity conducted was to increase the power generation since the demand has been escalated by the year of new technology evolved. Meanwhile, the transmission part also increased the efficiency to transmit power from power generation plant to consumer. There were two type of power transmission system which are overhead lines and underground cable. The overhead lines are the conductor wires that were connected in between transmission tower while underground cable are power cables that been buried underground. These two types of transmission system have varies of both advantages and disadvantages. The biggest disadvantages of overhead line are the openly exposition to the environment which can contribute to fault occurrence such as falling tree and lightning. And for underground cable, the biggest disadvantages are the costs either maintenance or capital cost since the constructional required to dig ground and removes unnecessary impurity that will affecting the operational conditions of the underground cable. In Malaysia, voltage range are classified in four different voltage level which are low voltage, medium voltage, high voltage and extra high voltage. For 500 kV transmission line is categorized as extra high voltage level. In Peninsular Malaysia, the 500 kV has been developed many years ago while it will be implemented in Sarawak power system in the near future.

The power quality disturbance were the results of the unfavorable conditions to the transmission lines. From the occurrence of faults, there will be power quality conditions depending onto the faults such as harmonics, transients and undervoltage conditions. According to figure below, World Bank Data of Electrical Power Transmission and Distribution Losses from 1971 to

2014 showed that there is a rapid polar change of power losses in transmission and distribution. The latest available data was in 2014 with losses of 5.792% compared to 3.85% in 2013. There is quite a bigger percentage cover only transmission and distribution part for a system power loss.

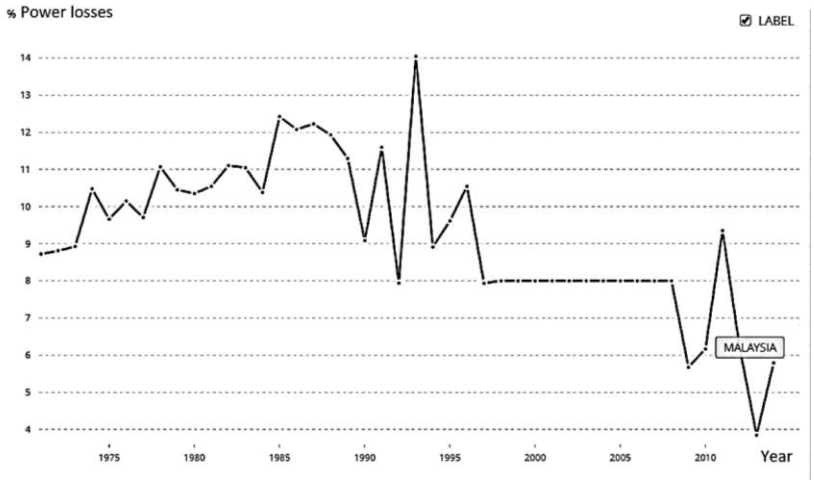

Figure 2.1: Electric power transmission and distribution losses (Malaysia) [14].

2.2 Power Quality Disturbance

Power Quality do effects in the system performance. When power quality occurs in a machine for example, the efficiency of the machine will be plummeted vary from its original condition. Therefore, there is an equipment for power quality detection in an electrical system to detect the source of the power quality occurrence hence to reduce the power quality disturbance. According to [15], major defect types of electrical energy supply were briefly listed here:

a) Phase voltage harmonic distortions, which happen due to the nonlinear loads delivering inrush currents
b) Voltage sag or brownout, which occur because of high loads, load imbalance, also reactive power and faults in power-supply networks
c) Temporary overvoltage or voltage swell, reactive load connection or lightning strokes [15].

2.2.1 Definition of Power Quality

Any abnormality or disturbance verify in the voltage, current and frequency from the standard rating is treated as a power quality (PQ) problem that results in failure or malfunctioning of electrical and electronic equipment [16]. When a system does not consist any power quality disturbances, hence the system will acquire high efficiency system with steady-state voltage,