
# UNIVERSITI TEKNIKAL MALAYSIA MELAKA

## ASSESSMENT ON THE IMPACT OF METAL OXIDE VARISTOR-ARRESTER FOR SERIES COMPENSATION ON HIGH VOLTAGE TRANSMISSION LINE USING PSCAD SOFTWARE

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Electrical Engineering Technology (Industrial Power) with Honours

by

**NUR RAUDHAH SALSABILA BINTI MOHD KHALID**

**B071310690**

**940708-14-6372**

FACULTY OF ENGINEERING TECHNOLOGY

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# DECLARATION

I hereby, declared this report entitled "Assessment on the Impact of Metal Oxide Varistor-Arrester for Series Compensation on High Voltage Transmission Line using PSCAD Software" is the results of my own research except as cited in references.

Signature :

Name : **NUR RAUDHAH SALSABILA BINTI MOHD KHALID**

Date : **12th DECEMBER 2016**

# APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Electrical Engineering Technology (Industrial Power) with Honours. The member of the supervisory is as follow:

……

(En. Adlan bin Ali)

# ABSTRAK

Penggunaan siri pampasan kapasitor pada talian penghantaran mempunyai banyak manfaat. Salah satu manfaatnya adalah ia meningkatkan kapasiti pemindahan kuasa terutama bagi talian penghantaran yang panjang. Walau bagaimanapun, kelemahan proses fana adalah ia membawa kepada arus kerosakan yang tinggi dan voltan yang tinggi semasa proses tersebut dan proses ini menjadikan sistem bekerja dalam keadaan yang sangat buruk. Untuk melindungi peralatan pada sistem penghantaran daripada kesan akibat voltan yang tinggi semasa kilat dan pensuisan, lonjakan penangkap diperkenalkan. Kertas kajian ini menggunakan perisian PSCAD untuk menganalisis kesan apabila menggunakan Metal Oxide Arrester (MOA) atau dikenali sebagai Metal Oxide Varistor-Arrester (MOV) pada siri pampasan talian penghantaran voltan tinggi. Kertas kajian ini menunjukkan simulasi bagi talian penghantaran tanpa menggunakan MOV dan talian penghantaran menggunakan MOV. Hasil kajian menunjukkan cara yang sesuai untuk mengurangkan masalah voltan tinggi dengan jayanya dan sistem akan bergerak dengan stabil.

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# ABSTRACT

The employment of series compensating capacitors in the transmission line has many benefits. One of them is that it increases the power transfer capacity especially for long transmission line. However, the drawback of the transient process is that it leads to high fault current and overvoltage during the process and it will make the system working in a very poor condition. To protect the equipment of the transmission system from the effects of lightning and switching overvoltage, surge arrester is introduced. This paper uses PSCAD software to analyse the impact when implementing Metal Oxide Arrester (MOA) or known as Metal Oxide Varistor-Arrester (MOV) in series compensated high voltage transmission line. This paper presents simulation for transmission line without the consideration of MOV and with the consideration of MOV. Result shows the suitable method to mitigate overvoltage effectively and ensure the system running stably.

# DEDICATION

To my beloved parents, especially my mother who believes in me when nobody else does. To my respected supervisor, En. Adlan, teachers pledge their lives to give students the tools to succeed and inspire them to do it. To Ahmad Izuddin, who gives me strength to face the world.

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# LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

| | | |
|---|---|---|
| AC | - | Alternating Current |
| ACSR | - | Aluminium Copper Steel Reinforced |
| ATWR | - | Ayer Tawar |
| BTRK | - | Bukit Tarek |
| DC | - | Direct Current |
| FTK | - | Fakulti Teknologi Kejuruteraan |
| FACTS | - | Flexible AC Transmission System |
| MCOV | - | Maximum Continuous Operating Voltage rating |
| MOA | - | Metal Oxide Arrester |
| MOV | - | Metal Oxide Varistor-Arrester |
| PSCAD | - | Power System Computer Aided Design |
| PSM | - | Projek Sarjana Muda |
| RMS | - | Root Mean Square |
| ROW | - | Right of Way |
| SCU | - | Series Compensation Unit |
| TCSC | - | Thyristor Controlled Series Capacitor |
| TNB | - | Tenaga Nasional Berhad |

# CHAPTER 1

# Introduction

## 1.0 Background of Study

The Thyristor Controlled Series Capacitor (TCSC) is one of the controllers used in Flexible AC Transmission System (FACTS). Series capacitors belong under this type of controllers which are a well-established concept in electrical power transmission especially high voltage transmission grids. It provides benefits such as improve the voltage drop and the transient stability of long lines, control the power division of load among several lines and increase the loading of the lines to improve the utilization of the transmission system [1].

The degree of compensation is the percentage of the line inductive reactance. If the line is 50% or 70% compensated, meaning that 50% or 70% of the inductive reactance is being installed as series capacitive reactance. However, the degree of compensation must be around the value of 50% to 70% only whereas the relaying will be more complex if the degree of compensation is high. Therefore, series compensated transmission lines were also introduced to reduce the series inductive reactance of the line which enhances the power transfer capability of the lines [2].

There are two types of series capacitors protection which include the protection of capacitor overvoltage and the protection of series capacitor equipment located on the insulated platforms. There are also two important aspects of protection system in series compensated transmission lines. The first one is the

protection of the capacitor bank from overvoltage. The second one is the protective relay system of the transmission line for distance protection.

However, the installation of these devices may cause serious problems for transmission lines protection such as single-phase reclose overvoltage will exceed permitting overvoltage range of high voltage transmission system that affects system safety operation and system equipment works in bad condition [3]. This problem can be overcome by using Metal oxide surge arrester (MOA) which is a protective device consists of Metal Oxide Varristor (MOV) that protect equipments in electrical systems concerning internal and external overvoltage. At normal operating voltages, MOV functions as high impedance while during surge conditions, it becomes low impedances [4]. MOV can be protected thus transient recovery voltage on circuit breaker can be reduced at both ends by bypassing the gap during internal faults. MOV can also limit the overvoltage on capacitor during external faults [5].

## 1.1 Problem Statement

In the recent past, one of the major problems in the power system is power instabilities. Demand of electrical power is continuously rising at a very high rate due to rapid industrial development especially in suburban area. To meet this demand, it is essential to raise the transmitted power along with the existing transmission facilities. The need for the power flow control in electrical power systems is very important to achieve an optimum power flow. With the increase loading of transmission line, the problem of transient stability after a major fault can become a transmission power limiting factor [6].

Series capacitor installations are protected against overvoltage using MOVs and forced triggered gaps. The triggering voltage of the gaps does not remain

constant and is dependent on environmental conditions [7]. After installing series compensation devices on the transmission line, it will cause two major problems which is problem on distance protection of transmission lines such as inversion of voltage and current signals that produce other frequency components. It will also cause problem on capacitor protection of transmission lines such as single-phase reclose voltage will exceed the permitting overvoltage range of the transmission system as shown in Figure 1, which may affects the system safety operation and the system equipment tends to work in poor condition.

| Nominal Voltage (kV) | Maximum Voltage (kv) | Minimum Voltage (kV) |
|---|---|---|
| 500 | 525 | 500 |
| 275 | 289 | 275 |
| 132 | 139 | 132 |
| Lower Voltages | 1.05 pu | 1.0 pu |

Table 1.0 Maximum system voltage in kV (Source: Pre-disturbance voltage limits for planning studies, TNB Transmission System Reliability Standards V2.0)

In Table 1.0, nominal system voltage is the phase to phase voltage of the system which is normally designed such as 11 kV, 33 kV, 132 kV, 275 kV and 500 kV systems. Maximum system voltage is the maximum allowable power frequency voltage which can occurs for long period whether no load or low load condition of the power system. Generally, in Malaysia, Tenaga Nasional Berhad (TNB) has set the maximum system voltage with tolerance of +5% of corresponding nominal system voltage for lower voltages up to 500 kV while the minimum system voltage has tolerance of -0% for lower voltages up to 500 kV.

## 1.2 Project Objective

In the simulation studies of The Assessment on the Impact of Metal Oxide Arrester/Varistor for Series Compensation on High Voltage Transmission Line, the simulation is undertaken in three cases using PSCAD software. The objectives are:-

1. To model the transmission line without the consideration of MOV.
2. To analyse the transmission line voltage with the consideration of MOV.
3. To recommend the suitable method to reduce overvoltage on the transmission line.

## 1.3 Project Scope

The transmission lines can be divided into three categories which are short, medium and long transmission line functioning as transmitting power from one to another. The main focus of this project is high voltage long transmission line. Medium and short transmission line will not be covered.

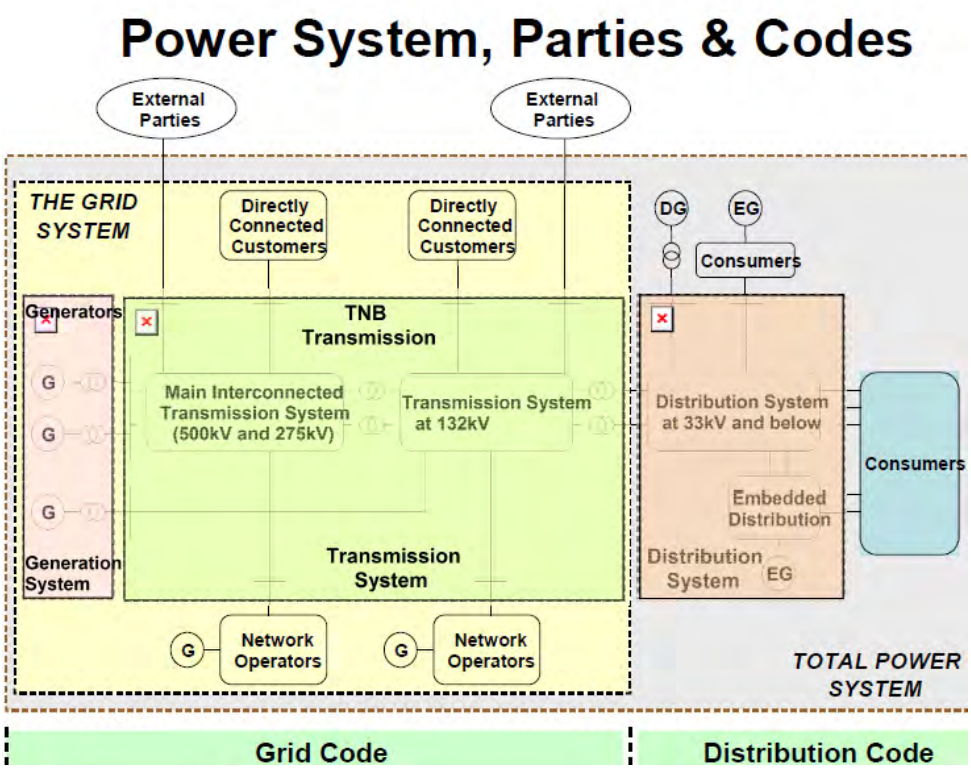


Figure 1.0 Structure of the Power System, connected Parties and applicable Codes (Source: Malaysian Grid Code V2015 New)

Based on the Figure 1.0, the grid system in Malaysia consists of generation, transmission and distribution system. For the transmission system, it is fully operated by TNB Transmission. The main interconnected transmission system has 500 kV and 275 kV. These two values are considered as high voltage for the transmission line. It can be directly connected to the customer especially heavy or large industries that use large power such as steel factory. The transmission system is also connected to network operators to monitor the line performance.

In Malaysia, the highest voltage for transmission line is overhead transmission system which is 145 km length and 500 kV transmission voltage located from Ayer Tawar - Bukit Tarek (ATWR – BTRK). It is fully operated by TNB.

The effects on the overhead long lines are usually corona and skin effect. Corona effect deals with bulk transfer of electrical energy that increases the line voltage and reduces the efficiency of high voltage transmission line. Skin effect happens when there is unequal distribution of current over the cross section of the conductor in AC systems that cause uncontrolled division of load among lines.

To overcome these problems, FACTS is introduced to allow flexibility in operation of transmission network to accomplished increase stability margins. Apart from mitigate overvoltage and control the division of load, FACTS Controllers allow can improve the transmission system with minimal infrastructure investment and environmental impact compared to the new construction of new transmission lines. There are two categories for FACTS Controllers which are Thyristor-based and Voltage-sourced converter-based FACTS. This project focuses on Thyristor-controlled series compensation (TCSC) using Metal Oxide Varistor-Arrester (MOV) that falls under Thyristor-based category to analyze the impact of Metal Oxide Varristor-Arrester on high voltage transmission line.

## 1.4 Thesis Outline

This thesis will have five chapters to be completed during Projek Sarjana Muda 1 (PSM 1) and Projek Sarjana Muda 2 (PSM 2). For the first chapter, the background of the study, problem statement, project objective and project scope for this project will be discussed. For the second chapter, it will discuss deeper on the theoretical information as well as the literature review that have been done from reviewing the past years journals. For the third chapter, it covers more on the software implementation for simulation and calculation will then be discussed. For the fourth chapter, results, verifications, analysis and discussions will be focused. The last chapter provides conclusion and recommendation for the future analysis.

# Chapter 2

# Literature Review

## 2.0 Introduction

For this chapter, the theoretical part is summarized shortly that covers important topic such as power transmission system, losses in transmission line, Flexible AC Transmission Systems (FACTS), type of FACTS controllers, basic principle of series compensation, series capacitor protection scheme, Metal Oxide Surge Arrester (MOV Arrester), the current voltage characteristic of MOV and the overvoltage on the transmission line system. The main interest on this topic is to analyze the impact of Metal Oxide Arrester/ Varristor for series compensation on high voltage transmission line using PSCAD Software

## 2.1 The Grid System in Malaysia

Based on the Figure 2.0, it illustrates on how many parties involved in the Grid Code. The Malaysian Grid Code is connected and linked with the grid system.