STATIC AND DYNAMIC IMPACT OF HVDC, TNB-EGAT INTERCONNECTION SYSTEM

SHAHIDA BINTI MOHD SAID @ SAYED

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Faculty of Electrical & Electronics Engineering
University Malaysia Pahang

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Signature : ______________________________

Author : SHAHIDA BINTI MOHD SAID @ SAYED

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ABSTRACT

HVDC interconnection TNB-EGAT system is the second stage of the grid interconnection between Malaysia and Thailand. This system is to export the electrical power during lower demand and import during TNB's peak load. The objectives of this project are to study the static and dynamic impacts of HVDC TNB-EGAT system. This study will also focus on modeling and simulating of the HVDC interconnection system by using Power System Computer Aided Design (PSCAD/EMTDC) software. The load flow analysis has been conducted by comparing the simulation from PSCAD with the actual data. Hence, the fault analysis also has been conducted by locating the fault at the HVDC modeling which is the DC line fault analysis and AC signal phase short circuit at inverter station analysis. This system is stabilized by having a transient stability analysis. The PSCAD software has the features that can be used to conduct such analysis. This analysis has been performed and the impacts have been monitored on the system and both power system utilities. From the analysis, some improvements have been suggested for the future system.

ABSTRAK

HVDC sistem interkoneksi TNB-EGAT merupakan tahap kedua dari interkoneksi grid antara Malaysia dan Thailand. Sistem ini adalah untuk eksport kuasa selama permintaan yang lebih rendah dan import selama beban puncak TNB. Tujuan dari projek ini adalah untuk mempelajari kesan statik dan dinamik sistem HVDC TNB-EGAT. Penyelidikan ini juga akan mengfokuskan pada pemodelan dan simulasi sistem interkoneksi HVDC dengan menggunakan Power System Computer Aided Design (PSCAD/EMTDC) perisian. Analisis aliran kuasa telah dilakukan dengan membandingkan simulasi dari PSCAD dengan data aktual. Oleh sebab itu, analisis kesalahan juga telah dilakukan dengan meletakkan kesalahan pada pemodelan HVDC yang merupakan garis analisis kesalahan DC dan isyarat AC rangkaian fasa pendek pada analisis stesen inverter. Sistem ini akan stabil dengan memiliki analisis kestabilan transien. Perisisan PSCAD mempunyai ciri-ciri yang boleh digunakan untuk melakukan analisis tersebut. Analisis ini telah dilakukan dan kesannya telah dipantau pada sistem dan utiliti sistem kuasa untuk keduanya. Dari analisis tersebut, beberapa pembaikan telah dicadangkan untuk sistem pada masa hadapan.

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LIST OF SYMBOLS

p.u	-	Per Unit
V	-	Voltage
P	-	Active Power
Q	-	Reactive Power
S	-	Apparent Power
W	-	Wattage
Var	-	Varians
IOrder	-	DC Current Order
α	-	Valve Ignition Delay Angle
γ	-	Commutation Margin Angle

LIST OF ABBREVIATIONS

PSCAD	-	Power System Computer Aided Design
EMTDC	-	Electromagnetic Transient
HVDC	-	High Voltage Direct Current
HVAC	-	High Voltage Alternating Current
DC	-	Direct Current
AC	-	Alternating Current
TNB	-	Tenaga Nasional Berhad
EGAT	-	Electricity Generating Authority of Thailand
PI	-	Proportional Integral
RMS	-	Root Mean Square
VDCOL	-	Voltage Dependent Current Order Limiter
CEA	-	Constant Extinction Angle

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CHAPTER 1

INTRODUCTION

1.1. Overview of The Project

As early as 1881 Mercel Deprez, inspired by experiments with arc lights across a DC generator, published the first theoretical examination of HVDC power transmission. He soon put theory into practice and by 1882 he transmitted 1.4 kW at 2 kV over a distance of 35 miles. Electric power transmission was originally developed with direct current. The availability of transformers and the development and improvement of induction motors at the beginning of the 20th Century, led to greater appeal and use of A.C. transmission. Through research and development in Sweden at Allmana Svenska Electriska Aktiebolaget (ASEA), an improved multi-electrode grid controlled mercury arc valve for high powers and voltages was developed from 1929. Experimental plants were set up in the 1930's in Sweden and the USA to investigate the use of mercury arc valves in conversion processes for transmission and frequency changing. D.C. transmission now became practical when long distances were to be covered or where cables were required. The increase in need for electricity after the Second World War stimulated research, particularly in Sweden and in Russia. In 1950, a

116 km experimental transmission line was commissioned from Moscow to Kasira at 200 kV. The first commercial HVDC line built in 1954 was a 98 km submarine cable with ground return between the island of Gotland and the Swedish mainland. In power transmission system, High Voltage Direct Current (HVDC) is used widely in most of modern countries. HVDC is used in transmission system for long distances. When HVDC is combined in AC power system, there are many impacts occurs inside the system such as static and dynamic impacts.

This project is to study the static and dynamic impact of HVDC, TNB-EGAT interconnection system in order to upgrade their system in power transmission system if the fault occurred. The analysis of this project is fully using the Power System Computer Aided Design (PSCAD) program. The static impacts of this project are load flow analysis and fault analysis. Moreover, the dynamic impact of this project is transient stability analysis.

The HVDC network is based on the actual of TNB-EGAT project. The simulation model consists of a static AC equivalent circuit, converter transformer, converter valve group, DC transmission line, converter controllers, DC filter and AC filters. The parameters of equivalent AC networks, HVDC converters, DC link, filters and etc. are modelled through the PSCAD/EMTDC program.

1.2. Objective

The objective of this project is to study the static and dynamic impact of HVDC, TNB-EGAT interconnection system. Hence, to conduct the load flow analysis, fault analysis and transient stability analysis of the system. Beside that, the objective is to model and simulate the HVDC interconnection system by using Power System Computer Aided Design (PSCAD)/EMTDC program.

1.3. Scope of The Project

The scopes of this project focus on modeling and simulating HVDC interconnection for TNB-EGAT system. This project has been modeled by referring the actual system of TNB-EGAT. Moreover, this project is focused on conducting the load flow analysis and fault analysis.

1.4. Problem Statement

From this project, there is having three problem statements. The first one is study of the static impacts that are important in order to planning, economic scheduling and control of an existing system as well as planning its future expansion. Its also provide with safety purpose too. The second one is study of dynamic impacts are important in order to maintain in stability after large, major and sudden disturbance. The third one understands the HVDC system.

1.5. Literature Review

Power systems around the world are experiencing continuous unprecedented change and stress due to increasing consumer load coupled with environmental and resource constraints. These problems have been alleviated to some extent by using HVDC transmission links [1]. High Voltage Direct Current (HVDC) transmission is widely recognized as being advantageous for long-distance, bulk power delivery, asynchronous interconnections and long submarine cable crossings. HVDC lines and cables are less expensive and have lower losses than those for three-phase AC transmission [2].

The 300 MW Thailand-Malaysia HVDC interconnection systems consist of Khlong Ngae converter station on the Thai border and Gurun converter station on the Malaysia border. Both stations are linked by a 300 kV DC overhead transmission line of 110 km. EGAT's Khlong Ngae converter station is situated at Sadao district in Southern Songkhla province, about 24 km from Thai-Malaysia border. TNB's Gurun converter station is located in Kedah, about 86 km from Malaysia's northern border [14]. A contract was signed between TNB and EGAT on 15 August 1997 for the development of the Malaysia-Thailand 300/600 MW HVDC Interconnection Project, to serve the following purposes which are sharing of spinning reserve between TNB and EGAT AC system, to take advantage of a more economical power exchange between both countries due to the different daily peak consumption periods, emergency assistance to either AC network and reactive power support (voltage control) to both AC networks [5].

In this project, there are having three analyses which are load flow analysis, fault analysis and transient stability analysis. These analyses are modeled in PSCAD program. PSCAD/EMTDC is a general-purpose time domain simulation program for simulating power systems electromagnetic transients and its controls. The modelling is referring to the CIGRE Benchmark with the actual parameter of data from TNB. The CIGRE HVDC Benchmark test model is used as the test system [1].

HVDC transmission applications can be broken down into different basic categories. Although the rationale for selection of HVDC is often economic, there may be other reasons for its selection. HVDC may be the only feasible way to interconnect two asynchronous networks, reduce fault currents, utilize long cable circuits, bypass network congestion, share utility rights-of-way without degradation of reliability and to mitigate environmental concerns. In all of these applications, HVDC nicely complements the AC transmission system [6].

1.6. Thesis Outline

This thesis includes five chapters. The brief outline of each chapter is presented as below:

i. Chapter 1

This Chapter 1 is an introduction which is the overview of the project, objective of the project, scope of the project description, problem statement regarding to this research and the literature reviews that previous works done by researchers.

ii. Chapter 2

This Chapter 2 is the detail explanation about the project which is about high voltage direct current (HVDC) that are includes the introduction, operation of HVDC, HVDC system configuration, HVDC converter station, differences of HVDC and HVAC, advantages of HVDC, application of HVDC, TNB side, EGAT side and the HVDC controls.

iii. Chapter 3

This Chapter 3 is about the details of static and dynamic impact of HVDC interconnection system which includes with introduction and the static and dynamics impact of the system. In this chapter is the analysis of the project that will discuss about what tools that are being used and what is the parameter are needed in circuit diagram of TNB-EGAT AC-HVDC network and the methodology by doing this project.

iv. Chapter 4

This Chapter 4 will discuss about the result that will achieve at the end of this project by doing the simulation of PSCAD. These results will be achieved by doing these analyses which are load flow analysis and fault analysis that is having a different type of fault.

v. Chapter 5

The last chapter is Chapter 5 which contains of the conclusion of overall project by state the final result that gained from the project. The future recommendations also stated in order to improve this project in the future undertakings.

CHAPTER 2

HIGH VOLTAGE DIRECT CURRENT (HVDC) TNB-EGAT INTERCONNECTION SYSTEM

2.1. Introduction

High voltage is used for transmission to reduce the energy lost in the resistance of the wires. Power in a circuit is proportional to the current but the power loss as heat in the wires is proportional to the square of the current. However, power is also proportional to voltage, so for a given power level, higher voltage can be traded off for lower current. Thus, the higher voltage can be produced the lower of the power loss. Power loss can also be reduced by reducing resistance. Commonly achieved by increasing the diameter of the conductor, but larger conductors are heavier and more expensive.

High Voltage Direct Current (HVDC) technology has characteristics which makes it especially attractive for certain transmission applications. HVDC transmission is widely recognized as being advantageous for long-distance, bulk power delivery, asynchronous interconnections and long submarine cable crossings. The number of

HVDC projects committed or under consideration globally have increased in recent years reflecting a renewed interest in this mature technology. New converter designs have broadened the potential range of HVDC transmission to include applications for underground, offshore, economic replacement of reliability-must-run generation, and voltage stabilization. Developments include higher transmission voltages up to ±800 kV, capacitor-commutated converters (CCC) for weak system applications and voltage-sourced converters (VSC) with dynamic reactive power control. This broader technology range has increased the potential HVDC applications and contributed to the recent growth of HVDC transmission. HVDC transmission applications can be broken down into different basic categories. Although the rationale for selection of HVDC is often economic, there may be other reasons for its selection. HVDC may be the only feasible way to interconnect two asynchronous networks, reduce faults, currents, utilize long cable circuits, bypass network congestion, share utility rights-of-way without degradation of reliability and to mitigate environmental concerns. In all of these applications, HVDC nicely complements the AC transmission system.

The interconnection between TNB and EGAT consists of the construction of a 110 km HVDC line (86 km TNB, 24 km EGAT) with DC converter stations (12-pulse) at both ends. The interconnection will be between Gurun 500/275 kV (50Hz) substation on the Malaysia side and Khlong Ngae 230 kV (50Hz) substation on the Thailand side. The converter station at Gurun will be constructed for bi-directional 300 MW monopolar operations. In the past, the AC transmission line system linked between Thailand and Malaysia to exchange the energy power with the capacity of 80 MW transferred from Sadao Substation in Thailand. At the present, the HVDC grid network is implemented for connection of the asynchronous 230 kV AC system of Thailand with 275 kV AC system of Malaysia. The capacity of HVDC interconnection between Thailand and Malaysia is 300 MW with the maximum overload capacity of 450 MW for 10 minutes. The 110 km DC overhead transmission line is connected at voltage level of 300 kV (approximately 24 km from the Thailand border and 86 km from Malaysia border).

Initially, the converter station is configured as a monopole converter of 300 MW. Provision has also been made for adding a second 300 MW pole in the future in order to extend the system into a bipolar configuration with a total capacity of 600 MW. The first objective of this connection is to provide various benefits of both countries comprising such as economic exchange of power between two different networks, enhancing system reliability, sharing spinning reserve, sharing experiences on HVDC operation and maintenance system to extend closer cooperation between Thailand and Malaysia. Figure 2.1 below is illustrated as TNB-EGAT AC-HVDC network schematic overview.

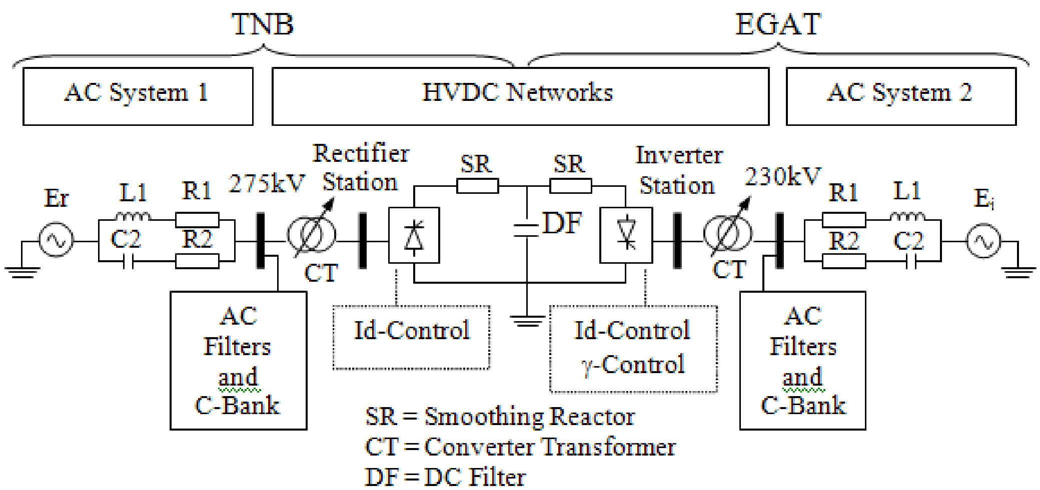

Figure 2.1: TNB-EGAT AC-HVDC Network Schematic Overview

2.2. Operation of HVDC

The power system is begin from power plant which is the electrical power is producing by generator. The generator can be operated by using steam from many sources like winding, nuclear, gas and coal. From power plant, electrical power will be