CHAPTER 1

INTRODUCTION

1.1 Motivation

Due to generation shortages within southern region of Thailand. Electricity Generating Authority of Thailand (EGAT) has already installed a 300-MW HVDC link to import power from northern Malaysia when needed. This HVDC link has advantages of interconnecting between the two unsynchronize systems, allowing full bi-directional control of power interchange, and improving reliability and dynamic performance of both AC transmission systems [1].

HVDC systems have the ability to control the transmitted power rapidly. Therefore, they have a significant impact on the stability of the associated AC power systems. Proper design of the HVDC control is essential to enhance performance of the transmission line so it will ensure satisfactory performance of the overall AC/DC. When power system is subjected to disturbances, dynamic stability can be improved by power control on the HVDC link [2, 3].

There are a number of papers examining the controllers to be implemented on the HVDC link using techniques such as : PI, PID, fuzzy, Artificial Neural Network (ANN) [4, 5, 6, 7]. Nevertheless, to have a proper controller, one needs to model the HVDC link which connects to the power system of interest. After getting such model, one can apply suitable controller such that it will improve the stability in the system.

In studying control systems, engineers must be able to model and analyze dynamic characteristics of the systems or plants. A mathematical model of a dynamic system is normally defined as a set of equations that represents the dynamics of the system accurately, or at least fairly well. A system may be represented in many different ways and, therefore, may have various forms of mathematical models, depending on ones perspectives. One mathematical model may be better suited than other models. With the increasing use of power electronic controllers, the availability of dynamic models, which provide insight into system behavior and facilitate analysis and design, will have considerable benefits [8].

The analysis of dynamic stability can be performed by deriving the linearized state space model of the system in the following form :

$$\dot{x} = Ax + Bu \qquad (1.1)$$
$$y = Cx + Du$$

where the matrices A and B also depend on the given operating conditions. The eigenvalues of the state matrix A determine the small-signal stability around the given operating point. The eigenvalues analysis can be used not only for the determination of the stability regions, but also for the design of the controllers [3]. In reference [9] it presented the system by state space and used the resulting matrices A and B to design the multi loop control scheme to be implemented in the system. It is shown that oscillations are damped out due to the action of the proposed controllers. In [6], it presented robust controllers for HVDC links in AC-DC power system using fuzzy logic controller. The purpose of controller is for fast stabilization of transient oscillations. To design this kind of controller, the linearized state space representation of the system is needed. Some references [10, 11] used the matrices A, B, C, and D to calculate M. M is a nxn finite dimensional linear time invariant system. The norm of elements M can be used to determine the system's amplitude gain. In those references, it is shown that M plays a fundamental role in the study of a system's stability robustness subject to bounded perturbations. From those references we see the great importance of the linearized state space representation of the system.

Many references [5, 6, 9] use a rather too simple AC-DC power system to evaluate the controller performance of the HVDC link. It consists of one generating unit, one HVDC link with parallel AC line and connected to infinite bus. The formulation of matrices as eq. (1.1) for this system is quite simple.

In this thesis we will develop the program to obtain a linearized state space model such that the power system can consist of multiple generators and HVDC links. Moreover, the AC network can consist of a number of buses depending on the structure of the actual system. To do that, we have to get the mathematical equations which represent the dynamic behaviors of all components. Also, interfacing those components together required some laborious mathematical manipulation. After all, we need to linearize all equations and arrange them in the matrix equation form. Then, we need to eliminate the non-state and non-input variables by substitution. So that, we get the representation of the system in the linearized state space form.

This program will be validated using Western System Coordinating Council (WSCC) 3-machine, 9-bus and will be tested on the Southern Thailand generation and transmission systems with 5 generating units, 1 HVDC link, of which it is connected to Malaysia, and the 28-bus and 41-branch AC transmission network to examine small-signal stability of that system.

1.2 Objectives

1. Develop an algorithm to generate linearized state space model of the power systems with multiple dynamic devices including HVDC links.
2. Test performance of the developed program on the Southern Thailand generation and transmission systems with 5 generating units, 1 HVDC link and 28-bus, 41-branch AC transmission network.

1.3 Scope of Work

1. The power systems of interest consist of multiple generating units, the AC network including constant power loads and HVDC links.
2. The HVDC link model used in this thesis is a constant-current controller for rectifier terminal, and a constant-extinction angle controller for inverter side.
3. The two-axis model of synchronous generator and the IEEE type I of exciter are used to represent the dynamic behaviors of the generating units.

1.4 Research Methodology

1. Literature reviews on background knowledge, modeling and applications of HVDC.
2. Study and develop model for the AC system which is suitable for electromechanical oscillation analysis and control.
3. Study how to incorporate HVDC model into the AC system.

4. Perform mathematical analysis to generate a state space model algorithm.
5. Develop a program to generate linearized state space representation of the overall system.
6. Validate the correctness of the developed program using the system of WSCC 3-machine, 9-bus.
7. Test and make necessary corrections with the network in southern part of Thailand.
8. Analyze the results.
9. Write the thesis.

1.5 Expected Contribution

It is expected that the linearized state model of the power systems with HVDC link will be useful for small signal stability analysis of the actual power systems. Additionally, it will be crucial for system operation and planning to design a proper controller for the HVDC link to help mitigate power oscillation within the actual power systems.

In chapter 2, modeling of HVDC link is discussed. Chapter 3 deals with modeling of power system consist of generator and transmission network. The steps to get linearized state space model of power systems with HVDC link will be elaborated in Chapter 4. Next chapter explains about state space model generation algorithm. Chapter 6 shows the test results. We will use the popular Western System Coordinating Council (WSCC) 3-machine, 9-bus system to validate the obtained eigenvalues of linearized system. Furthermore, the developed program is tested using the Southern Thailand generation and transmission systems with 5 generating units, 1 HVDC link, of which it is connected to Malaysia, and the 28-bus and 41-branch AC transmission network.