RATED-CAPACITY DISPATCH, SENSITIVITY ANALYSIS, AND CONTROLLER DESIGN OF VSC-BASED FACTS CONTROLLERS

By

Xinghao Fang

An Abstract of a Thesis Submitted to the Graduate

Faculty of Rensselaer Polytechnic Institute

in Partial Fulfillment of the

Requirements for the Degree of

DOCTOR OF PHILOSOPHY

Major Subject: Electric Power Engineering

The original of the complete thesis is on file
in the Rensselaer Polytechnic Institute Library

Examining Committee:

Joe H. Chow, Thesis Adviser

Sheppard J. Salon, Member

Jian Sun, Member

Murat Arcak, Member

Victor Chan, Member

Rensselaer Polytechnic Institute
Troy, New York

March 2008
(For Graduation May 2008)

ABSTRACT

Voltage-sourced converter (VSC) based Flexible AC Transmission System (FACTS) controllers, built on high-power electronic switching devices, are the state-of-the-art technology for voltage control and power flow control in a power system. Starting from the shunt and series voltage source models and various operating modes of VSC-based FACTS controllers, we have developed a common framework to model, simulate, and control a variety of VSC-based FACTS controllers, like Static Synchronous Compensator (STATCOM), Static Synchronous Series Compensator (SSSC), Unified Power Flow Controller (UPFC), Interline Power Flow Controller (IPFC), Generalized Unified Power Flow Controller (GUPFC) and Back-to-Back STATCOM (BtB STATCOM). This framework allows the investigation of the control capability and impact of the VSC-based FACTS controllers on a power system, especially the case of multiple VSCs like UPFC, IPFC, and BtB STATCOM.

In this research work, we go further to study and implement the rated-capacity dispatch strategies of FACTS controller with single or multiple VSCs, constrained by the physical limits of power electronic devices and power system operation. The dispatch strategies of multiple VSCs are emphasized because of the complexity, especially when the DC buses of the various VSCs are connected to allow active power exchange. Then the maximum dispatchability of the FACTS controllers on the critical transmission paths is investigated. In addition, the maximum power transfer capability of FACTS controllers with respect to voltage stability is investigated.

We also investigate the use of the sensitivity of FACTS controllers for system dispatch and new controllers siting. Two different sensitivity approaches are presented to analyze the effect of the FACTS controllers on the voltages and power flows in the system. One approach is the voltage-source model based method with the full Jacobian matrix including all the FACTS controller variables, and the other one is based on the equivalent-impedance model. Both methods can provide first-order approximation of sensitivities and the latter one is specially efficient. Using these approaches, the applications of sensitivity for power flow re-dispatch and optimal

location of new series VSCs are presented.

BtB STATCOM, consisting of two shunt VSCs with a common DC bus, is readily modeled based on the available shunt VSC model. Some efforts are devoted to systematically set up BtB STATCOM models, including both the steady-state and dynamic model, and also to implement various regulation modes into system dispatch and dynamic simulations. Then the performance of a BtB STATCOM in a practical system is evaluated. As expected to play a critical role in the future power grid, BtB STATCOM has many applications in power system, among which Grid Shock Absorber Concept is a very interesting topic. Focusing on this topic, we apply the BtB STATCOM model and an extra power-frequency controller in test systems to study and demonstrate the technical feasibility and benefits of the Grid Shock Absorber Concept. The scenarios of different fault cases are generated and the comparisons of large interconnected AC system and Grid Shock Absorber based segmentation are provided.