Optimal Allocation of FACTS Devices for Congestion Relief and Voltage Stability Improvement under Deregulated Power Systems

(R竞爭環境下の電力系統における混雑解消と電圧安定性向上を目的とした FACTS 機器の最適配置に関する研究)

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Recently, transmission congestion has become a challenging issue for some researchers as it frequently occurs due to significant increase in power transactions. Voltage stability has also become a concern since several costly accidents take place worldwide caused by voltage collapse. Basically, load shedding and generation re-scheduling are effective to solve transmission congestion and voltage instability. Nevertheless, such efforts are not preferable as they will change the established power transactions. Transmission expansion might also be the solution. However, this effort is not simple because expanding transmission will usually meet resistance from the society.

Flexible AC transmission systems (FACTS) device, a power electronic-based device able to control voltages and modify the power flow, becomes promising solution. To achieve the minimum investment cost and maximum benefit, the devices should be installed at the optimal locations. Therefore, it is essential to develop an effective approach able to accomplish those objectives.

The main purpose of this study is to develop an approach for power system planning by allocating multiple FACTS devices and evaluating their impact on the operation problem in order to minimize annual total cost. It implies to minimize devices investment cost and maximize benefit due to devices installation obtained by maximizing social welfare as well as minimizing load shedding and generation re-scheduling costs. The formulation takes into account a large number of operation states consisting of normal and contingency states, where probabilities of system states to occur are also considered. In addition, dynamic state transitions caused by specified contingencies are also simulated in the optimization problem to evaluate the benefit of FACTS control actions. To accommodate yearly load pattern, several load levels representing distinctive conditions are used.

The main contributions of this thesis are (1) application of FACTS devices allocation for
congestion relief and voltage stability improvement in the deregulated power systems. (2) The usage of FACTS devices not only under contingency state but also under normal state. (3) Incorporation of generation re-scheduling in case of contingency. (4) Incorporation of firm and non-firm load in case of emergency. (5) Inclusion of generator ramp limit in the transition period between normal and contingency states.

The outline of this thesis is summarized as the following. Chapter 1 consists of the background of proposing FACTS devices allocation approach and the objective of the study. Chapter 2 provides the basic theory of transmission congestion and voltage stability. Methods to evaluate voltage stability such as continuation power flow (CPF) and direct method are also described in this chapter. Furthermore, FACTS devices used to relieve congestion and improve voltage stability are discussed. Chapter 3 describes the formulation of FACTS devices allocation approach. In this chapter, the general problem formulation is initially described and then detailed problem formulations consisting of main and sub-problems are subsequently presented. Finally, sequential quadratic programming (SQP) to solve Optimal Power Flow (OPF) in the sub problem and particle swarm optimization (PSO) to solve the main problem are described. Chapter 4 presents a multi objective approach for optimal allocation of FACTS devices under regulated power system. The contribution of the approach is in optimally controlling FACTS devices under both normal and contingency states to minimize operation cost and meet voltage stability criterion. Thyristor-controlled series compensator (TCSC) is chosen as the allocated devices. Chapter 5 provides an approach for FACTS devices allocation for relieving congestion under deregulated power system. Generation re-scheduling is considered to relieve transmission congestion in case of contingency. Moreover, firm and non firm load are included, representing uninterruptable and interruptible load in case of contingency. Chapter 6 deals with FACTS devices allocation to relieve congestion and improve voltage stability under deregulated power system. This chapter presents the further development of approach in chapter 5 by incorporating voltage stability, utilizing additional FACTS devices i.e. static VAR compensator (SVC) and considering ramp limit of generator in the transition period between normal and contingency states. Chapter 7 provides the conclusions of the study and the future research. The author recommends speeding up the computation time by applying distribution computation on the approach.