ROBUSTNESS AND ADAPTIVITY ENHANCED CONTROLLER DESIGN FOR SMART GRID POWER SYSTEMS WITH HIGH RENEWABLE ENERGY PENETRATION

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論文題名　：ROBUSTNESS AND ADAPTIVITY ENHANCED CONTROLLER DESIGN FOR SMART GRID POWER SYSTEMS WITH HIGH RENEWABLE ENERGY PENETRATION
（再生可能エネルギー源が大量導入されたスマートグリッドのロバスト性・適応性強化制御系設計に関する研究）

区　　分　：甲

論　文　内　容　の　要　旨

The penetration of renewable energy in power system significantly increases. However it causes some issues on power systems such as frequency deviation due to unstable power outputs of renewable energy generation units, and rotor angle instability (low frequency oscillation) caused by decrease in the total inertia constant of conventional generating plants when the electric grid receives a large amount of power from the renewable energy generation units. This thesis proposes control system design by considering robustness and adaptivity to overcome the problem. In this thesis, the existing controllers, most of which are PID or lead-lag controllers, are optimized, so that they can exhibit better performance and that if this alone cannot attain desirable performance, new devices will be installed. The proposed control design will be applied to solve frequency deviation in isolated power systems, and rotor angle stability in interconnected power systems with high renewable energy penetration. In isolated power systems, robust control design is enough to handle frequency deviation. However, in interconnected power system, when the variations of total inertia constants are large, giving robustness to the controllers is not enough. We need to make the controllers adaptive to the changes in operating conditions due to the high penetration of renewable energy sources. In adaptive control, the controller parameters are changed depending on the situations. Here a system identification technique and the robust controller design method described above are combined into an in-direct adaptive controller design. The identified model is used to monitor discrepancy between the actual power system output and the expected output (model output). When a large discrepancy is detected, a new set of controller parameters is determined to adapt to the new situation. The simulation studies show that the proposed adaptive control scheme is able to stabilize power system under the changeable operation conditions and system uncertainties due to high penetration of renewable energy sources.

An outline of the thesis is presented as follows:

Chapter 1 - A brief description of smart grid power system is provided and challenges of smart grid application on power system are discussed. The challenge of smart grid on control scheme is specially highlighted. Furthermore, robustness and adaptivity of control system design on smart grid power system to improve power system stability are introduced.

Chapter 2 - The general theories of conventional robust control design are presented. The classification of system uncertainties modeling is provided. Then the conventional control system design considering system uncertainties to guarantee robustness of controller is given. The example of application of conventional control design on single machine infinite bus power system is presented.

Chapter 3 - This chapter introduces conventional adaptive control designs. First, direct adaptive control design especially MIT rule to adjust parameter of controller is explained. Then this chapter presents indirect adaptive control systems using iterative identification and control design method, and multi model adaptive control scheme. The several methods of identification and control system design are briefly explained.

Chapter 4 - This chapter shows the proposed robust control design and adaptive control scheme. The proposed robust control design using conventional control structures is described. The weakness of robust control design due to high renewable energy penetration in power system is discussed. Next, the proposed indirect adaptive robust control design is described.

Chapter 5 - This chapter presents the robustness and adaptivity enhanced controller design in isolated smart grid power system. The details of power system model, pitch model and principal operation of energy storage are given. To check the performance and robustness of proposed energy storage controller comparison with conventional energy storage controller, eigenvalues analysis and non linear simulation using Simulink/Matlab is applied.

Chapter 6 - This chapter concentrates on the application of proposed method to design adaptive robust power system stabilizer (PSS) in two-area four-machine power system. First, system modeling such as generator model, exciter model, and power system equipped with PSS is described. Then non linear simulation studies using ObjectStab are applied to evaluate damping performance and robustness of the proposed PSS in comparison with those of PSS designed without considering robustness and adaptivity against several system uncertainties.

Chapter 7 - General conclusion and recommendations for further research are given.