論　文　の　要　旨

題目：　A Study on Transient Stability and Effective Use of Synchronous Inverter under Introduction of Renewable Energy in Power Systems
（　電力系統における再生可能エネルギー導入時の過渡安定度及び同期化力インバータの効果的使用に関する研究　）

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Recently, renewable energies (REs) rapidly increase in power systems in the world. REs are very attractive since these are clean power generation methods that do not emit CO2. However, stable power supplies from REs are difficult since the outputs of REs such as photovoltaic generation (PV) and wind turbine generation (WT) depend on the weather conditions. Therefore, if REs are connected to the power system without special control, the stability of the power system may deteriorate and finally the supply and demand balance is collapsed. This thesis analyzes the influence of the uncertainty of RE on the transient stability of the conventional power system by using a critical clearing time (CCT), and then proposes a novel transient stability control based on a CCT-Distribution Factor (DF) which is sensitivity of CCT to controllable generation outputs. In addition, it is shown that the stability can be improved by effectively controlling inverter with battery. This inverter is named a synchronous inverter whose effective use for power system stabilization is also discussed.

Chapter 1 explains the background and the problem of the present power system concerned with REs. Mega solar and domestic solar panels are being introduced in Japan because of poor energy resources. However, the amount of power generated by PV has uncertain as it depends on climate. Confidence intervals are defined to handle this uncertainty. By using this, it is possible to perform system simulation considering the uncertainty of PV. Since a large number of synchronous generators are connected to the grid, the system can be operated stably. System stability has steady state stability that takes into consideration the relatively slow state and transient stability to evaluate instantaneous stability. In this thesis, it will consider the transient stability from the next chapter to evaluate uncertainty. This chapter also describes our team project in Taoyaka program in order to realize future sustainable society.

Chapter 2 explains the stability of power system and its analysis methods. Conventional stabilization control methods are also explained. CCT is often used to evaluate transient stability. As a calculation method of CCT, there are a time domain simulation method that calculates by drawing a trajectory of stability and instability and an energy function method using transient energy when it critical situation. In this thesis, it evaluates stability by the simulation method with less CCT error. There are mainly two methods to improve the stability. One is a

generator control and another is a FACTS control, which is a device using power electronics technology. After introducing the conventional control, the former is explained in Chapter 3 and the latter is explained in Chapter 4.

Chapter 3 proposes a novel approach, that is, the transient stability analysis and control methods based on CCTs. First, the characteristic of CCT is investigated when PV is introduced to conventional system. When simulation was performed using the power system model, it was confirmed that transient stability deteriorated due to uncertainty of PV. From this result, the characteristics of the influence of uncertainty of PV on CCT were investigated. Also, as the output of PV fluctuates, it is necessary to adjust the output of the generator in order to maintain the supply and-demand balance. Therefore, its optimum generator control to improve CCT is considered. The effectiveness of CCT-DF is confirmed by comparison with the simulation method and it is applied to an actual control. Then, the transient stability control through CCT is studied based on CCT-DF by controlling generator outputs. This chapter also discusses formulation and solution of robust optimization problem for secure power system operation against REs uncertainties. This method is a control to improve the CCT without moving as much as possible from the economical operation state obtained from the economic load dispatch system. Then, the effectiveness is verified by simulation.

Chapter 4 proposes a new design of the synchronous inverter for improving power system stability. Assuming the future situation, it is expected that synchronizing power also decreases with the decrease of synchronous generators in operation. Thus, the synchronous inverter, which have synchronizing power similar to synchronous generator, is designed for improving power system stability. Since this thesis proposes a single-phase synchronizing power inverter, it can be flexibly used as compared with a three-phase inverter. This is because it can be directly applied to inverters for household PV which are thought to increase further in the future. Also, the proposed control system has an advantage that it does not disturb the characteristics of the generator to be mounted by improving the protection circuit. The conventional functions for voltage and frequency controls are also implemented in the inverter. It can be confirmed that the proposed inverter has the same characteristics as the small signal analysis. This makes it possible to analyze with effective value and design the optimum parameters of the inverter that can use the conventional system analysis method and contribute to system stabilization.

Chapter 5 concludes this thesis through each chapter discussion. We examined the improvement of the transient stability by the generator control and the improvement of the transient stability by the inverter separately. In the future research, we propose to verify the effect when proposed methods are used at the same time, because the proposed inverter can calculate with effective value.