論 文 の 内 容 の 要 旨

論文題目　Voltage Stability Analysis and Its Control in a Multi-Machine Power System with High Penetration Levels of Photovoltaic Generation

（太陽光発電が大量連系された多機系統における電圧安定性解析とその制御）

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In recent years, it can be witnessed a rapid development of renewable energy throughout the world. The main motivations behind this fast-growing development are the rising environmental concerns, e.g. solving the environmental problems created by conventional energy system. Photovoltaic (PV) power which is an alternative, clean and sustainable energy source for the electricity production has a lot of advantages unlike other distributed generations. For instance, the PV modules can become a part of building located at or close to the electricity consumption points whereas wind power and other types of renewable energy based generation cannot. In addition, the cost of PV power has been reducing every year. Therefore, photovoltaic generation has been developing rapidly in Japan as well as all over the world. Some reports described results from studies examining some of benefits and challenges of meeting up to 20% of U.S. electricity demand with solar technologies by 2030. Japanese government also set out a target to install the PV systems of 53GW by 2030. It is important to carefully examine the impact of a large penetration of the PV systems on the system security and reliability.

The voltage stability of a power system refers to its ability to properly maintain steady, acceptable voltage levels at all buses in the network at all times, even after being subjected to a disturbance or contingency. A power system may enter a condition of voltage instability when the system is subjected to a steady increase in load demand or a change in operating conditions, or a disturbance (loss of generation, loss of major transformer or major transmission line). The voltage stability phenomena may occur in both transmission systems and distribution systems. Especially in recent years, the distributed generation such as PV

generation is rapidly developed all over the world, it is necessary to consider voltage stability constraint for planning and operation of distribution systems.

This research constructs models of PV systems, investigates the transient behaviors of the studied grid-connected multiple PV systems under different operating points and various disturbance conditions. The results show that a high penetration level of the PV systems operating to get maximum power has significant impact on the transient stability and the voltage stability of the power system. If the system is affected by a large disturbance, the dynamic response of the PV systems may cause the power system to be unstable. In many cases, disconnection of high penetration levels of the PV systems from the grid make power system voltage collapse.

Based on the simulation results, this research finds out dynamic mechanism of voltage collapse in a multi-machine power system installing high penetration levels of photovoltaic generation. There are two important factors that influence on power system instability. The first is the penetration level of the PV generation with respect to the total demand of the power system and the other is the dynamic characteristic of the PV generation during the fault. In conventional power system, it is difficult to recognize power system losing transient stability or voltage stability. However, with particular characteristics of the PV generation, the voltage instability phenomena are always occurs faster than rotor angle instability. Base on these analyses, power system stability can be improved by control the PV systems considering voltage stability.

The research proposes appropriate operation schemes for PV systems to get high efficiency of supplied power and enhance the power system voltage stability when the system is subject to a disturbance. To prevent voltage collapse in the power system, the simulation results will provide an appropriate penetration level of the PV generation integrated with the system in steady state and their inverters control strategy during the transient period under the disturbances. It is necessary and significant when the PV generation are rapidly developing in Japan as well as all over the world and the voltage stability concern is raising with distribution networks becoming more and more complicated.