学位論文内容の要旨

This thesis deals with different approaches to stabilize the grid connected wind farm. Due to the environmental and the economical concerns, it is expected that a huge number of wind farms are going to be connected with the existing networks. Therefore, it is essential to analyze both steady state and transient characteristics of the grid connected wind farms. In this study, different types of methods suitable for wind power application are presented to enhance the stability of fixed and variable speed wind turbine generator systems.

The drive train and generator dynamics have great influence on the fault analysis of fixed-speed wind turbine generator system (WTGS). Detailed comparative studies are carried out among six-mass, three-mass, and two-mass drive train models and finally one of those is recommended which is suitable for the fault analysis of fixed-speed WTGS.

Wind power fluctuation due to randomly varying wind speed is still a serious problem for power grid companies or transmission system owners (TSO), especially in the case of fixed speed wind generators. The wind power fluctuation usually occurs in the time scale of few sec to several hours, depending on the wind condition, wind turbine size, topology, etc. These wind power fluctuations are comparatively small in a wind farm than in a single WTGS on these time scales. But considering the isolated systems or as an option for future energy systems with high penetration of wind power generation, it is essential to emphasize the research on wind power smoothing. In this study, the wind power fluctuation in the time scale of minute range is focused. Energy Capacitor System (ECS) is proposed to smooth the output power of wind farm and to regulate the terminal voltage at its terminal. Moreover, it is reported that constant hydrogen can be generated from wind power by using comparatively economical topology of hydrogen generator when ECS connected at wind farm terminal is considered. It is also reported that a fuzzy logic controlled pitch controller can smooth the wind farm output power up to a certain extent.

Between the two types of trends, the fixed-speed WTGS has inferior fault ride through capability compared to that of variable speed WTGS. Therefore, fixed-speed wind generator that uses the squirrel cage induction generator needs additional tool to enhance the fault ride through capability. This is because it requires large reactive power to recover the air gap flux when a short circuit fault occurs in the power system. If sufficient reactive power is not supplied, then the electromagnetic torque of wind generator decreases significantly. Then wind generator and turbine speeds increase rapidly due to the large difference between mechanical and electromagnetic torques. As a result, the induction generator becomes unstable and it requires to be disconnected from the power system. However, the recent trend is to decrease the shut down operation because a shut down of large wind farm can have a serious effect on the power system operation. In this study, we proposed three-level voltage source converter (VSC) based STATCOM to enhance the low voltage ride through (LVRT) capability of fixed-speed WTGS. On the other hand, ECS can also be used for enhancing the LVRT capability of fixed-speed WTGS as it has reactive power control ability. Comprehensive study is carried out to enhance the transient stability of multi-machine power system including wind farms by using ECS. Besides these, it is also reported that fuzzy logic controlled pitch controller can enhance the transient stability of wind generator more than that with PI controller.

The damping characteristics of shaft torsional oscillation of steam turbine generator system are presented in many literatures. But the damping of blade-shaft torsional oscillations of fixed-speed WTGS has so far not been reported in literatures. In this thesis, it is also reported that STATCOM can be used to reduce the blade-shaft torsional oscillations of fixed-speed WTGS.

Doubly fed induction generator (DFIG), wound field synchronous generator (WFSG), and permanent magnet synchronous generator (PMSG) are widely used as variable speed wind generators. Another salient feature of this thesis is the stabilization of variable speed wind turbine (VSWT) driving a PMSG. Two types of electrical schemes of VSWT-PMSG are presented with their suitable control strategies. Finally, transient stability of both topologies is analyzed considering faults at different locations in the power system.

The simulation has been carried out by using the digital simulation software package PSCAD/EMTDC. For wind power fluctuation analysis, the real wind speed data is used, which is measured at Hokkaido Island of Japan. Different types of symmetrical and unsymmetrical faults are considered for the transient stability analyses of WTGS. It is concluded that the proposed approaches with their control strategy can be very effective to stabilize grid connected wind farm.

論文審査結果の要旨

近年、世界中で風力発電が増加しているが、風速変動に伴う風力発電機出力変動の問題があり、連系される電力系統に周波数変動や電圧変動などの悪影響を与える点が懸念されている。このような中で本論文では、ピッチ制御や無効電力補償装置による風力発電機の出力変動の平滑化、系統側での故障発生時における風力発電機の安定度改善、更には蓄電設備と電気分解装置との協調制御に基づいた風力発電機による水素製造システムに関する検討結果が示されている。

これを要するに、申請者は風力発電機の更なる導入を目的として、高品質の発電を行うシステムを構築すると同時に次世代エネルギーとして注目されている水素製造に関しても新たなシステムを提案し、その有効性を確認したものであり、電力工学、特に自然エネルギーの分野に対して貢献するところ大である。

よって、申請者は北見工業大学博士(工学)の学位を授与される資格があるものと認める。