学位論文内容の要旨

This thesis deals with the stability augmentation of grid connected wind farm by using Variable Speed Permanent Magnet Wind Generators. Since last decade, the penetrations of large number of wind farms into electrical grid system have been increasing significantly. In many countries, increasing of the penetration level of the wind generators into grid systems has led power system operators to revise the grid code connection requirements for their power system. The grid code prosecutes that the wind generator should give a contribution to the power control in case of abnormal operating conditions such as network disturbance. The wind generators should be remained stay online during a network disturbance. The Low Voltage Ride-Through (LVRT) grid code requirement should be taken into account when a short circuit occurs in grid system. Out of synchronism of a large number of wind generators can give serious impact on power system stability. Therefore, the interaction between wind farm and main power system such as transient and steady state characteristics has become important to be analyzed in order to augment dynamic stability of wind farms.

The Fixed Speed Wind Turbines with Squirrel Cage Induction Generators (FSWT-SCIGs) are widely used in wind farm due to their advantages of mechanical simplicity, robust construction, and lower cost. However, the FSWT-SCIG directly connected to the grid does not have any LVRT capability when a short circuit occurs in the system. Moreover, under steady state condition its reactive power consumption cannot be controlled and hence terminal voltage of the wind generator leads to large fluctuation. In this thesis, a new control strategy of variable speed wind turbine with permanent magnet synchronous generator (VSWT-PMSG) for stability augmentation of wind farm including fixed speed wind turbine with SCIG is proposed. A suitable control scheme for back-to-back converters of PMSG is developed to augment dynamic behavior of the wind farms. In order to avoid the converter damage, the protection scheme using DC chopper is embedded on DC link circuit. The simulation studies have been performed and it is shown that the proposed control system can stabilize the wind farms effectively.

Three phase voltage source converter (VSC) is commonly used in VSWT-PMSG system when it is connected to the grid system. However, the converter operating at high switching frequencies can generate high order harmonics and power losses. To reduce harmonic injection to the grid system, LCL filter is an attractive solution because of its many potential advantages such as higher harmonic attenuation and smaller inductances. However, resonance frequency of the filter can cause stability problem. Therefore, design of the current controller of voltage source converter should be carefully considered. In this thesis new control scheme of VSWT-PMSG connected to a grid system through LCL filter is proposed to enhance the stability of wind farm including squirrel cage induction generator based fixed speed wind turbine. The current controlled voltage source converter of PMSG system is developed based on the d-q rotating reference frame, in which the dynamic stability of the control system is analyzed based on frequency response of the bode diagram. The control strategies of overall wind farm have been investigated in transient and steady state analyses to show the capability and effectiveness of the proposed method. The results show that the terminal voltage of wind farm can be recovered effectively during and after the symmetrical and the unsymmetrical faults, and thus the transient stability of fixed speed wind generator can be enhanced.

Another salient feature of this thesis is an application of Fuzzy Logic Controller (FLC) to the current controlled VSC of PMSG in order to enhance dynamic stability of wind farms. The current controller is the most essential in design application of VSC, because it can dominate the performance of the distributed generation connected to a grid system. Change of parameters in the grid system can lead significant impact on the control system performance of the converter. The deviation of the grid system impedance will change gain margin and phase margin of the control system. The fuzzy logic controller is combined with conventional PI controller (Fuzzy-PI), and hence gain parameters of the PI controller can be adjusted based on tracking error. In addition, a simple method based on the bode diagram is proposed in order to design the membership function of the FLC. It is concluded the voltage source converter can be controlled effectively by using the proposed Fuzzy-PI controller.

In industrial applications, PI controllers are most widely used because of their simple structure and good performances in a wide range of operating conditions. In fixed gain controllers, these parameters are determined by methods such as the Zeigler and Nichols, optimum modulus criterion, pole placement, etc. However these methods sometimes bring about oscillatory responses. In addition, for the strong nonlinear system the global optimum solution is difficult to be achieved by using these methods. In this thesis, a novel design method of current controlled voltage source converter for VSWT-PMSG is proposed. The method is based on optimum tuning process of PI gain parameters of voltage source converter control system with the artificial immune system (AIS) algorithm considered. Simulation results show that the proposed method is very effective in enhancing the dynamic stability of the wind generator system.

Considering all aspect of VSWT-PMSG with proposed control system, it can be concluded that the transient and steady state stabilities of a wind farm combined also with FSWT-SCIG can be augmented effectively for severe network disturbance as well as randomly fluctuating wind speed.

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、種々の風力発電機の中でも永久磁石形同期発電機を用いたPMSG（Permanent Magnet Synchronous Generator）方式が、高効率である等の理由のため、世界的に普及している。加えて、PMSGは固定子回路にインバータを有し、その制御により発電機有効・無効電力を自在に調整できる特性も有している。近年、系統側での故障発生時等における風力発電機の安定性が問題となっており、安定度改善に関する研究が急務となっている。このような状況下において、本論文ではPMSG形風力発電機によるウインドファームの新しい安定化制御法を提案している。

これを要するに、申請者はPMSG形風力発電機による安定化制御を目的として、制御回路の設計にファジィ理論、人口免疫システムを提案し、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。