“Analysis, Design and Control of Doubly Fed Induction Generator for Wind Energy Conversion Systems”

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ABSTRACT
Population growth and industrialization are the main reasons for the exponential increase in the electrical power demand. The major sources of the power generation are fossil fuels like coal, petroleum and gas are depleting at a faster rate. The major concern with these fossil fuels are the greenhouse emissions which in turn leads to climate change. So there is need for increase in the power generation from the non-conventional energy sources like solar, wind and bio mass. With latest technological advancements, wind energy is becoming the cheapest of all the renewable energy sources. Doubly fed induction generators (DFIG) are typically used as a variable speed wind energy conversion system (WECS) due to the reduction in the size of the power converters and also the converter losses. So nowadays, this DFIG based WECS have the share about 50% of the total installed WECS all over the world. So the DFIG based variable speed grid connected wind energy conversion systems are used for the power generation. Still there are some reasons where the electricity through the grid connection is not feasible due to geo-graphic and economic constraints. The use of DFIG is also preferred in standalone mode for the power generation.

Normally, the voltage at the remote locations is not regulated at the desired value. This research aims the voltage regulation at the remote locations with the proper control of DFIG without adding any extra reactive power compensators. Attempts are made for achieving voltage regulation at the grid by the coordinated control of rotor side converter (RSC) and grid side converter (GSC) in addition to the conventional DFIG functionalities such as maximum power point tracking, decoupled control of active and reactive powers.

This research work aims to investigate the solutions for volatile power generation from the grid connected WECS and also the power quality problems at the grid. The variation in the power generation prevails when the wind energy penetration increases in the total power due to its intermittent nature of wind. So BESS is integrated with DFIG based grid connected WECS for smoothening the power and also for regulating the power feeding to the grid irrespective of the wind speed. Attempts are made for achieving the constant power output by modifying the control algorithm of the GSC and also by the proper selection of BESS using the previous wind data of the proposed system.

A new topology of grid connected DFIG based WECS is investigated by removing the GSC and also by integrating BESS in the DC link of RSC. The advantages of single VSC based DFIG are compared with the conventional double VSC based DFIG. Investigations are made on the proposed single VSC based DFIG with vector control and direct power control algorithms for the variations in the wind speed. Attempts are made for eliminating the rotor position sensor. Stator flux based model reference adaptive system control and simple position sensorless algorithms are used for estimating rotor position and speed.

Poor power quality is another major concern for the consumers as well as generating companies. Investigations are made for improving power quality in the distribution system with DFIG based WECS. Harmonic mitigation of loads connected at PCC has been achieved by modifying the control algorithm of GSC. Working of this DFIG as an active filter is proposed even at wind turbine stalling condition. A grid connected DFIG with BESS is also verified for both power smoothening and active filter capabilities without adding any extra power electronics components.

Detailed performance of all these configurations of grid connected DFIG based WECS for the power quality improvement are verified by the developed prototype in the laboratory using digital signal processor (DSP) dSPACE DS1103 controller. Detailed performance of the proposed control algorithms of DFIG are validated on a developed prototype for the dynamic changes in wind speeds.

In this research work, DFIG is also used for feeding standalone consumer loads. Voltage and frequency controllers (VFC) are investigated for a DFIG based variable speed SWECs to feed consumer loads. A mechanical sensorless is used for estimating the rotor position and speed. DFIG based SWECs is investigated with and without the energy storage elements like BESS. A prototype of VFC is developed to demonstrate the performance of VFC for DFIG based variable speed SWECs under linear, non-linear and dynamic loads at varying wind speeds. The performance of VFC is observed for maximum power point tracking, load leveling, load balancing, a neutral current compensation and harmonic elimination.