ABSTRACT

The energy demand of the world is increasing rapidly and the search for new energy sources is the top priority as the conventional sources will be exhausted quite soon. One such identified new energy source available in plenty and that can be continuously renewed is wind energy. The wind turbine technology has undergone a dramatic transformation from the year 1970. Wind energy will become a significant source of electrical energy supply. In a fast developing economy like India, the energy demand will be three to four times what it is today in the next ten years. Renewable energy such as wind energy will be one of the options to meet this demand.

There are two types of Wind Energy Conversion System (WECS) such as fixed speed and variable speed wind turbine driven energy systems. The most commonly used generator in fixed speed WECS is induction generator but it requires bulky excitation capacitors and bi-directional power flow controllers. However the power factor is low. In recent days, variable speed WECS combined with power electronic interfaces is becoming popular because of its capacity to harness wind power effectively and efficiently. The recent advancement in permanent magnet materials and power electronic devices makes permanent magnet generator more suitable for variable speed Direct Drive Wind Energy Conversion System (DDWECS).

This thesis covers different types of permanent magnet materials based on their magnetic, thermal and B-H characteristics and use of these characteristics in the implementation of permanent magnet generator. Conventional power electronics interface circuits with three stages of power
conversion such as rectifier, DC-DC boost chopper and PWM inverter are
widely used in WECS to obtain the desired voltage and frequency from
continuously varying PM generated voltage. The main focus of the research is
on the efficient power converter fed variable speed system with permanent
magnet synchronous generator. Reduction in power quality owing to dead
time in inverter and large value of inductive and capacitive filter is vulnerable
to electromagnetic interference noise. In addition, PWM inverter also creates
high switching stresses. These issues are also dealt with.

The Z-Source Inverter (ZSI) is proposed as a power conditioner in
DDWECS to reduce the number of power conversion stages to two as against
three in conventional system. The ZSI has buck-boost feature which is
possible because of additional shoot through state introduced in zero state of
the conventional inverter pulse width modulation and provides desired AC
output voltage. The unique impedance network exploits the shoot through
state to boost the input voltage. The shoot through pulse width is adjusted as
per the PMG generated voltage level to maintain constant load voltage. In
this thesis two PWM control methods such as carrier based third harmonics
control and modified space vector PWM (MSPWM) are employed to analyze
the performance of Z-source inverter. The two independent control variables
such as shoot through duty ratio and modulation index are suitably adjusted to
get the required voltage and power.

A new family of Z-source AC-AC matrix converter is introduced to
further reduce the three stages of power conversion into one and improve the
power quality. The Z-source matrix converter is a single stage power
converter for DDWECS. It provides a larger range of AC output voltage with
buck-boost operation. The performance of ZS-MC is predicted using two PWM control methods such as carrier based PWM scheme and Space Vector Pulse Width Modulation (SVPWM). The voltage and frequency generated by PMG are normally varying due to the intermittent nature of wind speed. Owing to the buck-boost feature of the ZSI and ZS-MC, it becomes a convenient source for grid or commercial load interfacing of WECS.

Further to improve the performance of DDWECS the Maximum Power Point Tracking (MPPT) controller is incorporated to the system. A smart speed sensorless scheme for generator has been introduced to avoid conventional sensors. Using this scheme the generator speed required for the existing wind velocity to generate maximum power is predicted. The proposed algorithm is remarkably faster and efficient which is confirmed by the results. The proposed ZSI based DDWECS and ZS-MC based DDWECS are compared with conventional system taking into account, the voltage gain, shoot through distribution, switching stress and Total Harmonic Distortion (THD) for different loading conditions. For predicting the switching stress the dc link voltage and inductor current of conventional and ZSI based DDWECS are measured experimentally. To predict the efficient method of power conversion, the efficiency of individual DDWECS is plotted for different loading conditions and wind velocity. To implement the MPPT algorithm the ZSI based DDWECS are connected with grid. Practical models of three systems such as 1) rectifier chopper with PWM inverter based PMG, 2) two stage rectifier and ZSI based PMG and 3) single stage ZS-MC based PMG are demonstrated and experimental results are compared with the respective simulation results.