This thesis has described the research work on developing the advanced wind energy conversion system employing new z-source power electronic converter interfacing a variable speed direct drive modular permanent magnet synchronous generator. Main attention is paid on developing flexible and economical new power electronic converters replacing the conventional one to transfer optimal power.

The wind energy industry is moving rapidly toward the adoption of variable speed systems for the benefits of reduced noise, increased energy capture, and for better economy. The permanent-magnet generator is a promising direct drive generator for variable speed wind energy conversion system (WECS). The progress in the permanent magnet materials fabrication has extended the PM generator lifetime and decreased the production cost. An AC/DC/AC power electronic conversion system is the most suitable type of grid interface for the above conversion system.

The cheap and reliable diode rectifier is used for AC/DC power conversion. The output of the poly phase generator can be conveniently rectified to generate a high quality DC link voltage.

With PM generator and diode rectifier system, the power control is set at the z-source inverter through an impedance network. The operation of the ZSI powered from a dc link with varying voltage is analyzed.

The following DC/AC converter systems have been investigated in detail by analysis, modeling and simulation. First two of them are incorporated in the hardware systems developed for practical experimentation.

- Simple z-source inverter.
- Quasi z-source inverter,
- Trans Quasi z-source inverter
- Trans z-source inverter

The operation and control of these systems are addressed in detail; the technical feasibility has been established. These inverters having the boosting capabilities, deliver the optimal real power captured from the wind to the grid, generate the desired reactive power and have satisfactory harmonic performance.
The results of analytical, numerical analysis, simulation and laboratory studies from the above-mentioned z-source converter based systems have demonstrated the performance of many alternative systems. A powerful prototype is also constructed for industrial appraisal. Chapter 2 of the thesis presents a review of the relevant literature showing the work done previously in the area of proposed research to plan further research effectively. It surveys the continuous developments in the area of wind power conversion systems and application of power electronics based converter for that. It presents the literature survey in the area of newly proposed z-source converters both for direct ac to ac and dc to ac conversion. Chapter 3 presents an overall detailed analysis of four different topologies of z-source inverters including quasi z-source inverter, trans–quasi z-source inverter, trans-z source inverter connecting unique impedance networks. Many analyses done on the topologies are not covered earlier in any literature towards improvement of efficient conversion methodology. Three different switching control methods namely simple boost control, maximum boost control and maximum constant boost control are applied in each topology. Their performance and suitability are monitored and compared in different angles through simulation as well as mathematical analysis. Chapter 4 focuses on developing a comprehensive dynamic mathematical model of the proposed wind power converters using state space averaging technique. These models are to be used for controller design purposes. General method for modelling power stages of dc-to-ac converters have been developed through the small signal state-space approach. Dynamic behaviour of the model is investigated by the transfer functions and simulating the step responses to selected input variables. It also focuses the design procedures of z-network components used for different topologies. Chapter 5 presents the design and development of closed loop wind power conversion systems employing the four topologies of z-source inverters one by one. On the basis of analysis in chapter 3, third harmonic injected (THI) maximum constant boost control switching technique is applied for all these systems. Designed systems are verified through simulation under MATLAB-SIMULINK environment. Results under steady states and dynamic states are studied and analysed which show many improvements not possible to achieve with conventional rectifier-inverter system. It also represents the ac-ac z-source converters both for single phase and three phase for direct conversion of variable voltage ac into a regulated and boosted form through a proposed novel simple feed-forward controller. It presents simulation as well as experimental results. The investigation reveals that these converters are not much suitable
for wind power conversion as it do not work on variable frequency source, rather works fine for variable voltage source.

Chapter 6 explains the hardware prototype developed in the laboratory for the simulated closed loop z-source inverter based wind power conversion systems in line with the simulated system. Microcontrollers are employed for generating THI-sine waveform and PID control operation. Each section of the system meant for specific purpose is designed, layout is prepared, suitable components are chosen, PCB is developed, fabricated and tested separately. All the sections are assembled and overall experimental results satisfy the results obtained and presented in chapter 5 during simulation.

7.1. Contributions

The original contributions of author are listed as follows:

- Application of four types of z-source inverters (simple ZSI, quasi ZSI, trans-quasi ZSI, and trans-ZSI) in place of conventional inverter are studied for variable speed PMSG wind power system.
- Z-Source ac-ac converter based closed loop system is proposed for variable voltage source.
- A set of new performance analysis are carried out for each of the above converters.
- Three existing switching control techniques are applied to the above converters and analysed. One of them is selected for the proposed closed loop conversion system.
- All the above converters are modelled using state space averaging technique and small signal analysis are carried out to study the dynamic response of the system
- Closed loop system employing all four z-source inverters are simulated for wind power conversion and steady state and dynamic analysis are performed.
- Hardware prototype of the closed loop system is developed designing each section carefully. Microcontroller programming is developed for successful implementation of the control logics.

7.2. Future development

As the proposed system present some drawbacks or have been incompletely developed, some future works are to be further considered
CHAPTER-7 CONCLUSIONS

- Integrated experimental setup: Hardware prototype is not integrated with PMSG and wind turbine system. This is required to work as a complete setup.
- Intelligent Maximum Power Point Tracking (MPPT) Algorithm could be developed the features independent of the wind turbine characteristics, and thus flexible and effective, and trainable online to behave adaptively.

To continue and complete the work presented in this dissertation, one can focus on a number of specific areas.

Considering the future importance of z-source converters, the author proposes application of this for following systems. Though some works have been started but immense development scopes are there with design of suitable control system:

- Adjustable speed drives, motor drives
- Grid-connected photovoltaic/ Fuel cell systems
- Autonomous power generation systems;
- Multilevel neutral point circuit development;
- Analysis of special operation modes typical for embedded network.
- Traction drives of fuel cell vehicles (FCVs). Because of the wide voltage range of the fuel cell, the inverter and the motor need to be oversized to accommodate the great constant power speed ratio. The Z-source inverter could be a cheap and reliable solution for this application.