ABSTRACT

World’s electricity demand is increasing at a rapid rate. Presently, most of our electricity demand is met by fossil fuels; oil, coal and natural gas. Fossil fuels are conventional resources and are not renewable, which means that they will not be replaced within the time-span of human necessity. These fossil fuels introduce many harmful pollutants into atmosphere and burning of contributes to environmental problems like global warming and acid rain. Besides, growing scarcity and rising prices of these fossil fuels may lead to economic instability in the future. There are also non-conventional sources of energy, which are renewable; they are solar, wind, biomass, geothermal, etc. Renewable energies are non-polluting. Nowadays, renewable energy sources play an important role in electricity generation. Among these renewable energy sources, solar energy draws increasing attention because of high dependability, absence of fuel cost, improvements in photovoltaic technology, and little maintenance. Furthermore, the solar energy characterizes a clean, pollution free and inexhaustible energy source.

One of the most potential and versatile methods for using the solar energy is its direct conversion into electrical energy with photovoltaic (PV) devices. But the conversion efficiency is very low when the PV array is directly connected to the load because of the nonlinear characteristics of the PV array. Therefore, the PV energy has to be qualified by a power conditioning system before it is consumed by an AC load and/or the grid. Since a high improvement is achieved in power electronics technology, power converters are mostly employed as the power conditioning system. Z-source inverter, the recently developed inverter topology is attractive for power conditioning applications because of its single stage boost and inversion
operations, high efficiency, more reliability and less cost. Maximum power point tracking (MPPT) is another important consideration that is taken into account when building a new PV power system. This is needed in order to extract maximum power output from a PV array under varying solar irradiance and temperature conditions. The Z-source inverters can be effectively controlled to extract the maximum power from the PV array.

This research work is started with the development of mathematical model of PV array. A generalized PV model is built based on the single diode equivalent circuit. The model is simulated using MatLab/Simulink software to study the I-V and P-V characteristics of the PV module under varying solar irradiance and temperature conditions. A realistic model of PV module is developed. A simple, novel and economic electronic load is developed for obtaining the data for the realistic model. The developed electronic load is used for fast display and recording of the characteristic of PV module.

Mathematical modeling of Z-source inverter is required to study the steady state behaviour and the dynamics introduced by the impedance network elements. The state-space averaging method is used in this work to derive the small-signal model of Z-source inverter. The capacitor voltages, inductor currents and load current are taken as state variables. The dynamic behaviour of the state variables is found out by perturbing the input voltage and the shoot-through duty ratio. Inductor current and capacitor voltage transfer functions are derived. From the small signal model, the impedance network elements are designed for minimal voltage ripple, current ripple and transient time period. The effectiveness of the derived mathematical model is verified by simulating and comparing the dynamics of the small signal circuit with the dynamics of the actual switching circuit. The simulation results obtained from both the small signal model and the actual circuit model show that the responses by two models agree to each other very well. The derived
model is proven to be accurate enough to predict the transient responses as well as the steady state values of the Z-source inverter.

The unique feature of the boost operation of Z-source inverter is achieved by introducing the shoot-through (DC supply short-circuiting) state in its switching cycle. Thus, the insertion of shoot-through states becomes the key point of the pulse width modulation (PWM) control methods for the Z-source inverter. Based on this principle, number of control methods has been presented so far in literature. The main control techniques: simple boost control, maximum boost control and maximum constant boost control are reviewed. This thesis focuses on devising new carrier based as well as space vector based PWM techniques to increase the performance indices of the Z-source inverter. A new sinusoidal carrier based simple boost PWM is proposed that uses the conventional sinusoidal reference while the carrier signal is a high frequency sinusoidal wave. This control scheme helps to maximize the voltage gain for a given modulation index. Another carrier based PWM strategy proposed in this work is the double carrier PWM that employs three sinusoidal reference signals and two high frequency triangular carrier signals. One of the carrier waves is given zero DC offset value whereas the other carrier wave is up-shifted to certain DC offset voltage to control shoot through duty ratio. Thus, the desired voltage gain can be obtained by varying the DC offset value, which in turn minimizes the voltage stress across the switches. A novel modified space vector PWM is also proposed by inserting four shoot-through states in a switching time period. The simulation studies of all the proposed PWM techniques are carried out in MatLab/Simulink software and the results are verified with experimental results. A comprehensive comparison of the various PWM strategies for Z-source inverter is performed. The comparison study shows that the modified space vector PWM (SVPWM) imparts least voltage stress across the
switching devices and gives minimum total harmonic distortion on output voltage and current.

Since the Z-source inverters realize the boosting and inverting operations in one power stage, it can be adapted as the MPPT controller in PV power conditioning systems. The MPPT changes the shoot-through duty cycle to keep the transfer power from the PV array to the load at maximum power point. The conventional perturbation and observation (P&O) method is reviewed and a modified P&O method is developed which can be accommodated for varying solar irradiance conditions. With similar concept, a modified incremental conductance algorithm is proposed. A fuzzy logic based MPPT technique is also proposed for PV-fed Z-source. They are checked for different operating conditions through simulation and are verified experimentally. Digital signal processor (DSP) controller is used to implement the algorithms.

The energy storage systems are on the basis of the achievement of very important and valuable ancillary services, able to significantly improve reliability, availability and power quality of modern power system. The energy storage systems require bidirectional converters to charge and discharge the storage element. Since the basic topology of Z-source inverter is limited to one directional power flow, it cannot be used for energy storage applications. A new bi-directional Z-source inverter topology is effectively utilized in literature to exchange energy between DC and AC side in both directions. But the switching techniques developed in literature produce poor quality of output waveforms. To solve this problem two new modified space vector PWM techniques are proposed in this work and their output total harmonic distortion (THD) is compared with the available PWM techniques. It is found that the proposed PWM methods give significant reduction in THD on output voltage and current.