CHAPTER 6

CONCLUSION AND SCOPE FOR FUTURE WORK

6.1 CONCLUSION

The goal of this thesis was to develop a simple circuit model of the PV module that can be used as a common platform by material scientists as well as power electronic circuit designers to develop better PV power plant. An elaborate literature survey was carried out on the circuit model of the mono junction crystalline as well as the thin film PV devices, DC to DC converters and MPPT algorithms. The need for developing the simplified circuit model was stressed in various studies.

In Chapter 2, the systematic MATLAB / Simulink modeling procedure for the equations of the PV module was presented. The physical equations governing the PV module were elaborately presented with numerical values of the module saturation current at various temperatures. It was seen that the PV module current Iph is a function of the solar irradiation. It was also seen that the module photo current increases slightly with the increase in temperature while the module reverse saturation current and the module saturation current increase drastically with the increase in temperature. This shows that the PV module output voltage is affected to a very large extent at high temperatures.

The above results were experimentally verified. The simulated values using the developed model were higher than the experimental values
by about 3% at normal insolation and hence the \( I_{PV} \) model was reasonably accurate. Simple validation procedure for the developed circuit model was proposed with the simulation circuit at the three remarkable points, namely, the short circuit current, the open circuit voltage and the maximum power point value and it is found that the simulation values closely follow the experimental values.

In Chapter 3, the detailed procedure of the MPPT design with the developed circuit model was discussed. The circuit model was used with DC-DC converter circuit and simulated for various values of irradiation. It was found that for constant load, the duty cycle was reduced from 0.41 for 1000 W/m\(^2\) to 0.2 for 500 W/m\(^2\). This variation coincided with the already available results in the literature. Then the performance of the developed circuit model in the closed control loop was tested in simulation and verified experimentally with P&O and IC MPPT algorithms. The experimental and simulation responses are compared graphically and the results were reasonably accurate. The improved experimental results were obtained with IC MPPT algorithm.

In Chapter 4, the practical problem of high ambient temperature faced by an Indian PV power plant was presented. The detailed study of the high temperature operation of the PV module was carried out using the circuit model. The closed loop control circuit with higher values of capacitors and a PI controller is used for obtaining improved output voltage throughout the day irrespective of high temperature. When this better quality DC output is fed to the grid tied inverter, the tripping due to grid-offs could be avoided.

In Chapter 5, the constructional details of different types of thin film modules required for circuit modeling was provided. Thin-film module parameters vary with irradiation and temperature and the difficulties in modeling of thin-film PV models due to these variations was presented with the literature survey. The amorphous silicon thin-film PV module was taken
to explain the circuit modeling procedure. The developed a-Si circuit model was verified for its accuracy with simulation circuits.

The need for the module integrated, fully controlled, DC-to-DC converter in PV power processing under higher temperature conditions existing in India was also presented in this thesis. For smooth and efficient operation of the PV modules in India and other high temperature countries, dedicated DC-DC converter is required for power processing.

6.2 SCOPE FOR FURTHER WORK

Research in the following areas can be carried out using the developed circuit model of the PV Module.

- Improving the accuracy of the circuit model without sacrificing its simplicity

- The higher temperature operation of the PV module, the practical Indian PV operation problem, could be taken up. The voltage output from the PV module is very much reduced at high temperature. By employing a fully controlled DC-DC boost converter, the current produced by the PV module can be converted into voltage required for the grid operation.
6.3 CONTRIBUTIONS OF THE THESIS

1. The developed circuit model of the PV module is a very useful tool for simulation studies and reasonably agrees with the experimental results. This circuit model of the PV module was used in the design of MPPT system.

2. The practical Indian problem of higher temperature operation of the PV module was analyzed and possible solutions discussed.

3. The thin-film PV modules, which are not easily available, were analyzed using the circuit model.