

## Chapter 8

### Conclusions and Recommendations

#### 8.1 Conclusion

The objective of this research, which was to develop an interactive menu-driven design tool that is capable of analyzing the technical and economic aspects of a stand-alone photovoltaic system has been achieved. The interactive menu-driven design tool developed in the course of this research is called PVONE. It was developed based on the Matlab programming language. All the results presented in Chapter 7, were obtained using the PVONE program. The basic equations for the insolation part of the model came from [2,15]. The author of this research then used these equations to develop the PVONE program that is interactive and user-friendly. Also incorporated into the PVONE program is a system design analysis, an energy output analysis, a storage analysis, and an economic analysis. PVONE is a design tool that can be used to estimate insolation at any location on the earth surface, design a stand-alone PV system, compare the energy output of the array designed to the load demand, size the storage requirement, perform an economic analysis, and then make a decision based on the net present value whether the PV system designed can be implemented at the location.

The PVONE program predicts insolation available at any location on the earth's surface under clear sky conditions and then uses the standard classification criteria to determine the range of insolation levels for the various day types and finally classifies the days of a chosen month according to day types then predicts a new set of insolation. The program also predicts the instantaneous insolation that is available for a chosen location under clear sky conditions and also predicts the total insolation that is available for a specific time interval for any location. From the results presented in Chapter 7, the predicted insolation is quite close to the actual insolation for Blacksburg. Observe that, Blacksburg was used only to test the model in this research. The question then is, why should a designer of photovoltaic systems use the PVONE program? The answer to this question is quite simple. In most remote regions of the world, there is no data available for actual insolation. The PVONE program can be used to estimate the insolation available for the remote location under clear sky conditions and then determine the range of insolation levels for the various day types based on the type of collector that will be used. The inhabitants of the remote location can be asked to estimate the number of each day type in a given month. Based on the information provided, an arbitrary insolation

data file can be created for the month. This data file is then used to run the program. For example, if the PVONE program determines that a rainy day at a chosen location is when the insolation is less than  $1.273 \text{ KWh/m}^2$ , by obtaining information from the inhabitants on which day(s) of the month was rainy, a different insolation value can be assigned to such day(s). A similar process can be carried out for the other days in the month. An insolation data file is created based on this information to run the program.

The results shown in Tables 7.6 and 7.11 clearly demonstrate that, by knowing the classification of a day, its predicted insolation is much closer to the actual insolation than the insolation predicted under clear sky conditions. The strength of the PVONE program to predict insolation, relies on knowing how the days of a month are classified and not on the actual insolation.

The second part of the PVONE program is used to design a stand-alone photovoltaic system and then determine its economic benefits. The results of three systems that have been designed based on maximum daily load, average daily load, and minimum daily load are presented in section 7.6. The PV array for each of the three systems was sized based on the average daily insolation. For all the systems designed, only the system that utilized the maximum daily load as the system load, and was sized based on the average daily insolation can be actually implemented in Blacksburg. This is because, it produced enough energy that provided for the annual load energy demand. The systems that utilized the average and minimum daily load as the system load and were sized based on the average daily insolation did not meet the annual load energy demand. For these systems to be implemented in Blacksburg, the number of modules and size of the storage will have to be increased. Observe that the modules and the storage system are the two most costly components of a stand-alone photovoltaic system. Increasing the size of these components increases the overall cost of the system. Another possibility for which both systems may be implemented, is to size them based on the minimum daily insolation. As discussed earlier, the cost of such a system will be too expensive because the system is much larger than what is actually needed. In general, stand-alone systems that are sized based on the minimum daily insolation are not cost effective. In this research, it was also discussed that for a photovoltaic system to be beneficial, it must have a positive net present value. As realized, in this research, a stand-alone system may have a positive net present value due to favorable economic conditions but the system is not able to meet the annual load energy demand. For a grid-connected system, the net present value may be used as the only factor that determines whether the system that has been designed is beneficial. For a stand-alone system, the annual energy output must satisfy the annual load demand. When this condition is satisfied, then the net present value is determined to find out whether the system is beneficial.

## 8.2 Recommendations

The following are some recommendations based on this research for future work in using photovoltaic systems to meet the energy needs in remote regions of the world;

- More research is needed to improve the efficiency of PV modules. Increased efficiency will reduce the need to use many modules, which reduces the overall cost of photovoltaic systems.
- The PVONE model can be applied to a more realistic scenario or an actual community. That is, it can be applied to a remote village in a developing nation.
- The economic benefits should take into consideration the environmental benefits of building a PV system as opposed to some other generating source.
- Study the effects of the socio-economic impact of building the PV system in the remote or rural community.