

# CHAPTER 1

## INTRODUCTION

Over the last two decades, there have been two major events that led the world's industrialized nations to look at renewable energy sources as a supplement to providing the projected increase in energy demand in their respective nations. These events include, the world's energy crisis of the mid 1970s and the increased awareness of the effects of emissions from fossil-fueled power plants to both humans and the environment. In order to ameliorate the potential harm from these emissions, governments in industrialized countries are currently debating and enacting pollution control regulations into laws. These laws are geared towards both small and large emission sources. For example, the United States Congress passed the "Clean Air Act Amendments" (CAAA) in 1990 which was later enacted into law when the bill was signed by President George Bush. Although the CAAA of 1990 addressed a wide range of issues, the provisions under title IV are geared primarily towards the utility industry. These regulations coupled with the depletion of the world's fossil fuel reserves, have once again focused attention on renewable energy sources.

Among a wide range of renewable energy projects in progress throughout the world, photovoltaic (PV) systems are the most promising as a future energy technology. The overall objective of photovoltaic technology is to obtain electricity from the sun that is cost competitive and even advantageous with respect to other energy sources. Photovoltaic generation is already a reality in some environments, but of their diffusion in rural areas, there still exists many constraints and the problem needs to be examined from the economic, technical, operational and institutional viewpoints [20]. Pertaining to the above mentioned problems, an interactive menu-driven design tool has been developed that addresses the technical and economic aspects of a stand-alone photovoltaic system. The design tool developed is called PVONE.

The PVONE design tool consists of three parts namely, insolation, system design, and economic analysis. Each of these parts is used to perform a particular task for designing a stand-alone photovoltaic system as follows;

1. Insolation: The PVONE program utilizes the concepts of the clear sky insolation model to predict the insolation available at any location on the earth's surface. The parameters used to specify a location are latitude, longitude and altitude. However, as we have experienced in our daily lives not all days in any given year will be sunny and as a result the total insolation predicted by the PVONE program will be much higher than the actual value available at a location. To get a handle on this situation, the PVONE program incorporates a standard classification criteria to set insolation level limits which will be used to classify the days for any given month of the year. Days satisfying the various insolation level limits will be

classified under that category. Based on how the days have been classified, the PVONE program utilizes mid and lower range multipliers to predict a new set of insolation for the month in question.

2. **System Design:** The PVONE program is also used to design the photovoltaic array based on the chosen photovoltaic module, the system design load, the type of load to be served by the system, and the daily insolation available at the location. After the array has been designed, the PVONE program performs an energy analysis to determine how much energy is produced by the array and whether the energy produced satisfies the load demand. Since insolation is not available during night hours and is less than adequate on certain days, the PVONE program sizes a storage system based on the type of battery specified. The storage system will be used to meet the load demand during periods when the array provides little or no energy to the system.
3. **Economic Analysis:** In this part of the program, the PVONE program utilizes the concepts of a life-cycle cost analysis for a stand-alone photovoltaic system including the land area cost and the control room cost as well as other major components needed to implement the system. The program then calculates the total cost of the system. Based on the total cost, interest rate and the loan down payment, the number of years required to payoff the loan is estimated. Utilizing these two variables with economic factors such as escalation rates and discount rates, the PVONE program determines the annual loan payment, the present value and the net present value of the system.

After developing the design tool, it was then used to predict insolation with Blacksburg, Virginia as the test site. Five cases of insolation were studied using both flat and tilt collectors. The results obtained from the PVONE program were compared to the actual insolation measured in Blacksburg in 1990. The design tool was also used to design three photovoltaic systems. The first system was designed with the maximum daily load as the system load. The second system designed utilized the average daily load as the system load and for the third system, the minimum daily load was used as the system load. The load demand for all the systems designed was a scaled down version of the load demand for Whittemore Hall at Virginia Tech. The load was scaled down to reflect actual load demand for small commercial buildings. All three systems were designed using Arco Solar M-55 photovoltaic modules and based on the average daily insolation in Blacksburg. The storage requirement for all three systems were sized based on the GC12V200B lead acid battery. To determine which of the three systems is feasible for Blacksburg, an economic analysis was performed using the PVONE program. Economic factors utilized in the analysis were the same for all three systems. Based on the annual energy output of the photovoltaic array and the net present value of the system, a decision was made on which of the systems can be implemented in Blacksburg.