

CHAPTER 6

Computer Model

6.1 Introduction

In the previous chapters, the underlying principles that a designer of photovoltaic systems needs to understand before beginning the design process have been addressed. This chapter discusses how the computer model developed is utilized. The logical structure of the computer model is presented including the variables that are needed to execute each block of the program. A detailed description of all the blocks that make up the computer model is presented. For a detailed description on how to use the program, see the appendix section of this research.

6.2 Programming Language

The computer model developed for this research is called PVONE and it is based on the MATLAB programming language. MATLAB is an interactive, matrix-based system for scientific and engineering numeric computation that encompasses visualization. MATLAB is a very fast programming language that solves complex numerical problems in a fraction of the time required by other programming languages such as FORTRAN or C. The fact that MATLAB is fast and can be run on several computer environments is what attracted me to develop the interactive computer model using this language.

6.3 General Description

The computer model developed for this research is called PVONE and it consists of twelve blocks labeled PV1 through PV12 which are interactive. Each block of the program performs a particular task and the user is asked for the input variables needed to execute any block of the program. In order to use this program, the user must have Matlab for Windows version 4.2c.1 or higher and the PVONE program installed in the computer's hard drive. Double

clicking the Matlab icon in the Program Manager window will open the Matlab command window. At the command prompt indicated by the symbol (>>) in the Matlab command window, type the program name and hit the return or enter key. Access to the program is obtained when the following statements appear on the computer's monitor,

1. Enter 1 at the cursor location to read the content of the program
2. To exit the program enter 0 at the cursor location, and
3. Enter PV block needed for analysis.

After entering each input variable requested by the program, hit the enter or return key.

At the end of executing any block of the program, statement 3 above will appear on the computer screen. To exit the program at any stage in your analysis, type 0 when statement 3 appears on the screen. The program also contains error messages that will appear on the screen and cause the program to stop analyzing any block. For example, if the month chosen to determine the insolation for a flat collector is January, which means a numerical value of one (1) was entered when the month variable was requested, and you want to know how much insolation is available at the location for a particular day and time, the program will request a Julian day and time. If a Julian day, such as 35 is entered, the program will check to make sure this value is within the month of January. Since 35 is a Julian day for February and not January, the program will display the following message on the screen: " Check Your Input Variables " and will stop executing this block of the program. To continue analyzing the aborted block, type the program name and enter block number again. Figure 6.1 below shows the logical structure of the PVONE program. By following the sequence depicted in figure 6.1, a complete analysis of predicting the amount of insolation available at a location, to designing a photovoltaic plant at the location and evaluating its economic performance over time is obtained. Note that after PV2 is executed, you can perform an insolation analysis for any month and collector by beginning either at PV3 or PV4. The only time necessary to run PV2 again, is when insolation needs to be determined for a new location. The remainder of this chapter discusses the input variables needed to run each block of the program. Results and discussions will be presented in chapter 7 and also in the appendix section of this research.

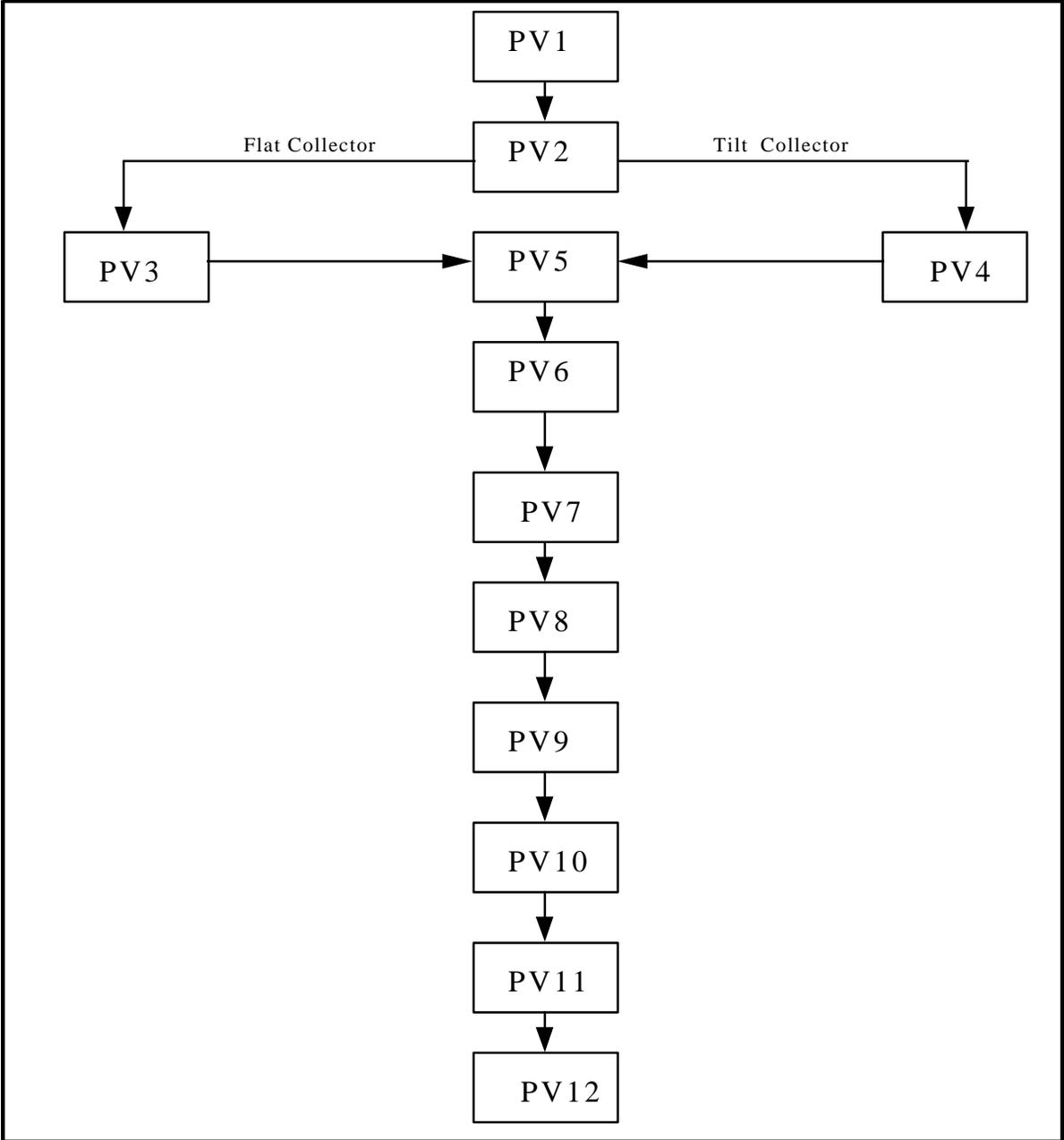


Figure 6.1: Logical Structure of the PVONE program

6.3.1 PV1 - Program Content

This block of the program simply contains the contents of the PVONE program. The output of this block is obtained by entering 1 when statement 3 above appears on the computer screen.

6.3.2 PV2 - Computation of Local Variables

To execute this block of the program, enter 2 when statement 3 above appears on the computer screen. With the exception of PV1, this block of the program must be executed before any other block as shown in figure 6.1 above. There is no output for this block of the program. The program will ask for a location and country along with following variables in order to execute this block of the program. The variables are;

- The Solar Constant in KW/m^2
- The Altitude of the location in Kilometers (Km)
- The Latitude of the location
- The Type of Climate of the location
- The Local Longitude for the location
- The Longitude of Standard Meridian for the location, and
- The Standard Clock Time of the location

The variables that are computed and stored are the approximate Sunrise and Sunset times at the location throughout the year. The name of location and country must be entered between special characters as shown in the appendix section of this research.

6.3.3 PV3 - Insolation Estimate For A Flat Collector

To execute this block of the program, enter 3 when statement 3 above appears on the computer screen. This block of the program is used to estimate the amount of insolation available at the location selected in PV2 under clear sky conditions in three scenarios as follows;

1. Instantaneous Insolation: This is the amount of insolation available for a chosen day and time at the location for a particular month of the year.
2. Total Insolation: This the amount of insolation available at the location between a specified time interval for a particular day and month of the year.
3. Daily Insolation: This the amount of insolation available at the location for all days of a specified month.

The following variables are need to execute this block of the program;

- Hemisphere of the location
- Month of the year (January = 1 and December = 12)
- Day of the Month specified by the Julian Day
- Time to Compute Instantaneous Insolation
- Time to Begin Recording Insolation
- Time to Stop Recording Insolation

The output files for this block of the program can be obtained by entering the appropriate value to each output question when it appears on the computer screen.

6.3.4 PV4 - Insolation Estimate For A Tilt Collector

This block of the program performs the same task as the block, PV3 above, except in this case the collector is tilted at an angle from the horizontal. Access to this block of the program is obtained by entering 4 when statement 3 above appears on the computer screen. The same variables used in PV3 will be requested along with the variable;

- Azimuth Angle.

The azimuth angle is the difference between the latitude of the location and the desired angle needed to tilt the collector. For example, if the latitude of a location is 35 degrees and the collector has to be tilted at angle of 45 degrees, the azimuth angle will be 10 degrees. This value should be entered in degrees only. The output files for this block of the program can be obtained by entering the appropriate value to each output question when it appears on the computer screen.

6.3.5 PV5 - Range of Insolation Levels

This block of the program uses the seven group classification given in [16] to determine the range of insolation levels on how the days in the month chosen either in PV3 or PV4 will be classified. It establishes a lower limit based on the amount of insolation for which days with insolation levels above this limit will be classified as sunny, then establishes upper and lower insolation limits for which days satisfying the various limits will be classified as mostly sunny, partly sunny, partly cloudy, cloudy, and overcast and finally establishes an upper insolation limit for which days with insolation levels below this limit will be classified as rain or snow days. By following instructions that appear on the screen, the output file specifying the range of insolation levels can be obtained.

6.3.6 PV6 - Classification of Days by Insolation Levels

This block of the program is used to select the days of the month that will be classified as sunny, mostly sunny, partly sunny, partly cloudy, cloudy, overcast and rain/snow days based on the range of insolation level determined in PV5 and on actual insolation data provided to the program. To execute this block of the program enter 6 when statement 3 above appears on the screen. PV2 and either PV3 or PV4 and PV5 must be executed before running this block of the program. There is a verification file that checks whether the month selected and the type of collector used either in PV3, or PV4 and PV5 are consistent with the values entered as the input variables for this block of the program. For example, if the month selected to do a flat collector analysis in PV3 was April, which means a numerical value of four, (4), was entered for the month variable, the file will check to verify that the same value was entered in PV5 and PV6 before the subroutine that performs the classification of days can be executed. If the month or collector variable is not consistent with what was selected previously in the above mentioned blocks, the error message, "Check Your Input Variables", will appear on the screen and the program will automatically stop executing this block of the program. By typing the program name and entering the block number, analysis of this block may be continued. You do not have to execute any of the previous blocks.

The data files needed to run this block will be explained in the appendix section of this research. The variables needed to execute this block of the program are;

- The Type of Collector used in the analysis
- The Year for which data is available to compare
- The Month of the year

There is no output file for this block of the program.

6.3.7 PV7 - Adjustment of Clear Sky Insolation

Access to this block is obtained by entering 7 when statement 3 above appears on the monitor. This block is used to adjust the insolation levels of the days in a month according to their classification as determined in PV6 by using the mid and lower range multipliers given in table 2.2 on page 20. The predicted insolation is then compared to the actual insolation in terms of percentage error. The variables used to run this block are;

- The Type of Collector Used in the Analysis
- The Month of the Year

The output files for this block of the program can be obtained by following instructions that appear on the computer monitor.

6.3.8 PV8 - Photovoltaic Module Characteristics

Access to this block of the program is obtained by entering 8 when statement 3 above appears on the screen. This block is used to determine the efficiency and area of the chosen photovoltaic module. The electrical characteristics that are requested in this block of the program will be used later in the design process to determine the array characteristics. The variables needed to run this block are;

- The Length of the Module in Meters
- The Width of the Module in Meters
- The Rated Power of the Module in Watts
- The Current at typical load in Watts
- The Short-Circuit current in Watts
- The Voltage at typical load in Volts
- The Open-Circuit voltage in Volts

The output file to this block of the program can be obtained by following instructions that appear on the computer monitor.

6.3.9 PV9 - Photovoltaic Array Analysis

Access to this block of the program is obtained by entering 9 when statement 3 above appears on the monitor. PV9 is used to determine the array characteristics of the proposed PV plant. There are two data files needed to run this block of the program. Details on these files are discussed in the appendix section of this research. The following variables are used to run this block of the program;

- Load Energy Demand
- Type of Load (A.C loads or D.C loads)
- Efficiency of the Power Conditioning Unit (Based on the type of Load)

- The Number of Power Conditioning Units
- The Packing Factor of the Module
- The Temperature Correction Factor of the Module
- The Soiling Factor
- Amount of Solar Energy for one day at the location
- The Number of Modules based on the decision whether to round up or round down
- The Number of Sub-Array Fields
- The Number of Modules in Parallel per Sub-Array
- The Number of Modules in Series per Sub-Array
- The Operating Frequency of the Array (Based on the power conditioning unit)
- The Output Current of the Array (Based on the power conditioning unit)

The variables listed above will be used in the subroutines to determine the array characteristics. The output characteristics of the PV array can be obtained by following instructions that appear on the computer monitor.

6.3.10 PV10 - Energy Output Analysis of a Photovoltaic System

This block of the program can be executed by entering 10 when statement 3 above appears on the monitor. This block of the program is used to determine how much energy is produced by the photovoltaic array designed in PV9 above and compares these values to load energy demand at the location on a monthly basis. Both graphical and numerical comparison of the energy output are provided. There is also a graphical output on how the PV system's output energy compares with the load demand for a single day. The output of this block is obtained by following the instructions that appear on the monitor. For the daily output energy comparison, the type of collector used must be specified. Instructions on how to specify the collector will appear on the monitor. There are no variables needed to execute this block of the program.

6.3.11 PV11 - Storage Requirements of a Photovoltaic System

Access to this block is obtained by entering 11 when statement 3 above appears on the monitor. PV11 is used to size the storage required by the stand-alone photovoltaic system that has been designed. The variables used to run this block of the program are;

- Coldest 24-hour Temperature at the location
- Capacity Correction Factor of the selected Battery
- Maximum Depth of Discharge of the Battery
- System Availability of the proposed PV System
- Individual Battery Capacity
- Nominal Battery Voltage

The output file for the storage system required by the stand-alone PV system can be obtained by following instructions that appear on the computer screen.

6.3.12 PV12 - Economic Analysis of a Photovoltaic System

To access this block, enter twelve, (12), when statement 3 above appears on the monitor. This block of the program is used to determine the total cost of the PV system. The program requests cost estimates of the various components including labor and then uses this information to calculate the total cost of the system. If money is borrowed to finance installation of the system, the program will request further economic assumptions. These assumptions will then be used to determine the amount of annual loan payments and the present value of the PV system at the end of its expected lifetime. Economic tables provided in Appendix C can be used to obtain the input variable, Uniform Present Worth. The variables used to run this block are;

- Expected Lifetime of PV System
- Cost per PV Module
- Support Structure Cost
- Cost per Power Conditioning Unit
This value is zero for a system designed to serve only DC loads
- Cost per Battery
- Wiring and Material Cost
- Design, Installation and Labor Cost
- Annual Property Increase
- Annual Insurance Premium
- Operations and Maintenance Cost
- Average Annual Price Escalation Rate over Lifetime of PV System in Percent
- Average Annual Discount Rate for Borrowing Money over Lifetime of PV
- Uniform Present Worth
- Percentage of PV costs deducted for Tax or Depreciation Credit
- Salvage Value of PV System after PV System Lifetime
- Loan Down Payment
- Number of Years Required to Payoff Loan
- Loan Discount Rate
- Annual Average Price Escalation Rate over term of Loan in Percent
- Loan Uniform Present Worth
- Control Room Cost
- Present Electricity Cost
- Annual Average Price Escalation Rate of Electricity
- Discount Rate for Alternative Investment
- Lifetime Uniform Present Worth

By following instructions that appear on the computer screen, the output files for this block of the program can be obtained.