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User's Manual for PVFORM: A Photovoltaic System Simulation Program For Stand-Alone and Grid-interactive Applications

D. F. Menicucci, J. P. Fernandez

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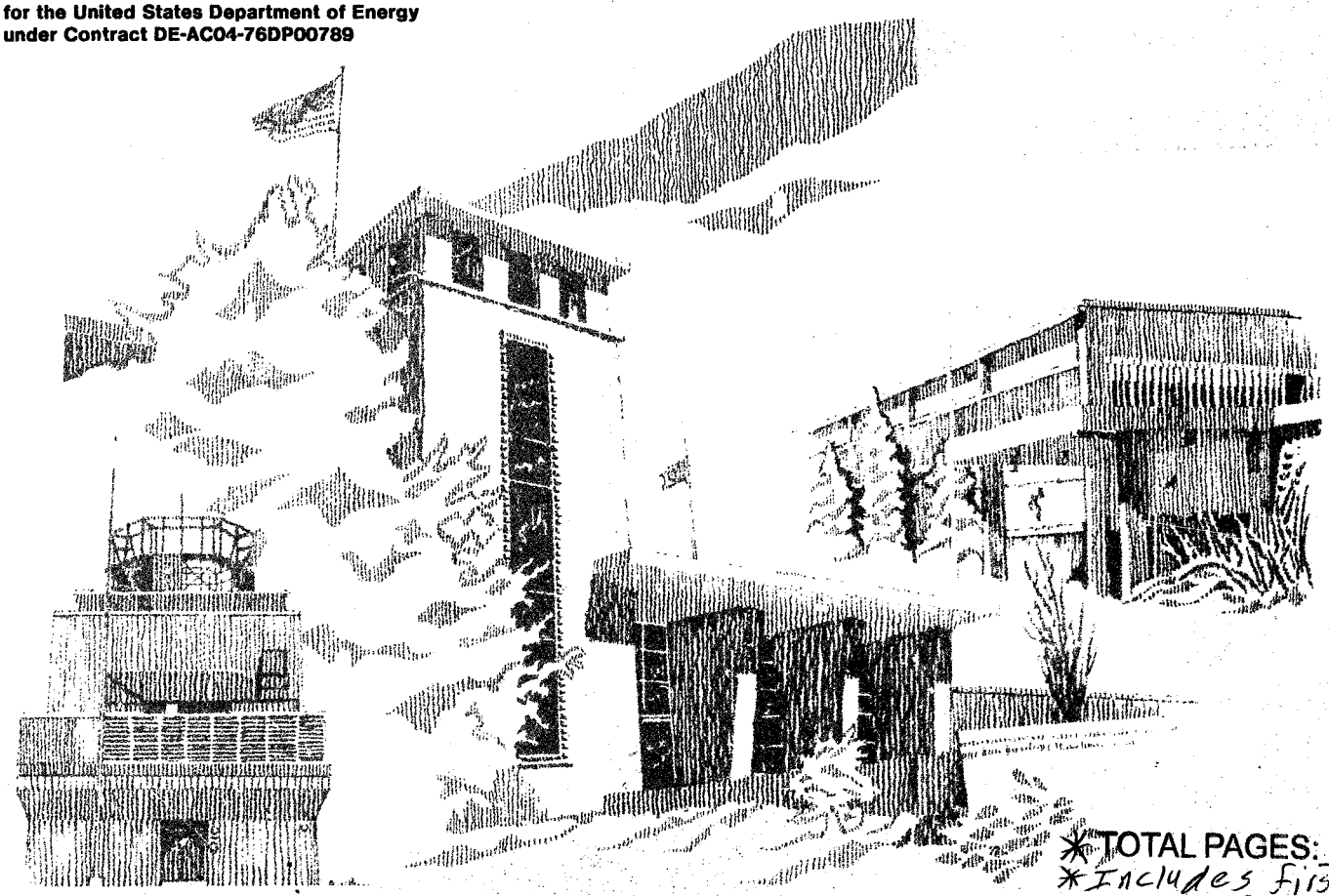

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ABSTRACT

Sandia National Laboratories has integrated improved photovoltaic (PV) system modelling techniques into a simplified program named PVFORM. The new model simulates hourly performance for a one-year period and is applicable to a grid-interactive or stand-alone PV flat-plate system. The program can be run on mainframe or personal computers. This manual describes how to operate the PVFORM program, with detailed examples of the required inputs. Sample outputs are also included and discussed. The document contains a copy of the PVFORM program on a floppy disk ready to use on an IBM personal computer.

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1. INTRODUCTION TO PVFORM VERSION 3.3[1]

During the design of a photovoltaic (PV) system, it is crucial to optimize the system's economic potential, given its proposed location and the expected operating conditions. The size of the system must be determined early in the design phase. Anticipated electrical load is the primary factor governing size of the system, but other factors are also important. Output is affected by weather (insolation level, ambient temperature, wind speed, etc.), which varies according to geographic location and season of the year, and by the mounting configuration (fixed, one-axis tracking, etc.). The amount of energy storage, if any, and its effect on size of the system must be determined. Initial costs must be kept within budget, and the economic benefits expected to be accrued over the system's lifetime must be maximized.

Computer simulations can be useful to the designer in analyzing the trade-offs possible with the system under design, provided that reliable results can be obtained. This manual describes a computer simulation program for PV system design that has been shown to provide performance predictions that are accurate to within 5% of actual experience. Welcome to PVFORM, and specifically to PVFORM Version 3.3!

Throughout this manual, the FORTRAN names of variables used in PVFORM Version 3.3 are enclosed in square brackets (for example, [IDYSKP]). In-text citations of references are enclosed in braces (for example, {6}).

Unless otherwise indicated with respect to a particular illustration, figures in this manual that depict either input to or output from PVFORM Version 3.3 make use of the default values of the various input and output parameters.

---

1 DISCLAIMER

This program was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government, any agency thereof, or any of their contractors or subcontractors. The views and opinions expressed herein do not necessarily state or reflect those of the United States Government, any agency thereof, or any of their contractors or subcontractors.

1.1 How PVFORM Version 3.3 Works

Given either the program-supplied default values or their user-supplied equivalents for each of a large number of input parameters (see Section 3 of this manual), PVFORM Version 3.3 performs a series of hourly calculations to determine the physical (photovoltaic) performance of the PV system being simulated. These iterative calculations sample the performance of the PV system throughout a simulated 365-day year of system operation. Within any simulated day on which system performance is sampled, the calculations are done "hourly" (24 times). The number of days sampled--and the interval between them--is determined by a user-variable input parameter called the Day Skip Factor [IDYSKP] that depends upon the purposes for which PVFORM Version 3.3 is being run. (See Section 2.2.2 of this manual for a complete explanation of the Day Skip Factor.) The results of these calculations are summarized on a monthly basis in output tables (see Section 4 of this manual).

You (the user) have the choice of simulating either a grid-interactive PV system or a stand-alone system. Figures 1 and 2 are block diagrams of simple stand-alone and grid-interactive photovoltaic systems, respectively. The program assumes that the simulated system is grid-interactive unless the Battery Analysis Flag [IBTFLG] (Section 2.2.6) has been set to "Y" or "1". If a grid-interactive system is modeled, the system is assumed to use power purchased from a local utility to supply that portion of the load not met by the simulated PV array. If the array produces more energy than can be consumed by the load, the excess energy is assumed to be sold back to the utility at a constant Energy Sellback Price [SELLBK] (Section 3.4.7).

If a stand-alone system is being modeled (that is, if [IBTFLG] has been set to "Y" or "1"), the program assumes that all energy produced by the simulated PV array is first applied to the external load, and any excess is then used to charge the battery bank. Energy that is not consumed either by the load or else by the batteries is considered to be wasted.

If you wish to model a stand-alone PV system, you will have to incorporate a backup energy source (such as a diesel-engine-driven generator) in the system; this is done by setting the capacity of the backup battery-charging system [CHRPWR] (Section 3.5.4) to a nonzero value and by specifying the conditions under which it will come into use.

You also have the option of causing PVFORM Version 3.3 to simulate the economic performance of the PV system under design. The same general arrangement of input, calculation, and output applies equally to the PV performance and to the economic performance aspects of a PVFORM run.

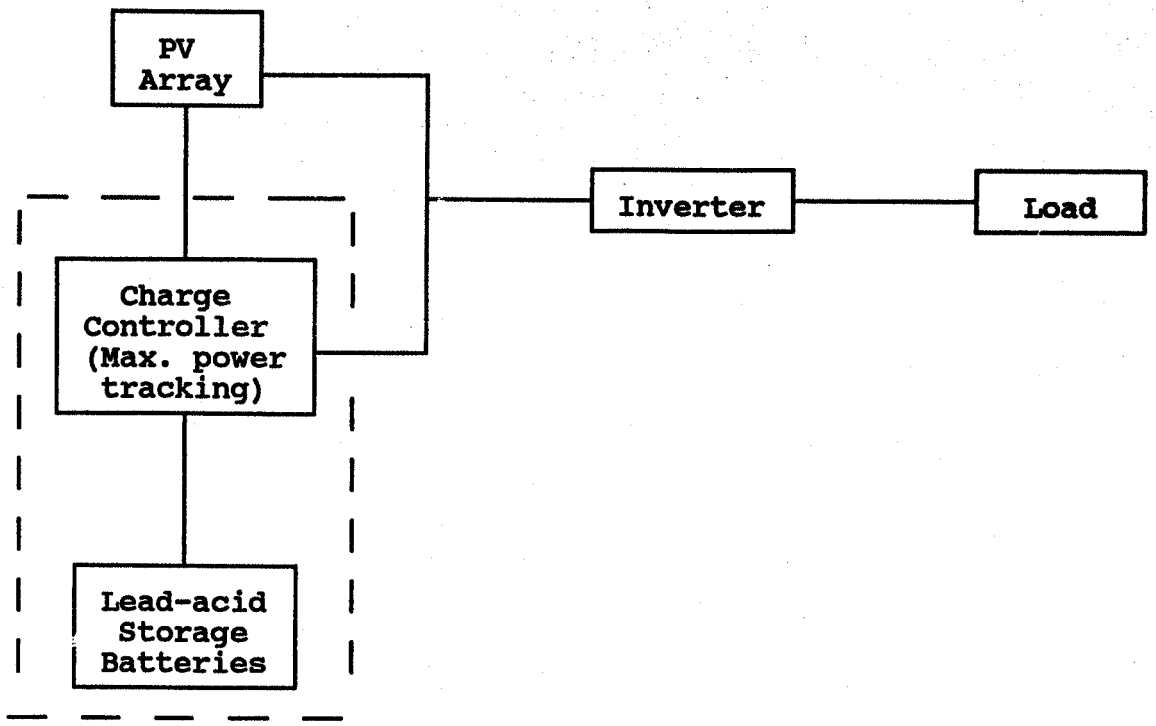

Figure 1. Stand-Alone Photovoltaic System

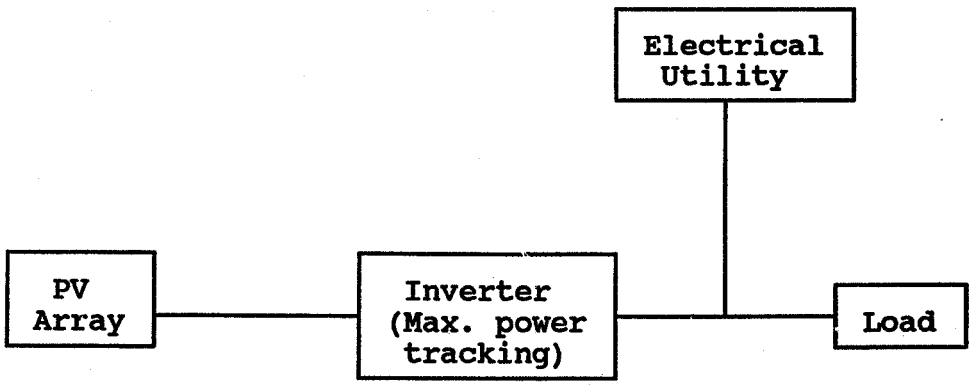

Figure 2. Grid-Interactive Photovoltaic System

1.2 What You Need To Run PVFORM Version 3.3

1.2.1 Hardware Requirements

PVFORM Version 3.3 will run on the family of IBM Personal Computers,[2] running MS-DOS Version 3.0 or later.[3] (The line-editor mode requires only MS-DOS Version 2.0 or later; see Appendix A for detail on using the line-editor mode.) PVFORM Version 3.3 should also run on any look-alike personal computer (PC) that is marketed as "IBM-compatible," although you may encounter unique problems in using some of these machines. Extensive testing of PVFORM Version 3.3 has been accomplished on a Leading Edge Model "D"[4] personal computer running MS-DOS Version 3.10. Whatever the make and model of the system unit, your system must include storage devices that are the equivalent of two disk drives, either floppy-disk or fixed-disk (hard-disk), in order to run PVFORM Version 3.3 successfully.

PVFORM Version 3.3 will also run on a minicomputer, such as a VAX 11/780,[5] or on any mainframe computer that supports ANSI FORTRAN 77. This manual, however, is written for the user who wants to run PVFORM Version 3.3 on a PC.

1.2.1.1 Mass Storage Capacity

PVFORM Version 3.3 requires a minimum of 256 kilobytes of random access memory.

1.2.1.2 8087/80287 Math Co-Processor

Although an Intel 8087 or 80287[6] math co-processor (or equivalent microchip) is not an absolute necessity for running PVFORM Version 3.3, the authors strongly recommend that you install one if your computer does not already incorporate it. The 8087/80287 decreases execution time by a significant margin. As a worst-case example, PVFORM Version 3.3 runs that took less than 20 minutes on a machine equipped with an 8087 required more than 9 hours on the same computer before the 8087 was installed!

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2 IBM Personal Computer is a registered trademark of International Business Machines Corp.

3 MS-DOS is a registered trademark of MicroSoft Corp.

4 Leading Edge and Model "D" are registered trademarks of Leading Edge Products, Inc.

5 VAX 11/780 is a registered trademark of Digital Equipment Corp.

6 Intel 8087 and 80287 are registered trademarks of Intel Corp.

1.2.2 Software Requirements

As a user of PVFORM Version 3.3, you have been provided two floppy disks (diskettes), one (Figure 3) labelled

P V F O R M
V E R S I O N 3 . 3

PROGRAM DISK

A Photovoltaic Simulation Code
Please copy and return diskette

Figure 3. Program Disk Label

and the other (Figure 4) labelled

P V F O R M
V E R S I O N 3 . 3

PVFORM source codes
TMY.DAT for Albuquerque, NM

Please copy and return diskette

Figure 4. Data Disk Label

These two diskettes will be referred to as the "Program Disk" and the "Data Disk," respectively, in the descriptions that follow. You should, as a very first step in becoming acquainted with PVFORM Version 3.3, copy both the Program Disk and the Data Disk onto storage media of your own. With these two disks, you have access to the specific software files described below.

1.2.2.1 Typical Meteorological Year (TMY) Data File (TMY.DAT)

Every time you run PVFORM Version 3.3, you must provide a "Typical Meteorological Year (TMY)" data file. Such data are produced by the National Climatic Center of the U.S. Department of Commerce's National Oceanic and Atmospheric Administration (NOAA) in Asheville, North Carolina,[7] in the form of magnetic

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7 The commercial telephone number for the National Climatic Center is (704) 258-2850; the FTS number is 672-0683.

media, including floppy disks and tapes suitable for a mainframe computer. These files are compiled for major metropolitan areas in the fifty United States and their possessions and territories, and for selected overseas locations. The TMY data represent a "typical" year of weather for a specific location. However, PVFORM Version 3.3 does not require NOAA TMY data as such. The requirement is that hourly weather data in the format required for PVFORM be provided in a compatible medium. (You can thus examine how your simulated PV system would perform in a specific meteorological year, not a "typical" year as determined by the NOAA.) The meteorological data in these files comprise 4 values for every hour of a 365-day year, or a total of 35,040 data points. For PCs, the required FORTRAN format is 4F5.0. The four values recorded for each hour are

- Direct radiation (KJ/m^2)
- Global radiation (KJ/m^2)
- Ambient temperature (°C × 10)
- Wind speed (m/s × 10)

As indicated on the diskette label, the Data Disk contains a TMY.DAT file for Albuquerque, New Mexico. For locations other than Albuquerque, a known source for TMY data files in disk format is

Ray Bahm
2513 Kimberley Ct NW
Albuquerque NM 87120

Phone: (505) 831-3911

1.2.2.2 Load Data File (USRLOAD.DAT)

You have the option of supplying a full year's worth of load data (365 simulated days times 24 hourly load values per day) to be used in the PVFORM Version 3.3 computations. If you exercise this option, by setting [LODFLG] = "2" (see Section 2.2.3), [IDYSKP] will be set to "1", and you will have to provide your own load data file in the following format:

All records are 80 characters long, and the first record in the file is a title, which must be included even if it is blank. Following the title are 365 sets of four records each. Each set of four records represents the load, in watts (W), for one day of the year. The first record in each set contains only the number

of the Julian day, written in FORTRAN format I4 (i.e., 0001 through 0365). The following three records in each set contain the load values, in watts (W), for the 24 hours in that day, with each record reflecting eight of the hours. The FORTRAN format for these three records is 8F10.0. Thus, for each four-record set, the load for the first hour is in the left-most ten positions of Record 2, and the load for the last hour is in the right-most ten positions of Record 4.

NOTE: Your other options with respect to the Load Profile Option [LODFLG] are either to input just one 24-hour load profile ([LODFLG] = "1"), to be applied to every day of the simulated year, or else to use the internal, program-supplied, default load profile ([LODFLG] = "0") (see Figure 5).

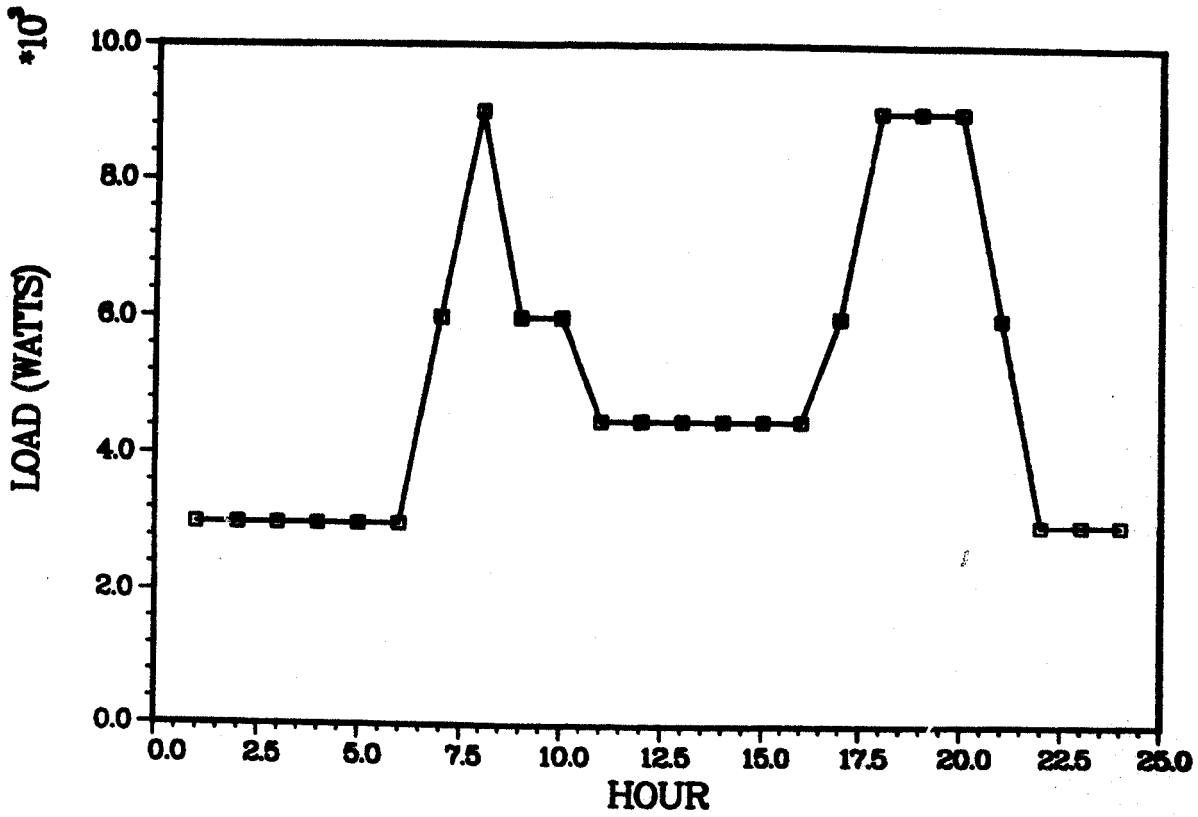

Figure 5. Plot of Default Load Profile, [LODFLG] = 0

1.3 How to Run PVFORM Version 3.3

The exact procedure you will need to follow in order to make successful PVFORM runs will depend largely on the specific makes, models, and configurations of hardware that constitute your computer system. The following are general guidelines only and must be supplemented and adapted for use with your particular PC system.

NOTE: If you intend to exercise the Hourly Write Option, by setting [IPRFLG] = "Y" (Sections 2.2.4 and 4.6), you should, as a preparatory step, prepare a blank, formatted, floppy disk for this purpose to be inserted in Drive A: when you are prompted to do so.

1.3.1 PC System with Two Floppy-Disk Drives

Insert your copy of the PVFORM Program Disk in Drive A: and your Data Disk in Drive B:. Type "A:" to set the A: drive as the default drive, and type "PVRUN" to execute.

1.3.2 PC System with One Floppy-Disk and One Hard-Disk Drive

After copying the PVFORM Program Disk and Data Disk to the desired drive (C: or D:) and subdirectory, display PVFORM as the current directory in that drive, and type "PVRUN" to execute.

1.4 Where PVFORM Version 3.3 Came From

PVFORM Version 3.3 is principally the work of an engineer at Sandia National Laboratories, Albuquerque (SNLA), with programming support from another engineer from the New Mexico Engineering Research Institute (NMERI), a subsidiary of the University of New Mexico under contract to SNLA:{1 2}

- David F. Menicucci, an employee of SNLA, is responsible for research, analysis, code design and development, and applications
- James P. Fernandez, an employee of NMERI, is responsible for small computer implementation and code testing, evaluation, and maintenance

Questions, comments, or suggestions should be forwarded to the appropriate individual at this mailing address:

Sandia National Laboratories
P.O. Box 5800
ATTN: Organization 6223
Albuquerque, New Mexico 87185

Telephone inquiries should be directed either to Dave Menicucci at (505) 846-3068 or to Jim Fernandez at (505) 844-8827.

PVFORM Version 3.3 uses several improved models developed by SNLA and its subcontractors. These include:

- The anisotropic radiation model developed by Richard Perez of the State University of New York at Albany{3 4}
- A cell-temperature model developed by Martin Fuentes, SNLA{5}
- A battery model developed by Richard Chapman, SNLA,{6} and by BDM Corporation under contract to SNLA{7}
- A power-conditioning model developed by Dave Menicucci, SNLA{8}
- A life-cycle-cost economics model developed by Dave Menicucci, SNLA

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2. MAJOR OPTIONS AVAILABLE IN PVFORM VERSION 3.3

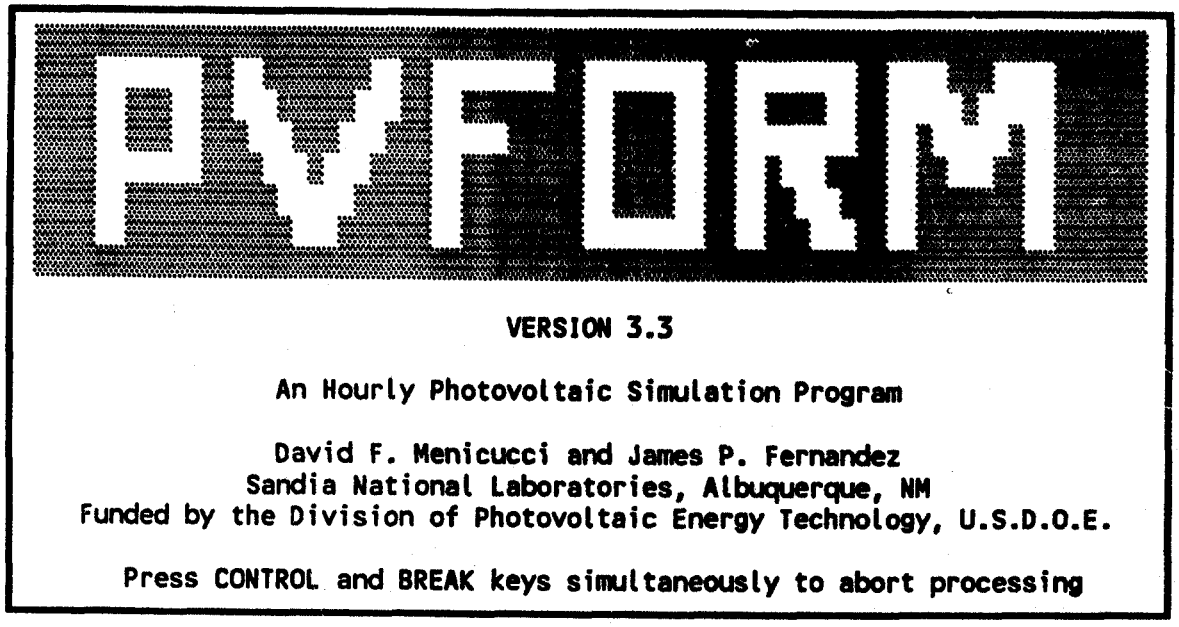
This section presents the various options available to you within PVFORM Version 3.3. In general, the sequence of presentation in this section corresponds to the sequence in which the program presents the options to you. Exceptions to this general rule are pointed out where they occur.

NOTE: Although the same major options are available to you regardless of the type of graphics adapter you have installed in your PC system, the format in which these options are displayed, and even the exact sequence in which they are presented to you, differ sharply depending on which type of adapter you are using. The input edit routine, during which you select the options you want and the values of the user-variable parameters you wish to vary from the default set of values (see Section 3) in a given PVFORM run, will function in either of two distinctly different modes: The more streamlined and straightforward mode is referred to hereafter as the "screen-oriented" or "screen-edit" mode. The less efficient, but nonetheless equally capable, mode is referred to hereafter as the "line-oriented" or "line-edit" mode. The two different modes pertain only to the operation of editing your input file. Execution and output are the same no matter which mode you employ in the input-editing function.

If you are uncertain whether your PC system will enable you to run the screen-oriented version of PVFORM Version 3.3, try the following simple test: Type "PVRUN" on your keyboard and observe whether the display on your monitor looks like Figure 6, including the prompt at the bottom of the screen concerning what to type when you are finished with the introductory screen. If it does, you can proceed to follow that prompt and the remainder of the instructions in the body of this manual (Sections 2 and 3) that apply to the screen-oriented input-editing mode. If your display does <u>not</u> match Figure 6, then you will have to follow the instructions in Appendix A to this manual that apply to the line-oriented input-editing mode of PVFORM.

2.1 The Introductory PVFORM Screen

If the screen editor can be used, the file that executes PVFORM Version 3.3 will be the one named PVRUN.EXE. When you first type "PVRUN.EXE" (or simply "PVRUN") following the prompt that identifies your current disk drive, your monitor will display the following (Figure 6):



Enter PVFORM input file (and path) to edit or <RETURN> for DEFAULT values

Figure 6. Introductory Screen

If you intend to edit a pre-existing PVFORM input file, type the filename and path that will provide access to this file. The prompt at the bottom of the introductory screen will change to read as shown in Figure 7:

```
PVFORM

VERSION 3.3

An Hourly Photovoltaic Simulation Program

David F. Menicucci and James P. Fernandez
Sandia National Laboratories, Albuquerque, NM
Funded by the Division of Photovoltaic Energy Technology, U.S.D.O.E.

Press CONTROL and BREAK keys simultaneously to abort processing

Attempting to use an older version input file   OUTPUT FILE WILL BE UPDATED
Press a key to continue
```

Figure 7. Modified Introductory Screen
(when pre-existing input file is to be edited)

NOTE: The differences between Version 3.3 of PVFORM and earlier versions of this basic simulation program are significant. "Older version input files," that is, input files created with earlier versions, are not upwardly compatible with Version 3.3. It is practically impossible, and certainly not worth the effort, to edit input files that were created with previous versions. You will save time, money, and mental energy if you create a new input file using the current Version 3.3 software.

If you wish to create a new PVFORM input file, type a carriage return (<Enter> or <Return>). The next screen (Figure 8) will then be displayed.

2.2 Modelling Options

Whether you have opted to edit an older, pre-existing input file or else have chosen to create a new one, the modelling options open to you are these:

- Selection of one Day Skip Factor [IDYSKP] out of 29 discrete integer values available
- Selection of one Load Profile Option [LODFLG] out of three discrete integer values available
- Whether to use the Hourly Write Option [IPRFLG]
- Whether to use the Economic Analysis Option [IECON]
- Whether to use the Battery Analysis Option [IBTFLG]

All these choices are made from the Modelling Options screen (Figure 8), which immediately follows the introductory screen.

2.2.1 Modelling Options Screen

If you elected to edit an older version input file, the name of that file is displayed at the first point on this screen where the cursor is positioned. This filename can be changed if you wish to save the current input file under a different name. If you opted for the default values, the cursor will point out a blank area on your monitor screen where you must enter a unique filename you have devised to identify this particular PVFORM run. Your filename may include any alphanumeric characters you choose, as defined by DOS file-naming conventions, but it may not include any spaces or special characters.

After you have entered an acceptable name for your input file, you must confirm or else change, as appropriate, both the drive letter and the filename of the TMY.DAT file you wish to have PVFORM use during this run, and also the correct drive letter and filename of the external load file (if any) you intend to use with Load Profile Option 2, [LODFLG] = "2" (see Section 2.2.3). An incorrect filename for either the TMY or the load data file will result in a message, **"Error number 2015"**, flashed quickly on the screen when execution of PVFORM begins. If this happens, verify the existence and name of the file you chose, or else start again. Except for your selection of one out of three "load profile options" (see Section 2.2.3), your remaining choices from

```
                    MODELLING OPTIONS

Save input file as :

TMY file specification     B:TMY.DAT

External load file spec.   B:USRLOAD.DAT

                Day skip factor          6

                Load profile option      0 internal load profile

                Hourly write option      N

                Economic analysis        N

                Battery analysis         N

PgUp = Previous screen    PgDn = Next screen    Esc = Exit editor
```

Figure 8. Modelling Options Screen

this screen are simple "Y" (yes) or "N" (no) inputs. For a description and illustration of the "Next screen" available, see Section 3.1 of this manual.

2.2.2 Day Skip Factor [IDYSKP]

The Day Skip Factor [IDYSKP] determines how often the TMY weather data will be sampled and how many times the calculations will be performed. The minimum value of [IDYSKP], the integer "1", means that no days of weather data will be skipped; every day in the 365-day simulation will be used in the calculations of system performance, system cost, battery performance, etc. The maximum value of [IDYSKP], the integer "29", means that the weather data will be sampled at intervals of approximately one month and that the calculations will be performed the minimum number of twelve times in the simulation of a 365-day year.

Your selection of an appropriate value of [IDYSKP] should be influenced primarily by consideration of the accuracy you desire in the results of PVFORM Version 3.3. The effect of increasing [IDYSKP] within the range of "1" through "29" is to decrease program execution time while also decreasing the accuracy of the

output. These contradictory effects are not easy to quantify. Very roughly, execution time is inversely proportional to [IDYSKP]. The loss of accuracy with increasing [IDYSKP] is dependent upon your particular application of a given PVFORM run and upon the entire set of user-variable input parameters you selected for that run. Note that PVFORM extrapolates (multiplies) monthly totals from the day(s) simulated for a given month. This method produces less accurate results because the day(s) simulated may be far from "typical" for that given month. See Figure 9 for a graphic portrayal of the effect of [IDYSKP] upon the accuracy of PVFORM's calculation of a basic output parameter, the dc energy produced by the simulated PV system. As a rule of thumb, any [IDYSKP] greater than "6" will introduce enough error into your calculations to make the results only marginally useful for purposes of analysis. For ballpark estimates (for getting the parameters roughly in line), values of [IDYSKP] greater than "6" will probably yield results of adequate accuracy. Once the gross estimates are done, move to a Day Skip Factor of "6" or less (preferably less).

If you elect to model a battery system, PVFORM Version 3.3 will automatically set [IDYSKP] = "1", because battery performance is a continuous variable: Today's state of charge (SOC), for example, is dependent on yesterday's charge and discharge schedule. Current SOC cannot be computed without knowing the complete SOC history; hence, PVFORM Version 3.3 cannot skip any days.

2.2.3 Load Profile Option Flag [LODFLG]

The Load Profile Option Flag [LODFLG] expresses your choice among three options with respect to the 24-hour power load profile against which the output of the simulated PV array will be matched:

[LODFLG] = "0"	You may use a single, 24-hour, program-supplied load profile and apply it to every day in the simulated year for which you want to have calculations performed.
[LODFLG] = "1"	You may use a single, 24-hour load profile that you supply and apply it to every day in the simulated year for which you want to have calculations performed.

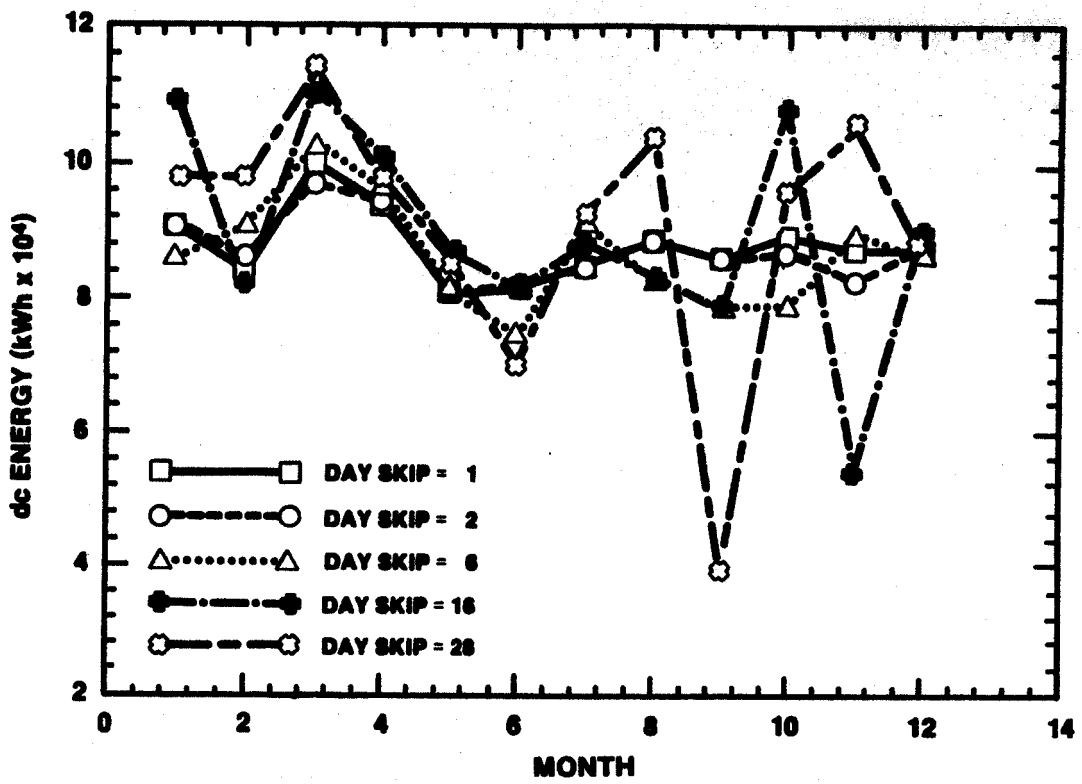


Figure 9. Effect of Day Skip Factor on Predicted Energy

[LODFLG] = "2" You may use an entire set of 365 (one for each day in the simulated year--regardless of how many times you want to have calculations performed), 24-hour load profiles that <u>you</u> supply and apply them to each day for which you want to have calculations performed.

If you set [LODFLG] = "0", you will obtain in output the results of calculations based on the set of 24 program-supplied default values (one for each hour of the day) for power load. See Figures 5 and 13.

If you set [LODFLG] = "1", you will be given an opportunity to edit the Load Profile screen, which displays the power values that you have selected, either intentionally or by default, for each hour of the profile day. See Section 3.3 for instructions on editing the Load Profile screen.

If you set [LODFLG] = "2", you will be required to provide a full year's worth of 24-hour load profile input data, and the program will effectively set [IDYSKP] = "1". See Section 1.2.2.2.

2.2.4 Hourly Write Option Flag [IPRFLG]

The Hourly Write Option Flag [IPRFLG] expresses your decision whether to have PVFORM Version 3.3 write, to a blank, formatted disk that you supply, a file (PLOT.DAT) of output data concerning system (and battery, if applicable) performance for every hour of every simulated day for which you have calculations performed. If you are executing PVFORM from a hard disk, the PLOT.DAT file will be written to the default drive. See Section 4.6 for a description of the output data and the format in which they are written to the disk file. A message (Figure 10) will be displayed, describing the amount of storage needed for the file, which will vary between 6 kilobytes and 1393 kilobytes, depending on the modelling options and the Day Skip Factor chosen.

```
YOU HAVE REQUESTED THE HOURLY WRITE OPTION

        Based on a day skip factor of 29

        PLOT.DAT will be approximately   26 kb large

If this will exceed the remaining storage capacity of
the default drive, place a blank formatted disk in the
default drive and continue.  If there is still not
enough capacity, choose the re-edit option on the next
screen and either increase the day skip factor or set
the hourly write option to 'N'.

If you have opted for battery subsystem modelling,
changing the day skip factor will not affect file size.

                PRESS A KEY TO CONTINUE
```

Figure 10. Hourly Write Option Caution Message

Set [IPRFLG] = "Y" if you want to invoke the hourly write option, or else set [IPRFLG] = "N" if you wish to omit this portion of output.

2.2.5 Economic Analysis Flag [IECON]

The Economic Analysis Flag [IECON] expresses your decision whether to have PVFORM Version 3.3 perform any economic analyses on your simulated PV system. If you set [IECON] = "N", no economic analysis will be done. You will not have an opportunity

to edit the System Cost Information screen (see Section 3.4), and the input parameters it contains will not be used in this particular PVFORM run.

If you set [IECON] = "Y", then you will probably wish to edit the input parameters that will be used in the economic analyses. These parameters are displayed on the System Cost Information screen. See Section 3.4 for descriptions of these parameters.

2.2.6 Battery Analysis Flag [IBTFLG]

The Battery Analysis Flag [IBTFLG] expresses your decision whether to simulate a stand-alone PV system, one with a bank of flooded lead-acid batteries to power the system when solar energy is insufficient. If you set [IBTFLG] = "N", then you have chosen to omit all battery-related portions of PVFORM Version 3.3, including those parts of the economic analyses that involve battery performance and costs. You will instead be simulating a grid-interactive PV system.

If you set [IBTFLG] = "Y", you have opted to use all of the features of PVFORM Version 3.3 that relate to the simulation of a stand-alone PV system. You have also opted to employ a Day Skip Factor [IDYSKP] = "1", and you will obtain output from PVFORM Version 3.3 based on the results of 365 sets of calculations. You will be enabled to edit the input parameters on the Battery Information screen (see Section 3.5).

2.2.7 When You Have Finished Editing Your Input File

As soon as you "Exit editor" by pressing the <Escape> key, your input selections, including the major modelling options and the value of each user-variable input parameter, are confirmed and are written to the file you named earlier (see Section 2.2.1). Your system will then display the following (Figure 11):

```
OUTPUT SUMMARY AND RE-EDIT OPTIONS

(S)creen     - output scrolls by quickly
(P)rinter    - output to device PRN
(D)isk file  - output to file with opportunity to view

(R)e-edit DEFAULTS
(E)dit a new input file

(Q)uit PVFORM environment and return to DOS

Choose S,P,D,R,E,Q ?
```

Figure 11. Output Summary and Re-Edit Options Screen

Follow the on-screen prompts to select the output device to which you want PVFORM to direct the results of its computations.

If you elect to have PVFORM write all the output to a disk file, the display will change as shown in Figure 12 to prompt you to enter either a new, unique filename for the disk file or else a <Return> for the default filename PVOUT.DAT.

```
OUTPUT SUMMARY AND RE-EDIT OPTIONS

(S)creen     - output scrolls by quickly
(P)rinter    - output to device PRN
(D)isk file  - output to file with opportunity to view

(R)e-edit DEFAULTS
(E)dit a new input file

(Q)uit PVFORM environment and return to DOS

Choose S,P,D,R,E,Q ? D

Enter file name or <RETURN> for PVOUT.DAT?
```

Figure 12. Modified Output Summary and Re-Edit Options Screen (when output is to be written to disk file)

If you elect to have output written to a disk file, you will be given an opportunity to view the contents of that file on your monitor. The following screen (Figure 13) will appear shortly after execution ("running") ends:

```
*** Use Cursor keys when viewing, Esc TO EXIT ***
Do you want to view PVOUT.DAT ?
```

Figure 13. "Viewing Output on Disk File" Screen

Once you have chosen "S", "P", or "D", as appropriate, your system will display the following (Figure 14):

```
Running PVFORM (8087 version) ...
```

Figure 14. "Running PVFORM" Screen

After PVFORM Version 3.3 finishes all the requested computations and has sent the output to the designated devices, your system will display the following (Figure 15):

```
Do you want to run again ? (Y/N)
```

Figure 15. "Do You Want to Run Again?" Screen

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3. USER-VARIABLE INPUT TO PVFORM VERSION 3.3

PVFORM Version 3.3 permits you to specify your own values for as many as 56 different input parameters for your PV system simulation. The program will set default values for any parameters you do not choose to specify.

3.1 Array Description Variables

The Array Description screen displays the eight user-variable input parameters that define the location, orientation, and general operating characteristics of the PV system you wish to simulate. The Array Description screen (Figure 16) is made available for you to edit in every PVFORM run.

ARRAY DESCRIPTION

Site latitude	35.0	degrees
Array tilt	35.0	degrees
Array azimuth	0.0	degrees east of south
Tracking flag	1	fixed tilt
Array area	260.0	square meters
Mismatch and line losses	.0350	fraction
Ground albedo	.30	fraction
Average array height	2.0	meters

PgUp = Previous screen PgDn = Next screen Esc = Exit editor

Figure 16. Array Description Screen

3.1.1 Site Latitude [TLAT]

The Site Latitude [TLAT] used in PVFORM Version 3.3 is the north latitude of the site where the PV array is located, expressed in positive degrees and tenths of a degree. For south latitudes, [TLAT] is expressed in negative degrees and tenths of a degree.

3.1.2 Array Tilt [TILT]

The Array Tilt [TILT] used in PVFORM Version 3.3 is the tilt angle of a flat-plate PV array with respect to horizontal, expressed in degrees and tenths of a degree. This parameter must be specified, at least by default, even for horizontal-tracking systems ([ITRK] = "2" or "3"), in which cases [TILT] serves as a location-holder rather than as the tilt parameter in array-performance calculations.

3.1.3 Array Azimuth [TAZM]

The Array Azimuth [TAZM] used in PVFORM Version 3.3 for north latitudes is the azimuth of a fixed, flat-plate PV array with respect to south, expressed in degrees and tenths of a degree east of south. For south latitudes, the value is expressed in degrees and tenths of a degree west of north (the Array Description screen changes to reflect this difference when a negative value is entered for [TLAT]). PVFORM Version 3.3 understands 360.0° to be the same orientation as 0.0° azimuth.

3.1.4 Tracking Flag [ITRK]

The Tracking Flag [ITRK] expresses your choice of the most appropriate among six available descriptions of the tracking system employed by your simulated PV system:

[ITRK] = "1"	A fixed, flat-plate PV array
[ITRK] = "2"	A PV array that tracks on a horizontal, east-west axis
[ITRK] = "3"	A PV array that tracks on an axis oriented north-south, with the entire axis tilted up from the horizontal at an angle of [TILT] degrees
[ITRK] = "4"	A PV array that tracks on a north-south axis with the plane of the array tilted up from the horizontal at an angle of [TILT] degrees

[ITRK] = "5" A PV array that tracks on a vertical axis with the plane of the array tilted up from the horizontal at an angle of [TILT] degrees

[ITRK] = "6" A PV array that tracks along two axes, maintaining an orientation "normal" to the direct beam radiation at all times

3.1.5 Array Area [SIZE]

The Array Area [SIZE] employed in PVFORM Version 3.3 is the area of the entire simulated PV array, that is, the sum of the areas of all of the modules, expressed in square meters and in tenths thereof.

3.1.6 Mismatch and Line Losses [TMLOSS]

The Mismatch and Line Losses [TMLOSS] used in PVFORM Version 3.3 are the sum of all mismatch and line losses throughout the PV system being simulated, expressed as a decimal fraction of the total dc power output from the PV array. Input values outside the range 0.00 < [TMLOSS] > 0.080 will cause the default value to be set. When the input value of [TMLOSS] is echoed in the Summary of PVFORM System Performance Input Parameters (Section 4.1), it is expressed as a percentage rather than as a decimal fraction.

3.1.7 Ground Albedo [REFL]

The Ground Albedo [REFL] used in PVFORM Version 3.3 is an indication of how reflective the ground surface is in the immediate area of the simulated PV array. For example, fresh snow cover has an albedo of 0.75 to 0.95, sandy soil has an albedo of 0.15 to 0.40, meadows and fields have an albedo of 0.12 to 0.30, densely built-up areas have an albedo of 0.15 to 0.25, and dark, cultivated soil has an albedo of 0.07 to 0.10. This value is used to calculate how much solar radiation is reflected off the earth's surface and onto the array.

3.1.8 Average Array Height [HEIGHT]

The name of this user-variable input parameter is self-explanatory. [HEIGHT] is expressed in meters and tenths of a meter above ground level. You should input the average height of the array, that is, one half the sum of the top height plus the bottom height. Any input values outside the allowable range of 0.0 < [HEIGHT] > 10.0 m will cause the default value of 2.0 m to be set.

3.2 Module Description and PCU Description Variables

The Module Description and Power-Conditioning Unit (PCU) Description screen (Figure 17) displays four input variables that together describe the thermal characteristics of the photovoltaic cells that make up the PV module(s) being simulated, plus two input variables that describe the power-conditioning system. The Module Description and PCU Description screen is made available for you to edit in every PVFORM run.

MODULE DESCRIPTION

Installed NOCT	46.00	degrees C
Reference temperature	46.00	degrees C
Reference efficiency	.0900	fraction
Efficiency reduction coef.	.0043	change/degree C

PCU DESCRIPTION

PCU input rating	26.00	kilowatts
PCU efficiency	.90	fraction

PgUp = Previous screen PgDn = Next screen Esc = Exit editor

Figure 17. Module Description and PCU Description Screen

3.2.1 Installed Nominal Operating Cell Temperature [TINOCT]

The Installed Nominal Operating Cell Temperature [TINOCT] used in PVFORM Version 3.3 is the temperature a PV module will achieve if it is subjected to a particular set of atmospheric test conditions with the module mounted in a specific configuration. Nominal operating cell temperature (NOCT) tests are conducted for modules on open racks under standard conditions of 800 W/m^2 insolation, 20°C air temperature, and 1 m/s wind speed. NOCT for the module(s) you are simulating should be obtained from the

manufacturer's specifications. Installed nominal operating cell temperature (INOCT) tests are conducted with the module mounted in a specific way (for example, with a 2-inch standoff from a roof surface). Thus, a specific module will have only one NOCT but many INOCTs, depending on mounting configuration. In PVFORM, [TINOCT] is expressed in degrees Celsius and tenths of degrees. See Reference 4 and the table below for assistance in selecting the appropriate [TINOCT] for your PV system.

Table 1.

Method for Estimating INOCT
from NOCT and Mounting Configuration

Rack Mount	INOCT = NOCT - 3°C
Direct Mount	INOCT = NOCT + 18°C
Standoff/Integral	INOCT = NOCT + X

W (inches)	X (°C)
1	11
3	2
6	-1

where W is standoff, entrance, or exit height/width, whichever is minimum.
Add 4°C if channeled.

3.2.2 Reference Temperature [REFTEM]

The Reference Temperature [REFTEM] used in PVFORM Version 3.3 is the temperature at which the manufacturer of the PV module has specified the efficiency of that module. You can also measure this parameter directly for your own system. It is used in PVFORM Version 3.3, together with the Reference Efficiency [REFEFF] (Section 3.2.3) and the Efficiency Reduction Coefficient [PWRDGR] (Section 3.2.4), to calculate the module's efficiency at any temperature other than [REFTEM]. It is expressed in degrees Celsius and tenths of degrees.

3.2.3 Reference Efficiency [REFEFF]

The Reference Efficiency [REFEFF] used in PVFORM Version 3.3 is the efficiency of the PV module when operating at the Reference Temperature [REFTEM]. Like most efficiencies, [REFEFF] is

expressed as a fraction, the ratio of energy output to energy input. When [REFEFF] is echoed in the Summary of PVFORM System Performance Input Parameters (Section 4.1), it is expressed as a percentage rather than as a decimal fraction.

3.2.4 Efficiency Reduction Coefficient [PWRDGR]

The Efficiency Reduction Coefficient [PWRDGR] used in PVFORM Version 3.3 is the rate at which the PV module's efficiency decreases with increasing temperature. Typical coefficients range from about 0.0030/°C to 0.0070/°C for silicon-cell modules. The unit of [PWRDGR] is fractional change in efficiency per degree Celsius. When [PWRDGR] is echoed in the Summary of PVFORM System Performance Input Parameters (Section 4.1), it is expressed in "%CHNG/DEG C".

3.2.5 Power-Conditioning Unit (PCU) Input Rating [PCRATE]

The PCU Input Rating [PCRATE] used in PVFORM Version 3.3 is the rated input of the inverter, expressed in watts (W). When [PCRATE] is echoed in the Summary of PVFORM System Performance Input Parameters (Section 4.1), it is expressed in kilowatts (kW).

3.2.6 Power-Conditioning Unit (PCU) Efficiency [EFFFP]

The PCU Efficiency [EFFFP] used in PVFORM Version 3.3 is the conversion efficiency of the inverter at full power, expressed as a fraction. When [EFFFP] is echoed in the Summary of PVFORM System Performance Input Parameters (Section 4.1), it is expressed as a percentage.

3.3 Load Profile Variables

The Hourly Load Profile screen (Figure 18) provides the user-variable input values of the external electrical load that the simulated PV system is to satisfy, with one load value for each of the 24 hours in a simulated day. The Hourly Load Profile screen is made available to be edited only when the Load Profile Option Flag [LODFLG] (Section 2.2.3) is set to "1".

HOURLY LOAD PROFILE

Hour	Load (watts)	Hour	Load (watts)	Hour	Load (watts)
1	3000.0	9	6000.0	17	6000.0
2	3000.0	10	6000.0	18	9000.0
3	3000.0	11	4500.0	19	9000.0
4	3000.0	12	4500.0	20	9000.0
5	3000.0	13	4500.0	21	6000.0
6	3000.0	14	4500.0	22	3000.0
7	6000.0	15	4500.0	23	3000.0
8	9000.0	16	4500.0	24	3000.0

PgUp = Previous screen PgDn = Next screen Esc = Exit editor

Figure 18. Load Profile Screen

3.4 System Cost Information Variables

The System Cost Information screen presents the nine user-variable input parameters that are essential to the economic modelling portions of PVFORM Version 3.3. The System Cost Information screen (Figure 19) is made available for you to edit only if the Economic Analysis Flag [IECON] has been set to "Y" (see Section 2.2.5).

SYSTEM COST INFORMATION

PV system cost	680.00	dollars/m² of array
O&M cost ratio	.0025	fraction
Discount rate	.120	fraction
Inflation rate	.070	fraction
System life	30.0	years
Backup energy cost	.40	dollars/kWh
Energy sellback price	.34	dollars/kWh
Battery cost	200.00	dollars/kWh
Average tax rate	.40	fraction

PgUp = Previous screen PgDn = Next screen Esc = Exit editor

Figure 19. System Cost Information Screen

3.4.1 Photovoltaic (PV) System Cost [CSTPVS]

The Photovoltaic System Cost [CSTPVS] used in PVFORM Version 3.3 is the overall cost per unit area, expressed in dollars and cents per square meter, of the PV system whose economic behavior you wish to simulate. This figure should normally include not only the acquisition and installation costs of the PV array itself, but also the acquisition and installation costs of the power-conditioning unit and the installation costs for the battery operating system (but not the acquisition cost of the batteries themselves). Also included are any fixed and indirect costs associated with the PV system. The "area" on which your estimate is based should be the same as [SIZE] (Section 3.1.5). The

default value of $680.00/m^2 assumes $544.00/m^2 of direct costs plus 25% ($136.00/m^2) of indirect costs.

3.4.2 Operating and Maintenance Cost Ratio [ROM]

The Operating and Maintenance Cost Ratio [ROM] used in PVFORM Version 3.3 is the ratio of operating and maintenance (O&M) costs to total PV system cost. "Total PV system cost" is the product of PV system costs per unit area [CSTPVS] (Section 3.4.1), times area [SIZE] (Section 3.1.5). [ROM] is expressed as a decimal fraction.

3.4.3 Discount Rate [DISCRT]

The Discount Rate [DISCRT] used in PVFORM Version 3.3 is the annual interest rate at which the owners of the simulated PV system can borrow money. [DISCRT] is expressed as a decimal fraction.

3.4.4 Inflation Rate [GINFL]

The Inflation Rate [GINFL] used in PVFORM Version 3.3 is the annual inflation rate experienced by the economy in which your simulated PV system will be operating. [GINFL] is expressed as a decimal fraction.

3.4.5 System Life [LIFE]

The System Life [LIFE] used in PVFORM Version 3.3 is the design life expectancy, expressed as an integer number of years, of the PV system whose economic performance you wish to simulate.

3.4.6 Backup Energy Cost [CBU]

The Backup Energy Cost [CBU] used in PVFORM Version 3.3 is the price, expressed in dollars and cents per kilowatt-hour, that the owners of the simulated PV system pay for the electrical power they purchase commercially for backup purposes.

3.4.7 Energy Sellback Price [SELLBK]

The Energy Sellback Price [SELLBK] used in PVFORM Version 3.3 is the price, expressed in dollars and cents per kilowatt-hour, at which your simulated photovoltaic system could sell PV-generated power, in excess of system requirements, back to the conventional power utility that provides your backup energy. An out-of-range value of [SELLBK] will be set to 85% of [CBU] (Section 3.4.6).

3.4.8 Battery Cost [CSTBAT]

The Battery Cost [CSTBAT] used in PVFORM Version 3.3 is the cost of the entire battery system (if any) per unit of storage capacity, expressed in dollars and cents per kilowatt-hour. "Storage capacity" in this context is the same as Battery Capacity [BATCAP] (Section 3.5.1).

NOTE: Unless the Battery Analysis Flag [IBTFLG] (Section 2.2.6) has been set to "Y", a value of [CSTBAT] = $0.00/kWh will be used in all computations involving this variable.

3.4.9 Average Tax Rate [TAX]

The Average Tax Rate [TAX] used in PVFORM Version 3.3 is the currently effective combined national and state tax rate applicable to your simulated PV system. When [TAX] is echoed in the Summary of PVFORM Economic Analysis Input Values (Section 4.2.1), it is named "Effective Tax Rate." [TAX] is expressed in both input and output as a decimal fraction.

3.5 Battery Information Variables

The Battery Information screen provides eight user-variable input parameters that describe the characteristics of the battery bank in your simulated PV system. The Battery Information screen (Figure 20) is made available for you to edit only when the Battery Analysis Flag [IBTFLG] has been set to "Y" (see Section 2.2.6).

BATTERY INFORMATION

Battery capacity	175.00	kWh
Minimum allowable SOC	.20	fraction
Full recharge at SOC of	0.00	fraction
Backup capacity	4000.0	watts
Full recharge interval	366	days
Beginning SOC	.99	fraction
Max charge efficiency	.80	fraction
Max discharge efficiency	.90	fraction

PgUp = Previous screen PgDn = Next screen Esc = Exit editor

Figure 20. Battery Information Screen

NOTE: The only kind of battery system PVFORM Version 3.3 can model is a bank of flooded lead-acid batteries.

3.5.1 Battery Capacity [BATCAP]

The Battery Capacity [BATCAP] used in PVFORM Version 3.3 is the average storage capacity of the battery operating system at some specified temperature, in kilowatt-hours and hundredths thereof. See the manufacturer's specifications for assistance in determining the value of [BATCAP].

3.5.2 Minimum Allowable State of Charge (SOC) [SOCMIN]

The Minimum Allowable State of Charge (SOC) [SOCMIN] used in PVFORM Version 3.3 is the lowest battery SOC that your simulated PV system will permit, expressed as a decimal fraction. If the SOC reaches this value, PVFORM will not allow any more energy to be drawn from the batteries. In effect, the program takes the simulated batteries off line.

3.5.3 Equalization State of Charge [SOCCHR]

Equalization is the full recharging (actually, the slight overcharging) of all the cells in a bank of flooded lead-acid batteries to ensure that the SOC in all cells is equal. The Equalization State of Charge [SOCCHR] used in PVFORM Version 3.3 is the SOC below which the backup energy system will automatically recharge the battery bank to full capacity. Like all states of charge used in PVFORM, [SOCCHR] is expressed as a decimal fraction. In Figure 20, [SOCCHR] is identified as "Full recharge at SOC of" (the value you provide).

3.5.4 Backup Capacity [CHRPWR]

The Backup Capacity [CHRPWR] used in PVFORM Version 3.3 is the capacity of the backup energy system that is incorporated in your simulated PV system to recharge the battery bank. [CHRPWR] is expressed in watts (W) and must be sufficiently large to charge the battery bank from [SOCCHR] to full SOC (SOC = 1.000) in a reasonably short time (approximately 6 hours).

3.5.5 Equalization Schedule [ICHRAT]

The Equalization Schedule [ICHRAT] used in PVFORM Version 3.3 is the interval, expressed as an integer number of days, between automatic rechargings of the battery bank by the backup power system. If a value of [ICHRAT] less than 366 is input, equalization will occur on schedule, regardless of the SOC of the batteries. If the system you are simulating does not have an automatic equalization capability, input [ICHRAT] = 366. In Figure 20, [ICHRAT] is identified as "Full recharge interval."

3.5.6 Beginning State of Charge [BEGSOC]

The Beginning State of Charge [BEGSOC] used in PVFORM Version 3.3 is the state of charge of the battery bank at the beginning (defined as 1 January) of the 365-day year being simulated.

3.5.7 Maximum Charge Efficiency [EFCMAX]

The Maximum Charge Efficiency [EFCMAX] used in PVFORM Version 3.3 is either the user-defined or the default maximum value of the function that relates charging efficiency to the SOC of the battery bank before charging begins. See Figure 21.

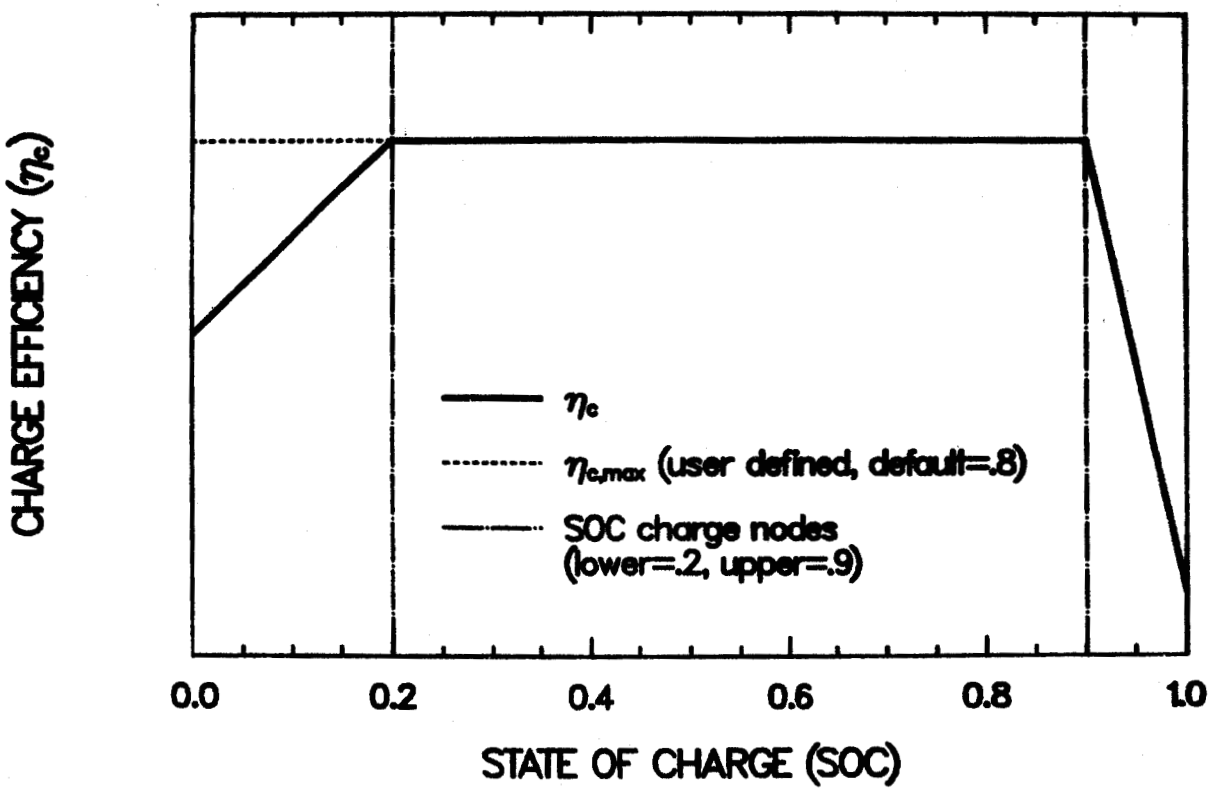

Figure 21. Charge Efficiency

3.5.8 Maximum Discharge Efficiency [EFDMAX]

The Maximum Discharge Efficiency [EFDMAX] used in PVFORM Version 3.3 is either the user-defined or the default maximum value of the function that relates discharge efficiency to the final SOC of the battery bank before discharging begins. See Figure 22.

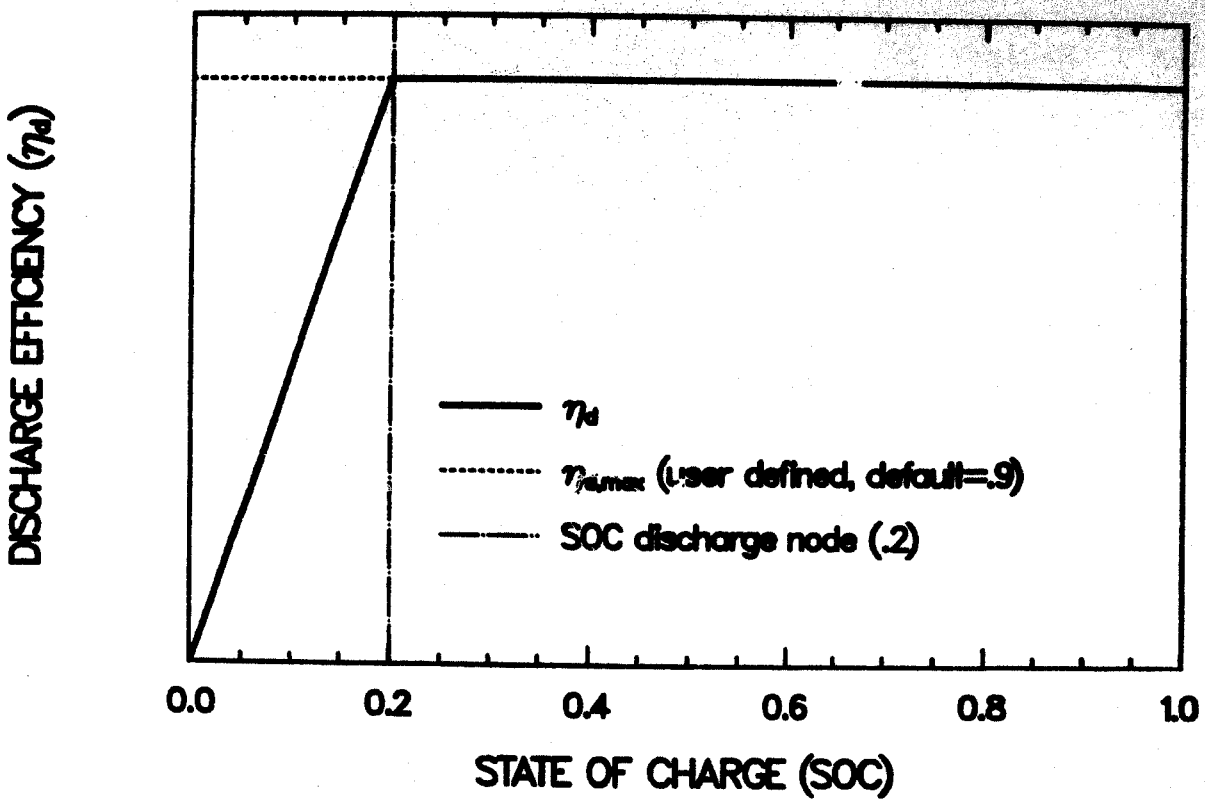

Figure 22. Discharge Efficiency

4. OUTPUT SUMMARIES AND DATA

4.1 Summary of PVFORM System Performance Input Parameters

The Summary of PVFORM System Performance Input Parameters illustrated below (Figure 23) will be displayed on your monitor, sent to your printer, or else sent to a disk file, during every PVFORM run, regardless of your selections among the modelling options.

SUMMARY OF PVFORM SYSTEM PERFORMANCE INPUT PARAMETERS
VERSION 3.3

DAY SKIP FACTOR	(IDYSKP)	1	DAYS
365 DAY LOAD PROFILE	(LODFLG)	YES	
HOURLY WRITE OPTION	(IPRFLG)	NO	
ECONOMIC ANALYSIS	(IECON)	NO	
BATTERY ANALYSIS	(IBTFLG)	YES	
TMY FILE NAME	(TMYNM)	C:TMY.DAT	
LOAD FILE NAME (LODFLG = 2)	(LODNM)	C:USRLOAD.DAT	
SITE LATITUDE	(TLAT)	35.0	DEGREES
ARRAY TILT	(TILT)	35.0	DEGREES
ARRAY AZIMUTH	(TAZM)	0.0	DEGREES
TRACKING FLAG	(ITRK)	FIXED TILT	
ARRAY AREA	(SIZE)	260.0	SQ METERS
AVERAGE ARRAY HEIGHT	(HEIGHT)	2.0	METERS
MISMATCH AND LINE LOSSES	(TMLOSS)	3.500	%
GROUND ALBEDO	(REFL)	0.300	
INSTALLED NOCT	(TINOCT)	46.00	DEGREES C
REFERENCE TEMPERATURE	(REFTEM)	46.00	DEGREES C
REFERENCE EFFICIENCY	(REFEFF)	9.000	%
EFFICIENCY REDUCTION COEFF	(PWRDGR)	0.430	%CHNG/DEG C
PCU INPUT RATING	(PCRATE)	26.000	KW
PCU EFFICIENCY	(EFFFP)	90.000	%

Figure 23. Summary of PVFORM System Performance Input Parameters

4.1.1 Day Skip Factor [IDYSKP]

The Day Skip Factor shown in the first line of this summary is an echo of the [IDYSKP] you provided in input. See Section 2.2.2.

4.1.2 Load Profile Option Flag [LODFLG]

The Load Profile Option Flag shown in the second line of this summary is an echo of the [LODFLG] you provided in input. See Section 2.2.3.

4.1.3 Hourly Write Option Flag [IPRFLG]

The Hourly Write Option Flag shown in the third line of this summary is an echo of the [IPRFLG] you provided in input. See Section 2.2.4.

4.1.4 Economic Analysis Flag [IECON]

The Economic Analysis Flag shown in the fourth line of this summary is an echo of the [IECON] you provided in input. See Section 2.2.5.

4.1.5 Battery Analysis Flag [IBTFLG]

The Battery Analysis Flag shown in the fifth line of this summary is an echo of the [IBTFLG] you provided in input. See Section 2.2.6.

4.1.6 TMY Filename [TMYNM]

The TMY Filename shown in the sixth line of this summary is an echo of the TMY file specification [TMYNM] you provided in input. See Section 2.2.1.

4.1.7 Load Filename [LODNM]

The Load Filename shown in the seventh line of this summary is an echo of the load filename [LODNM], for [LODFLG] = "2", that you provided in input. See Section 2.2.1.

4.1.8 Site Latitude [TLAT]

The Site Latitude shown in the eighth line of this summary is an echo of the [TLAT] you provided in input. See Section 3.1.1.

4.1.9 Array Tilt [TILT]

The Array Tilt shown in the ninth line of this summary is an echo of the [TILT] you provided in input. See Section 3.1.2.

4.1.10 Array Azimuth [TAZM]

The Array Azimuth shown in the tenth line of this summary is an echo of the [TAZM] you provided in input. See Section 3.1.3.

4.1.11 Tracking Flag [ITRK]

The Tracking Flag shown in the eleventh line of this summary is an echo of the [ITRK] you provided in input. See Section 3.1.4.

4.1.12 Array Area [SIZE]

The Array Area shown in the twelfth line of this summary is an echo of the [SIZE] you provided in input. See Section 3.1.5.

4.1.13 Average Array Height [HEIGHT]

The Average Array Height shown in the thirteenth line of this summary is an echo of the [HEIGHT] you provided in input. See Section 3.1.8.

4.1.14 Mismatch and Line Losses [TMLOSS]

The Mismatch and Line Losses shown in the fourteenth line of this summary are an echo of the [TMLOSS] you provided in input, but expressed as a percentage rather than as a decimal fraction. See Section 3.1.6.

4.1.15 Ground Albedo [REFL]

The Ground Albedo shown in the fifteenth line of this summary is an echo of the [REFL] you provided in input. See Section 3.1.7.

4.1.16 Installed Nominal Operating Cell Temperature [TINOCT]

The Installed Nominal Operating Cell Temperature shown in the sixteenth line of this summary is an echo of the [TINOCT] you provided in input. See Section 3.2.1.

4.1.17 Reference Temperature [REFTEM]

The Reference Temperature shown in the seventeenth line of this summary is an echo of the [REFTEM] you provided in input. See Section 3.2.2.

4.1.18 Reference Efficiency [REFEFF]

The Reference Efficiency shown in the eighteenth line of this summary is an echo of the [REFEFF] you provided in input. See Section 3.2.3.

4.1.19 Efficiency Reduction Coefficient [PWRDGR]

The Efficiency Reduction Coefficient shown in the nineteenth line of this summary is an echo of the [PWRDGR] you provided in input. See Section 3.2.4.

4.1.20 Power-Conditioning Unit (PCU) Input Rating [PCRATE]

The PCU Input Rating shown in the twentieth line of this summary is an echo of the [PCRATE] you provided in input. See Section 3.2.5.

4.1.21 Power-Conditioning Unit (PCU) Efficiency [EFFFP]

The PCU Efficiency shown in the twenty-first (and last) line of this summary is an echo of the [EFFFP] you provided in input. See Section 3.2.6.

4.2 Summary of PVFORM Economic Analysis

This three-part summary (Figures 24 through 26) will be output only if you set the Economic Analysis Flag [IECON] = "Y" (Section 2.2.5), either deliberately or else by default, during your edit of the Modelling Options screen (see Section 2.2.1).

4.2.1 Input Values

This portion of the Economic Analysis Summary (Figure 24) is an echo of the input values you selected, either deliberately or else by default, during your edit of the System Cost Information screen (see Section 3.4).

SUMMARY OF PVFORM ECONOMIC ANALYSIS

INPUT VALUES:

PV SYSTEM COST	(CSTPVS)	680.00	$/SQ MET
RATIO $O&M/$TOTAL COST	(ROM)	0.0025	FRACTION
DISCOUNT RATE	(DISCRT)	0.12	FRACTION
INFLATION RATE	(CFIXED)	0.07	FRACTION
SYSTEM LIFE	(LIFE)	30.	YEARS
BACKUP ENERGY COST	(CBU)	0.4000	$/KWH
ENERGY SELLBACK PRICE	(SELLBK)	0.3400	$/KWH
BATTERY COST	(CSTBAT)	0.0000	$/KWH
EFFECTIVE TAX RATE	(TAX)	0.400	FRACTION

Figure 24. Summary of PVFORM Economic Analysis, Input Values

4.2.1.1 Photovoltaic (PV) System Cost [CSTPVS]

The PV System Cost shown in the first line of this summary is an echo of the [CSTPVS] you provided in input. See Section 3.4.1.

4.2.1.2 Operating and Maintenance Cost Ratio [ROM]

The Operating and Maintenance Cost Ratio shown in the second line of this summary is an echo of the [ROM] you provided in input. See Section 3.4.2.

4.2.1.3 Discount Rate [DISCRT]

The Discount Rate shown in the third line of this summary is an echo of the [DISCRT] you provided in input. See Section 3.4.3.

4.2.1.4 Inflation Rate [GINFL]

The Inflation Rate shown in the fourth line of this summary is an echo of the [GINFL] you provided in input. See Section 3.4.4.

4.2.1.5 System Life [LIFE]

The System Life shown in the fifth line of this summary is an echo of the [LIFE] you provided in input. See Section 3.4.5.

4.2.1.6 Backup Energy Cost [CBU]

The Backup Energy Cost shown in the sixth line of this summary is an echo of the [CBU] you provided in input. See Section 3.4.6.

4.2.1.7 Energy Sellback Price [SELLBK]

The Energy Sellback Price shown in the seventh line of this summary is an echo of the [SELLBK] you provided in input. See Section 3.4.7.

4.2.1.8 Battery Cost [CSTBAT]

The Battery Cost shown in the eighth line of this summary is an echo of the [CSTBAT] you provided in input. See Section 3.4.8.

4.2.1.9 Average Tax Rate [TAX]

The Average Tax Rate shown in the ninth (and last) line of this summary is an echo of the [TAX] you provided in input. See Section 3.4.9.

4.2.2 Cost Summary (Figure 25)

COST SUMMARY:

TOTAL CAPITAL COSTS	(CPVDIR)	176800.00	TOTAL $
TOTAL LIFE CYCLE COST FOR PV GENERATED ENERGY	(TOTLCC)	80483.93	TOTAL $
TOTAL LIFE CYCLE COST FOR EQUIVALENT ENERGY PRODUCED CONVENTIONALLY	(CONLCC)	167799.50	TOTAL $
NET PRESENT BENEFIT	(TBENY)	87315.57	TOTAL $

Figure 25. Summary of PVFORM Economic Analysis, Cost Summary

4.2.2.1 Total Capital Costs (CPVDIR)

The Total Capital Costs shown in the first line of this summary represent the calculated present value of the total costs attributed to your simulated PV system. CPVDIR is defined in PVFORM Version 3.3 as the product of Photovoltaic System Cost [CSTPVS] (Section 3.4.1) times the Array Area [SIZE] (Section 3.1.5).

4.2.2.2 PV Energy Life Cycle Cost (TOTLCC)

The PV Energy Life Cycle Cost shown in the fifth line of this summary represents the total life-cycle cost of all the photovoltaically generated energy produced in a year by your simulated PV system.

4.2.2.3 Conventional Energy Life Cycle Cost (CONLCC)

The Conventional Energy Life Cycle Cost shown in the sixth line of this summary represents the total life-cycle cost of an equivalent amount of energy (i.e., Total Energy, as defined in Section 4.5.7) produced by conventional means at the Backup Energy Cost [CBU] (Section 3.4.6).

4.2.2.4 Net Present Benefit (TBENY)

The Net Present Benefit shown in the seventh (and last) line of this summary represents the net life-cycle cost benefit of using energy produced by your simulated PV system. This amount is the difference between TOTLCC and CONLCC:

$$TBENY = TOTLCC - CONLCC$$

If TBENY is positive, your PV system is cost-effective; if TBENY $\leq$ 0, your simulated PV system is not cost-effective.

4.2.3 Levelized and First-Year Costs (Figure 26)

LEVELIZED AND FIRST-YEAR COSTS:

PV ENERGY (LEVELIZED)	(PVLEC)	0.11511	$/KWH
PV ENERGY (1ST YEAR)	(PVLEC1)	0.22812	$/KWH
CONVEN. ENERGY (LEVELIZED)	(CNLEC)	0.24000	$/KWH
CONVEN. ENERGY (1ST YEAR)	(CNLEC1)	0.47560	$/KWH

Figure 26. Summary of PVFORM Economic Analysis, Levelized and First-Year Costs

4.2.3.1 Photovoltaic Energy (Levelized) Cost (PVLEC)

The Photovoltaic Energy (Levelized) Cost shown in the first line of this summary represents the PV Life Cycle Cost (TOTLCC) divided by the System Life [LIFE], expressed in dollars per kilowatt-hour of energy produced.

4.2.3.2 Photovoltaic Energy (First-Year) Cost (PVLEC1)

The Photovoltaic Energy (First-Year) Cost shown in the second line of this summary represents the initial capital investment in your simulated PV system per kilowatt-hour of photovoltaic energy produced.

4.2.3.3 Conventional Energy (Levelized) Cost (CNLEC)

The Conventional Energy (Levelized) Cost shown in the third line of this summary represents the Conventional Energy Life Cycle Cost (CONLCC) divided by the System Life [LIFE], expressed in dollars per kilowatt-hour of conventional energy produced.

4.2.3.4 Conventional Energy (First-Year) Cost (CNLEC1)

The Conventional Energy (First-Year) Cost shown in the fourth (and last) line of this summary represents the initial capital investment needed to produce, by conventional means at the Backup Energy Cost [CBU], an amount of energy equivalent to the yearly output from your simulated PV system, expressed in dollars per kilowatt-hour of conventional energy produced.

4.3 Summary of PVFORM Battery Analysis

This two-part summary (Figures 27 and 28) will be output only if you set the Battery Analysis Flag [IBTFLG] = "Y", either deliberately or else by default, during your edit of the Modelling Options screen (see Section 2.2.6).

4.3.1 Input Values

This portion of the Battery Analysis Summary (Figure 27) is an echo of the parameter values you selected, either deliberately or else by default, during your edit of the Battery Information screen (see Section 3.5).

SUMMARY OF PVFORM BATTERY ANALYSIS
FOR FLOODED LEAD ACID SYSTEM

INPUT VALUES:

BATTERY CAPACITY	(BATCAP)	175.00	KWH
MINIMUM SOC	(SOCMIN)	0.200	
EQUALIZATION SOC	(SOCCHR)	0.000	
BACKUP CAPACITY	(CHRPWR)	4000.000	WATTS
EQUALIZATION SCHEDULE	(ICHRAT)	366	DAYS
BEGINNING SOC	(BEGSOC)	0.990	
MAXIMUM CHARGE EFFICIENCY	(EFCMAX)	0.800	
MAXIMUM DISCHARGE EFFICIENCY	(EFDMAX)	0.900	

Figure 27. Summary of Battery Analysis, Input Values

4.3.1.1 Battery Capacity [BATCAP]

The Battery Capacity shown in the first line of this summary is an echo of the [BATCAP] you provided in input. See Section 3.5.1.

4.3.1.2 Minimum State of Charge [SOCMIN]

The Minimum State of Charge shown in the second line of this summary is an echo of the [SOCMIN] you provided in input. See Section 3.5.2.

4.3.1.3 Equalization State of Charge [SOCCHR]

The Equalization State of Charge shown in the third line of this summary is an echo of the [SOCCHR] you provided in input. See Section 3.5.3.

4.3.1.4 Backup Capacity [CHRPWR]

The Backup Capacity shown in the fourth line of this summary is an echo of the [CHRPWR] you provided in input. See Section 3.5.4.

4.3.1.5 Equalization Schedule [ICHRAT]

The Equalization Schedule shown in the fifth line of this summary is an echo of the [ICHRAT] you provided in input. See Section 3.5.5.

4.3.1.6 Beginning State of Charge [BEGSOC]

The Beginning State of Charge shown in the sixth line of this summary is an echo of the [BEGSOC] you provided in input. See Section 3.5.6.

4.3.1.7 Maximum Charge Efficiency [EFCMAX]

The Maximum Charge Efficiency shown in the seventh line of this summary is an echo of the [EFCMAX] you provided in input. See Section 3.5.7.

4.3.1.8 Maximum Discharge Efficiency [EFDMAX]

The Maximum Discharge Efficiency shown in the eighth (and last) line of this summary is an echo of the [EFDMAX] you provided in input. See Section 3.5.8.

4.3.2 Summary of PVFORM Battery Performance

In every column of this summary (Figure 28) except the first, the tabular entry gives, in exponential (engineering) notation, either a state of charge expressed as a fraction or else an amount of energy expressed in kilowatt-hours. Below the twelve individual lines, one for each month of the simulated year, are yearly average states of charge or else yearly total energies, as appropriate.

NOTE: The "(B1)" and similar annotations that appear on the bottom line of many column headings in several output summaries are identifiers of output parameters, some of which are used as part of other output parameters.

SUMMARY OF PVFORM BATTERY PERFORMANCE (KWH)

MO	AVERAGE DAILY MAX SOC (B1)	AVERAGE DAILY MIN SOC (B2)	ABSOLUTE MAX SOC (B3)	ABSOLUTE MIN SOC (B4)	BACKUP ENERGY TO CHRG BATT (B5)	BATTERY ENERGY TO LOAD (B6)
J	0.6041E+00	0.2276E+00	0.1000E+01	0.2000E+00	0.0000E+00	0.1703E+04
F	0.7758E+00	0.2958E+00	0.9879E+00	0.2000E+00	0.0000E+00	0.1816E+04
M	0.8295E+00	0.3343E+00	0.1000E+01	0.2000E+00	0.0000E+00	0.1996E+04
A	0.9697E+00	0.5181E+00	0.1000E+01	0.3629E+00	0.0000E+00	0.1941E+04
M	0.9182E+00	0.4880E+00	0.1000E+01	0.2000E+00	0.0000E+00	0.1914E+04
J	0.8842E+00	0.4371E+00	0.9946E+00	0.2000E+00	0.0000E+00	0.1824E+04
J	0.7868E+00	0.3482E+00	0.9911E+00	0.2000E+00	0.0000E+00	0.1954E+04
A	0.8732E+00	0.4152E+00	0.9938E+00	0.2000E+00	0.0000E+00	0.1982E+04
S	0.8711E+00	0.3831E+00	0.9883E+00	0.2000E+00	0.0000E+00	0.2019E+04
O	0.8843E+00	0.3997E+00	0.9903E+00	0.2000E+00	0.0000E+00	0.2092E+04
N	0.7106E+00	0.2532E+00	0.9191E+00	0.2000E+00	0.0000E+00	0.1926E+04
D	0.6025E+00	0.2009E+00	0.7418E+00	0.2000E+00	0.0000E+00	0.1779E+04
	0.8092E+00	0.3584E+00			0.0000E+00	0.2295E+05

BATTERY LIFE = 7.7 YEARS

Figure 28. Summary of Battery Analysis, Performance Summary

4.3.2.1 Month

The first column of this summary gives the initial letter of the name of the month for which the performance of the battery system has been analyzed.

4.3.2.2 Average Daily Maximum State of Charge (B1)

The second column of this summary gives the daily maximum state of charge, averaged over all the days of the month, that was reached by the battery system during the month.

4.3.2.3 Average Daily Minimum State of Charge (B2)

The third column of this summary gives the daily minimum state of charge, averaged over all the days of the month, that was reached by the battery system during the month.

4.3.2.4 Absolute Maximum State of Charge (B3)

The fourth column of this summary gives the absolute maximum state of charge reached by the battery system at any hour during the month.

4.3.2.5 Absolute Minimum State of Charge (B4)

The fifth column of this summary gives the absolute minimum state of charge reached by the battery system at any hour during the month.

4.3.2.6 Backup Energy to Charge Batteries (B5)

The sixth column of this summary gives the total energy (in kilowatt-hours) from the backup system that was used to charge the battery system during this month. This output value is used in computing the backup energy requirement for the PV system (see Section 4.5.3).

4.3.2.7 Battery Energy to Load (B6)

The seventh (and last) column of this summary gives the total energy (in kilowatt-hours) from the battery system that was applied to the load during this month. This output value is used in computing the "energy to load" requirement (see Section 4.5.4) and the "total energy" requirement (see Section 4.5.7) that are output in the System Performance Summary.

4.3.2.8 Battery Life

The final line entry in this summary is the calculated life expectancy of the batteries in the battery bank, based on the battery performance parameters you specified in input, as reflected in the first portion of this summary.

4.4 Summary of Array Performance

The Summary of Array Performance illustrated below (Figure 29) will be displayed on your monitor, sent to your printer, or else sent to a disk file, during every PVFORM run, regardless of your selections among the modelling options.

NOTE: The "(A1)" and similar annotations that appear on the bottom line of many column headings in several output summaries are identifiers of output parameters, some of which are used as part of other output parameters.

ARRAY PERFORMANCE (KWH)

MO	ARRAY PLANE INSOLATION (A1)	ARRAY DC ENERGY (A2)	ARRAY AC ENERGY (A3)	ARRAY TRACKING ENERGY (A4)	ARRAY ENERGY TO LOAD (A5)	ARRAY BACKUP ENERGY (A6)	ARRAY ENERGY TO CHARGE BATT (A7)
J	0.4222E+05	0.3953E+04	0.3546E+04	0.0000E+00	0.1237E+04	0.7804E+03	0.2290E+04
F	0.4577E+05	0.4266E+04	0.3829E+04	0.0000E+00	0.1295E+04	0.2485E+03	0.2534E+04
M	0.5554E+05	0.5082E+04	0.4551E+04	0.0000E+00	0.1517E+04	0.2069E+03	0.3029E+04
A	0.6111E+05	0.5509E+04	0.4944E+04	0.0000E+00	0.1659E+04	0.0000E+00	0.3193E+04
M	0.6300E+05	0.5504E+04	0.4944E+04	0.0000E+00	0.1785E+04	0.2147E+02	0.3093E+04
J	0.5849E+05	0.5067E+04	0.4548E+04	0.0000E+00	0.1741E+04	0.3557E+02	0.2807E+04
J	0.5896E+05	0.4943E+04	0.4438E+04	0.0000E+00	0.1675E+04	0.9130E+02	0.2763E+04
A	0.6031E+05	0.5141E+04	0.4617E+04	0.0000E+00	0.1698E+04	0.3956E+02	0.2919E+04
S	0.5702E+05	0.4943E+04	0.4432E+04	0.0000E+00	0.1544E+04	0.3721E+02	0.2888E+04
O	0.5736E+05	0.5038E+04	0.4535E+04	0.0000E+00	0.1472E+04	0.1560E+03	0.3063E+04
N	0.4772E+05	0.4385E+04	0.3944E+04	0.0000E+00	0.1319E+04	0.3552E+03	0.2625E+04
D	0.4377E+05	0.4135E+04	0.3712E+04	0.0000E+00	0.1275E+04	0.6662E+03	0.2438E+04
	0.6513E+06	0.5797E+05	0.5204E+05	0.0000E+00	0.1822E+05	0.2638E+04	0.3364E+05

Figure 29. Summary of Array Performance

In every column of this summary except the first, the tabular entry gives, in exponential (engineering) notation, an amount of energy expressed in kilowatt-hours. In every line of this summary except the last, the tabular entry represents the calculated total for the month indicated in the first column on that particular line; the final entry in each column gives a grand total of that output parameter for the entire 365-day year simulated in the PVFORM run.

4.4.1 Month

The first column of this summary gives the initial letter of the name of the month for which the performance of the simulated PV array has been analyzed.

4.4.2 Array Plane Insolation (A1)

The second column of this summary gives the calculated total radiative energy received on the PV array you have simulated.

4.4.3 Array DC Energy (A2)

The third column of this summary gives the calculated total dc energy produced by the PV array you have simulated.

4.4.4 Array AC Energy (A3)

The fourth column of this summary gives the calculated total ac energy produced by the PV array you have simulated.

4.4.5 Array Tracking Energy (A4)

The fifth column of this summary gives the calculated ac energy consumed by your simulated PV array tracking system.

4.4.6 Array Energy to Load (A5)

The sixth column of this summary gives the calculated ac energy, produced by your simulated PV array, that was applied directly to the load. See also Sections 4.5.4 and 4.5.7.

4.4.7 Array Backup Energy (A6)

The seventh column of this summary gives the calculated ac energy, produced by the utility (if your PV system is grid-interactive) or by the backup system (if your PV system is stand-alone) that was applied directly to the load. This column will contain positive, nonzero numbers when the PV array and the battery bank (if simulated) together cannot satisfy the load. See also Section 4.5.3.

4.4.8 Array Energy to Charge Batteries (A7)

The eighth (and last) column of this summary gives the calculated ac energy, produced by your simulated PV array, that was excess to the load and was therefore available to charge the battery bank. This column will contain positive, nonzero numbers when the PV array produces more energy than is required to satisfy the load.

4.5 Summary of System Performance

The Summary of System Performance (Figure 30) will be displayed on your monitor, sent to your printer, or else sent to a disk file, during every PVFORM run, regardless of the selections you made among the modelling options.

NOTE: The "(S1)" and similar annotations that appear on the bottom line of many column headings in several output summaries are identifiers of output parameters, some of which are used as part of other output parameters.

SYSTEM PERFORMANCE (KWH)

MO	LOAD DEMAND (S1)	BACKUP ENERGY (A6+B5)	ENERGY TO LOAD (A5+B6)	EXCESS ENERGY (S4)	WASTED ENERGY (S5)	TOTAL ENERGY (A5+B6+S4+S5)	HR PC OVRLD (S7)
J	0.3720E+04	0.7804E+03	0.2940E+04	0.0000E+00	0.1941E+02	0.2959E+04	0
F	0.3360E+04	0.2485E+03	0.3112E+04	0.0000E+00	0.0000E+00	0.3112E+04	0
M	0.3720E+04	0.2069E+03	0.3513E+04	0.0000E+00	0.4082E+01	0.3517E+04	0
A	0.3600E+04	0.0000E+00	0.3600E+04	0.0000E+00	0.9198E+02	0.3692E+04	3
M	0.3720E+04	0.2147E+02	0.3699E+04	0.0000E+00	0.6582E+02	0.3764E+04	0
J	0.3600E+04	0.3557E+02	0.3564E+04	0.0000E+00	0.0000E+00	0.3564E+04	0
J	0.3720E+04	0.9130E+02	0.3629E+04	0.0000E+00	0.0000E+00	0.3629E+04	0
A	0.3720E+04	0.3956E+02	0.3680E+04	0.0000E+00	0.0000E+00	0.3680E+04	0
S	0.3600E+04	0.3721E+02	0.3563E+04	0.0000E+00	0.0000E+00	0.3563E+04	0
O	0.3720E+04	0.1560E+03	0.3564E+04	0.0000E+00	0.0000E+00	0.3564E+04	0
N	0.3600E+04	0.3552E+03	0.3245E+04	0.0000E+00	0.0000E+00	0.3245E+04	0
D	0.3720E+04	0.6662E+03	0.3054E+04	0.0000E+00	0.0000E+00	0.3054E+04	0
	0.4380E+05	0.2638E+04	0.4116E+05	0.0000E+00	0.1813E+03	0.4134E+05	3

Figure 30. Summary of System Performance

In every column of this summary except the first and the last, the tabular entry gives, in exponential (engineering) notation, an amount of energy expressed in kilowatt-hours. In every line of this summary except the last, the tabular entry represents the calculated total for the month indicated in the first column on that particular line; the final entry in each column gives a grand total of that output parameter for the entire 365-day year simulated in the PVFORM run.

4.5.1 Month

The first column of this summary gives the initial letter of the name of the month for which the performance of the simulated PV system has been analyzed.

4.5.2 Load Demand (S1)

The second column of this summary gives the total ac load demand for the PV system you have simulated.

4.5.3 Backup Energy (A6 + B5)

The third column of this summary gives the total ac energy required from the backup system. This amount is the sum of the Array Backup Energy (A6) and the Backup Energy Needed to Charge Batteries (B5). See Sections 4.4.7 and 4.3.2.6, respectively.

4.5.4 Energy to Load (A5 + B6)

The fourth column of this summary gives the total ac energy generated by your simulated PV system (PV array plus backup system) that was applied to the load. This amount is the sum of the Array Energy to Load (A5) and the Battery Energy to Load (B6). See Sections 4.4.6 and 4.3.2.7, respectively.

4.5.5 Excess Energy (S4)

The fifth column of this summary gives the total ac energy, produced by your simulated PV system, that was excess to the Load Demand (S1). See Section 4.5.2. In a grid-interactive system, the Excess Energy is sold back to the utility. In a stand-alone system, Excess Energy is always zero, because any energy not applied to the load and not used to charge the batteries is wasted.

4.5.6 Wasted Energy (S5)

The sixth column of this summary gives the total ac energy that was wasted, either because the power-conditioning unit (PCU) was overloaded or else because (in a stand-alone system) the PV system produced more power than was needed to satisfy the load. In PVFORM Version 3.3, when an overload occurs, the PCU power is set equal to the maximum rated PCU input power [PCRATE]. The difference between the actual inverter output and the amount of power it could have produced had it been properly sized is also considered wasted power.

4.5.7 Total Energy (A5 + B6 + S4 + S5)

The seventh column of this summary gives the total ac energy generated by the PV system. Total Energy is equal to the sum of Array Energy to Load (A5), Battery Energy to Load (B6), Excess Energy (S4), and Wasted Energy (S5). See Sections 4.4.6, 4.3.2.7, 4.5.5, and 4.5.6, respectively.

4.5.8 Hours of Power-conditioning Unit Overload (S7)

The eighth (and last) column of this summary gives the total number of hours during the month (or total for the year) when the power-conditioning unit (PCU) was in an overloaded condition. A properly sized inverter will prevent overload during more than 99% of the total operational hours. However, it is normal to see a few hours of PCU overload during a 1-year simulation of a properly sized PV system. These overloads usually occur in very sunny but cool environmental conditions (typically during February at north latitudes and during August at south latitudes).

4.6 Hourly Write Option Summaries (PLOT.DAT File)

If you elected to employ the hourly print option ([IPRFLG] = "Y"), one or both of the following summaries (Figures 31 and 32) will be written to a disk file named PLOT.DAT. In order to view either of these summaries, you will have to use the DOS commands "TYPE" or "PRINT" after you have finished running PVFORM; these summaries are not automatically printed as part of PVFORM output. The data in these summaries may be useful for subsequent analysis or plots. The output parameters are described below in the order in which they appear in each hourly record. A day's record (24 hourly records) is created for each day on which you caused calculations to be performed by your choice of the Day Skip Factor [IDYSKP]. Each day's record is identified by a header line that gives the Julian date.

4.6.1 Photovoltaic (PV) System Characteristics Summary

This summary (Figure 31) will be written during every PVFORM Version 3.3 run in which [IPRFLG] = "Y", regardless of the type of system being simulated (grid-interactive or stand-alone).

4.6.1.1 Hour Identification

The first column of this summary (HR) contains an integer value from 1 through 24, representing the hour of the day.

4.6.1.2 Plane-of-Array Radiation

The second column of this summary (ARRAY INSOLATION) gives the calculated radiation in the plane of the simulated PV array during this hour, measured in watts (W) and expressed in exponential (engineering) notation.

4.6.1.3 Ambient Temperature

The third column of this summary (AMB TEMP) gives the ambient temperature during this hour at the location of the simulated PV array, as read from the TMY data file for that location. Ambient temperature is expressed in degrees Celsius (°C).

4.6.1.4 Wind Speed

The fourth column of this summary (WIND SPEED) gives the estimated wind speed during this hour at the height of the simulated PV module above the ground [HEIGHT]. Wind speed is expressed in tens of meters per second (m/s × 10).

JULIAN DATE 58

HR	ARRAY INSOLATION	AMB TEMP	WIND SPEED	CELL TEMP	DC POWER	AC POWER	TRACKING POWER	LOAD	POWER TO LOAD
1	0.000E+00	2.2	5.1	999.0	0.000E+00	0.000E+00	0.000E+00	0.300E+04	0.000E+00
2	0.000E+00	2.2	7.2	999.0	0.000E+00	0.000E+00	0.000E+00	0.300E+04	0.000E+00
3	0.000E+00	1.1	2.1	999.0	0.000E+00	0.000E+00	0.000E+00	0.300E+04	0.000E+00
4	0.000E+00	1.1	2.1	999.0	0.000E+00	0.000E+00	0.000E+00	0.300E+04	0.000E+00
5	0.000E+00	0.6	2.1	999.0	0.000E+00	0.000E+00	0.000E+00	0.300E+04	0.000E+00
6	0.000E+00	0.6	2.1	999.0	0.000E+00	0.000E+00	0.000E+00	0.300E+04	0.000E+00
7	0.745E+04	0.0	4.1	-1.2	0.178E+03	0.658E+01	0.000E+00	0.600E+04	0.658E+01
8	0.897E+05	1.1	3.1	8.5	0.905E+04	0.807E+04	0.000E+00	0.900E+04	0.807E+04
9	0.169E+06	5.0	1.0	26.7	0.159E+05	0.144E+05	0.000E+00	0.600E+04	0.600E+04
10	0.230E+06	6.7	1.0	37.0	0.207E+05	0.188E+05	0.000E+00	0.600E+04	0.600E+04
11	0.269E+06	8.9	1.5	42.0	0.238E+05	0.215E+05	0.000E+00	0.450E+04	0.450E+04
12	0.289E+06	10.6	1.5	46.1	0.251E+05	0.226E+05	0.000E+00	0.450E+04	0.450E+04
13	0.302E+06	13.9	1.5	50.8	0.257E+05	0.231E+05	0.000E+00	0.450E+04	0.450E+04
14	0.277E+06	14.4	1.5	48.8	0.237E+05	0.214E+05	0.000E+00	0.450E+04	0.450E+04
15	0.213E+06	16.7	3.6	37.9	0.192E+05	0.174E+05	0.000E+00	0.450E+04	0.450E+04
16	0.104E+06	16.1	1.5	30.3	0.965E+04	0.864E+04	0.000E+00	0.450E+04	0.450E+04
17	0.685E+05	16.1	4.6	21.6	0.657E+04	0.572E+04	0.000E+00	0.600E+04	0.572E+04
18	0.928E+04	15.6	4.6	15.4	0.260E+03	0.158E+02	0.000E+00	0.900E+04	0.158E+02
19	0.000E+00	12.2	5.1	999.0	0.000E+00	0.000E+00	0.000E+00	0.900E+04	0.000E+00
20	0.000E+00	10.6	4.6	999.0	0.000E+00	0.000E+00	0.000E+00	0.900E+04	0.000E+00
21	0.000E+00	11.1	1.5	999.0	0.000E+00	0.000E+00	0.000E+00	0.600E+04	0.000E+00
22	0.000E+00	9.4	1.5	999.0	0.000E+00	0.000E+00	0.000E+00	0.300E+04	0.000E+00
23	0.000E+00	8.3	4.6	999.0	0.000E+00	0.000E+00	0.000E+00	0.300E+04	0.000E+00
24	0.000E+00	8.3	3.1	999.0	0.000E+00	0.000E+00	0.000E+00	0.300E+04	0.000E+00

Figure 31. Summary of Photovoltaic System Characteristics

4.6.1.5 Cell Temperature

The fifth column of this summary (CELL TEMP) gives the calculated average cell temperature within the simulated PV array during this hour. Cell temperature is expressed in degrees Celsius (°C).

4.6.1.6 DC Power

The sixth column of this summary (DC POWER) gives the calculated dc power generated by the simulated PV array during this hour. DC power is measured in watts (W) and expressed in exponential (engineering) notation.

4.6.1.7 AC Power

The seventh column of this summary (AC POWER) gives the ac power generated by the simulated power-conditioning unit (PCU) during this hour. AC power is measured in watts (W) and expressed in exponential (engineering) notation.

4.6.1.8 Tracking Power

The eighth column of this summary (TRACKING POWER) gives the total ac power required during this hour by the simulated PV array tracking system. Tracking power is measured in watts (W) and expressed in exponential (engineering) notation.

4.6.1.9 Load Demand

The ninth column of this summary (LOAD) gives the total simulated ac load demand during this hour. Load demand is measured in watts (W) and expressed in exponential (engineering) notation.

4.6.1.10 Power to Load

The tenth (and last) column of this summary (POWER TO LOAD) gives the total ac power generated by the simulated PV system that is applied directly to the load during this hour. Power to Load is measured in watts (W) and expressed in exponential (engineering) notation.

4.6.2 Stand-Alone System Characteristics

This summary (Figure 32) will be created only during those PVFORM Version 3.3 runs in which you have chosen to simulate a stand-alone system, one incorporating a backup power source and a battery bank. A summary similar to the one illustrated below will follow the Summary of System Performance (Section 4.5) for each day analyzed in the PVFORM run.

HR	SOC	ARRAY TO BATTERY	BACKUP TO BATTERY	ARRAY TO LOAD	BATTERY TO LOAD	BACKUP TO LOAD
1	0.200E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.300E+04
2	0.200E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.300E+04
3	0.200E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.300E+04
4	0.200E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.300E+04
5	0.200E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.300E+04
6	0.200E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.300E+04
7	0.200E+00	0.000E+00	0.000E+00	0.204E+02	0.000E+00	0.598E+04
8	0.200E+00	0.000E+00	0.000E+00	0.705E+04	0.000E+00	0.195E+04
9	0.246E+00	0.915E+04	0.000E+00	0.600E+04	0.000E+00	0.000E+00
10	0.317E+00	0.138E+05	0.000E+00	0.600E+04	0.000E+00	0.000E+00
11	0.415E+00	0.193E+05	0.000E+00	0.450E+04	0.000E+00	0.000E+00
12	0.508E+00	0.185E+05	0.000E+00	0.450E+04	0.000E+00	0.000E+00
13	0.615E+00	0.210E+05	0.000E+00	0.450E+04	0.000E+00	0.000E+00
14	0.707E+00	0.181E+05	0.000E+00	0.450E+04	0.000E+00	0.000E+00
15	0.782E+00	0.148E+05	0.000E+00	0.450E+04	0.000E+00	0.000E+00
16	0.831E+00	0.951E+04	0.000E+00	0.450E+04	0.000E+00	0.000E+00
17	0.835E+00	0.779E+03	0.000E+00	0.600E+04	0.000E+00	0.000E+00
18	0.771E+00	0.000E+00	0.000E+00	0.536E+01	0.899E+04	0.000E+00
19	0.708E+00	0.000E+00	0.000E+00	0.000E+00	0.900E+04	0.000E+00
20	0.644E+00	0.000E+00	0.000E+00	0.000E+00	0.900E+04	0.000E+00
21	0.602E+00	0.000E+00	0.000E+00	0.000E+00	0.600E+04	0.000E+00
22	0.581E+00	0.000E+00	0.000E+00	0.000E+00	0.300E+04	0.000E+00
23	0.560E+00	0.000E+00	0.000E+00	0.000E+00	0.300E+04	0.000E+00
24	0.538E+00	0.000E+00	0.000E+00	0.000E+00	0.300E+04	0.000E+00

Figure 32. Summary of Stand-Alone System Characteristics

4.6.2.1 Hour Identification

The first column of this summary (HR) contains an integer value from 1 through 24, representing the hour of the day.

4.6.2.2 State of Charge (SOC)

The second column of this summary (SOC) gives the average state of charge of the simulated battery bank during this hour. State of charge is expressed as as a fraction, using exponential (engineering) notation.

4.6.2.3 Array Power to Charge Batteries

The third column of this summary (ARRAY TO BATTERY) gives the total dc power from the simulated PV array that was used to charge the battery bank during this hour. Array power to charge betteries is measured in watts (W) and expressed in exponential (engineering) notation.

4.6.2.4 Backup Power to Charge Batteries

The fourth column of this summary (BACKUP TO BATTERY) gives the total dc power from the simulated backup system that was used to charge the battery bank during this hour. Backup power to charge batteries is measured in watts (W) and expressed in exponential (engineering) notation.

4.6.2.5 Array Power to Load

The fifth column of this summary (ARRAY TO LOAD) gives the total ac power from the simulated PV array that was applied directly to the load during this hour. Array power to load is measured in watts (W) and expressed in exponential (engineering) notation.

4.6.2.6 Battery Power to Load

The sixth column of this summary (BATTERY TO LOAD) gives the total dc power from the simulated battery bank that was applied directly to the load during this hour. Battery power to load is measured in watts (W) and expressed in exponential (engineering) notation.

4.6.2.7 Backup Power to Load

The seventh (and last) column of this summary (BACKUP TO LOAD) gives the total ac power from the backup system that was applied directly to the load during this hour. Backup power to load is measured in watts (W) and expressed in exponential (engineering) notation.

5. REFERENCES

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4. R. Perez, R. Seals, and R. Stewart, "Modeling Irradiance on Tilted Planes: A Simpler Version of the Perez Model; US-Wide Climatic/Environmental Evaluation," Proceedings of the Biennial Meeting of the International Solar Energy Society (ISES-87), Hamburg, Federal Republic of Germany, October 1987

5. M. K. Fuentes, A Simplified Thermal Model of Photovoltaic Modules, SAND85-0330, Sandia National Laboratories, Albuquerque, NM, 1985.

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APPENDIX A

EDITING INPUT USING THE LINE-EDIT MODE

A.1. MODELLING OPTIONS AND THE MAIN MENU

The file that executes PVFORM Version 3.3 in the line-edit mode is named PVBATCH.BAT. When you first type "PVBATCH.BAT" (or simply "PVBATCH") following the prompt that identifies your current disk drive, your monitor will display the following (Figure A-1):

```
PVFORM

VERSION 3.3

An Hourly Photovoltaic Simulation Program

David F. Menicucci and James P. Fernandez
Sandia National Laboratories, Albuquerque, NM
Funded by the Division of Photovoltaic Energy Technology, U.S.D.O.E.

Press CONTROL and BREAK keys simultaneously to abort processing

Strike a key when ready . . .
```

Figure A-1. Introductory Screen

A.1.1 Modelling Options

The modelling options open to you are these:

- Selection of one Day Skip Factor [IDYSKP] out of 29 discrete integral values available
- Selection of one Load Profile Option Flag [LODFLG] out of three discrete integral values available
- Whether to use the Hourly Write Option [IPRFLG]
- Whether to use the Economic Analysis Option [IECON]
- Whether to use the Battery Analysis Option [IBTFLG]

When the line editor is used, these choices are made from the Modelling Option (OP) Record screen (see Section A.1.3), which can be accessed only by way of the Main Menu screen (Figure A-2). You can reach the Main Menu either from the Introductory Screen (Figure A-1) as described in Section A.1.2 below, or from any one of the nine possible records created during a PVFORM input edit session as described in Section A.2 below.

A.1.2 Main Menu

Once you have "struck a key when ready" to continue from the Introductory Screen (Figure A-1), or have typed "RT" and a carriage return (<Enter> or <Return>) to leave one of the input edit records (Figures A-13 through A-19), your monitor will display the following (Figure A-2):

```
PVFORM INPUT FILE EDITOR
COMPATIBLE WITH PVFORM VERSION 3.3

MAIN MENU. PLEASE INPUT AN ITEM NUMBER.

  1 - CREATE A NEW PVFORM INPUT FILE
  2 - EDIT AN OLD PVFORM INPUT FILE
  3 - DISPLAY THE CURRENT FILE IN THE SYSTEM
  4 - STOP EDITING, RUN PVFORM
```

Figure A-2. Main Menu

A.1.2.1 Creating a New PVFORM Version 3.3 Input File

If you respond to the Main Menu by entering a "1", your monitor will display this (Figure A-3):

```
CREATING A NEW PVFORM INPUT FILE
INPUT THE NAME OF THE FILE YOU WANT TO CREATE (12 CHAR MAX)
THE FILE NAME CAN NOT BE "USERINP.DAT"
```

Figure A-3. Creating a New PVFORM Input File

You respond by entering the unique name you have devised to identify this particular PVFORM run. Your filename may include any alphanumeric characters you choose, but it may not include any spaces or special characters. If you input an unacceptable name, PVBATCH responds with an error message, such as the one shown in Figure A-4.

```
ERROR TRYING TO OPEN THE FILE NAMED * fff          *.
PROBABLE CAUSE IS THAT A FILE BY THAT NAME ALREADY EXISTS.
RENAME OR DELETE THE EXISTING FILE AND TRY AGAIN
```

Figure A-4. "File Already Exists" Error Message

Once you have successfully entered an acceptable filename, your monitor will display the following (Figure A-5):

```
THE FOLLOWING LISTS THE RECORDS CURRENTLY IN THE PVFORM FILE.
TO EDIT ANY RECORD, INPUT THE TWO CHARACTER CODE TAKEN FROM THIS LIST:

     OP - MODELLING OPTIONS RECORD
     AR - ARRAY DESCRIPTION
     MO - MODULE DESCRIPTION
     PC - PCU DESCRIPTION

     RT - RETURN TO MAIN MENU
```

Figure A-5. Minimum Default Set of Records in Input File

The display shown above represents the minimum, default set of records that will be created during any PVFORM run.

There are five additional records that PVFORM can create but that are not shown above, because they are neither needed nor created when the minimum, default set of Main Menu options is selected. To create all of these additional records, you must set the Load Profile Option Flag [LODFLG] (Section 2.3.3), the Economic Analysis Flag [IECON] (Section 2.3.4), and the Battery Analysis Flag [IBTFLG] (Section 2.3.5) each equal to "1". Then PVFORM will display the names of the five additional records, as well as those of the records in the default set (Figure A-6):

```
THE FOLLOWING LISTS THE RECORDS CURRENTLY IN THE PVFORM FILE.
TO EDIT ANY RECORD, INPUT THE TWO CHARACTER CODE TAKEN FROM THIS LIST:

     OP - MODELLING OPTIONS RECORD
     AR - ARRAY DESCRIPTION
     MO - MODULE DESCRIPTION
     PC - PCU DESCRIPTION
     L1 - LOAD PROFILE - HRS 1-8
     L2 - LOAD PROFILE - HRS 9-16
     L3 - LOAD PROFILE - HRS 17-24
     EC - SYSTEM COST INFORMATION
     BA - BATTERY INFORMATION

     RT - RETURN TO MAIN MENU
```

Figure A-6. Maximum Set of Records in Input File

If you elect not to edit any of the records in the default PVFORM file (USERINP.DAT), as indicated by typing "RT" and pressing the "Enter" or "Return" key, your PVFORM run will employ the default values for <u>all</u> of the user-variable input parameters.

See Section 3 for instructions on editing any records <u>except</u> the Modelling Options (OP) Record in your new user input data file before you run PVFORM Version 3.3 with it.

A.1.2.2 Editing an Old PVFORM Version 3.3 Input File

If you respond to the Main Menu by entering a "2", your monitor will display this (Figure A-7):

```
EDITING AN OLD PVFORM INPUT FILE
INPUT THE NAME OF THE FILE YOU WANT TO EDIT (12 CHAR MAX)
THE FILE NAME CAN NOT BE "USERINP.DAT"
```

Figure A-7. Editing an Old PVFORM Input File

Your response should be to enter the name of a user-created input data file that you know already exists, keeping in mind that files created with earlier versions of PVFORM will be virtually impossible to edit with PVFORM Version 3.3. If the program responds to your first effort with an error message like the one shown below (Figure A-8),

```
ERROR TRYING TO OPEN THE FILE NAMED * ggg          *.
PROBABLE CAUSE IS THAT NO FILE BY THAT NAME EXISTS.
CHECK YOUR EXISTING FILES AND TRY AGAIN
```

Figure A-8. "No Such File" Error Message

abort PVBATCH by pressing the "Ctrl" and "Break" keys simultaneously, then check the directory of your disk files to find the exact name of the user-created input data file that you want to edit.

A.1.2.3 Displaying the Current PVFORM Version 3.3 Input File

If you respond to the Main Menu by entering a "3", your monitor will display the records in the current input file, as shown in Figure A-9, which illustrates the minimum default set of records created during any PVFORM run.

DISPLAY OF CURRENT FILE

RECORD 1 (MODELING OPTIONS)

DAY SKIP FACTOR	6.0000
LOAD PROFILE OPTION FLAG	1.0000
HOURLY WRITE OPTION FLAG	1.0000
ECONOMIC ANALYSIS FLAG	1.0000
BATTERY ANALYSIS FLAG	1.0000
TMY FILE SPEC	c:tmy.dat
HOURLY LOAD FILE SPEC	c:usrload.dat

RECORD 2 (ARRAY DESCRIPTION)

SITE LATITUDE (DEG)	35.0000
ARRAY TILT (DEG)	35.0000
ARRAY AZIMUTH (DEG)	.0000
TRACKING FLAG	1.0000
ARRAY AREA (SQ MET)	260.0000
MISMATCH AND LINE LOSSES (FRACT)	.0350
GROUND ALBEDO (FRACT)	.3000
AVERAGE ARRAY HEIGHT (M)	2.0000

RECORD 3 (MODULE DESCRIPTION)

INSTALLED NOCT (C)	46.0000
REFERENCE TEMPERATURE (C)	46.0000
REFERENCE EFFICIENCY (FRACT)	.0900
EFFIC. REDUCTION COEFF. (CHNG/DEG C)	.0043

RECORD 4 (PCU DESCRIPTION)

PCU INPUT RATING (W)	26000.0000
PCU EFFICIENCY (FRACT)	.9000

Figure A-9. Contents of Minimum Set of Records

For completeness and convenience, the default contents of the five additional records that may be created during any PVFORM run are shown on the next page in Figure A-10.

RECORD 5-7 (LOAD PROFILE)

HR	LOAD(W)
1	3000.0
2	3000.0
3	3000.0
4	3000.0
5	3000.0
6	3000.0
7	6000.0
8	9000.0
9	6000.0
10	6000.0
11	4500.0
12	4500.0
13	4500.0
14	4500.0
15	4500.0
16	4500.0
17	6000.0
18	9000.0
19	9000.0
20	9000.0
21	6000.0
22	3000.0
23	3000.0
24	3000.0

RECORD 8 (SYSTEM COST INFORMATION)

PV SYSTEM COST ($/M2)	680.0000
O&M/TOTAL COST (RATIO)	.0025
DISCOUNT RATE (FRACT)	.1200
INFLATION RATE (FRACT)	.0700
SYSTEM LIFE (YRS)	30.0000
BACKUP ENERGY COST ($/KWH)	.4000
ENERGY SELLBACK PRICE ($/KWH)	.3400
BATTERY COST ($/KWH)	200.0000
AVERAGE TAX RATE (FRACT)	.4000

RECORD 9 (BATTERY INFORMATION)

BATTERY CAPACITY (KWH)	175.0000
MINIMUM SOC (FRACT)	.2000
EQUALIZATION SOC (FRACT)	.0000
BACKUP CAPACITY (W)	4000.0000
EQUALIZATION SCHEDULE (DAYS)	366.0000
BEGINNING SOC (FRACT)	.9900
MAX CHARGE EFF (FRACT)	.8000
MAX DISCHARGE EFF (FRACT)	.9000

Figure A-10. Contents of Additional Records

If you have previously created or edited one or more PVFORM input files, that file on which you most recently worked will be displayed; otherwise, the default input file USERINP.DAT will be displayed. Following the display of the current file, PVBATCH will automatically return you to the Main Menu (Figure A-2).

A.1.2.4 Terminating Your Edit of the Input File

If you respond to the Main Menu by entering a "4", you thereby confirm the choices you have previously made among the modelling options and your previous selections of values for all the user-variable input parameters. Your monitor will display the following (Figure A-11):

```
Stop - Program terminated.

Where do you want input/output summary

(S)creen  (P)rinter  (D)isk file named PVOUT.DAT on this drive

?
```

Figure A-11. "Stop - Program terminated" Message

NOTE: Only the input-editing phase of PVFORM Version 3.3 has been terminated when this message appears: You are now assumed to be ready to have PVFORM perform all the calculations you have required and to prepare all the output you have requested.

Once you have entered your choice of output device ("S", "P", or "D"), your monitor will display the following (Figure A-12):

```
PVFORM Version 3.3 executing ...
```

Figure A-12. "PVFORM Version 3.3 executing ..." Message

A.2. EDITING INDIVIDUAL INPUT PARAMETERS

Individual input parameters may be edited, one at a time, in any sequence you desire, provided that you have elected the modelling options that will cause the input-edit record to be created that comprises the particular parameter you wish to edit. Once you have selected the proper record and displayed its contents, editing is a matter of following the on-screen prompts as they are presented to you: Identify the parameter you wish to edit, enter its number from the record, enter the new value you wish to assign to that parameter, and verify that the record now contains your chosen value.

Each of the input-edit records is described below, in the normal sequence in which they are presented to you for editing. For details on the parameters included in each record, you are referred to the appropriate section(s) of Section 3 of this manual.

A.2.1 Modelling Options (OP) Record

The Modelling Options (OP) Record comprises five user-set flags, [IDYSKP], [LODFLG], [IPRFLG], [IECON], and [IBTFLG], that determine which calculations will be run, how many times the calculations will be done, and which summaries will be produced as output. This record also includes the current and default file specifications (drive letters and filenames) that have been assigned to the TMY data file (see Section 1.2.2.1) and to the hourly load data file (see Section 1.2.2.2), respectively. The OP Record (Figure A-13) is created during every PVFORM run. See Section 2.2 for detailed discussions of each parameter that can be edited from the OP Record.

```
THESE ARE THE ITEMS AND VALUES IN THE OPTIONS RECORD
INPUT ONE OF THE FOLLOWING:
  - THE ITEM NUMBER THAT YOU WISH TO CHANGE
  - A ZERO TO EDIT ANOTHER RECORD

   PARAMETER                        CURRENT   DEFAULT      ALLOWABLE
                                     VALUE     VALUE         RANGE

1 DAY SKIP FACTOR                     6.        6.          1 - 29
2 LOAD PROFILE OPTION FLAG            0.        0.          0 - 2
3 HOURLY WRITE OPTION FLAG            0.        0.          0 - 1
4 ECONOMIC ANALYSIS FLAG              0.        0.          0 - 1
5 BATTERY ANALYSIS FLAG               0.        0.          0 - 1
6 TMY FILE SPEC            CURR = B:TMY.DAT                   DEF = B:TMY.DAT
7 HOURLY LOAD FILE SPEC    CURR = B:USRLOAD.DAT               DEF = B:USRLOAD.DAT
```

Figure A-13. Modelling Options (OP) Record

A.2.2 Array (AR) Description Record

The Array (AR) Description Record comprises eight user-variable input parameters, [TLAT], [TILT], [TAZM], [ITRK], [SIZE], [TMLOSS], [REFL], and [HEIGHT], that define the location, orientation, and general operating characteristics of the PV system you wish to simulate. The AR Record (Figure A-14) is created during every PVFORM run. See Section 3.1 for detailed discussions of each parameter that can be edited from the AR Record.

THESE ARE THE ITEMS AND VALUES IN THE ARRAY RECORD
INPUT ONE OF THE FOLLOWING:
- THE ITEM NUMBER THAT YOU WISH TO CHANGE
- A ZERO TO EDIT ANOTHER RECORD

PARAMETER	CURRENT VALUE	DEFAULT VALUE	ALLOWABLE RANGE
1 SITE LATITUDE (DEG)	35.0000	35.0000	-89 - 89
2 ARRAY TILT (DEG)	35.0000	35.0000	0 - 90
3 ARRAY AZIMUTH (DEG)	.0000	.0000	0 - 360
4 TRACKING FLAG	1.0000	1.0000	1 - 6
5 ARRAY AREA (SQ MET)	260.0000	260.0000	0 - 999999
6 MISMATCH AND LINE LOSSES (FRACT)	.0350	.0350	0 - .08
7 GROUND ALBEDO (FRACT)	.3000	.3000	0 - 1
8 AVERAGE ARRAY HEIGHT (M)	2.0000	2.0000	0 - 99

Figure A-14. Array (AR) Description Record

A.2.3 Module (MO) Description Record

The Module (MO) Description Record comprises four user-variable input parameters, [TINOCT], [REFTEM], [REFEFF], and [PWRDGR], that define the thermal characteristics of the photovoltaic cells that make up the PV module(s) being simulated. The MO Record (Figure A-15) is created during every PVFORM run. See Section 3.2 for detailed discussions of each parameter that can be edited from the MO Record.

THESE ARE THE ITEMS AND VALUES IN THE MODULE RECORD
INPUT ONE OF THE FOLLOWING:
- THE ITEM NUMBER THAT YOU WISH TO CHANGE
- A ZERO TO EDIT ANOTHER RECORD

PARAMETER	CURRENT VALUE	DEFAULT VALUE	ALLOWABLE RANGE
1 INSTALLED NOCT (C)	46.0000	46.0000	20 - 100
2 REFERENCE TEMPERATURE (C)	46.0000	46.0000	0 - 100
3 REFERENCE EFFICIENCY (FRACT)	.0900	.0900	0 - .25
4 EFFIC. REDUCTION COEFF. (CHNG/DEG C)	.0043	.0043	0 - .01

Figure A-15. Module (MO) Description Record

A.2.4 PCU (PC) Description Record

The PCU (PC) Description Record comprises two user-variable input parameters, [PCRATE] and [EFFFP], that define the general operating characteristics of the power-conditioning system you wish to simulate. The PC Record (Figure A-16) is created during every PVFORM run. See Section 3.2 for detailed discussions of the two parameters that can be edited from the PC Record.

```
THESE ARE THE ITEMS AND VALUES IN THE PCU RECORD
INPUT ONE OF THE FOLLOWING:
  - THE ITEM NUMBER THAT YOU WISH TO CHANGE
  - A ZERO TO EDIT ANOTHER RECORD

   PARAMETER                      CURRENT      DEFAULT       ALLOWABLE
                                   VALUE        VALUE          RANGE

1 PCU INPUT RATING (W)          26000.000    26000.000    0 - 9999999999
2 PCU EFFICIENCY (FRACT)             .900         .900    0 - 1
```

Figure A-16. PCU (PC) Description Record

A.2.5 Load Profile (L1 - L3) Records

The set of three Load Profile (L1 - L3) Records comprises 24 user-variable external electrical load values, one for each hour in a simulated day, that the PV system being simulated is to satisfy. The L1 through L3 Records (Figure A-17 illustrates the L1 Record only) are created only when the Load Profile Option Flag [LODFLG] has been set to "1".

THESE ARE THE ITEMS AND VALUES IN LOAD RECORD 1
INPUT ONE OF THE FOLLOWING:
- THE ITEM NUMBER THAT YOU WISH TO CHANGE
- A ZERO TO EDIT ANOTHER RECORD

PARAMETER	CURRENT VALUE	DEFAULT VALUE	ALLOWABLE RANGE
1 LOAD HR 1 (W)	3000.00	3000.00	0 - 999999
2 LOAD HR 2 (W)	3000.00	3000.00	0 - 999999
3 LOAD HR 3 (W)	3000.00	3000.00	0 - 999999
4 LOAD HR 4 (W)	3000.00	3000.00	0 - 999999
5 LOAD HR 5 (W)	3000.00	3000.00	0 - 999999
6 LOAD HR 6 (W)	3000.00	3000.00	0 - 999999
7 LOAD HR 7 (W)	6000.00	6000.00	0 - 999999
8 LOAD HR 8 (W)	9000.00	9000.00	0 - 999999

Figure A-17. Load Profile (L1) Record
(L2 and L3 similar, but not identical)

A.2.6 System Cost (EC) Information Record

The System Cost (EC) Information Record comprises nine user-variable input parameters, [CSTPVS], [ROM], [DISCRT], [GINFL], [LIFE], [CBU], [SELLBK], [CSTBAT], and [TAX], that describe the economic environment in which your simulated PV system is to operate. The EC Record (Figure A-18) is created only when the Economic Analysis Flag [IECON] has been set to "1". See Section 3.4 for detailed discussions of each parameter that can be edited from the EC Record.

THESE ARE THE ITEMS AND VALUES IN THE ECONOMIC RECORD
INPUT ONE OF THE FOLLOWING:
- THE ITEM NUMBER THAT YOU WISH TO CHANGE
- A ZERO TO EDIT ANOTHER RECORD

PARAMETER	CURRENT VALUE	DEFAULT VALUE	ALLOWABLE RANGE
1 PV SYSTEM COST ($/M2)	680.00	680.00	0 - 99999
2 O&M/TOTAL COST (RATIO)	.00	.00	0 - 1
3 DISCOUNT RATE (FRACT)	.12	.12	0 - 1
4 INFLATION RATE (FRACT)	.07	.07	0 - 1
5 SYSTEM LIFE (YRS)	30.00	30.00	0 - 99999
6 BACKUP ENERGY COST ($/KWH)	.40	.40	0 - 99
7 ENERGY SELLBACK PRICE ($/KWH)	.34	.34	0 - 99
8 BATTERY COST ($/KWH)	200.00	200.00	0 - 999
9 AVERAGE TAX RATE (FRACT)	.40	.40	0 - 1

Figure A-18. System Cost (EC) Information Record

A.2.7 Battery (BA) Information Record

The Battery (BA) Information Record comprises eight user-variable input parameters, [BATCAP], [SOCMIN], [SOCCHR], [CHRPWR], [ICHRAT], [BEGSOC], [EFCMAX], and [EFDMAX], that define the operating characteristics of the simulated battery bank in the stand-alone PV system you wish to simulate. The BA Record (Figure A-19) is created only when the Battery Analysis Flag [IBTFLG] has been set to "1". See Section 3.5 for detailed discussions of each parameter that can be edited from the BA Record.

THESE ARE THE ITEMS AND VALUES IN THE BATTERY RECORD
INPUT ONE OF THE FOLLOWING:
- THE ITEM NUMBER THAT YOU WISH TO CHANGE
- A ZERO TO EDIT ANOTHER RECORD

PARAMETER	CURRENT VALUE	DEFAULT VALUE	ALLOWABLE RANGE
1 BATTERY CAPACITY (KWH)	175.00	175.00	0 - 99999
2 MINIMUM SOC (FRACT)	.20	.20	0 - 1
3 EQUALIZATION SOC (FRACT)	.00	.00	0 - 1
4 BACKUP CAPACITY (W)	4000.00	4000.00	0 - 99999
5 EQUALIZATION SCHEDULE (DAYS)	366.00	366.00	0 - 99999
6 BEGINNING SOC (FRACT)	.99	.99	0 - 1
7 MAX CHARGE EFF (FRACT)	.80	.80	0 - 1
8 MAX DISCHARGE EFF (FRACT)	.90	.90	0 - 1

Figure A-19. Battery (BA) Information Record

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