Innovation for Our Energy Future

Recent Revisions to PVWATTS

B. Marion, M. Anderberg, and P. Gray-Hann

Presented at the 2005 DOE Solar Energy Technologies Program Review Meeting November 7–10, 2005 Denver, Colorado Conference Paper NREL/CP-520-38975 November 2005



NOTICE

The submitted manuscript has been offered by an employee of the Midwest Research Institute (MRI), a contractor of the US Government under Contract No. DE-AC36-99GO10337. Accordingly, the US Government and MRI retain a nonexclusive royalty-free license to publish or reproduce the published form of this contribution, or allow others to do so, for US Government purposes.

This report 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, 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 or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States government or any agency thereof.

Available electronically at http://www.osti.gov/bridge

Available for a processing fee to U.S. Department of Energy and its contractors, in paper, from:

U.S. Department of Energy Office of Scientific and Technical Information P.O. Box 62 Oak Ridge, TN 37831-0062

phone: 865.576.8401 fax: 865.576.5728

email: mailto:reports@adonis.osti.gov

Available for sale to the public, in paper, from:

U.S. Department of Commerce National Technical Information Service 5285 Port Royal Road Springfield, VA 22161 phone: 800,553,6847

phone: 800.553.6847 fax: 703.605.6900

email: orders@ntis.fedworld.gov

online ordering: http://www.ntis.gov/ordering.htm



Recent Revisions to PVWATTS

B. Marion, M. Anderberg, and P. Gray-Hann National Renewable Energy Laboratory, Golden, Colorado, bill marion@nrel.gov

ABSTRACT

PVWATTS is an Internet-accessible software program that allows the user to easily calculate the energy production and cost savings for grid-connected photovoltaic (PV) systems located throughout the United States. To ensure that PVWATTS continues to meet its users' needs, an online survey form was provided to users to identify areas for improvement. The results of the survey were used to prioritize improvements to PVWATTS in FY2005. PVWATTS was revised by changing the PV system specification input for system size from an AC power rating to a nameplate DC power rating; adding an input for an overall DC to AC derate factor; updating the residential electric rates; adding monthly and yearly solar radiation values for the PV array; and simplifying the user interface for Version 2.

1. Objectives

The purpose of this work was to add features to PVWATTS to improve the ease of use and provide more complete information on the performance of grid-connected photovoltaic (PV) systems. An easy-to-use PV-performance predictive model available to anyone via the internet facilitates the deployment and acceptance of grid-connected PV systems by providing a common predictor of expected performance for both buyers and sellers of PV systems.

2. Background and Technical Approach

The original PVWATTS¹ Version 1 (still available), released in 1999, is an Internet-accessible simulation tool for providing quick estimates of the electrical energy production of a grid-connected crystallinesilicon PV system for any of 239 locations. These locations correspond to the 239-station Typical Meteorological Year (TMY2) database² for the United States and its territories. Users select a location from a station map and set PV system parameters, or select default values, and PVWATTS performs an hour-byhour simulation that provides monthly and annual alternating current (AC) energy production in kilowatts and energy value in dollars. The performance model used by PVWATTS is based on Sandia National Laboratories' PVFORM³, but with fewer allowed specified inputs.

Before the release of Version 2⁴ in 2001, if the desired location was between TMY2 stations, the PVWATTS user needed to choose between two or more stations based on which station they judged to

be climatically similar, or in some cases, the nearest. PVWATTS Version 2 provides better performance estimates in these instances by using 40-km resolution data grid values of monthly global horizontal, direct normal, and diffuse horizontal solar radiation and maximum daily temperature to translate performance from a nearby TMY2 station to the desired grid cell. To run PVWATTS Version 2, users select the 40-km resolution grid cell containing the desired location from an interactive map, and then in the same manner as for Version 1, specify the system parameters, or accept the default values, and click the calculate button to initiate the performance simulation.

To ensure that PVWATTS is continuing to meet its users' needs, an online survey form was provided on the PVWATTS website for two months in early FY2005 so users could identify areas for improvement. The results of the survey were then used to prioritize improvements to PVWATTS.

3. Results and Accomplishments

A total of 51 respondents completed the online PVWATTS survey, classifying themselves as to business/occupation as follows:

- PV module manufacturer (4)
- Balance-of-systems manufacturer (3)
- Designer/installer (18)
- Consultant (8)
- University (2)
- National laboratory (0)
- State energy office (1)
- Consumer/buyer (15).

The largest number of responses came from the designer/installer and consumer/buyer classifications. Based on the survey, and keeping with the original intent of providing non-experts (consumers/buyers) with quick performance estimates for grid-connected systems, the changes outlined in the following paragraphs were made to PVWATTS.

3.1 System Size

The PV system specification input for system size was changed from an AC power rating to a nameplate DC power rating. The nameplate DC power rating information is more readily available, and is less open to interpretation as to how it is determined, than is an AC power rating. A nameplate DC power rating is also more consistent with how energy performance is reported for fielded systems and how most PV systems are currently marketed.

3.2 DC-to-AC Derate Factor

Capability to input an overall DC-to-AC derate factor was added for calculating a reference AC power rating by PVWATTS. The user may also have PVWATTS calculate a new overall DC-to-AC derate factor by specifying previously determined individual PV system component derate factors⁵. The use of derate factors offers more transparency for the loss factors used by PVWATTS, and permits loss factors to be changed, if desired, to better match system-specific components or loss mechanisms. A default DC-to-AC derate factor allows novice users to obtain realistic results without a detailed knowledge of system components. The individual component derate factors and their allowable ranges are listed in Table 1.

Table 1. PVWATTS Component Derate Factors

Item	Default	Range
PV module nameplate DC rating	0.95	0.80-1.05
Inverter and transformer	0.92	0.88-0.95
Mismatch	0.98	0.97-0.995
Diodes and connections	0.995	0.99-0.997
DC wiring	0.98	0.97-0.99
AC wiring	0.99	0.98-0.993
Soiling	0.95	0.30-0.995
System availability	0.98	0.00 0.995
Shading	1.00	0.0-1.00
Sun-tracking	1.00	0.95-1.00
Age	1.00	0.70-1.00
Overall	0.77	

3.3 Residential Electric Rates

The residential electric rates were updated with the latest available data. For Version 1, the latest data were for 2003, and for Version 2, the latest data were for 2002. (Data for Version 2 are much more extensive and not as quickly available as that for Version 1.)

3.4 Solar Radiation

The results page was revised to include monthly and yearly solar radiation values for the PV array. This is useful information for understanding performance differences between locations.

3.5 Simpler Version 2 Interface

Version 2 may now be launched with NREL's IMS PVWATTS Version 2 site, which provides a much simpler user interface because default settings are used for the most frequently used settings. The original method for launching Version 2 with the map server was retained to accommodate users already familiar with Version 2.

4. Conclusions and Future Direction

To ensure that PVWATTS continues to meet its users' needs, an online survey form was provided to users to identify areas for improvement. The results of

the survey were used to prioritize improvements to PVWATTS. In FY2005, PVWATTS was revised by changing the PV system specification input for system size from an AC power rating to a nameplate DC power rating; adding an input for an overall DC-to-AC derate factor; updating the residential electric rates; adding monthly and yearly solar radiation values for the PV array; and simplifying the user interface for Version 2.

For FY2006, we will be adding international TMY weather data for PVWATTS simulations for locations outside the United States. This will support international activities of the U.S. PV industry, build international interest in the use of PVWATTS for estimating the performance of grid-connected PV systems, and address a common FY2005 survey suggestion by PVWATTS users with international interests.

Both versions of PVWATTS reside on the National Renewable Energy Laboratory's Web site and may be accessed by pointing your browser to http://rredc.nrel.gov/solar/calculators/PVWATTS/.

ACKNOWLEDGEMENTS

This work was performed under DOE contract DE-AC36-99-GO10337.

REFERENCES

- ¹B. Marion and M. Anderberg. "PVWATTS–An Online Performance Calculator for Grid-Connected PV Systems," *Proceedings of the ASES Solar 2000 Conference*, June 16-21, 2000, Madison, WI.
- ²B. Marion and K. Urban. *Users Manual for TMY2s-Typical Meteorological Years Derived from the 1961-1990 National Solar Radiation Data Base*, NREL/TP-463-7668, Golden, CO: National Renewable Energy Laboratory, 1995.
- ³D. Menicucci and J. Fernandez. User's Manual for PVFORM: A Photovoltaic System Simulation Program for Stand-Alone and Grid-Interactive Applications, SAND85-0376, Albuquerque, NM: Sandia National Laboratories, 1988.
- ⁴B. Marion, M. Anderberg, R. George, P. Gray-Hann, and D. Heimiller, "PVWATTS Version 2 Enhanced Spatial Resolution for Calculating Grid-Connected PV Performance," *Proceedings of the 2001 NCPV Program Review Meeting, Lakewood, CO*, pp. 143-144.
- ⁵B. Marion, J. Adelstein, K. Boyle, H. Hayden, B. Hammond, T. Fletcher, B. Canada, D. Narang, A. Kimber, L. Mitchell, G. Rich, and T. Townsend, "Performance Parameters for Grid-Connected PV Systems," *Proceedings of the 31*st IEEE Photovoltaic Specialists Conference, Lake Buena Vista, FL, 2005, pp.1601-1606.

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to Department of Defense, Executive Services and Communications Directorate (0704-0188). Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OME control purpose.

currently valid OMB control number. PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ORGANIZATION.									
	REPORT DATE (DD-MM-YYYY)		PORT TYPE		3. DATES COVERED (From - To)				
	November 2005	Co	onference Paper	•					
4.	TITLE AND SUBTITLE					TRACT NUMBER			
	Recent Revisions to PVWAT	TS			DE-	AC36-99-GO10337			
					5h GRA	NT NUMBER			
					Job. Olta	INT NOMBER			
					5c. PROGRAM ELEMENT NUMBER				
6.	AUTHOR(S)				5d. PROJECT NUMBER				
	B. Marion, M. Anderberg, and	rion, M. Anderberg, and P. Gray-Hann NREL/CP-520-389		EL/CP-520-38975					
					5e. TASK NUMBER				
						C6.7101			
					1 400:7101				
					5f. WORK UNIT NUMBER				
7.	PERFORMING ORGANIZATION NA	PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) National Renewable Energy Laboratory 1617 Cole Blvd.		<u> </u>	8. PERFORMING ORGANIZATION REPORT NUMBER				
	National Renewable Energy I								
	1617 Cole Blvd.				NREL/CP-520-38975				
	Golden, CO 80401-3393	Golden, CO 80401-3393							
9.			10. SPONSOR/MONITOR'S ACRONYM(S)						
						NREL			
						11. SPONSORING/MONITORING			
						AGENCY REPORT NUMBER			
12.	2. DISTRIBUTION AVAILABILITY STATEMENT								
	National Technical Information Service								
	U.S. Department of Commerce								
	5285 Port Royal Road								
	Springfield, VA 22161								
13.	13. SUPPLEMENTARY NOTES								
14.	ABSTRACT (Maximum 200 Words)								
						easily calculate the energy production			
						hout the United States. To ensure that			
						vided to users to identify areas for			
						to PVWATTS in FY2005. PVWATTS			
	was revised by changing the PV system specification input for system size from an AC power rating to a nameplate DC power rating; adding an input for an overall DC to AC derate factor; updating the residential electric rates; adding								
	monthly and yearly solar radiation values for the PV array; and simplifying the user interface for Version 2.								
1-									
15. SUBJECT TERMS District Policy Colors DV/AATTC: DV/ANDEL									
Photovoltaics; solar; PVWATTS; PV; NREL									
16	16. SECURITY CLASSIFICATION OF: 17. LIMITATION 18. NUMBER 19a. NAME OF RESPONSIBLE PERSON								
	a. REPORT b. ABSTRACT c. THIS PAGE OF ABSTRACT OF PAGES								
	Unclassified Unclassified Unclassified UL 19b.TELEPONE NUMBER (Include area code)								
	130. TELLI OIL NOMBER (Module area code)								