

FLORIDA SOLAR



ENERGY CENTER[®]

FSEC STANDARD

Test Method for Photovoltaic Module Power Rating

FSEC Standard 202-05

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TEST METHOD FOR PHOTOVOLTAIC MODULE POWER RATING

FOREWORD

This forward is not part of the standard.

This document describes the testing and reporting requirements for certification of photovoltaic modules (PV) power ratings. The test methods and procedures chosen for this purpose are based on consensus standards of relevant committees of the Institute of Electrical and Electronic Engineers (IEEE), the American Society for Testing and Materials (ASTM), and the International Electrotechnical Commission (IEC).

The test method is primarily based on the PV module performance measurement in PowerMark document PV-3: *Test Requirements for a Certification and Labeling Program for Photovoltaic Modules* and ASTM E 1036-96 *Standard Test Methods for Electrical Performance of Non-Concentrator Terrestrial Photovoltaic Modules and Arrays Using Reference Cells*. Some requirements are taken from IEEE 1262, UL 1703, IEC 61215 and IEC 61646. Other specific ASTM test methods referenced herein, are also incorporated as mandatory test requirements for the purposes of this document.

The test methods and procedures described represent a minimum set of testing requirements for any product certification and labeling programs that may be developed for photovoltaic module power ratings. Additionally, these test procedures and the related equipment and facilities requirements represent a minimum set of test capabilities against which laboratories may be evaluated for testing in support of module certification and labeling programs.

This document, together with the following four documents, addresses the totality of the criteria and requirements of PowerMark for their PV module power ratings certification and labeling program:

PV-1 Criteria for a Model Quality System for Laboratories Engaged in Testing Photovoltaic Modules

PV-2 Model for a Third-Party Certification and Labeling Program for Photovoltaic Modules

PV-4 Operational Procedures Manual for the Certification Body of the Photovoltaic Module Certification Program

PV-5 Application and Certification Procedures for the Photovoltaic Module Certification Program

TEST METHOD FOR PHOTOVOLTAIC MODULE POWER RATING

1.0 INTRODUCTION

In 1976, the Florida Legislature enacted the Solar Energy Standards Act of 1976, Section 377.705, Florida Statutes. This law, effective October 1976, directs the Florida Solar Energy Center (FSEC) to develop standards for solar energy equipment sold or manufactured in the state, establish criteria for determining the performance of solar energy equipment, and maintain a test facility for evaluating solar energy equipment performance. It provides for FSEC to charge fees to cover cost of testing and allows the acceptance of test results from other testing organizations.

The Solar Energy Standards Act was amended in 1978 to require that after January 1, 1980, all solar systems manufactured and sold in Florida must meet the standards of FSEC and shall display results of performance tests in a manner prescribed by FSEC.

In 2001, FSEC started a program to test and certify the performance of solar photovoltaic (PV) modules. This test method and criteria were developed for FSEC's PV module performance certification program. This standard was developed to ensure that solar energy equipment manufactured or sold within the state is effective and represents a high level of quality of materials, workmanship, and design. The use of this standard is expected to enhance consumer confidence and improve the design and sizing of PV systems, thereby improving reliability and cost-effectiveness.

2.0 PURPOSE

The purpose of this document is to delineate the test method for determining the power ratings of photovoltaic modules for the FSEC certification and labeling program.

Testing and reporting requirements described in this document represent the minimum requirements against which photovoltaic modules shall be evaluated in terms of their quantitative response to electrical performance-based tests.

The test procedures represented provide the minimum capabilities against which laboratories may be assessed for testing in support of photovoltaic module certification and labeling.

3.0 SCOPE AND LIMITATIONS

Testing requirements set forth in this document shall be used for determining the power ratings of terrestrial flat-plate photovoltaic (PV) modules intended for power-generating applications. These requirements are not intended for use in testing and evaluation of PV concentrator modules.

This document covers the requirements for both indoor testing under a solar simulator and outdoor testing under natural sunlight.

This document is applicable to crystalline silicon, amorphous silicon, thin-film and other PV technologies.

This document also provides requirements for the minimum standards by which laboratories selected by manufacturers shall comply and operate to demonstrate their competence to rate PV modules whereby those ratings will be acceptable to the FSEC certification program.

4.0 DEFINITIONS

Terms defined in this section are relevant to PV module testing.

Air Mass (AM): A dimensionless quantity equal to the ratio of: (1) the actual path length of solar radiation through the atmosphere to (2) the vertical path length through the atmosphere at sea level. At sea level, for all but very large zenith angles z , $AM = \sec z$

AM 1.5 Standard Reference Spectrum: The solar spectral irradiance distribution (diffuse and direct) incident at sea level on a sun-facing 37 degree tilted surface from horizontal. The atmospheric conditions for AM 1.5 are: precipitable water vapor 14.2 mm, total ozone 3.4 mm, turbidity (base e, $\lambda=0.5 \mu\text{m}$) 0.27

I-V Data: The relationship between current and voltage of a photovoltaic device in the power-producing quadrant, as a set of ordered pairs of current and voltage readings in a table, or as a curve plotted in a suitable coordinate system (i.e., Cartesian).

Maximum Power (Pmp): The point on the current-voltage (I-V) curve of a PV module under illumination, where the product of current and voltage is maximum. For the purpose of this document, "rated" power is defined as Pmp at STC.

PV Module (flat-plate): The smallest environmentally protected, essentially planar assembly of solar cells and ancillary parts, such as interconnections, terminals, and protective devices such as bypass diodes where the assembly is intended to generate dc power under unconcentrated sunlight. The structural (load carrying) member of a module can either be the top layer (superstrate), or the back layer (substrate).

Reference Cell (photovoltaic): A photovoltaic cell whose short circuit current is calibrated at the specified irradiance of a standard reference spectrum.

Reference Module (photovoltaic): A packaged assembly of one or more photovoltaic cells whose short circuit current is calibrated at the specified irradiance of a standard reference spectrum.

Standard Test Conditions (STC): Conditions under which a module is typically tested in a laboratory: (1) irradiance intensity of 1000 W/ m^2 , (2) AM1.5 standard reference spectrum, and (3) cell or module temperature of 25 ± 2 degrees C.

Standard Operating Conditions (SOC): Same conditions as STC, except that the cell or module temperature is 45 ± 2 degrees C.

5.0 NOMENCLATURE

Hm = measured irradiance, kW/m^2
Imp = measured current at peak power
Impo = measured peak power current normalized to 1000 W/m^2
I_{PSTC} = peak power point current at standard test conditions
I_{SCSTC} = short circuit current at standard test conditions
Isc = measured short circuit current
IscO = measured short circuit current normalized to 1000 W/m^2
k = Boltzmann's constant, 1.38×10^{-23}
n = diode constant
Ns = the number of series connected cells in a module
P_{PSTC} = peak power at standard test conditions
P_{PSTC#N} = peak power at standard test conditions for test #N
STC = standard test conditions, 1000 W/m^2 , 25°C average module temperature and AM 1.5 spectral distribution
SOC = standard operating conditions, 1000 W/m^2 , 45°C average module temperature and AM 1.5 spectral distribution
Ta = module absolute temperature, °K
Tc = the average cell temperature measured at the back face of the module and corrected for the cell location in a module
Vmp = measured voltage at peak power
Voc = measured open circuit voltage
V_{PSTC} = peak power point voltage at standard test conditions
Voco = measured open circuit voltage normalized to 1000 W/m^2
V_{OCSTC} = open circuit voltage at standard test conditions
Vpo = measured voltage at peak power normalized to 1000 W/m^2
 α_1 = temperature correction coefficient of short circuit current
 α_2 = temperature correction coefficient of peak power current
 β_1 = temperature correction coefficient of open circuit voltage
 β_2 = temperature correction coefficient of peak power voltage
 \ast_1 = empirical first order peak power voltage normalization constant
 \ast_2 = empirical second order peak power voltage normalization constant
 ζ = open circuit voltage normalization constant: $\zeta = (nkT_a/q) (N_s/V_{mp})$

6.0 REFERENCES

ASTM G 173 Tables for Reference Solar Spectral Irradiance: Direct Normal and Hemispherical on 37° Tilted Surface.

ASTM E 927-04 Standard Specifications for Solar Simulation for Photovoltaic Testing.

ASTM E 973 Standard Test Method for Determination of the Spectral Mismatch Parameter Between a Photovoltaic Device and a Photovoltaic Reference Cell.

ASTM E 1036-02 Standard Test Methods for Electrical Performance of Non-Concentrator Terrestrial Photovoltaic Modules and Arrays Using Reference Cells.

ASTM E 1362 Standard Test Method for Calibration of Non-Concentrator Photovoltaic Secondary Reference Cells.

ASTM E 1799 Practice for Visual Inspection of Photovoltaic Modules.

IEC 904-1 Measurement Principles of PV Current-Voltage Characteristics.

IEC 904-2 Requirements for Reference Solar Cells.

IEC 904-3 Measurement Principles for Terrestrial PV Solar Devices with Reference Spectral Irradiance Data.

IEC 904-5 Determination of the Equivalent Cell Temperature of PV Devices by the Open Circuit Voltage Method.

IEC 904-6 Requirements for Reference Solar Modules.

IEC 904-7 Computation of Spectral Mismatch Error Introduced in the Testing of PV Devices.

IEC 904-8 Guidelines for the Measurement of Spectral Response of a PV Device.

IEC 904-9 Solar Simulator Performance Requirements.

IEC 904-10 Methods of Linearity Measurement.

IEC 60891 Procedures for Temperature and Irradiance Corrections to Measured I-V Characteristics of Crystalline Silicon Photovoltaic Devices.

IEC 61215 Crystalline Silicon Terrestrial Photovoltaic (PV) Modules – Design Qualification and Type Approval.

IEC 61646 Thin-Film Silicon Terrestrial Photovoltaic (PV) Modules - Design Qualification and Type Approval.

IEEE 1262 Recommended Practice for Qualification of Photovoltaic (PV) Modules.

UL Standard 1703 Standard for Safety: Flat-Plate PV Modules and Panels, Underwriters Laboratories Inc.

7.0 RECEIVING INSPECTION

On receiving modules, FSEC test laboratory staff shall visually inspect each of the modules and document their condition with appropriate sketches and photographs, if necessary, to show the location of defects or other irregularities. The inspection will include, but not be limited to the following:

- Shipping damage, poor workmanship, or mechanical mounting defects.
- Cracking, shrinkage, or distortion of polymeric material used for electrical insulation or isolation including failure of adhesive and tacky surface of plastic modules.
- Corrosion of fasteners, mechanical members, or electrical circuit elements.
- Bubbles, delamination, or the presence of foreign material.
- Mechanical distortion, buckling, or evidence of yielding.
- Broken, cracked or torn external surfaces.
- Broken or cracked cells.
- Cells touching one another or module frame.
- Terminals not bonded to the module or terminal box.
- Faulty interconnections or joints.
- Any other condition that may affect performance.

The receiving report as shown in Table 1 will be completed and returned to the module supplier within two weeks stating the expected date of delivery of the test report.

TABLE 1 MODULE RECEIVING REPORT

Module Type and Model
UL Listed and Designation
Date Received
Expected Date of Delivery of Test Report

Module Serial No.						
Shipping Damage?						
Carrier/Shipper Notified?						
Is Module Replacement Required?						
Is Module Replacement Ordered?						
Flaws in Workmanship?						
Flaws in Electrical Connectors?						
Flaws in Seals/Adhesives?						
Flaws/Voids in Encapsulant?						
Flaws/Cracks in Cells?						
Other Flaws and Damages						

Notes:

Other Comments:

Prepared by:

8.0 IRRADIANCE SOURCE AND MEASUREMENT

8.1 Irradiance Source

The light source may be natural sunlight or a solar simulator. If the natural sunlight is used, the performance measurements will be conducted on each module for at least three clear days with daily irradiance of at least 5.0 kWh/m² in the plane of the test modules. Only the module performance data obtained at an irradiance of 800 W/m² or greater and at a module temperature of 0°C to 60°C will be used for determining the module power rating. If a reference cell or reference module with other than identical electrical and optical properties of the test modules is used for irradiance measurement, a spectral mismatch correction shall be made to the measured data per ASTM E 973 or IEC 904-7.

If a solar simulator is used as the light source, it must meet the requirements of a Class A solar simulator as specified by ASTM E 927 or IEC 904-9.

8.2 Irradiance Measurement

The measurement of the irradiance on the module surface shall be conducted with a calibrated reference cell or reference module. A reference cell or module used for these tests should have the same optical and electrical properties, including the spectral response, as the modules under test. Such reference cell or module shall have been calibrated by a minimum of two qualified laboratories per ASTM E1362 (Standard Test Method for Calibration of Non-Concentrator Photovoltaic Secondary Reference Cells) or IEC 904-2 (Requirements for Reference Solar Cells) or IEC 904-6 (Requirements for Reference Solar Modules) using the ASTM G 173 or IEC 904-3 global reference spectrum. The calibration constants shall agree within ±2.0% of each other. If the reference cell or module is used at cell temperatures outside the temperature range of 23-27°C, a qualified laboratory shall have also measured the temperature coefficient of the calibration constant. The average value of the calibration constant and temperature coefficient measured by the qualified laboratories shall be considered the true value. An auxiliary reference cell or module of crystalline silicon may be used in addition to the spectrally matched reference cell or module for experimental purposes.

To the extent possible, FSEC owned reference cells or modules will be used for irradiance measurement. If the module technology is different from the FSEC owned reference cells, the module manufacturer/supplier shall be required to provide an environmentally encapsulated reference cell or module, that has been calibrated by at least two qualified laboratories as discussed above. Only in exceptional situations, where it is virtually impossible to use the reference cell or module of the identical optical and electrical properties as the test modules, a different reference cell or module may be used and the spectral mismatch correction applied.

For testing of amorphous silicon modules, the reference cell or module used will be stabilized prior to calibration. This reference cell or module will be stored in a dark and conditioned space, except when used for irradiance measurements for testing.

Alternatively, a crystalline silicon reference cell or module with a KG-5 filter may be used for testing amorphous silicon modules.

9.0 PRE-TEST EXPOSURE METHOD

The certified power rating from PV modules tested to this standard is expected to be repeatable, stable and representative such that ratings may be used to make comparison between models and types of modules. Some PV modules, amorphous silicon, cadmium telluride (CdTe), copper indium diselenide (CIS), copper indium gallium selenide (CIGS) as well as others, indicate performance changes after light exposure. The power output of CdTe is affected by previous voltage bias and light exposure. Light soaking changes are known to occur in the I-V curves of CIS and CIGS modules. Performance for some modules is known to degrade with initial exposure but to stabilize over time. This section describes pre-test exposure of test modules and a method to determine when the output power from the test modules has stabilized.

Following the receiving inspection of 7.0, all modules will be tested using the test procedure of 10.3 or 10.4. This first test (#1) provides an “out of the box” maximum power point mean power value for modules in the test group at standard test conditions ($P_{PSTC\#1}$). Prior to additional performance testing, all modules will be exposed to natural sunlight under load. This exposure will be no less than an accumulation of 60.0 kWh/m² and no more than 75.0 kWh/m² as measured by a calibrated Epply Precision Spectral Pyronometer (PSP) in the plane of the module.

At the completion of this first exposure, modules will undergo the second test (#2) per the test procedure of 10.3 or 10.4 to provide an average power value for the modules, $P_{PSTC\#2}$.

A standard paired t-test of means will be conducted on the P_{PSTC} data from test #1 vs. the P_{PSTC} data from test #2 to determine if there is a statistical difference between the two mean power measurements ($P_{PSTC\#1}$ vs. $P_{PSTC\#2}$) at the 95% confidence level. The null hypothesis, H_0 , is that the two means of STC maximum power are not statistically different and thus stabilization has been reached. The alternative hypothesis, H_a , is that there is a statistical difference between the two power means, one from before and one after exposure, and thus performance stabilization has not been indicated.

If, by the t-test results, H_0 is accepted and stabilization is indicated, then the mean values from test #2 will be used for the reporting in Section 11. If H_0 is rejected, then the modules will be exposed again to natural sunlight. This exposure period and any additional exposure period, if needed, will be of 60.0 kWh/m² and no more than 75.0 kWh/m². After each exposure period, the modules will be tested using the test procedures of 10.3 or 10.4. The $P_{PSTC\#N}$ values produced by subsequent test will be evaluated by t-test as defined above against the previous exposure interval $P_{PSTC\#N-1}$ values to determine if stabilization is indicated.

Exposure of the test modules will be continued in 60.0 kWh/m² to 75.0 kWh/m² exposure periods until performance stabilization is indicated at the 95% confidence interval by satisfaction of Ho.

Given stabilization, the mean values of the test that confirmed performance stabilization ($P_{PSTC\#N}$) will be used for the reporting in Section 11.

If, prior to stabilization, exposure time exceeds six months, interim status reports will be provided at six month intervals.

10.0 PERFORMANCE TEST METHOD

10.1 Purpose

The purpose of this test is to determine the PV module's rated power, P_{mp} , at STC and SOC, along with other performance parameters, V_{oc} , I_{sc} , V_{mp} and I_{mp} , from the measurements conducted on at least five test modules.

10.2 Temperature Coefficients and Voltage Irradiance Correction Factors

For testing in natural sunlight, the measured module performance data taken under existing irradiance levels, spectral conditions and module temperatures need to be translated to STC (and SOC) to get the nominal module ratings for standardization. This requires the knowledge of temperature coefficients of module power, current and voltage, and module voltage irradiance correction factors. It is not necessary to determine the temperature coefficients and correction factors for every module to be tested, that is, values obtained from another module of identical design and construction may be used.

The temperature coefficients and voltage irradiance correction factors will either be measured at FSEC or may be obtained from Sandia National Laboratories testing (King et al., 1997^{*}). The methods used for the measurement of the temperature coefficients and correction factors are described in IEC 60891 and ASTM E1036-02 Annex 2. The method for measurements of the temperature coefficients is also described in King et al., 1997. The FSEC test laboratory will either use the values available from Sandia National Laboratories (SNL) or determine the temperature coefficients of module power, voltage and current, and voltage irradiance correction factors in accordance with ASTM E1036-02 Annex 2.

^{*} King, D. L., Kratochvil, J. A., and Boyson, W. E., Temperature Coefficients for PV Modules and Arrays: Measurement Methods, Difficulties and Results, 26th IEEE Photovoltaic Specialists Conference, Anaheim, CA, September 29- October 3, 1997.

10.3 Indoor Test Procedure

A pulsed solar simulator (Spire 660 Sun Simulator) is used as the irradiance source for determining the module power ratings. The simulator is automated to take I-V curves of the reference module and test modules, using a personal computer.

The test modules' and reference module's optical surface shall be cleaned prior to the electrical performance measurements. The refrigerated temperature bath unit and the air conditioner shall be turned on and allowed to stabilize at 25°C. The computer, monitor and printer shall be turned on.

The test plane cart of the simulator shall be pulled out. The reference module shall be secured with two to four module holders and placed face up on the test plane and centered in the designated area of average irradiance. The reference module positive and negative terminals shall be connected to the designated plugs located at the front of the test plane cart. The test plane cart shall be closed completely. The new parameter file for the reference module shall be entered in the computer. The high voltage (HV) switch on the main electrical cabinet shall be enabled and the HV on the computer screen activated to latch the compressed air solenoid for cooling lamps. The I-V curve of the reference module shall be taken by clicking the *Run* button on the computer screen. The reference module I-V curve and its short circuit current shall be examined. If necessary, the lamp intensity may be adjusted to get the calibration value of the reference module short circuit current corresponding to irradiance of 1000 W/m².

The test plane cart shall be pulled out again and the reference module shall be removed from the test plane. Four thermocouples shall be glued to a test module back surface in four quadrants as per requirements of the ASTM E-1036 standard, and may be tied together and connected to one of the auxiliary inputs of the computer to record the module back surface temperature. The test module shall be secured with four module holders and placed face up on the test plane for I-V measurements centered as close as possible in the designated area of average irradiance. The test module positive and negative terminals shall be connected to the plugs at the front of the test plane cart. The cart shall be closed again and a new parameter file for the test module shall be entered in the computer. As with the reference module, the HV switch on the main electrical cabinet shall be enabled and the HV on the computer screen activated to latch the solenoid. The I-V curve of the test module shall be taken by clicking the *Run* button on the computer screen. At least three I-V curves shall be taken at different placements of the test module in the test plane area of $\pm 3\%$ uniformity of irradiance. Each of the performance parameters will be averaged for all the I-V curves taken on the same test module. If the test module temperature is other than 25°C (or 45°C), the performance parameters may be translated to their values at 25°C, as given by equations (5) and (6) in the next subsection.

This procedure shall be repeated on each of the test modules and their I-V curves shall be recorded.

10.4 Outdoor Test Procedure and Data Analysis

The test modules' and reference module's optical surfaces shall be cleaned prior to the electrical performance measurements. The modules shall be installed securely on a test stand or other suitable mounting structure. An automated I-V curve tracer may be used to record the I-V curves of test modules under natural sunlight. The test modules shall be connected to the curve tracer to record I-V data sequentially on all modules. A four-wire Kelvin probe shall be connected to each module terminal set to record the current and voltage independently i.e., the module terminal voltage is effectively measured without the wiring resistive voltage drop (i.e., IR loss, where I is the module output current and R is the resistance of the interconnected wiring between the module terminals and the recording device). Four thermocouples shall be glued to each module back surface in four quadrants as per requirements of the ASTM E-1036 standard, and may be tied together and connected to one of the auxiliary inputs of the multitracer to record the module back surface temperature. The calibrated reference module shall also be mounted in the plane of the test modules to measure the prevailing solar irradiance. I-V data shall be collected on each module for at least three days of daily total irradiance of 5 kWh/m² or greater in the plane of the test modules.

Concurrently with each set of I-V recordings, irradiance measurements shall be made with a spectrally matched reference module calibrated at both the National Renewable Energy Laboratory (NREL) and SNL, and the prevalent spectral distribution shall be recorded with a LI-COR 1800 spectroradiometer. The reference module terminals shall be connected to a high precision low resistance shunt resistor with a very low temperature coefficient (of the order of 0.0001/°C). This shunt effectively short circuits the reference module and measures the module's short circuit current by determining the voltage across the shunt at an auxiliary input channel of the curve tracer. The measured short circuit current is corrected to the calibration temperature of the reference module, and the irradiance on the test module is obtained by dividing the corrected short circuit current by the calibration constant.

Only the data with irradiance of 800 W/m² or greater, measured module back surface temperature between 0°C and 60°C, and spectral distribution close to AM 1.5 may be selected for analysis. The spectral distribution of global irradiance must be within ±10% of AM 1.5 conditions for each of the six wavelength ranges described in the ASTM E-927 standard, as specified below in the Table 2 (Note that the spectral distribution tolerance requirements are tighter than for a Class A simulator by a factor of 2.5).

The procedure for the selection of data to conduct software analysis is illustrated in Figure 1 below.

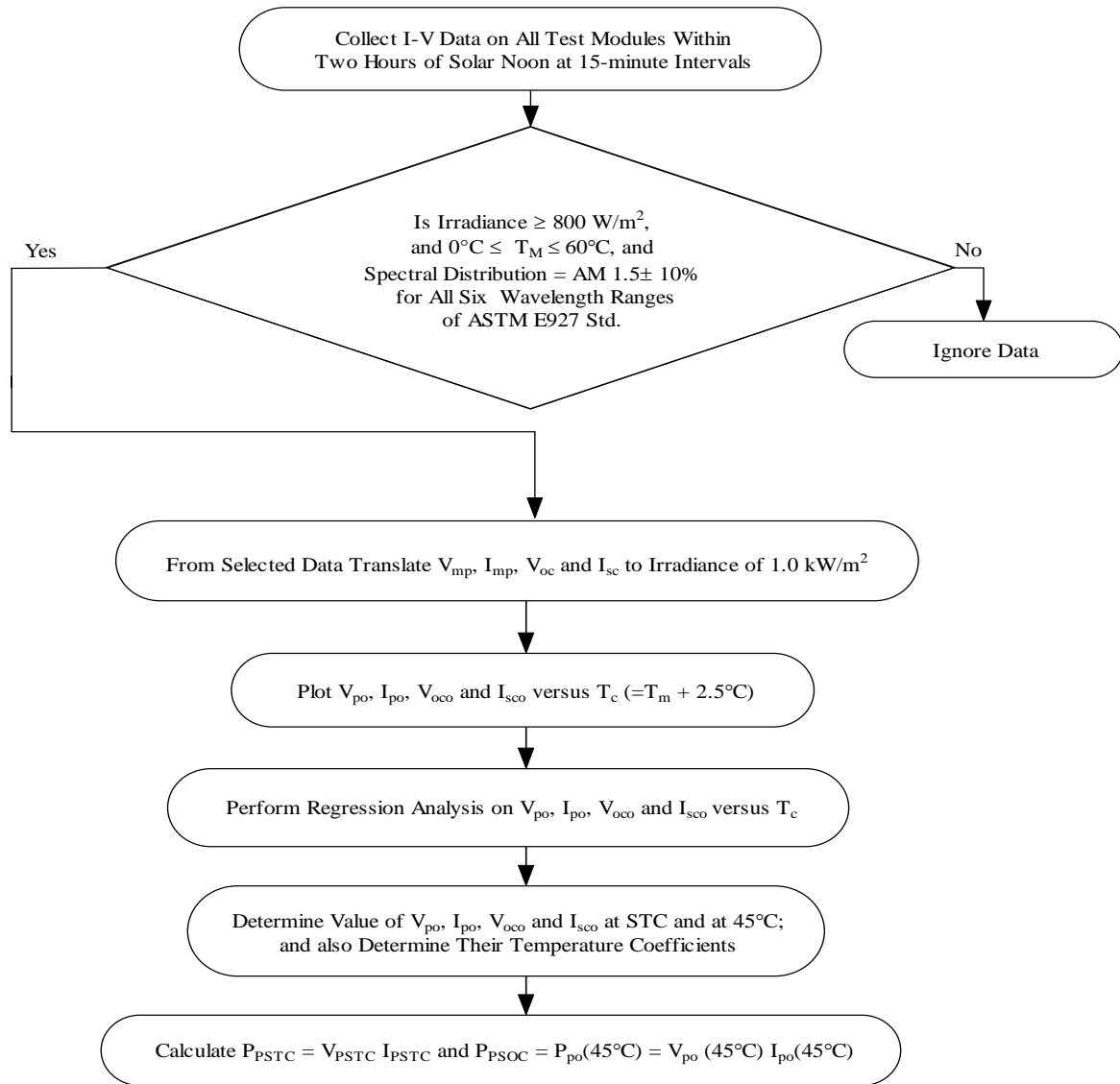


Figure. Data Selection and Analysis Procedure for Outdoor Testing at FSEC

TABLE 2. REQUIREMENTS FOR SPECTRAL DISTRIBUTION OF IRRADIANCE

(Percent of Irradiance Between 0.4µm and 1.1 µm at AM 1.5 Distribution in Different Wavelength Intervals)

Wavelength Range	ASTM E-927	Allowable
0.4 to 0.5 µm	18.5	16.6.0 to 20.4
0.5 to 0.6 µm	20.1	18.1 to 22.1
0.6 to 0.7 µm	18.3	16.5 to 20.1
0.7 to 0.8 µm	14.8	13.3 to 16.3
0.8 to 0.9 µm	12.2	11.0 to 13.4
0.9 to 1.1 µm	16.1	14.5 to 17.7

From each selected I-V curve data set, the module performance parameters are obtained. The measured values of the performance parameters, peak power voltage (Vmp), peak power current (Imp), open circuit voltage (Voc) and short circuit current (Isc) at the existing irradiance are normalized to the standard irradiance of 1000 W/m², as follows:

$$I_{po} = I_{mp}/H_m, I_{sco} = I_{sc}/H_m \tag{1}$$

$$V_{oco} = V_{oc} [1 + (\zeta \ln(H_m))] \tag{2}$$

$$V_{po} = V_{mp} [1 + \ast_1 \ln(H_m) + \ast_2 \{\ln(H_m)\}^2] \tag{3}$$

Where Ipo, Isco, Voco and Vpo are the normalized values of the respective parameters at irradiance of 1000 W/m² and Hm is the measured irradiance in kW/m².

The constant ζ is given by $\zeta = (nkT_a/q) (N_s/V_{mp}) = 0.06$ for crystalline silicon modules and n is the diode constant nearly equal to 1.1, k is Boltzmann's constant equal to 1.38x10⁻²³, Ta is the module temperature in absolute or °K of nearly 320 (i.e., 47°C), Ns is the number of series connected cells in a module, \ast_1 and \ast_2 are constants determined empirically and differ for modules of different technology and/or construction. The values of these constants may be obtained from the Sandia Module Database or measured, if necessary.

(If a reference cell or module with other than identical electrical and/or optical properties of the test modules is used for outdoor testing, the performance data shall be corrected for spectral mismatch error per ASTM E 973 or IEC 904-7.)

The normalized performance parameters Ipo, Vpo, Isco and Voco at the measured temperatures shall be converted to their values at STC and SOC temperatures of 25°C and 45°C, respectively, either by linear regression analysis or by using the known values of temperature coefficients. For regression analysis, the performance parameters Ipo, Vpo, Isco and Voco are plotted versus the corrected module temperature (measured back surface temperature + 2.5°C) to obtain the values of each performance parameter at 25°C module temperature for STC. At least 20 data points are needed to conduct the regression analysis. The module power rating is determined as the product of the module peak power current and voltage at STC.

$$P_{PSTC} = V_{PSTC} \cdot I_{PSTC} \quad (4)$$

Similarly, the performance parameters at SOC may also be determined from the linear regression analysis plots as the respective values at 45°C module temperature.

Alternatively, the performance parameters at the measured module temperature may be translated to their values at 25°C, as given by the following equations:

$$I_{SCSTC} = I_{SCO} / [1 + \alpha_1 (T_c - 25)], \quad I_{PSTC} = I_{PO} / [1 + \alpha_2 (T_c - 25)] \quad (5)$$

$$V_{OCSTC} = V_{OCO} / [1 + \beta_1 (T_c - 25)], \quad V_{PSTC} = V_{PO} / [1 + \beta_2 (T_c - 25)] \quad (6)$$

Where I_{SCSTC} and I_{PSTC} are the STC values of module short circuit and peak power currents, respectively, and V_{OCSTC} and V_{PSTC} are the STC values of module open circuit and peak power voltages, respectively. α_1 and α_2 are the temperature coefficients of module short circuit and peak power currents, respectively, and β_1 and β_2 are the temperature coefficients of module open circuit and peak power voltages, respectively. T_c is the corrected module temperature i.e., measured module temperature + 2.5°C. Only selected measurements taken at irradiance of 800 W/m² or greater and module temperature of 0°C to 60°C shall be used for translated values for performance parameters. Translated values of module peak power and other performance parameters for each module shall be averaged to provide the test value

The performance parameters at SOC may be determined from similar equations by replacing 25 with 45 as the reference temperature.

The module power ratings and other performance parameters at STC are averaged for the test modules and reported for certification.

11.0 REPORTING

The test report on module performance will include the following:

- Module identification and description for each of the test modules
- Reference cell identification and description
- Irradiance source identification
- Performance parameters P_{mp} , V_{oc} , I_{sc} , V_{mp} , and I_{mp} at STC for each of the test modules and averaged for all test modules
- I-V curve of a module with P_{mp} closest to the average P_{mp}

An example of a test report is shown in the attached table.

PHOTOVOLTAIC MODULE PERFORMANCE REPORT

FSEC Solar Flash Simulator (SFS)

Test Date: July 16, 2003

Test Module/Array Description	Reference Cell Description
Module Identification/Type. KC125G; Multi Crystal	Description Type/Material MSX-5 Multi
Manufacturer Name Kyocera Solar	Cell Identification / Serial No. Ser: 7124
Model No. KC125G	Manufacturer BP Solar
Semiconductor Material (Si, CIS, CdTe) Si	Calibration Laboratory (NREL, SNL) NREL,SNL
Semiconductor Structure (single/multicrystalline, amorphous). Multicrystalline	Calibration Procedure (E1039 , E1125, E1362) N/A
Junction (single, dual, triple) Single	Calibration Constant 0.314@ STC
Cell Stringing (series x parallel) 36 X 1	Factor Spectrum (global or direct normal) Global
Overall Dimensions (L x W x D). 142.5 X 65.3 X 3.6 (cm)	Spectral Response (attach table or curve) N/A
Weight 12.2 Kg	Temperature Coefficient N/A
Voltage Temperature Coefficient	Date Last Calibrated 02/07/2003
Current Temperature Coefficient	

Solar Simulator SPI-Sun 660
STC – Standard Test Conditions (1000 W/m², 25°C and Air Mass 1.5)

Module: Serial No.	1. B1526		2. B0896		3. B1766		4. B0847		5. A0266		Average	
PARAMETER	STC	SOC	STC	SOC	STC	SOC	STC	SOC	STC	SOC	STC	SOC
Open Circuit Voltage (Voc)	21.79		21.65		21.71		21.71		21.71		21.69	
Short Circuit Current (Isc)	7.68		7.63		7.65		7.64		7.71		7.66	
Voltage at Peak Power (Vmp)	17.13		16.95		17.13		17.04		16.99		17.04	
Current at Peak Power (Imp)	6.83		6.78		6.83		6.78		6.83		6.81	
Peak Power (Pmp)	117.06		114.84		116.94		115.51		116.36		116.09	
Fill Factor (FF)	0.70		0.70		0.70		0.70		0.70		0.70	
Efficiency (total area, %)	12.58		12.34		12.57		12.41		12.45		12.48	

Notes: (1) A small module (calibrated indoors and outdoors) was used in place of a reference cell. Calibration Uncertainty: ±4%.

Uncertainty of SFS Test Measurements: ±5%

Summary

Based on the measurements conducted at the FSEC PV Test laboratory, the power rating of Kyocera KC125 modules is

116 Watts \pm 5% at STC

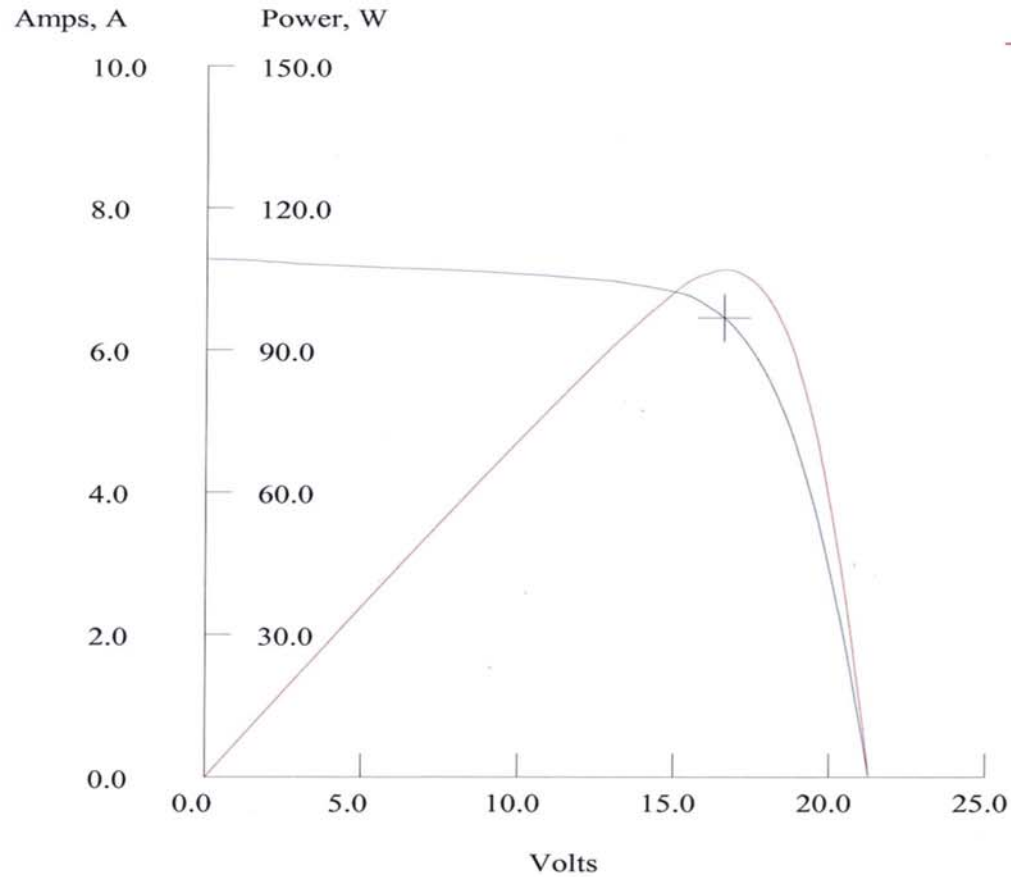
The other measured module performance parameters at STC are as follows:

Open Circuit Voltage, Voc	21.7 Volts
Short Circuit Current, Isc	7.7 Amperes
Voltage at Peak Power, Vmp	17.0 Volts
Current at Peak Power, Imp	6.8 Amperes
Fill Factor	0.70
Efficiency (based on total area)	12.5%

_____	Date: _____	_____	Date: _____
Test Operator		Program Director.	

1. STC = Standard Test Condition of 1000 Watts/m², cell temperature of 25 C and air mass 1.5 spectral distribution.

Note: The results directly relate to the sample of five specific KC 125 modules, which were selected by random sampling.



FLORIDA SOLAR ENERGY CENTER®
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Title: Gobind Kyocera KC-120
 Operator: Demi
 ID: 6512_1
 Cell Type: Si-multi
 09:32:38 01/31/2002
 Tested at:
 Irr: 101 mW/cm2
 Temp: 24.2 degC
 Corrected to:
 Irr: 100 mW/cm2
 Temp: 24.2 degC
 Voc: 21.28 V
 Isc: 7.287 A
 Rs: 0.415 Ohm
 Rsh: 42.054 Ohm
 Pmax: 106.87 W
 Vpm: 16.57 V
 Ipm: 6.449 A
 FF: 0.689
 Ef,c: 1068.66%
 Comment: first test
 prm7124 Isc @ 0.317
 sfs set @ 1.15
 Channel: 1

Measured on a **SPI-SUN SIMULATOR™ 660**

