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An American National Standard

Standard Practice for Determining Reporting Conditions and Expected Capacity for Photovoltaic Non-Concentrator Systems[1]

This standard is issued under the fixed designation E2939; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice provides procedures for determining the expected capacity of a specific photovoltaic system in a specific geographical location that is in operation under natural sunlight during a specified period of time. The expected capacity is intended for comparison with the measured capacity determined by Test Method E2848.

1.2 This practice is intended for use with Test Method E2848 as a procedure to select appropriate reporting conditions (RC), including solar irradiance in the plane of the modules, ambient temperature, and wind speed needed for the photovoltaic system capacity measurement.

1.3 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E772 Terminology of Solar Energy Conversion

E2848 Test Method for Reporting Photovoltaic Non-Concentrator System Performance

2.2 *IEEE Standards:*[3]

IEEE 1547-2003 Standard for Interconnecting Distributed Resources with Electric Power Systems

3. Terminology

3.1 Definitions of terms used in this practice may be found in Terminology E772, IEEE 1547-2003, and Test Method E2848.

3.2 *Definitions:*

3.2.1 *expected capacity, photovoltaic system, n*—the predicted power rating that is derived from meteorological data and a performance model that describes a specific PV system in a specific location and time period.

3.2.2 *measured capacity, photovolaic system, n*—the output power of a photovoltaic system measured according to Test Method E2848.

3.2.3 *performance model, photovoltaic system, n*—a computer model which, at a minimum, simulates the operation of a particular photovoltaic system using plane-of-array irradiance, ambient temperature, and wind speed data as inputs to calculate the instantaneous, simulated power output.

3.2.4 *performance simulation period, photovoltaic system, n*—the period of time over which a single expected capacity prediction is performed. Compare with data collection period in Test Method E2848.

3.2.5 *plane-of-array irradiance, POA, n*—see *solar irradiance, hemispherical* in Terminology E772.

3.2.6 *simulated power output, photovoltaic system, n*—photovoltaic system power output derived from meteorological data and a performance model.

3.2.7 *time resolution, meteorological data, n*—the time interval between individual meteorological data points that has a maximum averaging interval of 1 h, used to calculate both the reporting conditions and the expected capacity.

4. Summary of Practice

4.1 Test Method E2848 provides a procedure to measure the capacity of a photovoltaic system. The procedure involves a

[1] This practice is under the jurisdiction of ASTM Committee E44 on Solar, Geothermal and Other Alternative Energy Sources and is the direct responsibility of Subcommittee E44.09 on Photovoltaic Electric Power Conversion.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from Institute of Electrical and Electronics Engineers, Inc. (IEEE), 445 Hoes Ln., Piscataway, NJ 08854, http://www.ieee.org.

multiple linear regression of output power as a function of plane-of-array irradiance, ambient air temperature, and wind speed data collected during the data collection period, which is a relatively short time period, typically between three and 30 days. Using the regression results, the expected capacity (in watts) is then calculated by substitution of a set of reporting conditions consisting of plane-of-array irradiance, ambient air temperature, and wind speed appropriate for the system under test into the regression equation.

4.2 Although Test Method E2848 states that its procedure is suitable for acceptance testing of newly installed photovoltaic systems (i.e. acceptance testing), it provides only general guidance for the selection of the reporting conditions and no guidance for predicting expected capacity prior to test. Both the reporting conditions and the expected capacity are necessary for acceptance testing.

4.3 This practice provides guidance for selecting the reporting conditions needed for Test Method E2848. This practice also provides a procedure for determining the expected capacity of a photovoltaic system.

4.4 The procedure for determining expected capacity consists of the following steps:

4.4.1 Procure meteorological data that will be representative[4] of the POA irradiance, ambient air temperature, and wind speed conditions during the data collection period.

4.4.1.1 This is best accomplished by using meteorological data that is of the same time of year and same weather conditions seen or expected to be seen during Test Method E2848.

4.4.2 Procure or develop a performance model representative of the photovoltaic system,

4.4.3 Substitute the meteorological data into the performance model to calculate the instantaneous, simulated power output of the photovoltaic system, and

4.4.4 Use the data set to calculate the expected capacity according to Section 9 of Test Method E2848.

4.5 The expected capacity can then be compared with the capacity measured during an acceptance test of a photovoltaic system, if both capacities are determined from the same reporting conditions.

5. Significance and Use

5.1 This practice can be used to determine an expected capacity for an existing or a proposed photovoltaic system in a particular location during a specified period of time (see *data collection period* in Test Method E2848).

5.2 The expected capacity calculated in accordance with this practice can be compared with the capacity measured according to Test Method E2848 when the RC are the same.

5.3 The comparison of expected capacity and measured capacity can be used as a criterion for plant acceptance.

5.4 The user of this practice must select the performance simulation period over which the reporting conditions and expected capacity will be derived. Seasonal variations will likely cause both of these to change with differing performance simulation periods.

5.5 When this practice is used in conjunction with Test Method E2848, the performance simulation period and the data collection period must agree. If they do not agree, the comparison between expected and measured capacity will not be meaningful.

5.6 Historical or measured[5] plane-of-array irradiance, ambient air temperature, and wind speed data can be used to select reporting conditions and calculate expected capacity. If historical data are used, the data collection period should match the time period of the measured data in terms of season and length.

5.7 The simulated power output that is used to calculate the expected capacity should be derived from a performance model designed to represent the photovoltaic system which will be reported per Test Method E2848.

6. Meteorological Data Procurement

6.1 Select a meteorological data set that includes at a minimum plane-of-array irradiance, ambient temperature, and wind speed for a minimum of five contiguous days. This data set will be used to calculate reporting conditions and expected capacity. Another disadvantage is that historical data is rarely measured in the plane-of-array. Therefore, the data will have to be transposed into the plane-of-array, which will have errors when compared to actual measurements. Historical or measured meteorological data may be used to calculate reporting conditions and expected capacity. Both have advantages and disadvantages.

6.2 The advantage of using historical data to calculate reporting conditions is that the reporting conditions and associated expected capacity can be calculated in advance of the construction of a project. This is beneficial when this practice and Test Method E2848 are used for the purpose of acceptance testing. The disadvantage of using historical data for calculating reporting conditions is that actual meteorological conditions during the test may differ from historical conditions. This may increase uncertainty in the comparison of expected capacity to capacity measured per Test Method E2848.

6.3 Generally, it is recommended to use historical data to select reporting conditions, as this will allow the reporting conditions and expected capacity to be calculated in advance of the capacity measurement per Test Method E2848.

6.4 When applicable, the averaging interval used in this practice should be the same as the averaging interval used in Test Method E2848.

7. Performance Model Procurement

7.1 Select a performance model that at a minimum converts POA irradiance, ambient temperature, and wind speed into simulated power output.

[4] In the event that data is not available that will be representative for the system, the user of the practice may translate the data so that it is representative. All translations should use industry standards when possible, and when not possible, industry best practices. All translations of meteorological data shall be documented and included in the report.

[5] Here measured data refers to data measured during the Test Method E2848 test procedure.

7.2 Use the selected performance model and the selected meteorological data to derive simulated power output.

8. Reference Conditions Determination

8.1 As applicable, conduct data filtering of the meteorological data and the simulated power output per 9.1 of Test Method E2848.

8.2 After filtering, the data set must represent no less than 750 total minutes that span at least three days. For example, an averaging interval of 15 min requires a minimum of 50 data points. In the event the data points represent less than 750 min after filtering, extend the test period until 750 min of data points exist after filtering.

8.3 If historical meteorological data were selected, use POA irradiance, ambient temperature, and wind speed during the same time of year as the expected test period associated with Test Method E2848 to calculate the reporting irradiance, reporting ambient temperature, and reporting wind speed. In the event that the test period is unknown at the time of RC selection, generate monthly tables of reporting irradiances, reporting ambient temperatures, and reporting wind speeds. The purpose of using seasonal tables of reporting conditions is to account for seasonal biases in the reporting conditions; therefore, the number of seasonal reporting conditions may vary by climate and location. In areas with strong seasonality, more granular seasonal tables are recommended. In areas with little seasonality, less granular tables may suffice. At a minimum, four and at a maximum twelve sets of reporting conditions are recommended.

8.3.1 Compare POA irradiance, ambient temperature, and wind speed of the filtered data that will be used to calculate reporting conditions to the filtered POA irradiance, ambient temperature, and wind speed measured during the Test Method E2848 test. If applicable, report differences between the conditions.

8.3.2 The comparison is applicable only if this practice will be used for an operational plant. This step can occur after the selection of reporting conditions and the calculation of expected capacity in the event that the measured data is not available when the reference conditions are selected and the expected capacity calculated.

8.4 Calculate the irradiance value that exceeds 60 % of the filtered irradiance data. This is the reporting plane-of-array irradiance.

8.5 Calculate the arithmetic mean ambient temperature of the filtered data. This is the reporting ambient temperature.

8.6 Calculate the arithmetic mean wind speed of the filtered data. This is the reporting wind speed.

9. Expected Capacity Calculation

9.1 Use the filtered POA irradiance, filtered ambient temperature, filtered wind speed, and filtered simulated power data to calculate the regression coefficients specified in 4.2 of Test Method E2848.

9.2 Calculate the power using the regression coefficients from 10.1 and the reporting conditions from Section 9 of this practice per 4.3 of Test Method E2848.

9.3 This power is the expected capacity.

10. Report

10.1 The user ultimately determines the amount of information to be reported. At a minimum the user shall report the following:

10.2 Description of performance model including:
10.2.1 Input parameters,
10.2.2 Software used for performance modeling, and
10.2.3 Modeled system location.

10.3 Resource data set selected for determining reporting conditions and expected capacity:
10.3.1 Source of the data,
10.3.2 If the data is measured or modeled,
10.3.3 Location at which the resource data was measured or modeled,
10.3.4 If the data is historical or measured.[6]
10.3.4.1 If the data is historical, the time period the historical data spans, and
10.3.5 If applicable, differences in POA irradiance, ambient temperature, and wind speed between data used for Test Method E2848 and this practice. These differences will be reported pre- and post-filtering.

10.4 Filtering criteria used.

10.5 Calculated reporting conditions or table of reporting conditions.

10.6 Calculated expected capacity or table of expected capacities.

10.7 Calculated regression coefficients or tables of regression coefficients, a_1, a_2, a_3, and a_4.
10.7.1 The mean and standard deviation of the residuals for the data used to derive the regression(s) shall be reported as an indicator of the quality of the regression(s).
10.7.2 All simulated system performance data, POA irradiance data, ambient temperate data, and wind speed data shall be included in this report as an appendix in a tabulated text format.

11. Keywords

11.1 performance; photovoltaics; reporting; systems

[6] Here measured data refers to data measured during the Test Method E2848 test.