Solmetric White Paper:

Winning Contracts with PV Array Testing

Contents

Introduction

This white paper is intended for solar PV project developers, EPC's, operation & maintenance companies and other solar service providers who want to win more business by promoting their use of best practices. Advanced I-V curve tracing measurement tools can be turned to your competitive advantage during the sales phase of new PV systems and O&M contracts. This paper helps you realize this advantage by providing language that you can conveniently re-use in your proposals.

By specifying measurements made with the Solmetric PV Analyzer, you are demonstrating your commitment to quality and performance. PVA measurements during the commissioning process will ensure quality and reduce risk for the developers, EPC's, investors and solar service providers.

This white paper contains two main parts:

1. Background. This section contains background about I-V curves and commissioning in FAQ format. It is a summary of key technical and business drivers for measuring I-V curves in field applications. Further information can be found at www.solmetric.com.

2. Proposal/Contract Language. This section contains wording about the specific procedures, measurement results, and documentation requirements for the I-V curve measurements. This language can be adapted for or included in any of the following:

   a. Request for Information (RFI)
   b. Requests for Proposal (RFP)
   c. Proposal
   d. Statement of Work (SOW)
   e. Contractual Agreement

Background: I-V Curves in Field Applications

What is an I-V curve?

The output power of a PV array depends on the voltage at which it is operated. For a given type of PV module, there will be a particular operating point that delivers the highest output. It is the job of the inverter to find that point and to track it as environmental conditions change.

The I-V curve is just a collection or path of possible operating points, represented as a curved line on a graph of output voltage versus current. The curve starts at the short circuit current and ends at the open circuit voltage. The maximum power point is located at the knee of the curve.

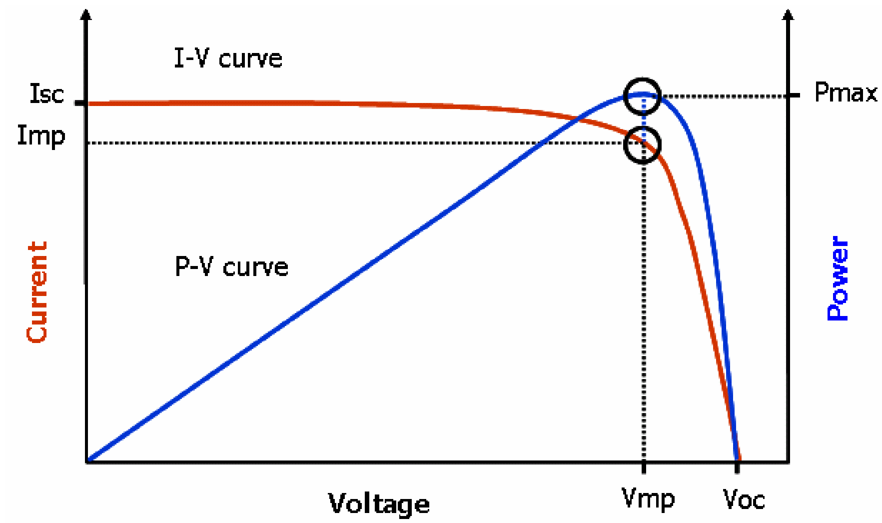

Figure 1 I-V and P-V curves for a PV module or string, showing key parameters

Where has I-V curve tracing been used in the PV industry?

I-V curve tracing has been used for decades in PV R&D, manufacturing, and field testing. It is the most comprehensive measurement that can be performed on a PV module, string or array.

What accounts for the increasing popularity of I-V curve tracing for field testing?

In the past year, the availability of affordable, compact, rugged, easy to use curve tracers has changed the game in PV system testing. The Solmetric PV Analyzer also allows the user to compare the measured I-V curve with the predictions of built-in PV models, giving immediate indication of the health of the array. Automated data analysis tools make quick work of digesting and displaying the test results for even very large multi-Megawatt PV projects.

What are the benefits of I-V curve tracing?

Reduced test time

I-V curve tracing measures multiple performance parameters with a single electrical connection and a single measurement step. The curve tracer is connected to the output terminals of the combiner box, after isolating the combiner from the rest of the PV system. Inserting one PV fuse at a time allows testing individual strings. Data recording is automated and the entire process typically takes less than 15 seconds per string.

No need to bring the inverter on-line to test PV string performance

Traditional test methods required the inverter to be brought on-line in order to measure PV string performance under load. I-V curve tracing eliminates this requirement by measuring the performance of each PV string under all load conditions. This means you can test the array much earlier in the project, avoiding the long wait to bring the inverter on-line.

Reduced start-up and commissioning risk

Testing the array before the inverter is brought on-line means less risk of array-side problems showing up during start-up or commissioning.

More detailed measurement results

I-V curve tracing is the most comprehensive test possible for PV arrays. In addition to measuring the traditional parameters such as short circuit current and open circuit voltage, it uniquely measures the maximum power point of each string. And the shape of the measured I-V curve gives important troubleshooting information.

Automated data recording and analysis

I-V curve measurement data is digitally recorded, eliminating data recording errors. The Solmetric I-V Data Analysis tool automatically produces three displays of array performance, making it easy to visually demonstrate that PV strings are performing consistently and in line with expectations. If performance problems are present, the tool quickly draws attention to them and identifies the problem strings.

Detailed performance baseline

PV arrays are extremely robust and reliable, but they do degrade gradually with time.

Occasionally a module will fail. I-V curve tracing gives you a detailed baseline against which to compare measurements over the life cycle of the PV system. Module degradation and failures are easily demonstrated, facilitating module warranty claims.

Taken as a whole, these advantages reduce the costs and risks associated with PV system construction and testing, and provide a baseline for ongoing maintenance.

Why is the Solmetric PV Analyzer (PVA) the best choice for measuring I-V curves?

The Solmetric PV Analyzer combines an affordable, compact, fast and easy-to-use I-V curve measurement tool with built-in PV performance modeling, allowing users to immediately determine whether a PV module or string is performing to its potential. If it is not, the I-V curve provides critical information about potential causes of the performance problem. Advanced data analysis tools make fast work of analyzing data and providing exhibits to communicate test results to system stakeholders. And if it is ever needed, responsive tech and application support is at your service.

The Solmetric PV Analyzer is also specifically designed to accurately measure high-efficiency PV modules, which require more time for electrical charge to properly transition as the I-V load curve is being traced.

Proposal/Contract Language for Array Commissioning

PV Array Commissioning Tests - Before Substantial Completion

String I-V Curve Trace tests shall be performed in accordance with procedures detailed in this section, and test data shall be recorded, prior to commissioning of the Generating Facility.

String I-V Curve Test

Purpose: I-V curve tracing is the most comprehensive measurement that can be performed on PV modules, strings and arrays. Using a single electrical connection and a single test, I-V curve tracing measures the Open Circuit Voltage, Short Circuit Current, Max Power Voltage, Max Power Current, Maximum Power and Fill Factor of the selected PV string. The detailed shape of the I-V curve gives insight into the causes of any performance issues.

Scope: All strings

Party: EPC technical personnel or contracted testing service

Schedule: During Commissioning

Equipment/ Materials:

- Rubber insulating gloves and other PPE
- Fuse puller
- I-V Curve Tracer such as Solmetric PVA-600 or Daystar DS-100
- Test leads

Procedure:

- Follow the manufacturer's procedures for use of the I-V curve tracer.
- Shut down the inverter.
- Locate the combiner box at which string I-V curves will be measured.
- Electrically isolate the combiner box from other PV array segments by opening its DC disconnect switch.
- Electrically isolate the combiner box buss bars from PV source circuits by lifting all of the string fuses.
- Connect the curve tracer to the buss bars (be aware of array and instrument polarities).
- Measure the I-V curve. Sweep the load such that it operates the array over its entire range from Isc to Voc (or as the load will allow). Record voltage and current readings for at least 10 steps in the curve (100 points is preferred).
- For each I-V curve, measure and record the irradiance in the plane of the array, the temperature on the backside of a typical PV module, and the date and time. Measure the irradiance and temperature values within 10 seconds of the I-V curve measurement. The I-V curve should be measured in less than 1s so that rapid irradiance and module backside temperature changes have minimal effect on the shape of the curve
- Also record the ambient temperature.

Conditions:

This test will be conducted under full sun with irradiance of at least 500 W/m2 and stable sky conditions (no cirrus clouds or fast moving clouds near sun) within the time period of four hours centered about solar noon. Solar noon can be determined using reference tools such as: http://www.esrl.noaa.gov/gmd/grad/solcalc/

If such conditions are not available due to weather conditions, then the Engineering Procurement and Construction (EPC) Provider or testing service shall not conduct such test until the earlier of the date on which such conditions exist and 5 business days following the date on which the test would otherwise have been conducted. If, upon the expiration of the foregoing period, such conditions are still not available, then the test will be conducted within 5 more days. In this case any anomalous data apparently due to changing sky conditions shall be re-measured under stable sky conditions.

Criteria:

Open Circuit Voltage

Verify that the string Open Circuit Voltage is within 5% of expected values as determined from module manufacturer's data sheet (Voc at STC and temperature coefficient of Voc) and measured module temperature.

Under stable irradiance and temperature conditions, the Open Circuit Voltage for each string should conform to within 2% of the average Open Circuit Voltage of all the strings in the same combiner box.

Short Circuit Current

Under sky conditions of 500 W/m2 or greater, the measured current should be within 5% of the expected Isc calculated using equation below:

$Isc\_expected = 0.95 \cdot n \cdot Isc\_ref \cdot G/Gref$

Where:

- 0.95 = factor to account for soiling, misalignment, and other factors.
- n = number of modules or strings tested in parallel
- Isc_expected = expected short-circuit current of the test segment
- Isc_ref = module short-circuit current at some specified reference conditions (typically STC)
- G = measured plane of array irradiance, W/m2
- Gref = irradiance at specified reference conditions for Isc_ref, W/m2

Under stable irradiance and temperature conditions, the Short Circuit Current for each string should conform to within 2% of the average Short Circuit Current of all strings in the same combiner box.

Maximum Power

Compare the measured Maximum Power value to the predictions of an advanced PV model such as the Sandia PV Array Model or 5-Parameter Model. If advanced models are not available, use a simple model based on values provided by the module manufacturer's data sheet. The Max Power of each string should be within 5% of the modeled Max Power.

Under stable irradiance and temperature conditions, the measured Max Power value of each string should conform to within 2% of the average Max Power of all strings in the same combiner box.

Comments:

If results show anomalies, including fill factor, voltages, or currents outside expected limits, or anomalies on the I-V curve, then modules should be investigated for bypass diode conduction, out-of-tolerance module performance, or other possible problems. Any flaws must be rectified and any modified strings should be re-tested.