Standardizing PV System Documentation and Verification

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International concern regarding the safety and quality of PV system installations is growing. Incorrectly installed or commissioned systems can create a fire hazard or even increase the risk of electrocution. Consider the well-documented "thermal event" that occurred in Bakersfield, California, on April 5, 2009 (see "The Bakersfield Fire," February/ March 2011, *SolarPro* magazine). It is generally accepted that an undetected fault-to-ground was present in a grounded current-carrying source circuit conductor at this site, and that this first fault set the stage for the eventual fire. A subsequent analysis of utility-owned and -operated rooftop PV systems in North Carolina revealed the presence of undetected ground faults in approximately 10% of the systems surveyed.

Proper commissioning procedures are among the best defences against fire or electrocution hazards. While guidelines and best practices for PV system commissioning in North America are patchwork at best, in 2009 the International Electrochemical Commission (IEC) published an international standard, IEC 62446, that defines minimum requirements for documenting, commissioning and inspecting grid-connected PV systems.

In this article I provide an overview of IEC 62446, which can be purchased in its entirety from the IEC website (iec.ch) for approximately $150. In addition to the general content outlined here, the standard includes informative appendices with model certificates, reports and procedures. While compliance with IEC 62446 is not mandatory in North America at this time, the standard clearly provides a set of internationally recognized best practices for system integrators and O&M providers. Since these entities are already performing many of the tasks described in the standard, the effort and cost to harmonize internal practices with those outlined will be relatively small. Anyone engaged in the preparation of documents and standards for projects going out to bid will likely find the requirements outlined in IEC 62446 useful and relevant to their work as well.

IEC 62446

This international standard was published in March 2009. It is formally entitled Grid-Connected Photovoltaic Systems—Minimum Requirements for System Documentation, Commissioning Tests and Inspection. The emphasis on documentation is interesting to note. In effect, system documentation is the evidence used to demonstrate that appropriate precautions and tests have been undertaken prior to handing over a PV system to the property owner. The standard is organized into two parts: system documentation requirements and system verification requirements, which include inspection and testing.

System Documentation

System documentation requirements are laid out in Clause 4, which describes the minimum documentation that should be provided for the benefit of the customer, inspector or maintenance technician following the installation of a grid-connected PV system. These requirements are organized into six categories: system data, wiring diagram, datasheets, mechanical design information, O&M information, and test results and commissioning data.

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System data

Minimum system data requirements outlined in IEC 62446 include basic nameplate information and details that you would expect to find on the cover page of a PV plan set or a system commissioning package. Nameplate data requirements include rated system power and the manufacturers, models and quantities of PV modules and inverters. Cover page data requirements include contact information for the customer, system designer and system installer, plus relevant project dates.

Wiring diagram

According to IEC 62446, system documentation for a grid connected PV system shall include at minimum a single-line wiring diagram. A list of subsections outlines the specific information that needs to be included in the notes or tables associated with the wiring diagram.

Annotations to the single-line diagram must include general information about the quantity and type of modules, as well as specific details about the source-circuit and subarray makeup. IEC 62446 also requires information about the location and type of balance of system components. Details need to be provided regarding conductor sizes and overcurrent protection device ratings.

In addition to equipment grounding details, in particular module frame grounding, any connection to an existing lightning protection system needs to be identified, as do the locations, types and ratings of ac or dc surge protection devices. IEC 62446 also details minimum information requirements regarding the existing ac electrical system.

Datasheets
Per IEC 62446, module and inverter datasheets must be provided in the system documentation at a minimum requirement. An informational note clarifies: “The provision of datasheets for other significant system components should also be considered.”

Mechanical design

A datasheet for the array mounting system needs to be provided, at a minimum. Where applicable, structural engineering documents, soil testing results and so forth can also be provided.

O&M information

Meeting the requirements found in subsection 4.6 of IEC 62446 (see sidebar) is inherently more subjective than other system documentation requirements. Proper documentation of system O&M information depends upon the audience and may involve a significant investment in time and resources on the project back end. While basic O&M templates can be developed for residential and commercial clients, templates for commercial projects invariably require more customization. This is especially true when a facility’s maintenance personnel are expected to take on routine maintenance activities for the PV system.

4.6 O&M Information

Operation and maintenance information shall be provided and shall include, at a minimum, the following items:

a) Procedures for verifying correct system operation.

b) A checklist of what to do in case of a system failure.

c) Emergency shutdown and isolation procedures.

d) Maintenance and cleaning recommendations (if any).

Test results and commissioning data

IEC 62446 requires that copies of test results and commissioning data be included in the documentation package. At a minimum, this must include the results of the verification tests outlined in Clause 5 of the standard.

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System Verification

The requirements laid out in Clause 5 apply to both initial and periodic verification of a grid-connected PV system. Initial verification takes place upon completion of a new installation, as well as whenever "additions or alterations to exiting installations" are made. Periodic verification is intended to ensure that "the installation and all its constituent components remain in a satisfactory condition for use." It is worth noting that IEC 62446 requires that a "skilled person, competent in verification" perform initial or periodic verification. Section 690.4(E) of the National Electrical Code similarly requires that a qualified person install PV systems. By extension, persons verifying PV systems should be knowledgeable regarding PV systems and the electrical equipment used in their construction, and trained to avoid all associated hazards.

System verification is achieved through inspection, followed by testing. These steps must be documented in a verification report.

PV installation test IEC 62446 describes a variety of techniques for shorting a string during testing and taking measurements using clip-on ammeters.

However, the use of dedicated PV test instruments, like this Seaward Solar PV100 tester, simplifies the process, making it quicker and safer for technicians.

Inspection

The requirements found in this subsection are intended to be completed "prior to energizing the system." Inspection activities are broken into four subcategories: dc system, overvoltage and shock, ac system, and labeling and identification. While IEC 62446 includes a fair amount of detail regarding inspection requirements, companies should defer to the NEC and the local AHJ when setting internal quality-assurance and quality control standards.

Testing

Testing of PV systems should be conducted in accordance with NFPA 70E, Electrical Safety in the Workplace, published by the National Fire Protection Association. To mitigate electrical hazards, workers must employ personal protective equipment commensurate with the electrical energy present, follow proper procedures and use appropriate tools. IEC 62446 requires that the ac circuits be tested first, then the following six dc circuit tests be performed, preferably in this order:

1) Test continuity of equipment grounding conductors and system grounding conductors (if applicable).

2) Test polarity of all dc cables and check for correct cable identification and connection.

3) Test open-circuit voltage [Voc] for each PV source circuit.

4) Test short-circuit current [Isc] for each PV source circuit.

5) Test functionality of major system components (switchgear, controls, inverters), including inverter anti-islanding.

6) Test the insulation resistance of the dc circuit conductors.

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The methods for performing these tests are generally familiar to all electricians. However, difficulties may arise if the technician is unaware of the extent to which PV circuits need to be segmented and isolated for these tests to be performed properly. Therefore, it is important that anyone performing these tests be specifically qualified with regard to PV systems.

Combinations of standard electrical test equipment can be used to complete the required tests, such as a megohm meter paired with either a digital multimeter or a clamp meter. Increasingly, specialized test equipment is available for PV applications. For example, the PV100 solar installation test kit from Seaward Solar includes everything needed to test to IEC 62446: a continuity and insulation resistance tester, a digital multimeter and a dc current clamp.

While IEC 62446 does not specify the order of the tests, there is logic behind the order that it recommends. For example, if equipment is properly bonded to earth, then it is inherently safer to work around in the event of a fault; and if polarity tests are not completed before functional tests are performed, then equipment may be damaged at start-up due to reverse polarity or overvoltage.

Note that in the event that a test indicates a fault, the standard requires that all previous tests be repeated after the fault is rectified. This is because the fault may have influenced earlier test results.

The subsections related to the specific dc circuit tests provide instructions on how to perform the verification tests, as well as how to interpret the results. For example, IEC 62446 describes two short-circuit test procedures, the results of which can be measured using either an in-line or a clamp-on ammeter. Similarly, two test methods are provided for the PV array insulation test, as well as a recommended procedure and a table for interpreting the results (see Table 1).

Test Method	System Voltage (*Voc stc* x 1.25)	Test Voltage	Minimum Insulation Resistance
Test Method 1 Separate tests to Array positive and Array negative	<120v	250v	0.5MΩ
	120 – 500v	500v	1MΩ
	<500v	1000v	1MΩ
Test Method 2 Array positive and negative shorted together	<120v	250v	0.5MΩ
	120 – 500v	500v	1MΩ
	>1000v	1000v	1MΩ

Table 1: Insulation resistance test results are satisfactory, according to the test methods and procedure outlined in IEC 62446, if they are not less than the values shown here.

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