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DEVELOPMENT OF INTERIM TEST METHODS AND PROCEDURES FOR DETERMINING THE PERFORMANCE OF SMALL PHOTOVOLTAIC SYSTEMS

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ABSTRACT: The National Renewable Energy Laboratory (NREL) is developing tests and procedures that will determine if the configuration of a small photovoltaic (PV) system is suitable for its intended use, and if the system will perform as specified. An overview of these procedures is presented in this paper. Development of standard test procedures will allow designers, manufacturers, system integrators, users, and independent laboratories to assess the performance of PV systems under outdoor prevailing conditions. An NREL Technical Report detailing the procedures is under way, and the IEEE Standards Coordinating Committee 21 (SCC21) has established a project on this subject. The work will be submitted to the IEEE SCC21 and International Electrotechnical Commission Technical Committee 82 (IEC TC82) for consideration as a consensus standard. Certification bodies such as PowerMark and PV Global Approval Program (PVGAP) may adopt the IEC and IEEE documents when testing systems. Developing standardized test methods and procedures at NREL to evaluate the outdoor performance of PV systems will encourage product quality and promote PV standards development. Standardized tests will assure people that PV systems will perform as specified for their intended applications. As confidence in PV systems increases, the successful commercialization of PV will grow internationally.
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1. BACKGROUND

Selection and validation, through type testing, of the appropriate design and construction of a PV system and its subsystems is a critical area of concern with regard to meeting and optimizing performance, operation and maintenance (O&M), reliability, and safety. Over- or undersizing a system, inadequate subsystem and component selections, and improper interface matching have been concerns over the years with regard to meeting performance requirements and cost. Failure or reduced performance of systems due to exceeding the operational limits of subsystems and components within the system has led to misunderstandings regarding why the system failed to meet its application load requirements. Exaggerated performance expectations and marginal design limits have also led to failure in parts of the system and have increased O&M system cost. Users must feel assured that a system will meet its intended design and application load requirements. This barrier to acceptance of PV systems can be reduced and eliminated with the proper tools one can reference for design and performance verification.

The test document will fill a testing void and provides the catalyst and focus for establishing the technical foundation and bridging the institutional barriers needed to reduce uncertainty that a system's performance will be what its designers and builders claim. The need for a document was recently made more apparent with the initiation of a PVGAP at the international level and is in response to concerns that PV systems being fielded must meet performance standards and that these standards include system-level performance type tests. The title of the test procedure is prefaced with the word "interim" because experience in using the procedures is needed before a consensus standard is developed and accepted by the PV community through its activities with the IEEE SCC21 and IEC TC82 national and international standards-making bodies. Both entities have initiated projects to develop test standards and will need the technical basis and validation of test procedures such as those presented in this document before a consensus is achieved by the PV community.

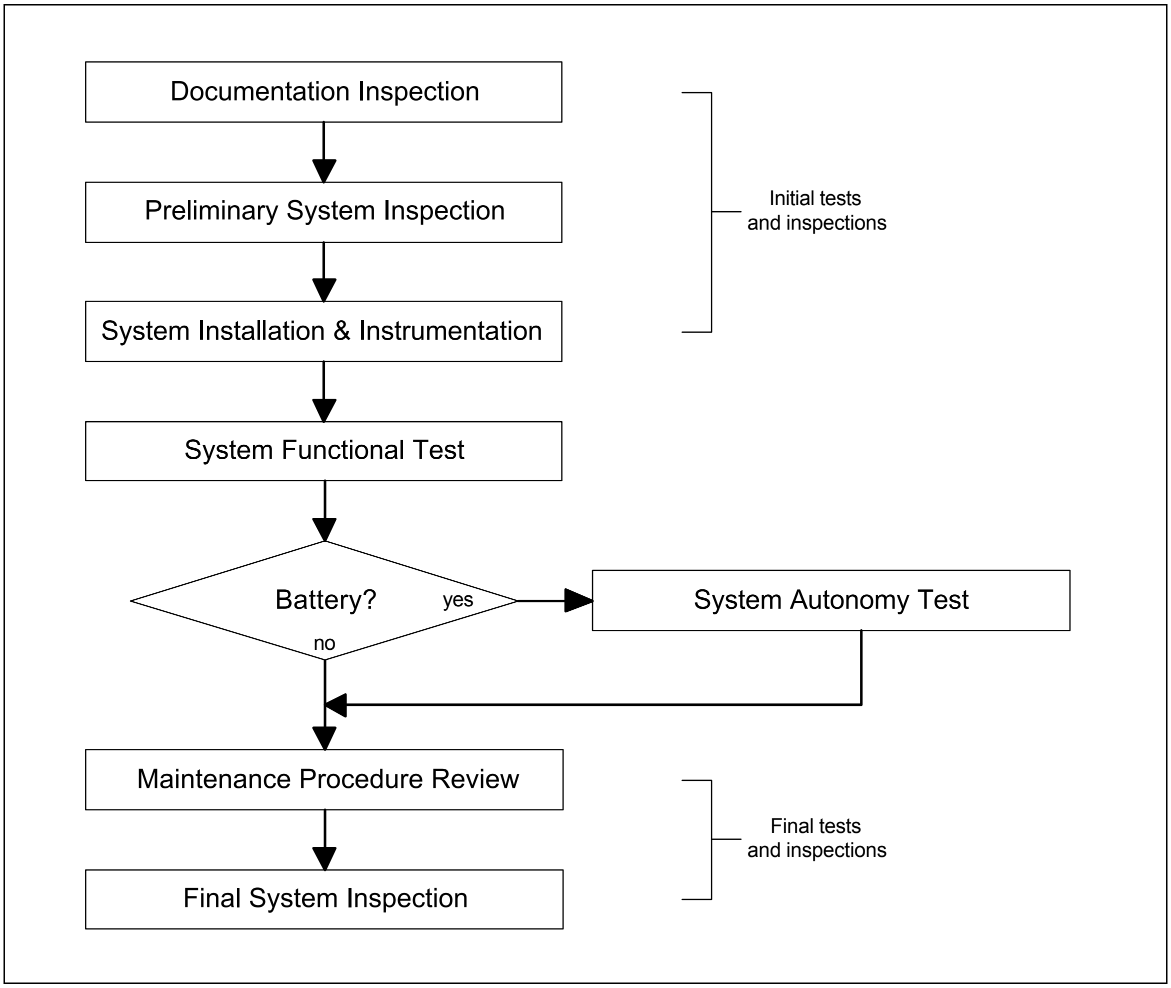

Figure 1: Small PV systems test sequence

2. OVERVIEW OF THE TEST PROCEDURES

The test procedures NREL is developing are intended to evaluate the performance of stand-alone and utility-tied PV systems up to 5 kW. One complete system is required for testing. The test sequence is shown in Figure 1. The test system should include documentation and all parts for installation. All measurements, notes, and comments are compiled into a test report. The procedures can be broken down into four areas: initial system tests and inspections; system functional test; system autonomy test; and final system tests and inspections. The procedures do not address component or system reliability, safety, or compliance to mechanical or electrical codes.

2.1 Initial Tests and Inspections

Documentation inspection, preliminary system inspection, and system installation and instrumentation comprise the initial tests and inspections. Before the performance of a PV system can be tested, the system must have been shipped in its entirety, undamaged, and the documentation should include instructions on the proper installation, operation, and maintenance of the system.

The documentation inspection consists of making an inventory of the documentation shipped with the PV system; recording all given specifications for the system, load, and components; and reviewing the documentation to verify that system installation, operation, and maintenance can be performed.

The preliminary system inspection consists of checking all electrical and mechanical system components against the parts list to verify the system has been shipped in its entirety and that nothing is damaged.

Using the system installation instructions, the system is assembled. Any problems with the installation instructions or assembly process are noted. The instrumentation to monitor the performance of the PV system is installed at this time.

2.2 System Functional Test

The system functional test is performed by monitoring the PV system during several weeks of normal outdoor operation: Initiate system operation according to the manufacturer's instructions. Cycle the load according to its designed load profile, and verify it starts and operates properly. If a load and load profile are not provided with the system, one or several realistic loads and profiles will need to be selected. During normal system operation, measure and record the voltage drops throughout the system. From the data collected during this test, and depending on the system configuration, determine the power output of the array, the charge and discharge setpoints of the charge controller, and the operating characteristics of the inverter.

2.3 System Autonomy Test

The system autonomy test determines how long a fully charged battery can satisfy the system load with no contribution from the PV array. This test should only be run after the system functional test and should only be run on systems with a battery protected by low-voltage disconnect (LVD) circuitry.

With the PV array disconnected, use the load to discharge the battery until it reaches LVD. Disconnect the load, reconnect the array, and while monitoring the ampere-hours (Ah) into the battery, charge the battery until the charge controller begins regulating and the battery has accepted a predetermined number of Ah. (During tests conducted at NREL, 125% of the rated Ah battery capacity was used as the target yielding favorable results.) Again, disconnect the array, reconnect the load, and while monitoring the Ah withdrawn from the battery, discharge the battery until it reaches LVD. The system autonomy, often referred to as "days of autonomy," is calculated as the amp-hours withdrawn from the battery divided by the daily load amp-hours.

2.4 Final Tests and Inspection

As part of the final system tests, the system maintenance procedures are reviewed to verify that maintenance can be performed without undue difficulty. An example of a difficult procedure would involve having to disassemble a system in order to inspect the water level of flooded batteries. At the conclusion of all tests, a final inspection is conducted on the system. Any damage or problems with the system components are noted.

The results of all tests, having been compiled in the test report, are compared against the system specifications to determine if the system meets its performance specifications.

3. NREL TEST VALIDATION AND FUTURE WORK

To date, these procedures have been tested on two small PV indoor lighting systems consisting of one module, a fluorescent lighting load, a charge controller, and a 12 volt battery. The functional test procedures were conducted over a 3-week period, followed by a 2-week system autonomy test. In the process of using these tests, improvements have been incorporated into the procedures.

Future work at NREL will involve validating the procedures on other types of PV systems. Some examples include outdoor area lighting systems; water-pumping systems with no battery storage; and grid-tied systems with and without battery storage. The NREL procedures will be submitted to the IEEE SCC21 and IEC TC82 for consideration as a consensus standard.

As work progresses with the NREL procedures, we expect that the tests will evolve into accepted practice in small PV system performance testing.

4. CONCLUSION

Developing standardized test methods and procedures at NREL to evaluate the outdoor performance of PV systems will encourage product quality and promote PV standards development. Standardized tests will assure users that PV systems will perform as specified for their intended applications. As confidence in PV systems increases, the successful commercialization of PV will grow internationally.

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