

Qualification Standard for Photovoltaic Concentrator Modules

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QUALIFICATION STANDARD FOR PHOTOVOLTAIC CONCENTRATOR MODULES

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ABSTRACT: The paper describes a proposed qualification standard for photovoltaic concentrator modules. The standard's purpose is to provide stress tests and procedures to identify any component weakness in photovoltaic concentrator modules intended for power generation applications. If no weaknesses are identified during qualification, both the manufacturer and the customer can expect a more reliable product. The qualification test program for the standard includes thermal cycles, humidity-freeze cycles, water spray, off-axis beam damage, hail impact, hot-spot endurance, as well as electrical tests for performance, ground continuity, isolation, wet insulation resistance, and bypass diodes. Because we can't verify concentrator module performance using solar simulator and reference cell procedures suitable for flat-plate modules, the standard specifies an outdoor I-V test analysis allowing a performance comparison before and after a test procedure. Two options to this complex analysis are the use of a reference concentrator module for side-by-side outdoor comparison with modules undergoing various tests and a dark I-V performance check.

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1. BACKGROUND

In 1997, an IEEE working group began developing a qualification standard for photovoltaic concentrator modules as a result of industry concern that the lack of a standard was affecting the marketing and sales of their products [1]. The first draft was based on evaluation tests developed in the late 1980s at Sandia National Laboratories and published in a Sandia report in 1992 [2]. It followed the general outline of tests in the IEC Standard 61215 and the IEEE standard 1262-1995 for flat-plate modules [3,4]. These flat-plate standards, the result of more than a decade of module and standards development, have contributed greatly to the present level of flat-plate module reliability such that manufacturers can back their products with guarantees as long as 25 years [5].

Since the publication of these earlier documents, photovoltaic materials technology and concentrator module development have advanced. Efforts in module reliability research have produced a better understanding of known and potential failure mechanisms associated with photovoltaic concentrator modules, especially regarding the effects of moisture ingress. The results of

these efforts and experience gained have been used in formulating new tests and modifying earlier tests for a proposed concentrator qualification standard.

In following the outline of tests for flat-plate module standards, the working group identified some fundamental differences between the two technologies that required significantly different test approaches. Most flat-plate modules have a thin two-dimensional geometry, whereas concentrator modules usually have optics that are mounted away from the cells, forming a three-dimensional structure. As a result, one major difference between flat-plate standards and the proposed concentrator standard is that the concentrator standard has parallel test sequences for concentrator receivers and modules. A receiver is defined as an assembly of one or more PV cells that accepts concentrated sunlight and incorporates the means for thermal and electrical energy removal. A module is the smallest, complete, environmentally protected assembly of receivers and optics and related components, such as interconnects and mounting, that accepts unconcentrated sunlight. Figure 1 shows two linear concentrator modules and an associated receiver. Another significant deviation from the flat-plate standards arises

from the difficulty in measuring performance after a test sequence because most concentrator modules cannot be accurately characterized with solar simulators. Later in the paper, we will discuss proposed power conversion efficiency tests, as well as two optional performance checks, to replace the use of indoor simulators.

All tests and procedures in this paper are under consideration by the IEEE working group. We plan to ballot on the proposed standard later this year, in hopes of reaching a consensus for the final standard. We have submitted an earlier draft for consideration by an International Electrotechnical Commission working group, as a proposed international qualification standard.



(a)



(b)

Figure 1. a) Two linear concentrator modules ready for qualification standard testing, at the Photovoltaic Testing Laboratory at Arizona State University East. b) A receiver for the linear concentrator receiver tests.

2. OVERVIEW OF QUALIFICATION TEST PROGRAM

Figure 2 shows the proposed test program in the most recent draft (April 2000) of the proposed standard. It requires 7 receivers, 5 modules, and, for a receiver design with inaccessible bypass diodes, 1 specially constructed receiver. Details for the temperature extremes, exposure duration, isolation determinate procedures, etc., are in the latest draft of the standard. In this paper, we will only discuss each sequence in general terms that will still, in many cases, contain tests similar to flat-plate qualification tests. Many of these tests are based on ASTM standards [6].

2.1 Baseline

Referring to Figure 2, we propose baseline tests for electrical performance, ground continuity, electrical isolation, and wet insulation resistance, along with visual inspections to determine the initial status of the modules and receiver sections.

2.2 Sequence A

In this sequence, we specify a test for bypass diodes and a thermal cycle test for two receivers.

2.3 Sequence B

Sequence B specifies thermal cycle tests different from that in Sequence A and humidity-freeze tests for two receivers and with parallel tests for two modules involving thermal cycling, humidity-freeze, electrical isolation, and terminations.

2.4 Sequence C

Here, we recommend damp heat exposure for two receivers, followed by a test for electrical isolation.

2.5 Sequence D

This sequence involves several module stress tests, including outdoor exposure, water spray, off-axis beam damage, hail impact, and hot-spot endurance.

2.6 Sequence E

For receivers in which the by-pass diodes are inaccessible, we specify a specially prepared receiver having access to diodes for a bypass diode test.

2.7 Final Test and Inspections

All modules and receivers are subjected to final tests of visual inspection, electrical performance, electrical isolation, wet-insulation resistance and ground continuity.

3. ELECTRICAL PERFORMANCE TESTS

A critical question after many stress tests is the performance of the photovoltaic concentrator module or receiver. In the case of flat-plate photovoltaic modules, a solar simulator and reference cell provides a means to verify performance after a stress test. Photovoltaic concentrator modules, however, are critically dependent on the concentrated light incident on the receivers (See Figure 1). We have developed three possible tests to verify any degradation in the performance of modules and receivers. One of these is described in more detail in another presentation at this conference [7]. The testing organization conducts baseline outdoor performance tests under various temperature and solar irradiance conditions while measuring output currents and voltages to obtain an analytical expression for the module and receiver performance. After a stress test or series of tests, the module is again measured outdoors, and its performance, under conditions encompassed by the analysis parameters, is compared with that predicted by the analytical expression for the module's performance. It takes a lot of time to determine the analytical equation for the module's performance, so we explored two other possible determinations of any module performance degradation.

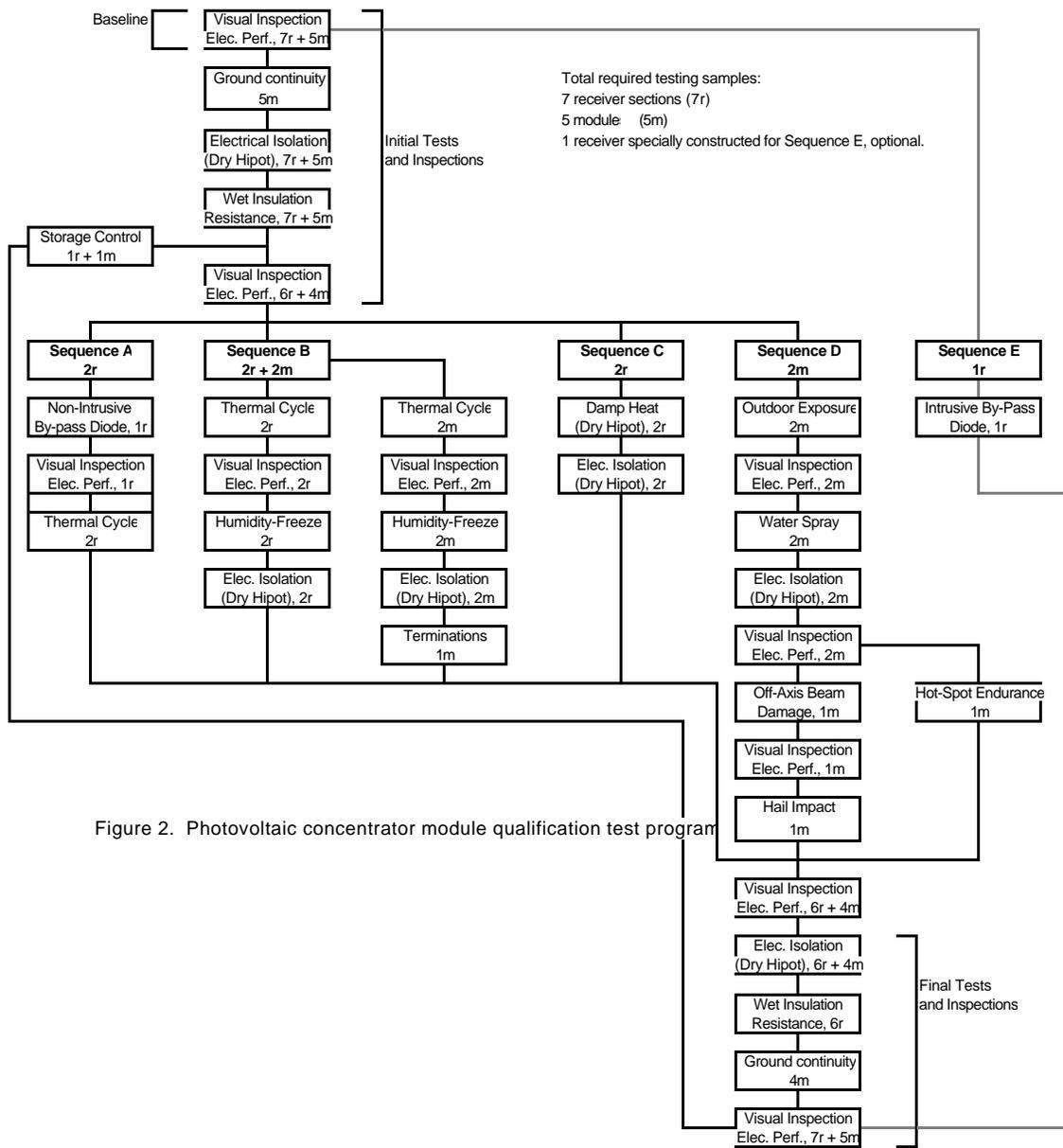


Figure 2. Photovoltaic concentrator module qualification test program

A second possible test for characterizing module performance uses a reference module. This module is not subjected to any stress tests, and its performance is measured along with all other test modules. After a module is subjected to a test sequence, its performance is again compared with that of the reference module to determine any degradation.

The third possible test for identifying degradation in modules is the use of dark current-voltage (I-V) measurements before and after intermediate stress tests. This procedure, as well as the use of a reference module, provides simpler means for determining module and receiver performance degradation resulting from increases in series resistance or breaking of connections. It is not intended to be used as the criterion for passing the final tests.

4. CONCLUSION

For almost three years, we have been developing a set of test procedures to qualify photovoltaic concentrator modules as reliable products in the marketplace. In building upon the considerable experience in flat-plate standards, we had to explore alternative test procedures because of fundamental differences between the two photovoltaic technologies. The most significant differences are the need for testing of the receiver separately from the module and the much large size of a typical module, necessitating the development of new procedures for identifying performance degradation after stress testing. While the details of the tests and procedures are under consideration by the IEEE working group, we plan to ballot on the proposed standard later this year in hopes of reaching a consensus for the final standard. We have submitted a draft of this qualification

standard for consideration by an International Electrotechnical Commission working group as a proposed international standard.

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