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INTERNATIONAL STANDARD

NORME INTERNATIONALE

Concentrator photovoltaic (CPV) modules – Thermal cycling test to differentiate increased thermal fatigue durability

Modules photovoltaïques à concentration (CPV) – Essai de cycles thermiques pour la détermination de la durabilité renforcée à la fatigue thermique

IEC 62925:2016-12(en-fr)

IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
www.iec.ch

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The text of this standard is based on the following documents:

FDIS	Report on voting
82/1185/FDIS	82/1210/RVD

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

INTRODUCTION

IEC 62108 defines IEC requirements for the design qualification of concentrator modules for long-term operation in general open-air climates. This standard, IEC 62925, is not compulsory with but will supplement IEC 62108 by providing tests that differentiate thermal fatigue durability of concentrator modules for deployment in a larger range of applications and climates.

CONCENTRATOR PHOTOVOLTAIC (CPV) MODULES – THERMAL CYCLING TEST TO DIFFERENTIATE INCREASED THERMAL FATIGUE DURABILITY

1 Scope

This document defines a test sequence that will quickly uncover CPV module failures that have been associated with field exposure to thermal cycling for many years. This document was specifically developed to relate to thermal fatigue failure of the HCPV die-attach, however, it also applies, to some extent, to all thermal fatigue related failure mechanisms for the assemblies submitted to test.

IEC 62108, the CPV module qualification test already includes an accelerated thermal cycle sequence in one leg of the testing, however, the parameters of that test only represent a qualification level of exposure. This test procedure applies more stress and will provide a route for comparative testing to differentiate CPV modules with improved durability to thermal cycling and the associated mechanical stresses.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 62108:2016, *Concentrator photovoltaic (CPV) modules and assemblies – Design qualification and type approval*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1
durability
system's capacity to resist degradation specific for a particular stress or set of stresses

Note 1 to entry: The durability with respect to all relevant stresses shall be assessed in order to gain information about the anticipated performance of the system.

3.2
reliability
probability for a system to perform and maintain its designed function in specific conditions for a specified period of time

Note 1 to entry: In this context the term reliability shall be accompanied by three numbers: a) a specified period of time, b) a criterion that quantifies its performance at that time and c) the probability that the criterion will be met.

3.3
concentrator receiver
group of one or more concentrator cells and secondary optics (if present) that accepts concentrated sunlight and incorporates the means for thermal and electric energy transfer. A receiver could be made of several sub-receivers. The sub-receiver is a physically standalone, smaller portion of the full-size receiver

[SOURCE: IEC 62108:2016, 3.4]

3.4
concentrator module
group of receivers, optics, and other related components, such as interconnection and mounting, that accepts unconcentrated sunlight. All above components are usually prefabricated as one unit, and the focus point is not field adjustable

Note 1 to entry: A module could be made of several sub-modules. The sub-module is a physically stand-alone, smaller portion of the full-size module.

[SOURCE: IEC 62108:2016, 3.5]

3.5
concentrator assembly
group of receivers, optics, and other related components, such as interconnection and mounting that accepts unconcentrated sunlight. All above components would usually be shipped separately and need some field installation, and the focus point is field adjustable

Note 1 to entry: An assembly could be made of several sub-assemblies. The sub-assembly is a physically standalone, smaller portion of the full-size assembly.

[SOURCE: IEC 62108:2016, 3,6]

4 Sampling

For non-field-adjustable focus-point CPV systems or modules, a number of modules that contain at least 20 separate PV cells are required. Test failure is based on the failure of 5 % of the submitted cells; therefore submission of more than 20 cells is encouraged.

If coordinated between the submitting manufactured and testing laboratory, disassembly of the submitted module(s) into a separate receiver or receivers for the thermal cycling sequence is acceptable and encouraged. This approach may be desirable in order to reduce thermal mass thereby enabling the possibility to achieve a faster temperature ramp rate. Following the thermal cycling sequence, the receiver shall be reassembled into its module configuration for the outdoor exposure. The original submission of receivers for test is also acceptable, provided they may subsequently assembled into a module for the required outdoor exposure.

5 Marking

Each receiver or module section should carry the following clear and indelible markings:

- name, monogram, or symbol of manufacturer;
- type or model number;
- serial number;
- polarity of terminals or leads (color coding is permissible);
- maximum system voltage for which the module or assembly is suitable;
- nominal maximum output power and its tolerance at specified condition;

- the date, place of manufacture, and cell materials should be marked, or be traceable from the serial number.

If representative samples are used, the same markings as on full-size products should be included for all tests, and the marking should be capable of surviving all tests sequences.

6 Testing

If some test procedures in this document are not applicable to a specific design configuration, the manufacturer should discuss this with the certifying body and testing agency to develop a comparable test program, based on the principles described in this standard. Any changes and deviations shall be recorded and reported in details, as required in Clause 8, item j).

7 Rating

The rating system is based on the number of cycles completed with total cell failure less than 5 %. Cell failure is defined in 10.2.3 as a shorted cell or an inactive cell due to an electrical open. The number of required cycles according to Formula (2), 10.3.3, is equivalent to five times the qualification level of thermal cycling testing (IEC 62108) and therefore earns a rating of 5Q upon successful completion (< 5 % cell failure). There also exists the possibility to achieve a rating higher or lower than 5Q by completing more or less cycles than defined by Formula (2). Rating shall be based on integer intervals according to Formula (1):

$$rating = 5\frac{N_C}{N_R} \quad (1)$$

Where

N_C is the number of completed cycles with a total cell failure of less than 5 % and,

N_R is the number of required cycles according to Formula (2).

The rating achieved shall be an integer product of Formula (1) and will default to the next lower rating if N_C is in between an integer interval. For instance, if Formula (1) results in 4,9, the rating received is 4Q.

Every interval of cycling represents an amount of service life. Therefore the 5Q rating is intended to correspond with a minimum service life with total cell failures less than 5 % due to thermal fatigue related failure mechanisms.

It is up to the discretion of the submitting party and testing laboratory as to what interval of testing is attempted and at what interval(s) the outdoor evaluation and performance testing are made.

8 Report

Following testing, a certified report of the qualification tests, with details of any failures and re-tests, should be prepared by the test agency. Each test report should include at least the following information:

a) a title;

b) the name and address of the laboratory, and the location where the tests were carried out, if different from the address of the laboratory (such as on-site location);

c) unique identification of the test report (such as the serial number), and on each page an identification to ensure that the page is recognized as a part of the test report, and a clear identification of the end of the test report;

d) name and address of client, where appropriate;

e) description and identification of the item tested;

f) characterization and condition of the test item;

g) date of receipt of test item and date(s) of test, where appropriate;

h) identification of ramp rate and number of cycles used (Formula (1));

i) reference to sampling procedure, where relevant;

j) any deviations from, additions to, or exclusions from the test method, and any other information relevant to a specific tests, such as environmental conditions;

k) measurements and examinations supported by tables, graphs, sketches, and photographs as appropriate after completion of each cycling interval and any failures observed;

l) a statement of the estimated uncertainty of the test results, where relevant;

m) a signature and title, or equivalent identification, of the person(s) accepting responsibility for the content of the report, and the date of issue;

n) where relevant, a statement to the effect that the results relate only to the items tested;

o) a statement that to maintain the rating, the manufacturer shall report to and discuss with the certifying body and testing agency every change they made;

p) a statement that the report shall not be reproduced except in full, without the written approval of the laboratory.

A copy of this report should be kept by the manufacturer for reference purposes.

9 Modifications

Any changes in design, materials, components, or processing of the modules and assemblies may require a repetition of this test sequence. Manufacturers shall report to and discuss with the certifying body and testing agency every change they have made.

10 Test procedure

10.1 General

The test sequence is as follows:

a) Cell evaluation.

b) Thermal cycling.

c) Outdoor exposure.

d) Cell evaluation.

If it is desired to periodically evaluate the test articles at the designated cycling intervals, steps a) and d) are combined and the sequence repeated.

10.2 Cell evaluation

10.2.1 Purpose

The purpose of this evaluation is to determine if any of the included PV cells have failed through testing. This document is intended to evaluate the thermal fatigue durability of the CPV die-attach. When the die-attach cracks due to thermal fatigue, the thermal resistance of this layer increases and ultimately causes thermal runaway of the attached PV cell when placed on-sun. Thermal runaway of the PV cell typically results in an electrical short across the cell that is detected with the following evaluation. Provisions to detect an electrically open cell are also provided.

10.2.2 Procedure

a) All PV cells are forward biased to a level that causes electroluminescence emission of a pristine cell.

b) If a cell or cells fail to emit, they may be individually probed to determine if an electrical short exists. This step may consist of an evaluation of the cell's dark current and voltage response. This electrical method of determining if each individual cell is an electrical short may be substituted for step a) if desired.

For some cell technologies, the electroluminescence emission is in the visible spectrum; therefore the emission from each cell may be visually evaluated. In the case the emission is not within the visible spectrum, the emission may be evaluated by use of a camera with a quantum efficiency that overlaps the normal electroluminescence emission of those cells.

If the module or string of cells biased presents as electrically open, the location of the open shall be determined and electrically jumped in order to continue the thermal cycling sequence. To locate the open, continuity checks and/ or forward biasing smaller portions of the string until the open is found should be conducted.

10.2.3 Requirements

Any cell that fails to emit and/or is evaluated as an electrical short is considered a failure for the purpose of this standard. It is at the discretion of the submitting party and test laboratory to ascertain the root cause of the failure. Only if, through this root cause analysis, it can be demonstrated that thermal fatigue is not the cause of cell failure, the failed cell may be removed from the failed population.

Any cell that is removed from the active string of the module by an electrical open is also considered a failure for the purpose of this document.

If a cell is initially shorted prior to the first thermal cycling interval, it should not be considered in the failed population and be replaced by a pristine cell.

10.3 Thermal cycling

10.3.1 Purpose

The purpose of the thermal cycling test is to determine the ability of the receivers to withstand thermal mismatch, fatigue, and other stresses caused by rapid, non-uniform or repeated changes of temperature.

10.3.2 Test sample

Either module(s) or their contained receiver(s) are applicable for the thermal cycling test.

10.3.3 Procedure

Thermal cycling is to be conducted between –40 ˚C and 110 ˚C with dwell times of 5 min at ±5 ˚C of the dwell temperature. The average temperature ramp rate ($\dot{T}$) is variable, with a maximum of 30 ˚C/min, and will set the required number of cycles (N_R) according to Formula (1).

$$N_R = 105{,}56 + 2787{,}8\,\dot{T}^{-0{,}166} \quad (2)$$

The number of required cycles for any ramp rate is considered as an equivalent test. Figures 1 and 2 are provided to illustrate this relationship and its consequence on overall test time.

NOTE 1 Thermal cycling parameters are based on:

a) IEC 62108: A 2,5 ˚C/min ramp rate results in 5x the number of TCA2 cycles;