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TECHNICAL SPECIFICATION

Photovoltaic (PV) modules – Test methods for the detection of potential-induced degradation –
Part 2: Thin-film

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PHOTOVOLTAIC (PV) MODULES – TEST METHODS FOR THE DETECTION OF POTENTIAL-INDUCED DEGRADATION –

Part 2: Thin-film

FOREWORD

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IEC TS 62804-2 has been prepared by IEC technical committee 82: Solar photovoltaic energy systems. It is a Technical Specification.

The text of this Technical Specification is based on the following documents:

Draft	Report on voting
82/1958/DTS	82/2001A/RVDTS

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Technical Specification is English.

A list of all parts in the IEC 62804 series, published under the general title *Photovoltaic (PV) modules – Test methods for the detection of potential-induced degradation*, can be found on the IEC website.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

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- reconfirmed,
- withdrawn,
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INTRODUCTION

Potential-induced degradation (PID) refers to any PV module degradation that is caused by the stress of an electric potential between the active cell circuit and the external surfaces or parts of the PV module.

The applied stresses, with system voltage being the principal factor in IEC 62804 series documents, manifest themselves in different degradation modes that depend in part on the module technology. Therefore, a series of technical specifications is being developed to define PID tests for different PV module technologies and differing PID modes.

IEC TS 62804-1:2015, *Photovoltaic (PV) modules – Test methods for the detection of potential-induced degradation – Part 1: Crystalline silicon* defines test methods for evaluating power loss by PID in crystalline silicon PV modules.

IEC TS 62804-1-1:2020, *Photovoltaic (PV) modules – Test methods for the detection of potential-induced degradation – Part 1-1: Crystalline silicon – Delamination* defines a test method for evaluating delamination by PID associated with electrochemical processes in crystalline silicon PV modules.

This part of IEC 62804 defines test methods for evaluating power loss by PID in thin-film PV modules with moisture sensitive components and those which use moisture barrier encapsulation because of such sensitivity.

A future document will be required for evaluating corrosion and delamination associated with electrochemical processes in thin-film PV modules and modules with moisture sensitive components with moisture barrier packaging. Further documents in the series may be introduced in the future for emerging module technologies, mechanisms, or evaluation methods.

In addition to the IEC 62804 series, IEC 61215-2:2021 contains a PID test (MQT 21) with methods and severities from IEC TS 62804-1: 2015 method (a) with modifications to avoid some recognized test-specific degradation and polarization for application to various flat plate module types. The PID test method in IEC 61215-2:2021 is shorter and simpler than those given in this document.

Voltage potential that exists between the active circuit and the module surfaces directly or indirectly connected to earth can lead to module degradation by multiple mechanisms including ionic transport in the encapsulant, superstrate or substrate; hot carriers in the cell, redistribution of charges that degrade the active layer of the cell or its surfaces, failure of adhesion at interfaces, and corrosion of module components. Along with the factor of system voltage, these processes are most active in wet or damp environments, and in environments prone to soiling of modules with conductive, acidic, caustic, or ionic species that lead to increased conduction on the module surfaces. Certain failure mechanisms may only be active with the module electrically biased in one polarity depending on the cell construction, module materials, and design. The testing in this document therefore specifies the evaluation of the effects of voltage stress in both polarities for modules that may be operated in either polarity, or when applicable, uniquely in the polarity defined by the manufacturer's documented specifications and installation instructions.

Considering this document is applicable to modules with a functional moisture barrier packaging, a procedure is provided in Annex A to evaluate the functionality of the moisture barrier for the purposes of PID evaluation. If the moisture barrier is not sufficiently functional, the moisture ingress is likely to affect (usually increase) PID rate during accelerated testing in the environmental chamber and largely invalidate projections that this document provides about PID rate in the field.

There are many module designs, which span crystalline silicon, compound semiconductor, thin-film and tandem technologies. These can exhibit differing sensitivities of the absorber layer, differing laminate constructions and interfaces, and different mounting types with differing ability to resist charge transfer between the laminate and ground. Based on the great variability in acceleration factor between use condition and test, which has been measured in one instance involving a thin-film module technology to vary between one and two orders of magnitude with the singular change of the edge clip material holding the module [1][1], a unique stress level for accelerated testing of all module types covered by this document is not given at this time. Instead, a protocol for evaluating the acceleration factor for PID degradation of thin film modules with respect to climate zones is provided. Use of the acceleration factor method is therefore motivated because considerable variability in acceleration factor has been found depending on the thin film product and mounting [1]. Whether the phenomenon is specific to thin film products has not been clarified.

To overcome the significant variability, this document offers procedures for evaluating the relative rate (or acceleration) of current transfer and degradation in the chamber versus the field, which has been found useful for evaluating thin-film technologies in the absence of the variable of moisture ingress into the module [2-6]. The user may therefore calculate the relative PID resistance in the chamber condition versus the field condition which to better forecast the power degradation rate by PID in the use. Using of rate of coulomb transfer in the field and chamber as a basis provides a platform for comparison of test results. With the understanding of how many coulombs are transferred in the use environment per year, one can project power loss by PID for the desired number of years in the use environment based on the measured coulombs transferred and any observed power loss by PID in the environmental chamber, in the absence of moisture ingress and significant power recovery if the factor of system voltage bias is removed.

Differing module constructions transfer PID-inducing current between the cells and ground differently as a function of extent of moisture on the surfaces and temperature. The charge density profile of transferred coulombs across the module will vary as a function of temperature and humidity on the module surfaces as well. To maintain representative temperatures and humilities for the PID testing, an option to accelerate the PID testing with the factor of elevated system voltage in the field is additionally offered in this document.

Thin-film modules may exhibit metastability and other effects, whereby the history of exposure to factors including light and heat may influence power performance either reversibly or irreversibly. Without attention to this, such effects can hinder the quantification of the PID incurred in the PID stress test. To normalize for such extraneous power changes exhibited by modules in this PID test, the power performance after a PID chamber stress test is examined relative to any change in power of in-chamber control modules undergoing the same stress regime excluding the factor of system voltage stress.

This document also includes options to mitigate power changes due other test-specific effects resulting from the unrepresentative conditions of heat and darkness that IEC 61215-2 MQT 19, Stabilization, alone will not correct. These options include application of light or forward bias voltage before and during the PID stress test. This document additionally contains a light and heat exposure sequence that may be optionally applied to the modules after the PID stress test to obtain the power performance of the module after such recovery procedure. During IEC 61215-2 MQT 19, Stabilization, the factor of system voltage is not applied, a condition that does not normally occur in the field.

The voltage levels applied in testing are the modules' nameplate-rated system voltage. This results in a voltage level that is typically above that experienced in the field because:

a) voltage levels are reduced due to their elevated operating temperature under sunlight,
b) they are operated at maximum power and therefore a lower maximum power voltage than system voltage that is associated with the open-circuit voltage of the modules,
c) most of the modules are not at the extremes of the series string, and
d) due to safety factors or other design criteria, modules may be in strings below the module rated system voltage.

[1] Numbers in square brackets refer to the Bibliography.

However, modules connected in series strings that are in open circuit and uncontrolled by a maximum power tracker, for reasons including being disconnected from their load, may experience uncontrolled and significantly higher voltages than experienced by the modules maintained at the maximum power point even though system installation standards require voltage levels to be below system voltage. The voltage levels applied in testing is thus the modules' nameplate-rated system voltage. This provides a small element of acceleration over typical use conditions, while maintaining a system voltage level that modules may actually experience in the field.

It is known that variability in manufacturing processes can affect the susceptibility of modules to system voltage stress. Periodic retesting of modules by the test protocols contained herein with internal quality assurance programs such as given in IEC 62941, and with external audits, will aid in verifying not only the durability of the design of the module to system voltage stress, but also the effects of any variability of the materials and manufacturing processes. Due to the extended length of time required to perform the tests contained herein, it is anticipated that module manufacturers themselves will apply them.

PHOTOVOLTAIC (PV) MODULES – TEST METHODS FOR THE DETECTION OF POTENTIAL-INDUCED DEGRADATION –

Part 2: Thin-film

1 Scope

This part of IEC 62804 defines apparatus and procedures to test and evaluate the durability of photovoltaic (PV) modules to power loss by the effects of high voltage stress in a damp heat environment, referred to as potential-induced degradation (PID). This document defines a test method that compares the coulomb transfer between the active cell circuit and ground through the module packaging under voltage stress during accelerated stress testing with the coulomb transfer during outdoor testing to determine an acceleration factor for the PID. It is designed for thin-film PV modules and modules containing moisture sensitive films protected by vapour barrier packaging, principally with one or two glass surfaces. This document tests for the degradation mechanisms involving mobile ions influencing the electric field over the semiconductor absorber layer or electronically interacting with the films such that module power is affected. This document does not specifically test for electrochemical corrosion or delamination associated with application of system voltage. This document does not contain pass or fail criteria and it is not intended for design qualification.

The procedures contained herein, with testing in chamber in combination with in the field or testing in the field alone are intended for use when it is desired to quantify the acceleration provided by the applied stress levels over regular use conditions in the natural environment using coulombs transferred between the module and ground as the index for damage incurred by PID. The procedures for quantifying the acceleration are not recommended when coulombs transferred are not an indicator of damage by PID to the module. The procedures are not directly applicable when moisture ingress into the module laminate occurs affecting PID rate, and to the extent that there is power recovery when the factor of system voltage bias is removed after correctly applying the procedures herein, within the period of testing.

The protocols given herein give results according to the chamber stress levels applied and the module grounding configuration used in the test. Because the stress method of testing in an environmental chamber employs a non-condensing humidity level to serve as a conductive pathway to electrical ground, it frequently applies relatively less stress toward the centre of the module face. Also, the method can evaluate the effectiveness of some construction methods to mitigate PID; for example, the use of rear rail mounts, edge clips, and insulating frames. The test, however, does not include all the factors existing in the natural environment that can affect the PID rate. The actual durability of modules to system voltage stress depends on the actual environmental conditions under which they are operated.

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 60068-2-78:2012, *Environmental testing – Part 2-78: Tests – Test Cab: Damp heat, steady state*

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*

IEC 60721-2-1:2013, *Classification of environmental conditions – Part 2-1: Environmental conditions appearing in nature – Temperature and humidity*

IEC 60904-1, *Photovoltaic devices – Part 1: Measurement of photovoltaic current-voltage characteristics*

IEC 60904-3, *Photovoltaic devices – Part 3: Measurement principles for terrestrial photovoltaic (PV) solar devices with reference spectral irradiance data*

IEC TS 60904-13, *Photovoltaic devices – Part 13: Electroluminescence of photovoltaic modules*

IEC 61215-1, *Terrestrial photovoltaic (PV) modules – Design qualification and type approval – Part 1: Test requirements*

IEC 61215-2:2021, *Terrestrial photovoltaic (PV) modules - Design qualification and type approval - Part 2: Test* procedures

IEC 61724-1, *Photovoltaic system performance – Part 1: Monitoring*

IEC 61730-1, *Photovoltaic (PV) module safety qualification – Part 1: Requirements for construction*

IEC 61730-2, *Photovoltaic (PV) module safety qualification – Part 2: Requirements for testing*

IEC TS 61836, *Solar photovoltaic energy systems – Terms, definitions and symbols*

IEC 61853-1:2011, *Photovoltaic (PV) module performance testing and energy rating – Part 1: Irradiance and temperature performance measurements and power rating*

IEC TS 62804-1:2015, *Photovoltaic (PV) modules – Test methods for the detection of potential-induced degradation – Part 1: Crystalline silicon*

IEC TS 62804-1-1:2020, *Photovoltaic (PV) modules – Test methods for the detection of potential-induced degradation – Part 1-1: Crystalline silicon – Delamination*

IEC 62941, *Terrestrial photovoltaic (PV) modules – Quality system for PV module manufacturing*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC TS 61836 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

4 Samples

All samples for test shall be of representative and identical materials, construction process, and characteristics. For application of the tests in either 5.2 or 5.3, procure two samples for each polarity of the system voltage that is specified or allowed in the module documentation, along with two samples to be used as control modules. If the polarity of the modules connected into module strings is not specified, two replicas for each polarity are required. If the module documentation and the nameplate specify usage of the module in strings of only one voltage polarity with respect to ground (one terminal of the module string tied to ground), then the modules selected for testing under system voltage bias shall be stressed only in that specified polarity. Procure double the number of representative and identical samples for performing the tests in both 5.2 and 5.3 or testing according to 5.2.6. If additional certainty is sought, for example, if there are concerns of partial shading of modules leading to localized damage of the absorber layer, the number of modules for test and for use as controls may be increased.

Sample types chosen for application of this document shall be protected by functioning vapour barrier of the module encapsulation. Annex A is given for the evaluation of effective moisture barrier of the module type for the purposes of PID evaluation.

The PV module samples shall have been manufactured from specified materials and components in accordance with the relevant drawings and process sheets and have been subjected to the manufacturer's normal inspection, quality control and production acceptance procedures. The PV modules shall be complete in every detail and shall be accompanied by the manufacturer's handling, mounting, and connection instructions. When the PV modules to be tested are prototypes of a new design and not from production, this fact shall be noted in the test report (see Clause 6).

When submitted to another party for testing, the submitted modules shall be complete and accompanied by the manufacturer's handling, mounting and connection instructions, including the maximum permissible system voltage. Markings on the module shall conform to the requirements of IEC 61215-1 and IEC 61730-1.

The test results apply only to the module construction tested. To evaluate modules using more than one component source, module design, cell design, process design, or differing process set points and tolerances, then a set of modules for each permutation shall be procured for testing. Changes of the junction box, cables, and connectors do not indicate retest unless modifications to the module laminate for any electrical penetration of conductors through it are made. In cases where the cell, module, or materials process variability or tolerances are large, testing of more than two samples per polarity will be useful for improving the confidence in the results.

If the PV module is provided with and is specified for use with a specific means for grounding, then the grounding means shall be included and considered a part of the test sample. If the PV module is provided with and is specified for use with means for mounting that could additionally influence the module grounding, then the means for mounting shall be included and considered a part of the test sample.

5 Tests

5.1 General

Measurement of current transfer between the cell circuits of modules and ground in the natural environment is employed for evaluating the resistance of the particular design to system voltage stress in the given environment. Tests are grouped into methods that either:

a) evaluate the relative rate (or acceleration) of current transfer and degradation in the chamber versus the field, or

b) use of modules in the field with increased system voltage applied as an accelerant.

The schema of test procedures is shown in Table 1. In view of the potential for metastabilities and test-specific artifacts that may vary among module types, in conjunction with Table 1, consult with the manufacturer for information, guidance, and recommendations for selecting appropriate test procedures.