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BSI Standards Publication

Photovoltaic (PV) modules – Test methods for the detection of potential-induced degradation

Part 1-1: Crystalline silicon – Delamination

National foreword

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The UK participation in its preparation was entrusted to Technical Committee GEL/82, Photovoltaic Energy Systems.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Part 1-1: Crystalline silicon – Delamination

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FOREWORD

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Technical Specification are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC TS 62804-1-1, which is a Technical Specification, has been prepared by IEC technical committee 82: Solar photovoltaic energy systems.

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

Draft TS	Report on voting
82/1566/DTS	82/1596A/RVDTS

Full information on the voting for the approval of this Technical Specification 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.

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.

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- withdrawn,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.

A bilingual version of this publication may be issued at a later date.

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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. This part of IEC 62804 is for testing and evaluating the durability of crystalline silicon PV modules for PID in the mode of delamination (PID-d), as may be induced by the stress factors of moisture and system voltage.

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 defines test methods for evaluating power loss by PID in crystalline silicon PV modules.

IEC TS 62804-1-1 defines a test method for evaluating delamination by PID in crystalline silicon PV modules.

IEC TS 62804-2 defines test methods for evaluating power loss by PID in thin-film PV modules and modules with moisture-sensitive components and moisture-barrier packaging.

Additional TSs in the series may be introduced in the future for emerging module technologies, mechanisms, or evaluation methods.

Delamination of PV modules is a failure mode that can lead to electrical shocks, ground faults, rapid moisture ingress or collection of condensed moisture and can be associated with corrosion, some loss in photocurrent and hotspots due to degraded transmission of light to the solar cells, and visual undesirability. Various delamination modes are seen occurring in fielded modules for which standardized methods for accelerated testing do not exist to predict these vulnerabilities.

Delamination in crystalline silicon PV modules has been found to occur associated with electrochemical reactions on the silicon PV cell surface and metallization (Mon and Ross, 1985, Matsuda *et al.* 2012). Moisture has been found to sometimes accelerate the adhesion loss at interfaces in PV modules, along with elevated sodium concentration on the cell surface within the module package, which may result from the electric field of system voltage stress (Dhere *et al.,* 2002, Bosco *et al.*, 2017, Wohlgemuth *et al.*, 2017, Li *et al.,* 2018). Modules with encapsulation materials of low bulk resistivity have been found to have greater susceptibility to PID-d under electric fields due to system voltage stress (Hacke *et al.*, 2016). Modules that do not exhibit significant power loss by PID-shunting (PID-s) or PID polarization (PID-p) modes may still be prone to degradation by the delamination mode examined in this document if, for example, the cells are made durable to power loss by these modes, but the encapsulation is of low bulk resistivity.

Elevated dissolved moisture content in encapsulants has been found to increase the bulk conductivity of many encapsulants (Berghold *et al.*, 2014). An accelerated test is therefore provided in this document to evaluate modules for susceptibility to delamination under the stress factors of moisture and system voltage. While mounting and grounding configuration may be optimized to mitigate PID degradation modes, as a test of the laminate, glass surfaces are grounded in this document independent of consideration of the intended mounting and grounding configuration of the module.

The conductivity of glass and resultant charge transfer through it enable electrochemical reactions within the laminate when subjected to a voltage potential. Therefore, this document is intended primarily for modules with one or two glass faces. To date, module package resistivity has been measured to vary by several orders of magnitude. Accordingly, the testing protocol herein has been found to differentiate susceptible modules from durable modules as a function of resistivity for this delamination mode (Hacke *et al.*, 2016). The stress test conditions contained herein are highly accelerated and have been determined to differentiate susceptibility of modules to this degradation mode; but their acceleration factor with respect to the rate of occurrence in various natural environments has not been established. Annex A gives examples of the degradation modes manifested by application of the protocol and visually similar examples from the field.

Delamination may additionally occur by other mechanisms, such as from the reaction products of photocatalysis (Matsuda *et al.*, 2012), and may not manifest under this or other presently existing standardized testing protocols.

It is known that variability in manufacturing processes can affect the susceptibility of modules to system voltage stress. Periodic retesting of module samples by the test protocols contained herein, by internal quality assurance programs such as given in IEC TS 62941, and by 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.

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

Part 1-1: Crystalline silicon – Delamination

1 Scope

This part of IEC 62804 defines procedures to test and evaluate for potential-induced degradation-delamination (PID-d) mode in the laminate of crystalline silicon PV modules—principally those with one or two glass faces. This document evaluates delamination attributable to current transfer between ground and the module cell circuit. Elements driving the delamination that this test is designed to actuate include reduced adhesion associated with damp heat exposure, sodium accumulation at interfaces, and cathodic gas evolution in the cell circuit, metallization, and other components within the PV module activated by the voltage potential. The change in power of crystalline silicon PV modules associated with the stress factors applied (the purview of IEC TS 62804-1) is not considered in the scope.

Modules are tested in a climactic chamber with damp heat and application of module-rated system voltage to the cell circuit in each polarity that is specified or allowed in the module documentation. This document does not differentiate the effects of some construction methods of mitigating PID—for example, the use of rear rail mounts, edge clips, and insulating frames that may serve to electrically isolate the module faces to varying extents. The actual durability of modules to system voltage stress will depend on the mounting design and the environmental conditions under which the modules are operated. These tests are intended to assess the sensitivity of the PV module laminate to PID-d irrespective of actual stresses under operation in different climates and systems.

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 61215-1:2016, *Terrestrial photovoltaic (PV) modules – Design qualification and type approval – Part 1: Test requirements*

IEC 61215-2:2016, *Terrestrial photovoltaic (PV) modules – Design qualification and type approval – Part 2: Test procedures*

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

IEC TS 62941, *Terrestrial photovoltaic (PV) modules – Guidelines for increased confidence in PV module design qualification and type approval*