IEC TS 63202-4

Edition 1.0 2022-06

TECHNICAL SPECIFICATION

colour inside

Photovoltaic cells –
Part 4: Measurement of light and elevated temperature induced degradation of crystalline silicon photovoltaic cells

IEC TS 63202-4:2022-06(en)

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

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

About the IEC
The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications
The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform
The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, …). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished
Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc
If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch
Discover our powerful search engine and read freely all the publications previews. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org
The world's leading online dictionary on electrotechnology, containing more than 22 300 terminological entries in English and French, with equivalent terms in 19 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC TS 63202-4

Edition 1.0 2022-06

TECHNICAL SPECIFICATION

colour inside

Photovoltaic cells –
Part 4: Measurement of light and elevated temperature induced degradation of crystalline silicon photovoltaic cells

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 27.160

ISBN 978-2-8322-3924-7

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

_____

PHOTOVOLTAIC CELLS –

Part 4: Measurement of light and elevated temperature induced degradation of crystalline silicon photovoltaic cells

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

IEC TS 63202-4 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
82/1994/DTS	82/2043/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.

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 https://www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at https://www.iec.ch/standardsdev/publications.

A list of all parts in the IEC 63202 series, published under the general title *Photovoltaic cells*, 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 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.

IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

PHOTOVOLTAIC CELLS –

Part 4: Measurement of light and elevated temperature induced degradation of crystalline silicon photovoltaic cells

1 Scope

This part of IEC 63202 describes procedures for measuring the light and elevated temperature induced degradation (LETID) of crystalline silicon photovoltaic (PV) cells in simulated sunlight.

The requirements for measuring initial light induced degradation (LID) of crystalline silicon PV cells are covered by IEC 63202-1, where LID degradation risk of PV cells under moderate temperature and initial durations within termination criteria of 20 kWh·m^{-2} are evaluated.

Energy yield of PV modules is significantly affected by the inherent LETID performance of the PV cells, which are used in it. This LETID performance includes LID and other degradation mechanisms. The procedures described in this document are to evaluate the degradation behaviour of PV cells under elevated temperature and longer duration of light irradiation. The degradation rate, maximum degradation ratio and possible regeneration are determined by comparing the cell maximum power, P_{max}, at Standard Test Conditions (STC) during the light irradiation process with respect to the initial P_{max}. A P_{max} degradation profile with respect to cumulative irradiation is presented, which helps cell manufacturer to judge whether the cells are prone to LETID before being assembled into modules.

Different from some other standards which separate boron-oxygen induced LID from LETID or are limited to charge carrier injection induced degradation [1][1], the overall degradation under light irradiation at elevated temperature is included in the procedures described in this document. The overall degradation, determined using this procedure, is more relevant to various degradation mechanisms under field condition and gives a better evaluation of LETID risk. For cells with strong initial degradation within around 20 kWh·m^{-2}, the procedures to measure initial light induced degradation (LID) in IEC 63202-1 can be applied. Compared with module LETID detection method described in IEC TS 63342, higher injection level under open-circuit condition is used to shorten the test duration, while the temperature is identical.

The procedures described in this document can be used to detect the LETID risks of PV cells [2],[3] and to judge the effectiveness of LETID mitigation measures, e.g. quick test for production monitoring, thus helping improve the energy yield of PV modules.

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

IEC 60904-2, *Photovoltaic devices – Part 2: Requirements for photovoltaic reference devices*

---

1 Numbers in square brackets refer to the Bibliography.

IEC 60904-9, *Photovoltaic devices – Part 9: Classification of solar simulator characteristics*

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

IEC 63202-1:2019, *Photovoltaic cells – Part 1: Measurement of light-induced degradation of crystalline silicon photovoltaic cells*

IEC TS 63202-2:2021, *Photovoltaic cells – Part 2: Electroluminescence imaging of crystalline silicon solar cells*

IEC TS 63342, *Light and elevated temperature induced degradation (LETID) test for c-Si Photovoltaic (PV) modules: Detection*

3 Terms and definitions

For the purposes of this document, the terms and definitions in IEC TS 61836 and IEC 63202-1 apply.

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

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

4 Apparatus

The following apparatus are required to perform the LETID test defined in this document.

a) A light soaking apparatus with temperature controller that meets following requirements:
   1) one or more irradiance sensors (meeting the requirements of IEC 60904-2) to monitor the cumulative irradiance;
   2) the means to mount test cells co-planar with the irradiance sensors;
   3) the capability to control cell temperature in the range of (75 ± 2) °C during the light irradiation with an irradiance of (1 000 ± 50) $W \cdot m^{-2}$;
   4) relative humidity ≤ 50 %;
   5) internal air shall be free of corrosive or contaminating contents.
b) Solar simulator: class BBB (or better) steady-state solar simulator in accordance with IEC 60904-9, featuring a capability to provide irradiance of (1 000 ± 50) $W \cdot m^{-2}$ on cells mounted in the environmental chamber.
c) The apparatus necessary to take an I-V curve as defined in IEC 60904-1.

5 Sampling

A minimum of twenty PV cells are required for this test. EL images of the cells shall be taken using the method given in IEC TS 63202-2 to ensure that they have no abnormalities. Test cells are randomly selected from the same production batch. If cells are selected using a special sampling criteria, the detailed sampling specification shall be included in the final report. All samples for this test shall be assigned a unique identification number for tracking and reporting purpose.

Selected PV cells shall be stored in a sealed and dark container free of corrosive or contaminating contents at (25 ± 5) °C and relative humidity ≤ 50 %. The selected PV cells shall not undergo any other pre-treatment such as LID stabilization.

6 Measurement

a) The light irradiation procedure shall be taken under inert gas or using a transparent glass cover to avoid oxidization. If transparent glass is used, the irradiance intensity shall be monitored by irradiance sensor covered with the glass.

b) Following procedures required in IEC 60904-1, measure the I-V curve of each sampled cell at STC. Each measurement shall be repeated three times consecutively and P_{max} is recorded as the average value of the three tests. Between each measurement, the cells shall be rested for more than 3 s.

c) Place the sampled cells in the test chamber described in Clause 4, item a). When the cell temperature is 60 °C or larger, expose all the sampled cells to the solar simulator with irradiance of (1 000 ± 50) W·m^{-2}. During light illumination, the cell temperature shall be maintained in the range of (75 ± 2) °C. The cells are kept in open-circuit condition. The relative humidity shall not be larger than 50 %.

d) After the light irradiation dose as described in item c) has accumulated to (0,5 ± 0,025) kWh·m^{-2}, take the cells out of test chamber and store in dark at (25 ± 5) °C and relative humidity $\leqslant$ 50 % for 2 h, and then repeat item b). Other than the minimum illumination time required for item b), cells shall be kept protected from light and current. Specifically, they shall be kept in the dark and protected from room lights, until re-introduced into the next high-temperature elevated temperature exposure step.

e) Repeat steps b) and c) to reach different cumulative irradiation doses. The designed accumulative irradiation dose are (1 ± 0,05) kWh·m^{-2}, (2 ± 0,1) kWh·m^{-2}, (4 ± 0,2) kWh·m^{-2}, (8 ± 0,4) kWh·m^{-2}, (16 ± 0,8) kWh·m^{-2}, (24 ± 1,2) kWh·m^{-2}, (48 ± 2,4) kWh·m^{-2}, (96 ± 4,8) kWh·m^{-2}, and (168 ± 8,4) kWh·m^{-2}.

f) After each I-V measurement step for every designed cumulative irradiation dose, calculate the degradation ratio of all the sampled cells using the following formulae:

$$\Delta P_{max}(i)=\frac{P'_{max}(i)-P_{max}(i)}{P_{max}(i)} \quad (1)$$

$$\Delta V_{OC}(i)=\frac{V'_{OC}(i)-V_{OC}(i)}{V_{OC}(i)} \quad (2)$$

$$\Delta I_{SC}(i)=\frac{I'_{SC}(i)-I_{SC}(i)}{I_{SC}(i)} \quad (3)$$

Where i is the index of the sampled cell, $P_{max}(i)$, $V_{OC}(i)$, $I_{SC}(i)$ are initial P_{max}, V_{OC}, I_{SC} of the sampled cell with index i, and $P'_{max}(i)$, $V'_{OC}(i)$, $I'_{SC}(i)$ are P_{max}, V_{OC}, I_{SC} of the sampled cell with index i after each irradiation step.

g) After each I-V measurement step for every designed cumulative irradiation dose, calculate the average degradation ratio of the sampled cells using the following formulae:

$$\Delta P_{max}=\frac{\sum_{i=1}^{N}\Delta P_{max}(i)}{N} \quad (4)$$

$$\Delta V_{OC}=\frac{\sum_{i=1}^{N}\Delta V_{OC}(i)}{N} \quad (5)$$

$$\Delta I_{SC}=\frac{\sum_{i=1}^{N}\Delta I_{SC}(i)}{N} \quad (6)$$

Where $N$is the number of sampled cells, ΔP_{max}, ΔV_{OC}, ΔI_{SC} are average degradation ratio in P_{max}, V_{OC} and I_{SC} of the sampled cells.

h) During each I-V measurement step for every designed cumulative irradiation dose, measurement of electroluminescence (EL) of the sampled cells together with I-V measurement is recommended. EL measurement is to determine whether or not cells are damaged due to repeated handling. If any damage is observed, by either EL test or other ways, the data shall be specially marked in the final report.

i) Terminate the process after cumulative irradiation dose reaches (168 ± 8,4) $kWh \cdot m^{-2}$.

j) At least one control cell is recommended to be tested together with the sampled cells for every designed cumulative irradiation dose in order to evaluate the influence of testing and handling on cell P_{max}. Other than time for IV and EL measurement, the control cells shall be kept in a sealed and dark container at room temperature.

7 Report

The report shall include at least the following elements:

a) description of the sampled cells, i.e. cell type, numbers, date of manufacturing, etc.;

b) the initial I-V characteristics of the sampled cells, including at least P_{max}, V_{oc}, I_{sc};

c) the table of the degradation ratio of each sampled cell $\Delta P_{max}(i)$, $\Delta V_{OC}(i)$, $\Delta I_{SC}(i)$ after each irradiation step;

d) the initial and final EL images of each sampled cell;

e) a statement of the estimated uncertainty of the test results;

f) an indication of cells where damage was observed, noting the cell number and the type of damage;

g) and the following contents are recommended:

h) plot of the degradation curve (e.g. Annex A) of typical individual sampled cell over duration of irradiation;

i) box-chart plot of the degradation ratio at each irradiation step of the set of sampled cells and the average degradation ratio of the sampled cells ΔP_{max} at each irradiation step.

j) box-chart plot of the degradation ratio at each irradiation step of each control cell, if control cells are tested as recommended in Clause 6, item j).