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colour inside

Ground-mounted photovoltaic power plants – Design guidelines and recommendations

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GROUND-MOUNTED PHOTOVOLTAIC POWER PLANTS – DESIGN GUIDELINES AND RECOMMENDATIONS

FOREWORD

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- the subject is still under technical development or where, for any other reason, there is the future but no immediate possibility of an agreement on an International Standard.

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

IEC TS 62738, 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:

Enquiry draft	Report on voting
82/1291/DTS	82/1374/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.

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

- transformed into an International standard,
- 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- withdrawn,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

This document sets out general guidelines and recommendations for the design and installation of utility scale ground-mounted photovoltaic (PV) power plants. The focus is largely on design aspects that differ from those of conventional residential and commercial PV systems. Power plants are a significant and growing component of the PV market, yet design methodologies range considerably, partly due to the fact that systems are not accessible to the public or non-qualified personnel. Overall guidelines are still needed to ensure safe, reliable, and productive systems.

GROUND-MOUNTED PHOTOVOLTAIC POWER PLANTS – DESIGN GUIDELINES AND RECOMMENDATIONS

1 Scope

This document sets out general guidelines and recommendations for the design and installation of ground-mounted photovoltaic (PV) power plants. A PV power plant is defined within this document as a grid-connected, ground-mounted system comprising multiple PV arrays and interconnected directly to a utility's medium voltage or high voltage grid. Additional criteria is that PV power plants are restricted from access by non-qualified persons and are continuously monitored for safety and protection, either by on-site personnel or by active remote monitoring. Technical areas addressed are those that largely distinguish PV power plants from smaller, more conventional installations, including ground mounted array configurations, cable routing methods, cable selection, overcurrent protection strategies, equipotential bonding over large geographical areas, and equipment considerations.

Safety and design requirements are referenced to the applicable requirements of IEC 62548 to address distinct differences relative to the design requirements for residential, commercial and other non-power plant applications. In general, existing standards are referenced wherever possible for uniformity. Emphasis is placed on systems employing d.c. string based systems using large scale central inverters or 3-phase string inverters, but relevant sections are also applicable to systems employing a.c. modules or d.c./d.c. converters. Medium voltage transformers, switchgear, collection systems, substations, utility interconnection, auxiliary loads, energy storage systems, and communication services are addressed, but discussion is mostly limited to recommended references to other standards and requirements.

Rooftop-mounted systems, building integrated PV (BIPV) and building applied PV (BAPV) are not included in the scope of this document. The principles of restricted-access power plants are not compatible with systems on buildings, which are used for purposes other than power generation.

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 60076-1, *Power transformers – Part 1: General*

IEC 60076-2, *Power transformers – Part 2: Temperature rise for liquid-immersed transformers*

IEC 60076-3, *Power transformers – Part 3: Insulation levels, dielectric tests and external clearances in air*

IEC 60076-4, *Power transformers – Part 4: Guide to the lightning impulse and switching impulse testing – Power transformers and reactors*

IEC 60076-5, *Power transformers – Part 5: Ability to withstand short-circuit*

IEC 60076-7, *Power transformers – Part 7: Loading guide for mineral-oil-immersed power transformers*

IEC 60085, *Electrical insulation – Thermal evaluation and designation*

IEC 60137, *Insulated bushings for alternating voltages above 1000 V*

IEC 60183, *Guidance for the selection of high-voltage A.C. cable systems*

IEC 60228, *Conductors of insulated cables*

IEC 60255-21-3, *Electrical relays – Part 21: Vibration, shock, bump and seismic tests on measuring relays and protection equipment – Section 3: Seismic tests*

IEC 60296, *Fluids for electrotechnical applications – Unused mineral insulating oils for transformers and switchgear*

IEC 60364-5-52, *Low-voltage electrical installations – Part 5-52: Selection and erection of electrical equipment – Wiring systems*

IEC 60364-5-54, *Low-voltage electrical installations – Part 5-54: Selection and erection of electrical equipment – Earthing arrangements and protective conductors*

IEC 60502-1, *Power cables with extruded insulation and their accessories for rated voltages from 1 kV (Um = 1,2 kV) up to 30 kV (Um = 36 kV) – Part 1: Cables for rated voltages of 1 kV ((Um = 1,2 kV) and 3 kV (Um = 3,6 kV)*

IEC 60502-2, *Power cables with extruded insulation and their accessories for rated voltages from 1 kV (Um = 1,2 kV) up to 30 kV (Um = 36 kV) – Part 2: Cables for rated voltages from 6 kV (Um = 7,2 kV) up to 30 kV (Um = 36 kV)*

IEC 60853 (all parts), *Calculation of the cyclic and emergency current rating of cables*

IEC 60870-5-104, *Telecontrol equipment and systems – Part 5-104: Transmission protocols – Network access for IEC 60870-5-101 using standard transport profiles*

IEC TR 60890, *A method of temperature-rise verification of low-voltage switchgear and controlgear assemblies by calculation*

IEC 60947-3:2008, *Low-voltage switchgear and controlgear – Part 3: Switches, disconnectors, switch-disconnectors and fuse-combination units*

IEC 60947-3:2008/AMD1:2012
IEC 60947-3:2008/AMD2:2015

IEC 61000-4-2, *Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test*

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

IEC 61238-1 (all parts), *Compression and mechanical connectors for power cables*

IEC 61427-2, *Secondary cells and batteries for renewable energy storage – General requirements and methods of test – Part 2: On-grid applications*

IEC 61439-1, *Low-voltage switchgear and controlgear assemblies – Part 1: General rules*

IEC 61439-2, *Low-voltage switchgear and controlgear assemblies – Part 2: Power switchgear and controlgear assemblies*

IEC 61643-32, *Low-voltage surge protective devices – Part 32: Surge protective devices connected to the d.c. side of photovoltaic installations – Selection and application principles*

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

IEC TS 61724-2, *Photovoltaic system performance – Part 2: Capacity evaluation method*

IEC TS 61724-3, *Photovoltaic system performance – Part 3: Energy evaluation method*

IEC 61850 (all parts), *Communication networks and systems for power utility automation*

IEC 61936-1, *Power installations exceeding 1 kV a.c. – Part 1: Common rules*

IEC 62109-1, *Safety of power converters for use in photovoltaic power systems – Part 1: General requirements*

IEC 62109-2, *Safety of power converters for use in photovoltaic power systems – Part 2: Particular requirements for inverters*

IEC 62271-1, *High-voltage switchgear and controlgear – Part 1: Common specifications for alternating current switchgear and controlgear*

IEC 62271-100, *High-voltage switchgear and controlgear – Part 100: Alternating current circuit-breakers*

IEC 62271-102, *High-voltage switchgear and controlgear – Part 102: Alternating current disconnectors and earthing switches*

IEC 62271-103, *High-voltage switchgear and controlgear – Part 103: Switches for rated voltages above 1 kV up to and including 52 kV*

IEC 62271-200, *High-voltage switchgear and controlgear – Part 200: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV*

IEC TS 62271-210, *High-voltage switchgear and controlgear – Part 210: Seismic qualification for metal enclosed and solid-insulation enclosed switchgear and controlgear assemblies for rated voltages above 1 kV and up to and including 52 kV*

IEC TR 62271-300, *High-voltage switchgear and controlgear – Part 300: Seismic qualification of alternating current circuit-breakers*

IEC 62305-2, *Protection against lightning – Part 2: Risk management*

IEC 62446-1, *Photovoltaic (PV) systems – Requirements for testing, documentation and maintenance – Part 1: Grid connected systems – Documentation, commissioning tests and inspection*

IEC 62446-2, *Photovoltaic (PV) systems – Requirements for testing, documentation and maintenance – Part 2: Grid connected systems – Maintenance of PV systems* (to be published)

IEC 62548:2016, *Photovoltaic (PV) arrays – Design requirements*

IEC 62817, *Photovoltaic systems – Design qualification of solar trackers*

IEC 62852, *Connectors for DC-application in photovoltaic systems – Safety requirements and tests*

EN 50539-11, *Low-voltage surge protective devices – Surge protective devices for specific application including d.c. – Part 11: Requirements and tests for SPDs in photovoltaic applications*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 62548 as well as the following 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
PV power plant
grid-connected, ground-mounted PV system comprising multiple PV arrays and interconnected directly to a utility's medium voltage or high voltage grid

Note 1 to entry: Additional criteria are that PV power plants are restricted from access by non-qualified personnel and are continuously monitored for safety and protection, either by on-site personnel or by active remote monitoring.

3.2
electrically skilled person
person with relevant education and experience to enable him or her to perceive risks and to avoid hazards which electricity can create

3.3
electrically instructed person
person adequately advised or supervised by electrically skilled persons to enable him or her to perceive risks and to avoid hazards which electricity can create

3.4
ordinary person
person who is neither a skilled person nor an instructed person

3.5
string wiring harness
cable assembly that aggregates the output of multiple PV string conductors along a single main conductor

Note 1 to entry: The harness may or may not include fusing on the individual string conductors. The wiring harness typically does not include a disconnect device in line.

4 Compliance with IEC 62548

The design, erection and verification of PV power plants as defined in this document should generally comply with the requirements of IEC 62548 and its references to the IEC 60364 series.

Specific exceptions and variations to the requirements of IEC 62548 called out in this document are permissible due to the restricted access conditions placed on PV power plants.

5 PV array system configuration

5.1 General

This clause discusses PV array earthing, control, layout and mechanical configurations found in PV power plants.

5.2 Earthing configurations

5.2.1 General

Considerations for earthing a PV array are addressed in this clause. The requirements of manufacturers of PV modules and manufacturers of power conversion equipment (PCE) to which the PV array is connected shall be taken into account in determining the allowable or required system earthing arrangements.

5.2.2 Use of un-earthed d.c. circuits

When installed with a residual current monitoring system and/or with isolation resistance detection, PV systems with un-earthed d.c. arrays offer robust earth fault protection. A failure in any cable (positive or negative), causing a short circuit from the cable to an earthed surface results only in a shift of the array voltage reference from a floating state to an earth-referenced state. It does not create a closed circuit for fault current to flow, and therefore does not present a fire hazard. Un-earthed d.c. circuits are also a requirement where simple separation or isolation from an earthed a.c. system is not provided by the inverter or a transformer.

5.2.3 Use of high-ohmic earthed d.c. circuits

High-ohmic earthed systems may be used in plants where operators want to achieve some of the benefits of an un-earthed or floating system while still maintaining an array voltage reference to ground to prevent potential induced degradation (PID). Resistance values are set to limit fault current to a target level (below 300 mA for example) in case of a hard fault occurring on the unreferenced d.c. circuit pole. This significantly reduces the arcing and fire causing currents that can occur with grounded systems, specifically those without supplemental high-sensitive ground fault detection.

5.2.4 Use of functionally earthed d.c. circuits

Protective earthing of any of the conductors of the PV array is not permitted. Earthing of one of the conductors of the PV array for functional reasons is allowed through internal connections inherent in the PCE or other earth fault protective device if designed and qualified for this configuration. Functionally earthed d.c. array based systems are sometimes used to prevent module PID.

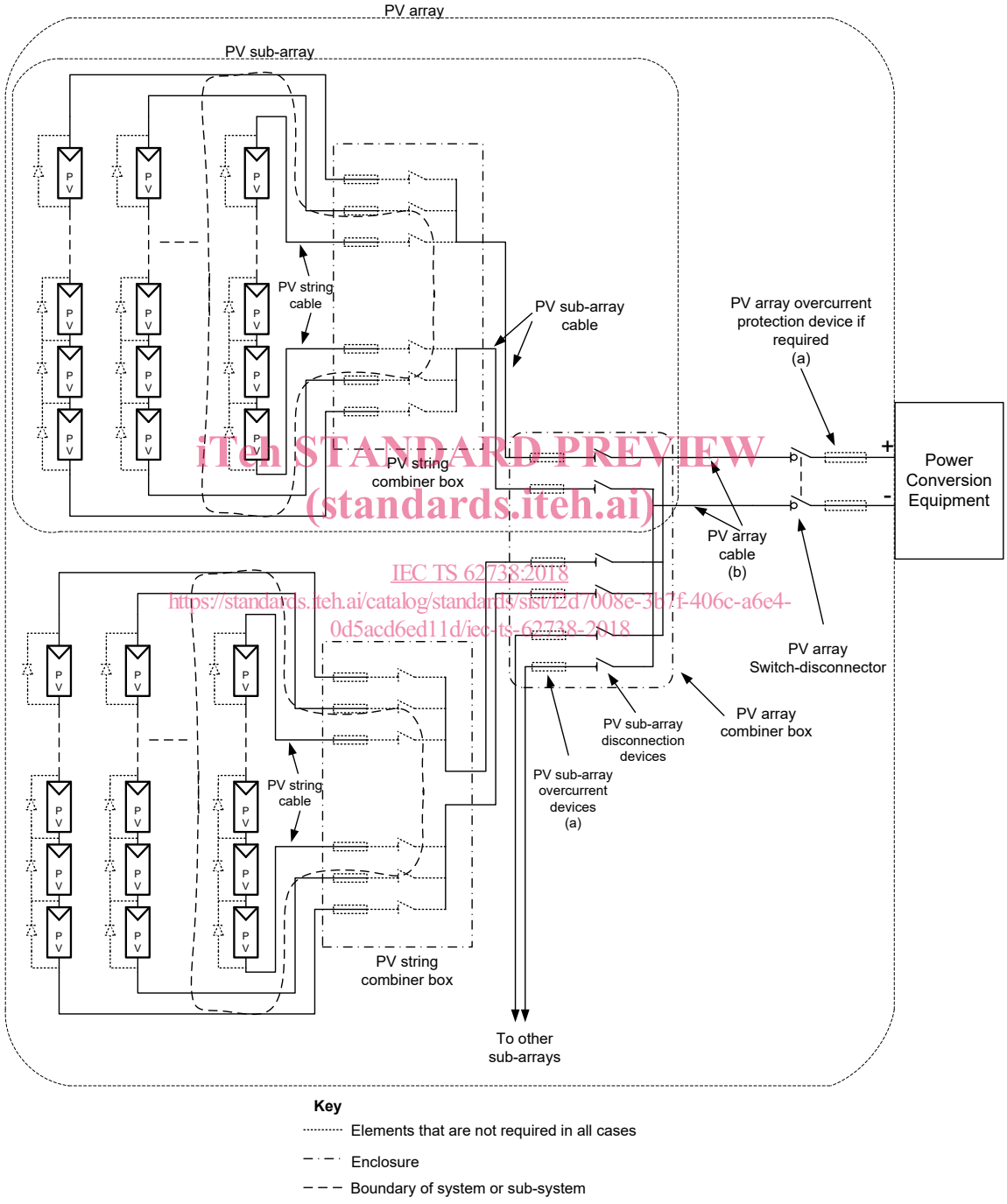
5.3 Array electrical diagrams

5.3.1 General

Figure 1 through Figure 4 show the typical array electrical configurations for PV power plants. Typical power plants employ multiple array-PCE “blocks” resembling the configurations shown in Figure 1 through Figure 3. Power plants may also employ string inverter configurations as shown in Figure 4, or module level micro-inverters.

5.3.2 Multiple sub-array configurations

PV arrays in power plants are most often configured with multiple sub-arrays. The sub-arrays are connected to large central inverters having multiple d.c. inputs, as shown in Figure 2 and Figure 3, or to PCEs with a single d.c. input via a separate PV array combiner box (refer to Figure 1). Overcurrent protection and cable sizing within the various sections of the PV array(s) are dependent on the limiting of any back-fed currents from the PCE and from parallel connected arrays.



SOURCE: IEC 62548

a) Overcurrent protection devices where required see 6.3.

b) In some systems the PV array cable may not exist and all the PV strings or PV sub-arrays may be terminated in a combiner box immediately adjacent to or inside the power conversion equipment.

Figure 1 – PV array diagram – multiple parallel string case with array divided into sub-arrays