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Land usage of photovoltaic (PV) farms – Mathematical models and calculation examples

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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LAND USAGE OF PHOTOVOLTAIC (PV) FARMS – MATHEMATICAL MODELS AND CALCULATION EXAMPLES

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IEC TR 63149, which is a technical report, has been prepared by IEC technical committee 82: Solar photovoltaic energy systems.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
82/1319/DTR	82/1411/RVDTR

Full information on the voting for the approval of this technical report 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- withdrawn,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.

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

IMPORTANT – The 'colour inside' logo on the cover page of this publication 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.

INTRODUCTION

It is very important to calculate the land usage of PV power plants. If the plant is poorly designed, it would result in either a waste of land due to too large an area, or the loss of power generation because of shading between arrays. This TR gives a simple calculation for a quick guideline of the land usage of PV farms. For accurate and optimum land usage design, a more sophisticated numerical computation is encouraged.

The key factor to affect land usage of PV plants is the distance between PV arrays. The calculation of the distance between PV arrays is affected by the following factors:

- Sun-Earth relationship;
- solar declination angle (determining the date of a year);
- solar hour angle (determining the time of a day);
- latitude of the location of PV plant;
- azimuth of PV array;
- tilted angle of PV array;
- flat land or tilted land;
- efficiency of PV modules;
- mounting and tracking arrangements if used (e.g. fixed, single-axis tracking, double-axis tracking);
- the coordinates system (ground horizontal coordinates, equatorial coordinates);
- the ratio of length and width of PV array, and
- the possible maximum mechanical tilted angle of PV array, etc.

Increased land usage comes with power generation. To maximise generation and minimise land usage has many advantages including decreasing cost.

LAND USAGE OF PHOTOVOLTAIC (PV) FARMS – MATHEMATICAL MODELS AND CALCULATION EXAMPLES

1 Scope

This document is aimed at building mathematical models for calculation of the distance between arrays, to farthest avoid shading and reasonably reduce the land usage of PV farms.

In general, there will be longest south-north shading on the day of the winter solstice. The boundary condition to calculate the south-north (S-N) distance between PV arrays used in this document is based on winter solstice. The longest east-west (E-W) shading is on the time when the sun is in the east. The users can change the boundary conditions (date and time) depending on local conditions (latitude, land limitation, facing direction, etc.), the formulas are all the same.

The shading distance calculation is based on date and time boundaries, not based on shading energy losses that may be very complicated. The no-shading distance calculation in this document is only for the distance between PV arrays, not for other surrounding objects, but the formula can also be used to calculate the no-shading distance between the objects and PV arrays. Where shading occurs on the PV array site other calculations are required that are not within the scope of this document. The no-shading distance calculation is based on the northern hemisphere in this document, but all fomulas can also be used for the southern hemisphere.

The no-shading calculation model is different for fixed PV arrays and PV systems with solar trackers. This document derives mathematical models for both fixed PV arrays and solar trackers.

For solar trackers, there are 2 different coordination systems: the Ground Horizontal Coordinates (GHC) and Equatorial Coordinates (EC).

This document provides land usage calculations of PV farms for the following array types:

- Fixed PV array on flat-land and face to the south
- Fixed PV array on flat-land and face to non-south direction
- Fixed PV array on tilted land and face to the south
- Horizontal E-W tracking in Equatorial Coordinates
- Tilted E-W tracking in Equatorial Coordinates
- Pole-Axis tracking in Equatorial Coordinates
- Double tracking in Equatorial Coordinates
- Solar Azimuth tracking in ground horizontal coordinates
- Manual solar altitude tracking in ground horizontal coordinates
- Double tracking in ground horizontal coordinates

In the following clauses, the different coordinates systems are introduced and the land usage calculations for different operational models are provided.

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 TS 62727:2012, *Photovoltaic systems – Specification for solar trackers*