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Calculation procedure to improve the assessment of photovoltaic generation in solar maps

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Abstract

The Zero Energy Building (ZEB) target and the higher affordability of photovoltaic (PV) systems are pushing Governments and large Companies operating in electricity generation and distribution network management to develop tools able to better define the potential productivity of PV systems on a large scale, such as solar maps. However, solar maps mainly consider phenomena related to weather and geometry, with a low level of detail on second order effects. This research aims at the integration of additional technical aspects into solar maps, by means of diagrams able to increase the reliability in the assessment of potential electricity generation. For this purpose, more technical factors are taken into account, such as the variation of PV panel efficiency with cell temperature, the shadow cast by the preceding PV panel array, here including the action of by-pass diodes, and the ratio of active area over the area available for installation.

Keywords: PV generation; solar maps; by-pass diode.

1. Introduction

This paper proposes a calculation procedure that may be used by urban planners and energy managers to assess the potential generation of electricity from PV systems installed on flat roofs. This calculation procedure starts from

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available data of solar radiation and corresponding outdoor air temperature and calculates additional phenomena that can be consistently determined by means of geometry considerations. In particular, given the azimuth and minimum spacing of the PV arrays, this calculation procedure defines the PV module tilt to maximize electricity generation.

Nomenclature

Symbols

A	Area [m²]
C	Multiplier coefficient [-]
d	Length or distance [m]
E	Energy [kWh/(m^2·y)]
G	Solar radiation (yearly) [kWh/(m^2·y)]
h	Solar altitude [°]
IAM	Incidence Angle Modifier [-]
α	Angle [°]
β	Tilt [°]
η	Efficiency [-]
θ	Incidence angle [°]
(τα)	Transmittance-absorptance product [-]

Subscripts

Beam	Pertaining to the beam solar radiation
Diff	Pertaining to the diffuse solar radiation
El	Electric
n	With reference to incidence angle normal to the PV module
Optβ	Referred to the optimum tilt
Pan	Pertaining to the PV panel
PVGen	Pertaining to PV electricity generation
R	Ratio
Sh	Pertaining to the shadow
Sky	Pertaining to the sky
Sp	Referred to spacing between PV arrays
Surf	Referred to the module surface
Unsh	Referred to the unshaded condition
View	Pertaining to the optical view
θ	With reference to actual incidence angle with respect to the PV module

The assessment of the optimum tilt angle aimed at the maximization of solar energy exploitation is still subject of interest, since several authors still actively work on this topic. For instance, Yadav and Chandel [1], Duffie and Beckman [2], Lunde [3], Gunerhan and Hepbasli [4] and other authors suggest complex algorithms (Genetic Algorithms, Simulated Annealing techniques, Particle Swarm Optimization or Artificial Neural Networks,…) for this purpose. However, even if very complex algorithms are used to assess the best tilt angle from a theoretical point of view, just a very small enhancement is given over the near tilt angle values. Moreover, phenomena consequent to other technical factors imply higher effects on actual electricity generation.

This paper focuses specifically on PV arrays and takes into account phenomena such as: (i) the effect of transmission and absorption of sunrays through the glass cover of the PV modules (to achieve higher accuracy in the calculation of solar radiation at low sun altitudes), (ii) the decay in the performance consequent to the increase of cell temperature and (iii) the operation of bypass diodes. In fact, this paper focuses on PV modules installed on parallel arrays and considers shaded PV modules. The design procedure here proposed takes advantage of a large set of parametric simulations to provide the best tilt of PV arrays according with the given constraints, i.e. PV array azimuth and minimum spacing between the PV arrays. In particular, the PV arrays spacing may vary based on PV