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Anti-reflective coated glass and its impact on bifacial modules' temperature in desert locations

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Abstract

Without any doubt does anti-reflective coating (ARC) on solar glass help to boost the annual module performance in the range of 3 to 4% for monofacial modules with Sunarc AR coated glass under moderate climate conditions [1] which certainly differ from desert climates. In this work three bifacial and one monofacial photovoltaic modules, with different glass coatings, are installed in a desert region as the Atacama Desert in Chile, with the optimum tilt for the location and same surrounding conditions. From the results it is observed that the glass/glass bifacial modules with ARC on both glass sheets can achieve a mean performance ratio (PR) of up to 5% higher than a module without coating in any of both glasses. It is also observed that the thermal dependence of PR for modules with ARC on both glasses and its operative temperature are larger compared to modules without coated glass.

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Keywords: Photovoltaic module; anti-reflective coating; outdoor measurements; module temperature; performance ratio.

1. Introduction

In a photovoltaic (PV) system, the solar irradiance doses and the module operating temperature are the most important factors for energy yield. For bifacial PV systems, albedo is another important factor [2-4]. For high albedo higher energy yield is expected. The term albedo (Latin for white) is defined as the ratio of the reflected light by a surface compared to that received by it. In [5], J. A. Coakley constructed a global map of the diurnally averaged surface albedo for winter and summer solstice conditions, under cloud-free skies. It is clear that desert locations have an albedo in the range of 25 to 40%, and it is estimated to be seasonal invariant. These computations match with the visual experience and measurements performed by the authors in the Atacama Desert in Chile. The authors measured a modal albedo of approximately 25% in winter, for a 30° tilted installation using a CMA11 albedometer of spectral range (50% points) between 285 to 2800 nm.

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Nomenclature

ρ	ribbon conductivity (Ω mm^2 m^{-1})
b	cell spacing (m)
E_{DC}	direct current energy (W h)
G	global in-plane irradiance (W m^{-2})
G_b	net global in-plane irradiance (W m^{-2})
G_{STC}	global in-plane irradiance at standard test conditions (1000 W m^{-2})
H	global in-plane irradiation (W h m^{-2})
H_b	net global in-plane irradiation (W h m^{-2})
I	electrical current (A)
I_{MPP}/G_b	ratio between output current at maximum power point and net global in-plane irradiance (mA W^{-1} m^2)
I_{SC}/G	ratio between short circuit current and global in-plane irradiance (mA W^{-1} m2)
I_{SC}/G_b	ratio between short circuit current and net global in-plane irradiance (mA W^{-1} m^2)
L	cell length (m)
n_{busbar}	amount of busbar per cell
P	power (W)
P_{norm}	normalized power
t	ribbon thickness (mm)
T_a	ambient temperature (K)
T_m	module temperature (K)
V	voltage (V)
w	ribbon width (mm)
Y_A	Module energy yield (W h W$_P$$^{-1}$)
Y_R	Reference energy yield

1.1. Effective albedo

The ground albedo spectrum depends on the land material composition. Although the spectral-integrated value falls in the same range for several different materials, diverse ground composition not necessarily affect in the same way to the PV system under evaluation. Therefore the spectral response for different albedos depends on ground and solar cell materials [6]. M.P. Brennan et al. in [7] proposed an index called effective albedo, for different PV cell technologies and several surface reflectivities. The authors show that for desert areas the infrared (IR) wavelengths have an important contribution to the albedo spectrum, specifically with sandstone, which is mainly found in desert places as the Atacama Desert, Chile. The effective albedo for monocrystalline silicon (c-Si or mono-Si) is estimated to be approx. 0.63, which is close to the index estimated for polycrystalline silicon (p-Si, mc-Si or poly-Si). Fig. 1 plots (a) the reflectance for different ground materials as sandstone, concrete construction and green grass, and (b) the evaluated spectral albedo response of each material under an estimated solar spectrum for the Atacama Desert.