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Near-field partial shading on rear side of bifacial modules

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Abstract

It is well-known that near-field shading reduces the power output of a PV system drastically, especially when inhomogeneous shading creates a large current mismatch between series-connected solar cells. Typically, the front side irradiance is very uniform and near-field shading is avoided. In contrast, for bifacial panels, the rear side contribution is effected much more, both by the inhomogeneity of the rear irradiance and by (unavoidable) near-field objects, including the mounting system. In this paper, outdoor and indoor irradiance and IV measurements are combined with LT-spice modelling to show the limited effect of rear side shading on the performance. We will show that the actual rear side irradiance for an actual, tilted, equator-facing system, with cell-size resolution, varies between 47 and 83 W/m^2. Varying distance and position of near-field objects, the drop in current is in good quantitative agreement with the measured reductions in rear side irradiance. Increasing the reflectance of the near-field object strongly reduces the effective shading, the measured loss in rear irradiance and the current drop in the IV curve.

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1. Introduction

Bifacial PV panels convert to electricity both the irradiance on the front, dominated by direct light, and the irradiance on the rear, typically diffuse light originating from the sky and scattered light from the surroundings and underground [1]. The front side irradiance is typically homogeneous, when transmission losses (dust, snow, etc.) are absent. In contrast, the rear side irradiance is often more inhomogeneous. For example, the contribution by ground-reflection is effected by the self-shade and also the view factor angles are different for the top and bottom part of the

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panels [2]. Furthermore, to prevent shading of direct light, PV installations are designed to have all structural and functional parts at the rear side. These items, like cables and racks, will influence the irradiance on the rear.

2. Experimental details

The rear side irradiance per cell was measured using solar cells, laminated between two transparent foils, including an absorbing layer behind the solar cell, exactly blocking the rear of the solar cell. This set-up made these measurement cells monofacial, but allowed the light incident on the inter-cell area of the bifacial module of interest to be transmitted.

Indoor IV-curves were recorded with 1000 W/m^2 front side irradiance by a steady-state solar simulator. Diffuse rear irradiance was created by placing scattering white panels at 1 m distance behind the module. A black, white or aluminium-coloured object of 10 cm wide and 25 cm high was placed at a variable distance between the module and the scattering panels and positioned to shade two cells or four cells from the same string. The rear side irradiance per cell was measured under the same conditions. Fig. 0 shows a sketch of the measurement set-up.

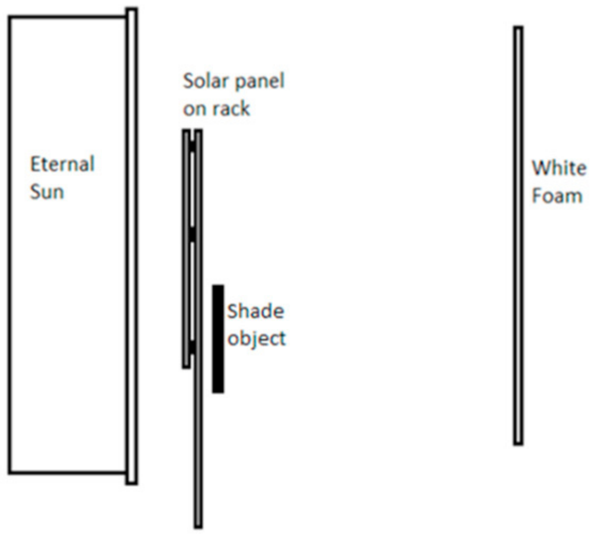

Fig. 0. Sketch of the measurement set-up. The distance between the steady-state solar simulator and the module ensures 1000 W/m^2 irradiance. The shade object can be placed between 1 and 30 cm behind the rear of the bifacial module. The white foam is placed about 1 metre behind the module.

The effect of inhomogeneous irradiance was simulated with LT-spice by serial connection of sixty equivalent circuit, using the one diode model. It was assumed that the light-generated current scaled linearly with the total irradiance on the cell. The simulated module was divided in three strings with bypass diodes.

3. Results

3.1. Outdoor irradiance measurements with near-field shade

Fig. 1 shows the distribution of the measured rear irradiance per cell for an equator-facing bifacial module on a rooftop rack. The cell with the lowest rear irradiance, 47 W/m^2 has only 55% of the highest irradiance, 83 W/m^2. However, due to the additional, homogeneous front irradiance of 845 W/m^2 the total irradiance on the module is only reduced by 2.2% compared to a homogeneous front + rear irradiance of 845 + 83 W/m^2. Note that the inhomogeneity is partly due to inhomogeneities in the albedo light and partly due to objects near the rear side, in particular the lower irradiance at the fourth and fifth row of cells, counted from the top.

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