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Bifacial photovoltaic systems energy yield modelling

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Abstract

A bifacial photovoltaic model was developed not only to calculate the power and energy yield for bifacial modules for various setup and installation conditions but also to identify suitable bifacial module applications and markets. The bifacial model shows that the energy yield for bifacial modules is very much location dependent and hugely influenced by how they are setup and installed. There is a need to have the modules mounted at a certain elevation above the ground to gain maximum energy yield. It is also important to ensure there is no blockage for the direct sun to shine on the area directly beneath the module. For locations at low latitude, a higher elevation is required. For locations at high latitude, the probability of the direct sunlight reaching the ground directly under the module is higher. Therefore, less module mounting elevation is required. However, there is a saturation point for energy yield improvement with increased module mounting height. In addition to the mounting height, a sufficient length of clearance path in front of the module array should be considered. The model also shows that the ground reflectance is one of the key parameters for bifacial module performance. The model indicates that >10% of energy yield gain with 20% background reflectance from REC bifacial multi-crystalline silicon solar module array with a bifaciality of 0.6 is achievable in Konstanz, Germany. This correlates well with the measured field energy yield data of the bifacial prototype modules.

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Keywords: Energy yield; Bifacial solar modules

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1. Introduction

In recent years, the bifacial solar module has gained much attention [1]. However, there is currently no commercially available software to model the performance of a bifacial photovoltaic system such as PVSYST photovoltaic software [2]. Modelling the field performance of bifacial modules presents a number of difficulties that are not present for monofacial modules. The bifacial system modelling is significantly more complex than the monofacial system modelling due to the need to estimate the rear illumination of the module, which depends on the percentage of diffused radiation, the sun elevation, the background reflectance, the height of the module above the ground and the module tilt angle. In addition, the field performance of bifacial modules is highly dependent on the location and system design. In this paper the development of an empirical model for the field performance of a bifacial photovoltaic module is discussed. The model attempts to overcome a number of challenges in modelling the rear side illumination for different module heights, module tilts, ground albedos, diffuse radiation components (primarily due to atmospheric effects) and solar positions.

2. Simulation process flow

The simulation process flow for developing a bifacial photovoltaic model in this work is shown in Figure 1. The inputs to the simulation flow chart are module performance details, system installation details and the global horizontal irradiance (GHI) data.

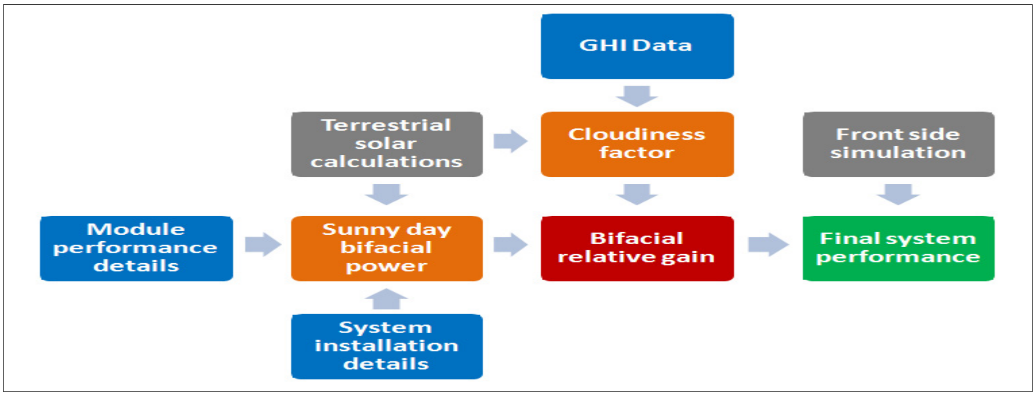

Fig. 1. The bifacial modelling process flow. The GHI data, the module performance details and the system installation details are the inputs. The terrestrial solar calculation and the front side power simulation are used in the primary calculation. The sunny day bifacial power and the cloudiness factor are used in the secondary calculation. The bifacial relative gain is calculated in the tertiary calculation and the final system performance can be simulated.

The sunny day bifacial power is calculated using solar geometry to determine the front and rear power output using terrestrial solar radiation based on the sun position and system location [3]. The model of diffused radiation and ground reflected radiation is based on the work published by G. M. Masters [4]. For the sunny day calculation, the cloudiness factor is not considered. The cloudiness factor is the GHI data at a given time as a percentage of the ideal GHI available on a clear day at the relevant point in time, which is calculated in the terrestrial solar calculations. For this work, the additional power from the rear side of the bifacial module is added to the power produced from the front side to provide the total module power. By assuming this, the series resistance effects and other potential effects cannot be considered.

There are three major parameters that are used in calculating the rear side illumination: (1) the diffused radiation incident at the rear of the module, (2) the diffuse and direct beam component incident on a horizontal plane, and (3) the length of the shadow cast behind the module, considering only the distance directly behind the module. In addition, the rear side illumination has a complex dependence on the height of the module above the ground, the tilt