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Enhancing optical performance of bifacial PV modules

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Abstract

In contrast to monofacial cells, bifacial solar cells are able to harvest sunlight from both front and rear side. Bifacial cells can be encapsulated into different module structures: glass/glass, glass/transparent backsheet or glass/backsheet. Under real-world conditions, a glass/glass or glass/transparent backsheet bifacial PV module produces higher energy yield due to the absorption of the light scattered from the ground and surroundings. However, due to the glass/glass or glass/transparent backsheet design, the module is associated with two additional optical loss mechanisms: transmittance loss of infrared light passing through bifacial cell and transmittance loss on module inactive area (cell-gap area). In this paper, we demonstrate several novel approaches to reduce the transmittance losses and optimize the front side power of the bifacial PV module under standard test conditions (STC). To reduce the bifacial cell transmittance loss at near-infrared wavelengths, we apply an infrared (IR) reflective coating on the rear glass of the glass/glass bifacial modules. Using this approach, a current gain of about 1% is achieved. Alternatively, the bifacial cell transmittance loss can be minimized using a textured module rear cover. Demonstration of this approach on a textured transparent backsheet shows a current gain of about 0.3%. Furthermore, to reduce the cell-gap transmittance loss, we use a white reflective coating on the rear glass. Through in-depth characterization, we optimize the white reflective coating and the module design. The bifacial module with optimized white reflective coating generates about 3% more current, as compared to a standard glass/glass bifacial module without any coating. Incorporating both IR reflective and white reflective coatings, a current gain of about 4% is observed.

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Keywords: bifacial solar cells; glass/glass bifacial module; cell transmittance loss; cell-gap loss; optical gain; IR reflective coating; white reflective coating

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Nomenclature

λ	wavelength
$\phi_{AM1.5G}$	photon flux of AM1.5G standard spectrum
EQE	external quantum efficiency
$EQE_{mod,front}$	external quantum efficiency of module, measured from front side
$EQE_{mod,rear}$	external quantum efficiency of module, measured from rear side
IR	infrared
J_{sc}	short-circuit current density
$J_{sc,mod,IR}$	short-circuit current density of module with IR-reflective coating
$J_{sc,mod,ref}$	short-circuit current density of reference module (no coating)
$J_{sc,mod,front}$	short-circuit current density of module, calculated using front side EQE
LCOE	levelized cost of electricity/energy
q	charge constant
$R_{IR-coating}$	reflectance of IR reflective coating
STC	standard test conditions
T_{mod}	transmittance of bifacial cell encapsulated in glass/glass module

1. Introduction

A study of the levelized cost of energy (LCOE) of PV in Singapore reveals that the grid parity of solar electricity can be achieved either with aggressive price reduction or with innovative technology strategy [1]. For instance, focusing on the technology innovation, the study suggests that increased module sustainability, decreased module degradation rate per annum, as well as increased module energy yield are some key points that will further reduce the LCOE of PV in Singapore [1]. Bifacial technology is a very promising concept to achieve high module energy yield. Bifacial solar cell absorbs light from its front and rear side [2, 3]. Under bifacial illumination, more current/power will be generated per unit area of solar module. Furthermore, due to the reduced bow in bifacial cells, less cell breakage occurs during the modularization process [4, 5]. The latest International Technology Roadmap for Photovoltaic (ITRPV 2016) [6] has forecasted that bifacial technology will increase its global market share from approximately 5% in year 2016 to about 30% within the next ten years.

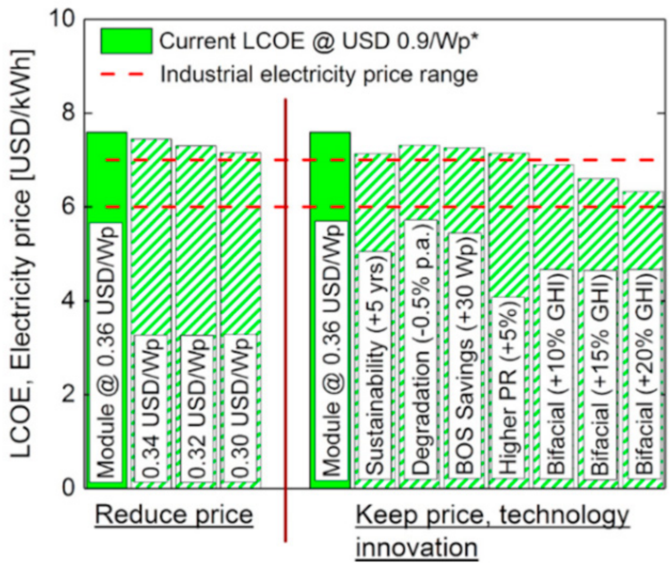

Fig. 1. Levelized cost of energy (LCOE) study of PV in Singapore [1].