Proof of concept for an integrated module-tracker design with improved bifacial energy yield

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Bifacial system optimization approaches

Bifacial photovoltaic systems are expected to become mainstream technology at a 5 years' time horizon, further reducing the Levelized Cost of Energy (LCOE) of PV. More and more stakeholders are already showing strong interest in new system optimization schemes taking advantages of the latest bifacial module design benefits.

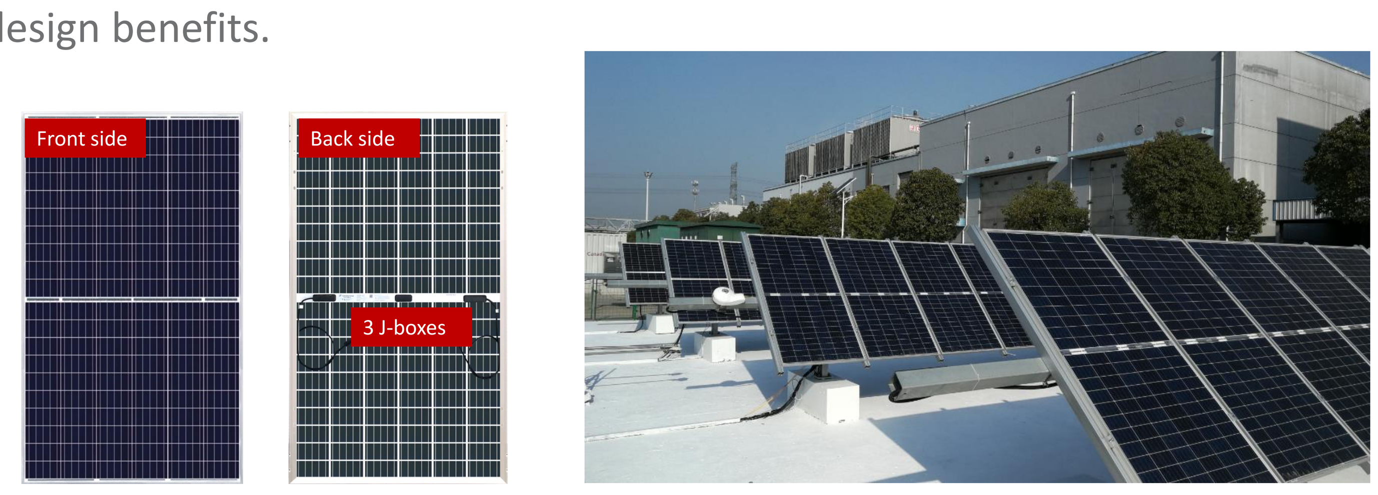


Figure 1. Best system design with lower LCOE

Bifacial module with single axis tracker system is one of the best system design solutions in Figure 1. Most of module manufacturers have promoted back side glass with white grid design in order to increase module power on front side. However, how to reduce backside shading and irradiance non-uniformity is still an important topic. In this paper, we analyzed through ray-tracing performance modeling two optimization schemes for improving bifacial module rear side shading loss, irradiance distribution and non-uniformity, for the case of one portrait single-axis tracker system.

Modeling for module transparent gap design

Canadian Solar has developed its own ray-tracing model based on professional third party software with Rhinoceros +DIVA in Figure 2. It will provide a more accurate simulation approach for irradiance distribution on back side with specified system information and detailed mounting structure. Key parameters including module layout and rail structure sensitivity analysis can be analyzed through the tool in Figure 3.

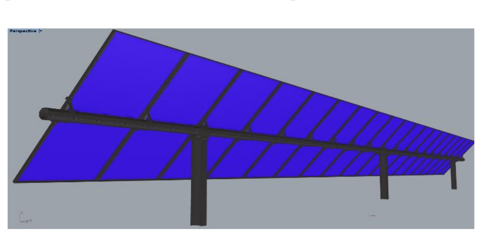


Figure 2. Rhino 3D solid model

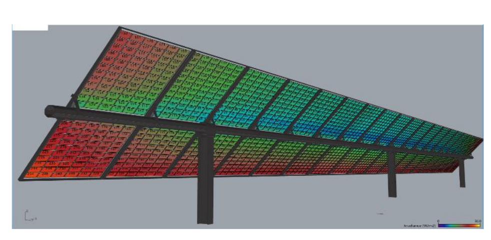
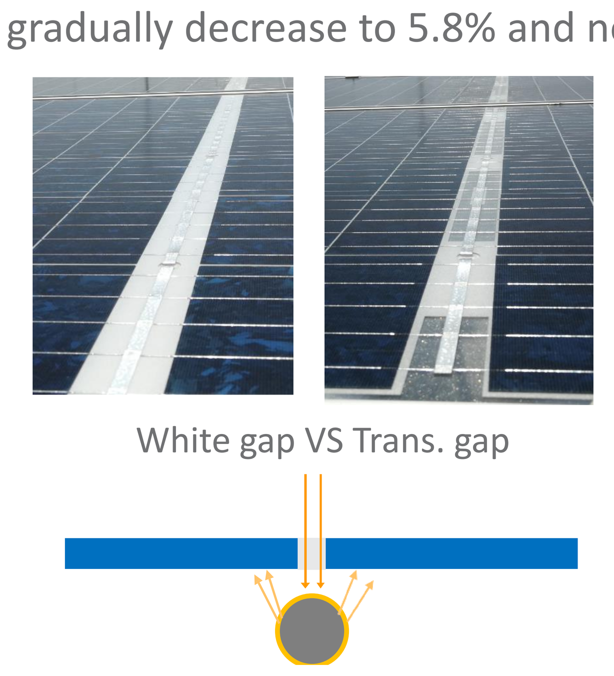


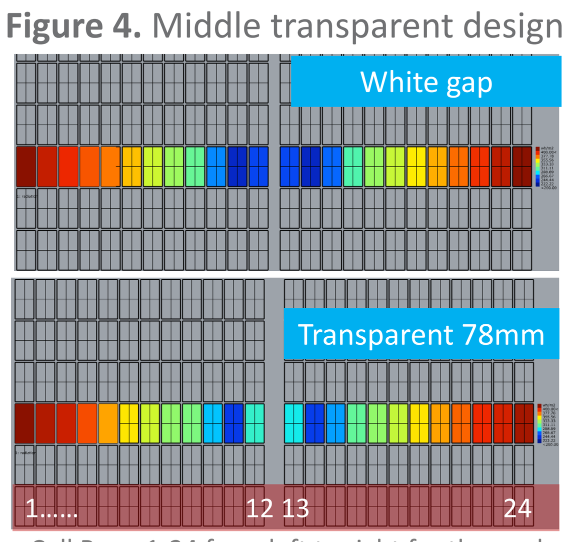
Figure3. DIVA ray-tracing model

One approach including in fine-tuning the transparent gap existing in the module layout has been studied. For a typical single axis tracker with one portrait module installation, torque tube leads to shading loss and irradiance non-uniformity on back side, which leads to more energy yield loss. For bifacial module with half-cut technology, three J-boxes locate in the middle of a module. Current design is to put white painting on back glass. Our proposal design is to make the gap between J-boxes transparent in Figure 4. The light will go through transparent gap and reflect on back side by torque tube. A simple schematic picture and 3D ray-tracing model can be shown in Figure 4 and 5. Basic system information is listed in Table 1. 38mm transparent gap can bring obvious improvements by 1.4% shading factor and 1.2% non-uniformity on back side separately. As transparent gap increases, shading factor will gradually decrease to 5.8% and non-uniformity will reach 25.4%.



White gap VS Trans. gap

Figure 4. Middle transparent design

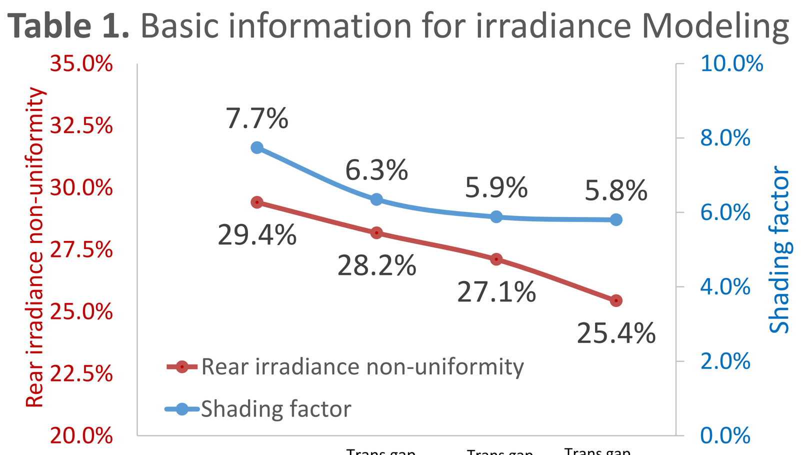


Cell Row: 1-24 from left to right for the analysis

Figure 5. Simplified back side irradiance distribution

Item	Description
Location	Los_Angeles, US A typical clear sky day
Module Type	Canadian Solar bifacial module (3U-PB-FG)
System design	1-axis tracker； GCR :0.33； PV Array :5*13(1P); Ground albedo:0.8
Key dimension	Array height：1.5m; The distance between tube to back glass is 60mm
Transparent gap distance	38mm，58mm，78mm

Table 1. Basic information for irradiance Modeling



Shading factor=1-[G(back with tube)/G(back W/O tube)-1]

Rear irradiance non-uniformity= [Max(Gback)-Min(Gback)]/[Max(Gback)+Min(Gback)]

Figure 6. Back side irradiance non-uniformity and shading factor results based on different gap design

Modeling for various rail height

The second approach to optimize backside shading and irradiance distribution is to look at various distance between the rear module glass and torque tube. The distance is decided by tracker rail height. 3D ray-tracing model with different distance and irradiance distribution has been showed in Figure 7. As the distance increases from 50mm to 90mm, the shading factor and non-uniformity on back side will decrease by 2.0% and 3.9% separately in Figure 8.

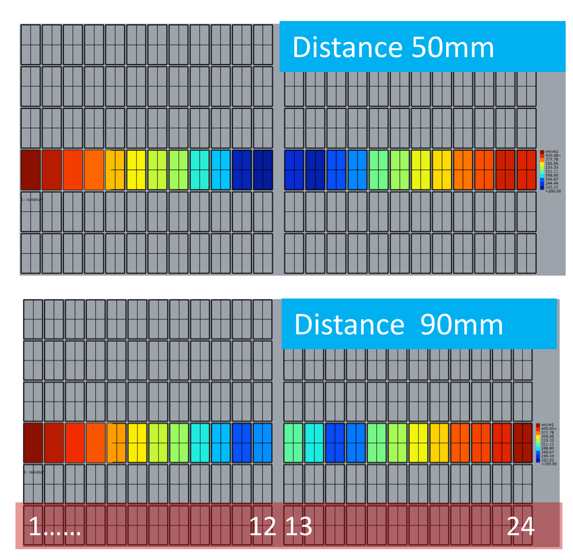


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Figure 7. Back side irradiance distribution map

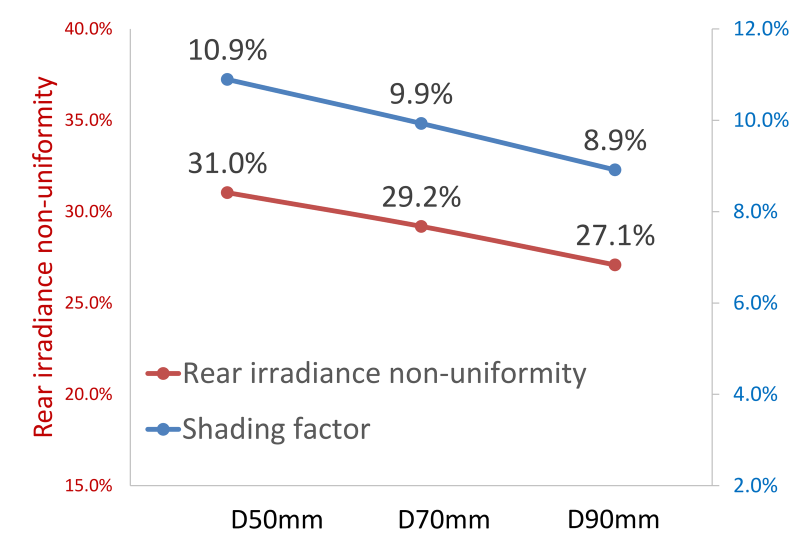


Figure 8. Back side irradiance distribution comparison between no tube and tube.

Experimental Validation

Field test was also implemented for several months in an attempt to verify the simulation results. On-site experiment with 38mm transparent gap and 80mm clearance between back glass and torque tube has been showed in Figure 9. Test results showed averagely 0.3% bifacial gain benefits from proposed optimized design.

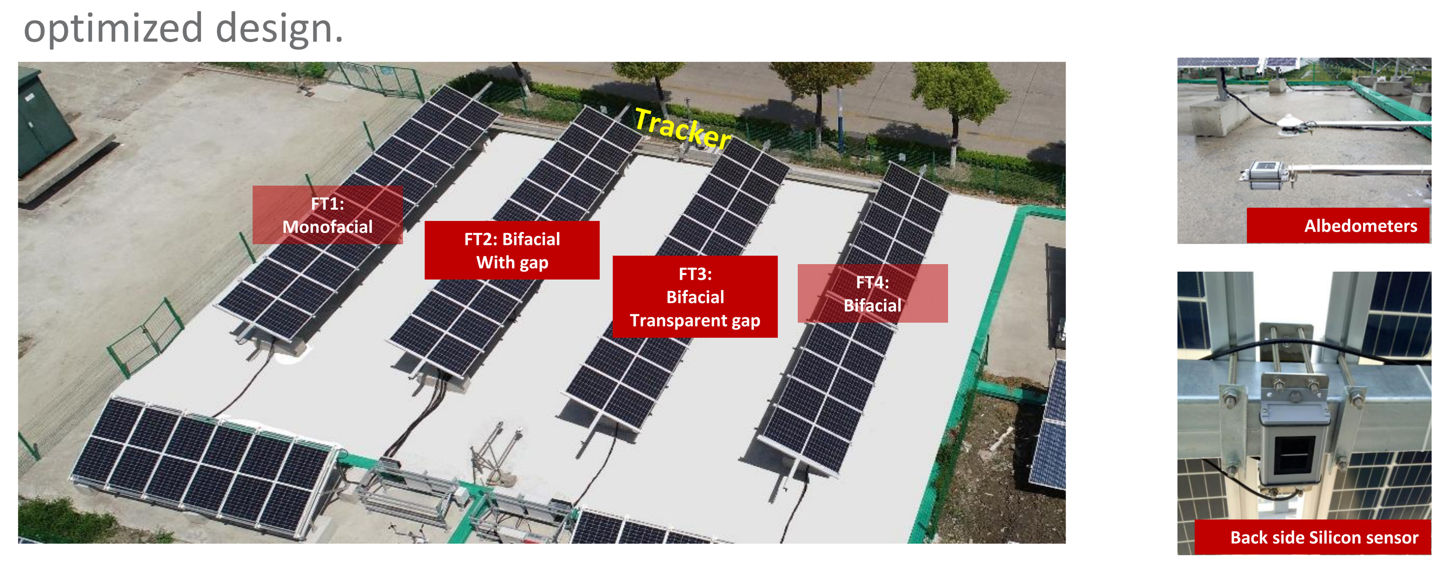


Figure 9. On-site energy yield test photos

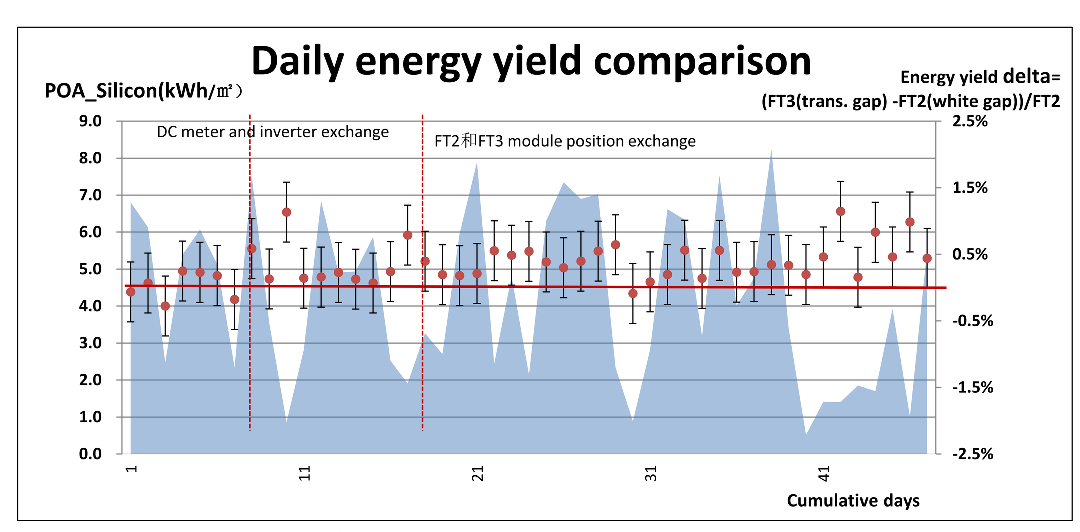
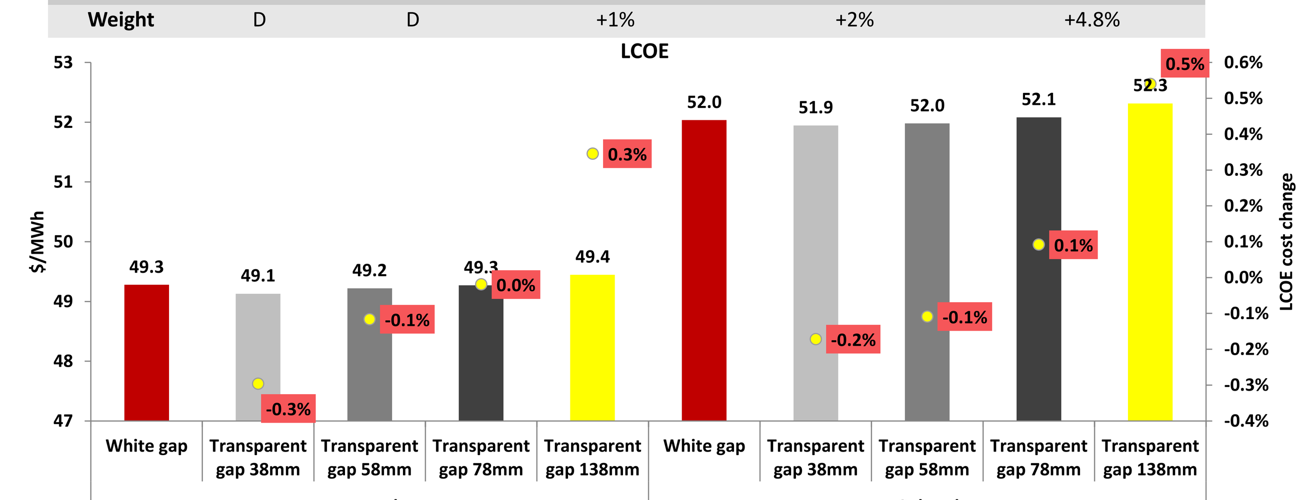


Figure 10 . Energy yield test results

LCOE evaluation for optimization design

LCOE evaluation was taken based on two typical cases in US and China. Key impact factors including energy yield gain, cost increase, module dimension and weight have been considered into LCOE calculation. The result showed case 2 with 38mm transparent gap can bring the lowest LCOE.

	Baseline Case1 White gap	Case2 Transparent 38mm	Case3 Transparent 58mm	Case4 Transparent 78mm	Case5 Transparent 138mm
Energy Yield	A	+0.3%	+0.4%	+0.5%	+07%
Cost	B	B	+0.4%	+0.8%	+1.7%
Dimension	C	C	C+20mm	C+40mm	C+100mm
Weight	D	D	+1%	+2%	+4.8%



Conclusions

Two effective approaches to improve bifacial gain are reasonable module transparent gap and rail height design. ray-tracing model has been proved well predict bifacial benefits with experimental validation. Best LCOE can be figured out through accurate simulation and detailed system cost information based on specified projects.

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