Analysis of bifacial PV systems in the Middle East

Bifacial | PV systems incorporating bifacial modules require careful design and integration to maximise the additional yield they offer. Drawing on extensive field studies, researchers from LONGi Solar describe the optimum design of bifacial systems in the desert conditions of the Middle East, to which bifacial technology is especially well suited

To meet the demand of reducing the levelised cost of energy (LCOE) of PV power plants, the evolution of solar cells and modules is moving towards higher efficiencies. High-efficiency solar cells, abbreviated as PERX (i.e. PERC, PERT and PERL), HIT (heterojunction with intrinsic thin layer) and IBC (interdigitated back contact), are becoming more and more sophisticated under the impetus of drastically increasing demand. Such solar cells have excellent rear passivation so that the aluminum layer at the rear side of the BSF cell can be removed. At this point, the rear of the cell can absorb incident light and form an equivalent cell parallel to the front. After encapsulation, 60/72 bifacial cells become a bifacial module [1].

Due to the higher yield they offer, high-efficiency bifacial modules are gaining more popularity and becoming a new favourite in the PV industry. Although many PV industry insiders believe that 2018 will witness the beginning of the era of bifacial modules in the Middle East area, they still wonder how bifacial modules work, what extra yield bifacial modules will result in and how to use bifacial modules properly. In this paper, we explore the key questions relating to bifacial modules and systems in the Middle East.

Fundamental and extra yield of bifacial modules

As is shown in Figure 1, since the rear side is transparent, the bifacial module can absorb not only the incident light at the front side, but also light at the rear, which is generally composed of diffusive light from the sky, reflective light from the ground and sometimes beams that can arrive at the rear in the summer evening. This indicates that the bifacial modules receive and then absorb more light. Therefore the features of bifacial modules are:

1) Higher current
2) Higher power
3) Almost the same voltage,

Which should be remembered for designation.

To evaluate the extra yield of bifacial modules (versus conventional poly-Si modules), one should take into consideration the following two aspects. One is the improvement from poly-Si to PERX, which is composed by the better spectral response and lower power loss at high temperature. As a result, PERX modules generally have 3% more yield than conventional poly-Si modules, which is currently unable to be simulated by PVsyst. The other is the extra yield stemming from the incident light at the rear side, which can be approximately simulated by PVsyst [2-7].

For a typical utility-scale plant in Middle East, a common system choice is a north-south horizontal tracker. Here, by employing PVsyst, the extra yield of bifacial modules is estimated for Dubai, UAE, with poly-Si as a reference, as is shown in Figures 2a-2c. The capacity of the PV system is 25.6kW and 25.2kW for a conventional poly-Si system and a bifacial system, respectively. The modules are 320W for poly-Si and 360W for bifacial, with a bifaciality of 75%. The ground used in the simulation is yellow sand, common in the Dubai area. The DC/AC ratio is set to about the optimal value for Dubai. The height of the module in the system is defined as the distance between the ground and the tracker axis. The ground coverage ratio is defined as the module width/system pitch.

It is found that the poly-Si fixed-tilt system could yield 1,761.53kWh/kWp per year in Dubai, according to databases provided by MeteoNorm Station. The poly modules in the tracker system could produce more energy due to the sun-tracking effect; the yearly energy yield gain could be about 117.6%, as is shown in Figure 2d. It is found that the energy yield gain reaches the peak point in June, and then falls back in the winter. This is reasonable because the incidence angle modifier loss of the horizontal tracker in winter is much more than that in summer. However if bifacial modules are used in the tracking system, the energy yield performance in the winter would be improved. It is shown that the bifacial tracking system would have

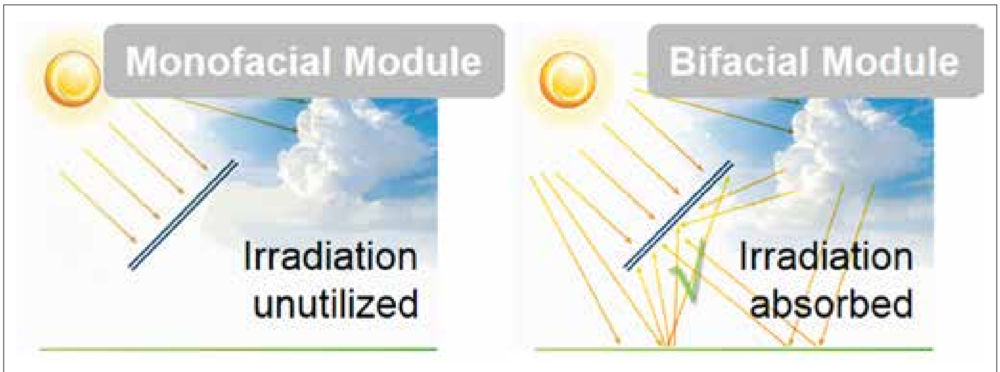

Figure 1. Working mechanism of bifacial modules

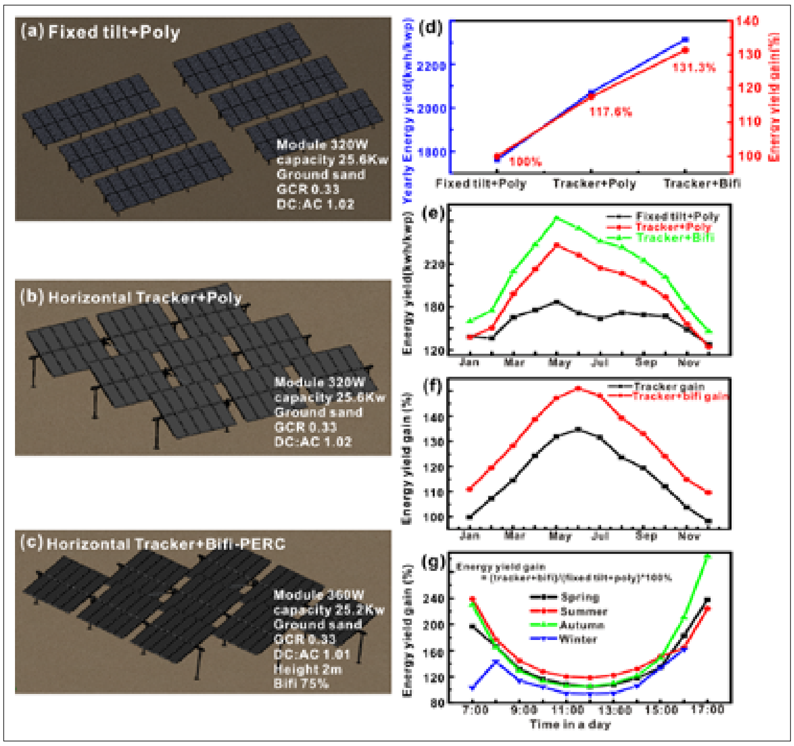

Figure 2. The energy yield of a poly-Si fixed-tilt system, a poly-Si horizontal tracker system and a bifacial-horizontal tracker system, and the energy yield gain of different systems at different times compared to the poly fixed-tilt system

a yearly energy gain of about 131.3% compared to the poly fixed-tilt system. It is about 11.6% higher than the poly-tracking system, but the cost could be just only a little higher.

Figure 2e shows the energy yield of different systems in different months. It seems that the highest energy yield appears in May. However Figure 2f shows that the highest energy yield gain of the tracking system appears in June, little different from the energy yield data. The bifacial tracking system energy yield gain differs from different months, but the bifacial module gain is very stable. Figure 2g shows the energy yield gain of the bifacial system in a day, this is very important for the inverter capacity design. It is obviously that the energy yield gain of the bifacial-tracking system mainly came in the morning and evening; irradiation at this time is not very high. The highest energy yield gain could reach 304% in the autumn evening. The energy yield gain from 11:00 to 13:00 should be paid more attention; the highest irradiation in a day often happens at this time and output often reaches the inverter capacity limit at this time. It is less than 100% in winter from 11:00 to 13:00; in autumn and spring, it is between 106% and 110%; in the summer, it is the highest, appearing from 120% to 122%.

Therefore, a preliminary conclusion is that on trackers, the bifacial modules can produce 14.6% (11.6% from more light absorbed at the rear and 3% from the benefit of the PERX technology) more yield than poly-Si modules with the bifacial gain varying across the seasons in one year and according to the time of day.

How to design bifacial systems with better yield

Since the light absorbed by the rear side is one important part for bifacial modules, more factors will have an influence on the output of bifacial modules than conventional poly-Si module, which means more attention should be paid to the design of bifacial systems, on both the DC and AC sides.

DC design

In our research, the extra yield ascribed to the incident light at the rear can be strongly associated to the albedo of the ground, the latitude of the project location, the diffusive light ratio in the plant, the tilt of the module, the ground coverage ratio (GCR) and the rack height. For a typical scenario in the Middle East, the ground is in general covered by yellow sand, which has an albedo of 30-40%. The latitude of the project location and the diffusive light ratio in the plant are fixed for a given area. Therefore, the design of a tracking system should pay special attention to the GCR and the height.

Figure 3 mainly shows the effect of the module height and GCR on the system output. In Figure 3b, the module height in the bifacial-tracking system indeed has an influence on the energy yield. This is because the tilt angle of the module in the tracking system varies with time; especially in the morning, the scattering light proportion in the sunlight reaches the highest so the tilt angle is the largest to catch the diffuse light. This also means the energy yield gain in morning could reach more than 300%. So increasing the height of the tracking system can increase energy yield gain, but it would have a higher system cost. Therefore, there should be a tradeoff between yield and cost.

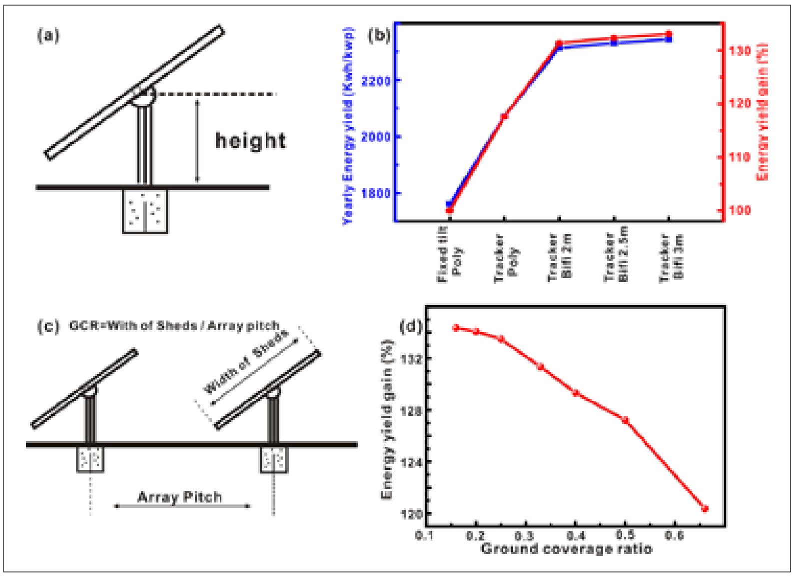

Figure 3. The energy yield gain of bifacial-tracking system varies with the module height and the ground coverage ratio

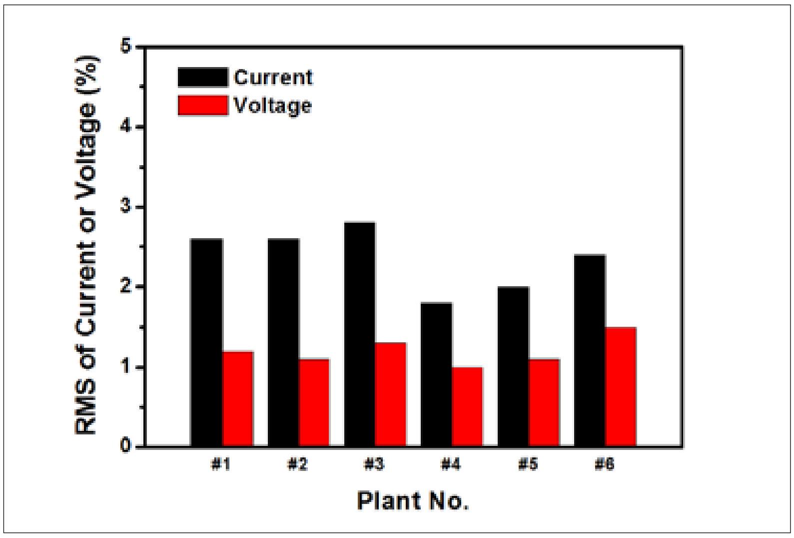

Figure 4. RMS of current of voltage in the plants

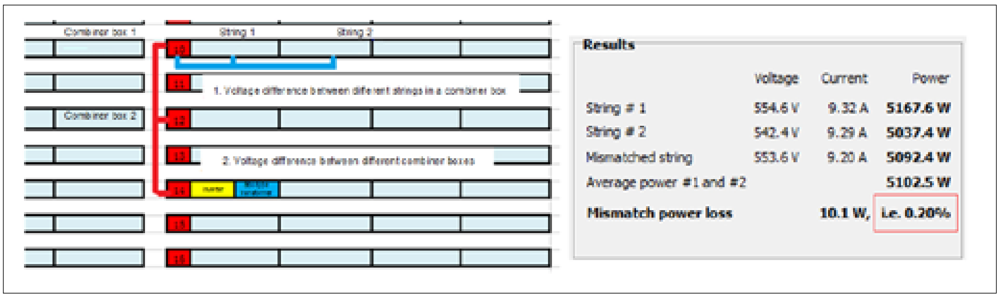

Figure 5. Mismatch loss caused by the different wire lengths

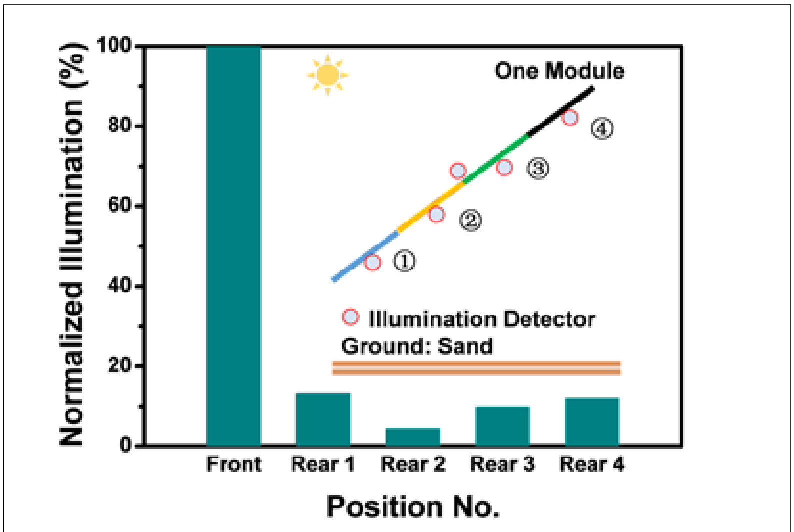

Figure 6. Measured irradiation at different heights of the rear side. The values were measured at the same moment

Figure 3d shows that the energy yield gain of the bifacial-tracking system increases as the GCR decreases. It is evident that decreasing the GCR could increase the ground area available to scatter light, which would increase the diffuse light on the backside of the module. It can be seen that the energy yield gain increases almost linearly from GCR 0.5 to 0.25; it increases very slowly from GCR 0.25 to 0.1, suggesting that the increase in scattered light from decreased GCR at this range results in only a small portion reaching the backside of the module. However, the reduction of GCR may increase the land cost, the wire cost and the power loss on wire. Therefore, a good design of bifacial systems should balance the cost related to GCR and the yield. In the Middle East, the land cost is generally very low, so it is recommend a smaller GCR be adopted for a better investment return rate.

Design of AC side

When the rear side is taken into consideration, a big challenge is the heavier mismatch among bifacial modules and strings, which is one of the most important factors for AC side design. The possible causes of mismatch are as follows:

1) Inconsistency of modules. Through the tests on some PV modules shown in Figure 4, it is found that the current RMS of common PV modules in the first year is 2%, and the voltage RMS is 1-1.5%.

Electrical performance inconsistency can be further aggravated by non-uniform degradation of PV modules over their entire lifetime. According to the industry consensus, the degradation of a bifacial module is 2% in the first year, and 0.5% per year for the following years. However, the degradation of each PV module is inconsistent, which increases the mismatch loss of the PV string.

2) As is shown in Figure 5, since the cable length and thus ohmic loss are different for each string, the voltage of PV strings is different. Generally, the voltage mismatch loss caused by wire length inconsistency is about 0.2% of the total yield.

3) Bifacial modules also withstand the mismatch loss caused by non-uniform incident illumination on the backside. When a PV module is installed on the bracket, there would be height difference inside the module, and the radiation intensity received by the module on the backside varies with different positions.

Figure 6 shows the measured irradiation on the front side of a PV module and the measured irradiance at different heights on the backside (Golmud, yellow sand background, fixed rack with tilt of 36 degrees, minimum height above ground: 50 cm, and rear irradiation normalised by the front value). It can be found that the radiation received at different heights on the backside of the module is different, which results in mismatch. According to the test data shown in Figure 6, RMS caused by the heights difference on the backside

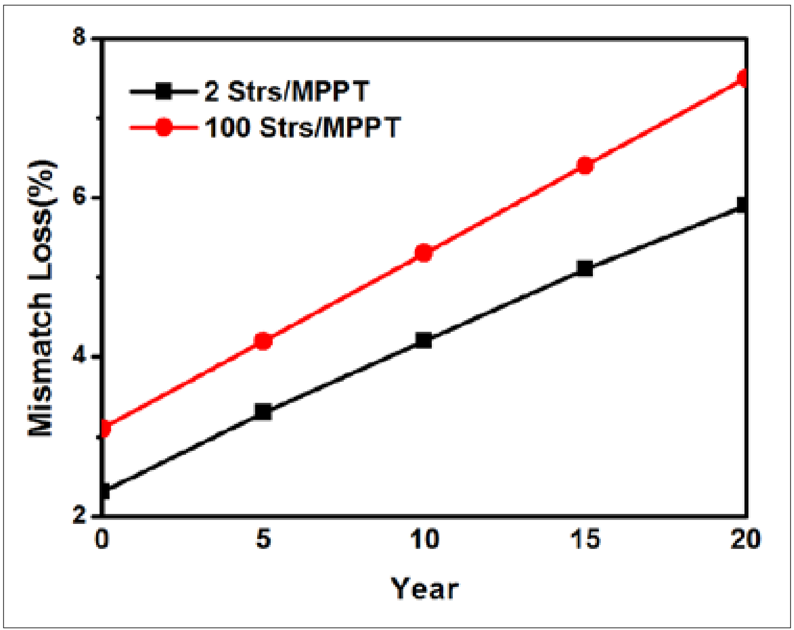

Figure 7. Mismatch loss evaluated by Monte Carlo method, with different densities of MPPTs

increases by about 3%. Combined by the RMS of the module itself, the current dispersion rate of the PV module is 5%. Even if the voltage dispersion rate of the bifacial PV module is consistent with that of the common PV module, the yield loss caused by the voltage and current mismatch is much larger than that of the common PV module. In addition, it should be mentioned here that this mismatch is existing mainly inside the bifacial module, so it is not so effective to eliminate the mismatch when optimisers are applied.

One of the most effective methods to reduce mismatch for PV plants is higher inverter MPPT density. For the bifacial module with a heavier mismatch, this is more effective. Since there are few methods to measure the mismatch, the mismatch loss under different MPPT density is calculated using the Monte Carlo statistical simulation, as shown in Figure 7 (boundary condition: current dispersion rate 5%, voltage dispersion rate 1.5%, annual RMS increase 0.1%, first-year power degradation 2%, and degradation every year after the first year 0.5% during the entire lifetime).

It can be seen that at the beginning, the gap of mismatch loss between two strings per MPPT and 100 strings per MPPT is about 0.8%. It indicates that compared to 100 strings per MPPT, two strings per MPPT will lead the yield by 0.8% in the first year.

Due to non-uniform degradation of modules over the years, the mismatch loss increases over time and the gap is simultaneously increasing. When viewing the entire lifetime mismatch loss, it can also be found that the weighted average mismatch loss over 20 years is up to 4.9% for 100 strings per MPPT solution, while only 3.8% for two strings per MPPT solution. This indicates that for a bifacial system, two strings per MPPT will lead to 1.1% more yield and the plant needs more MPPTs to guarantee the maximal output of bifacial modules [8-10].

Therefore, to exploit the energy yield of a bifacial module system as much as possible, a better choice is employing more MPPTs, which can effectively minimise the mismatch caused by bifacial modules and help fully realise the value of the bifacial modules.

Conclusions

To conclude, the performance of bifacial modules in the Middle East has been investigated. It is revealed that bifacial modules can improve the yield of 14.6% in a typical Middle East area, compared to conventional poly-Si modules. More importantly, the system design for bifacial modules requires greater effort for an optimal performance. On the DC side, greater height and smaller GCR are helpful for increasing yield, while on the AC side, solutions with more MPPTs should be adopted since bifacial systems have a higher mismatch. Based on this analysis, we believe a promising future of bifacial system in Middle East. ■

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Authors

Dr. Chen Zhu is director of the Module Design Centre at LONGi Solar, focused on PV module technology research and development, product design and technology strategy analysis. He earned his BSc degree in theoretical physics and Ph.D. in condensed matter physics from Nanjing University. After he got his Ph.D. he worked for Hanwha-Solarone, now Hanwha QCELLS, as solar cell R&D assistant director. More recently he worked for Renesola as director of Product Centre, leading on cell and module R&D, product design and process development.

Dr. Songming Liu is director of the System Integration Centre, LONGi Solar, focusing on PV module energy yield research, system integration application programme development, PV system measurement and PV system standards. Dr. Liu earned his Ph.D in physics from Nanjing University in 2007. He has worked in renewable energy industry for 11 years; his research experience covers crystalline silicon modules, thin-film PV modules, PV system design and PV standards.

Zhichao Wang is a senior R&D engineer of the System Integration Centre, LONGi Solar, and skilled in bifacial system design R&D, product and system outdoor testing and PV system energy yield data analysis. Zhichao Wang got his BSc degree in optical information science and master degree in precise instrument technology from Hefei University of Technology. After that he worked for CPV company Suncore as an outdoor testing engineer, he then he worked for Trina Solar as senior system testing and analysis engineer.

Dr. Qiangzhong ZHU is manager of the Module Design Centre at LONGi Solar, focusing on PV module technology RD&, product design, energy yield of new product and module reliability. He earned his BS degree in Theoretical Physics and Ph.D in optical engineering from Sun Yat-Sen University. After he got his Ph.D he worked for Trina solar as manager of the module design centre.

Dr. Jun Lv is the adjunct associate professor of the University of New South Wales, associate professor of Sanjiang University and the vice president of Longi Solar Technology Co., Ltd. He is mainly focused on renewable energy materials science and technology. Dr. Lv has more than 10 years of research experience on renewable energy, environmental materials, silicon solar cells, PV modules and PV systems. Recently, his research expertise has covered solar cell engineering and technology, solar module design, power output forecast and analysis.