Delivering on the Promise of Bifacial Modules

White Paper

To fully benefit from bifacial module field performance, it is crucial to understand how the modules are specified, manufactured, and tested. Understanding how the bifacial coefficient is specified on paper, verified in the factory, how it may degrade in the field, and be protected by the manufacturers' warranty, are all important factors in securing the expected performance gain from bifacial modules.

The views presented here are the result of practical experience with bifacial modules following the 2019 release of the PI Berlin white paper, Bifacial PV Technology - Ready for Mass Deployment authored by Dr. Lars Podlowski.

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1. Introduction

External factors and site-specific conditions that influence actual bifacial gain in the field can have a significant impact on how well a bifacial module performs. But before installation occurs, it is crucial for the buyer to pay close attention to the module itself and the key role it plays in enabling a bifacial gain in system performance.

If the bifacial gain of the module does not meet expectations, it is unlikely the loss will be made up for by better-than-expected site conditions unless they have been significantly underestimated during the planning process.

2. Procurement

A well procured bifacial module is fundamental to the bifacial gain

In purchasing bifacial modules, multiple steps can, and should, be taken by the buyer to ensure the bifacial module delivers the fundamental gain in performance that is expected. This is especially important if the bifacial modules are being sold at a premium to mono-facial modules and the owner expects to monetize the bifacial gain.

Bifacial modules performing as expected is not a given. Many manufacturers regard the bifacial gain as an added benefit passed on to the buyer at very little added cost. That means specifications are often poorly defined, very little testing is conducted and bifacial power guarantees may be nonexistent.

The supply contract used to buy bifacial modules is therefore key to ensuring specifications are well defined, sufficient testing is conducted and supporting guarantees are negotiated upfront.

3. Differences in Design

Bifacial modules are constructed differently to mono-facial modules

Apart from the obvious fact that a bifacial solar cell is used instead of a mono-facial cell, the packaging around the cell is also modified to ensure that the rear side of the modules becomes transparent to light. Mono-facial modules typically have a single piece of 3.2 mm thick glass on the front and an opaque polymer sheet on the back.

The back of bifacial modules is made transparent by either using a second layer of glass on the back instead of an opaque polymer sheet, or by using a transparent polymer sheet. If a second layer of glass is used on the back, then the thickness of the front glass is usually reduced from 3.2 to 2.0 mm to minimize the weight gain. The mechanical properties of this new construction have both benefits and potential risks.

Surface treatment on the glass may affect performance

The surface treatment on the glass may impact bifacial performance. The front side typically has an anti-reflective coating (ARC) which gives the glass a transmission rate of 93 %. The rear side glass may not have an ARC and the transmission may be reduced to 91 %. Some rear side glass is also printed with a white grid pattern that increases the internal reflectivity of light from the cell gaps, but may partially shade some of the cells on the rear side if not placed accurately.

Durability of transparent back sheets needs to be proven

Instead of glass, the use of transparent polymer back sheets at scale in PV modules is relatively new and comes with a limited field track record. The ability of the back sheet to remain transparent and mechanically stable throughout the module's lifetime should be proven through extended testing. These type of long-term performance demands on transparent polymers are by their very nature challenging. Polymers are not inherently stable in sunlight and require sufficient chemical additives to remain stable (which also adds cost). Unstable polymers may allow moisture to ingress and may lose transparency, thus resulting in lower transmittance values.

Watch out for unintended shading

Lastly, the location of the racking, frames, junction box and cabling on the back of the module plays a role in any potential shading of the rear side of the module that may occur in the field. The location of the junction box and routing of the cables should be checked to ensure no such shading exists or guides how the module should be installed in the field to avoid such a problem.

4. Specifications

Bifacial cells are not symmetrical

A bifacial solar cell is not equal on both sides – its internal structure is not symmetrical. The rear side of a bifacial cell is inherently less efficient than the front side, even under the same illumination conditions. This difference is captured by the 'bifacial coefficient' which is the ratio of the rear to the front side power expressed as a percentage (assuming that the illumination conditions on both sides are the same).

Bifacial coefficients vary significantly

Bifacial coefficients typically range from 65 to 70 % for modules with p-type solar cells (common today), between 80 and 90 % for n-type solar cells (less common though growing) and higher than 90 % for heterojunction solar cells (a few manufacturers). Heterojunction solar cells are closer to being symmetrical in design, which is why the performance of the front and rear side is so similar.

The cost of technologies which improve the bifacial coefficient are also higher, so the decision to go with a higher coefficient may not always make commercial sense. Indeed, in some cases, the bifacial coefficient of p-type cells may be deliberately lowered by the manufacturer to achieve the best tradeoff between front and rear side power. Improving rear side power can result in lower front side power. If most of the power generated by a bifacial module still comes from the front, the module overall may produce more power in the field if the coefficient is lowered (this optimization will play less of a role in modules with higher inherent coefficients such as those with n-type and heterojunction solar cells).

The tolerance on bifacial coefficients can be very broad, if defined at all

Manufacturers usually specify bifacial coefficients as a range, not a single fixed number. This is because the bifacial coefficient will naturally vary from module to module but, unlike front side power, modules are not sorted or grouped according to their rear side power or bifacial coefficient. The bigger the spread of bifacial coefficients in a population of modules, the more an impact it may have on expected bifacial gain. Just as with mono-facial modules, the performance of all the modules in a string will depend on the worst performing module

The bifacial coefficients quoted by a range of major manufactures, extracted from publicly available datasheets, are as seen in Figure 1. Some manufacturers do not quote any bifacial coefficient (Vikram, Boviet, HT-SAAE and Sunpreme).

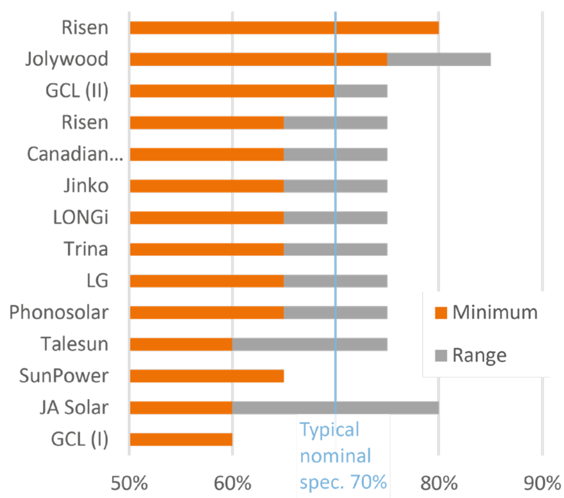

Figure 1: Manufactured published specifications for bifacial coeffi-cients

Most manufacturers of p-type bifacial modules specify a 70 % coefficient with a relatively broad tolerance of +/-5 %. As the specification includes a negative tolerance, it means that the actual 'out of the box' coefficient being guaranteed is only 65 %, not 70 %.

This tolerance is broad and how the module performs in the field will very much depend on where in the tolerance range the bulk of the modules are produced. One manufacturer, JA Solar, has a coefficient specified with a tolerance of +/-10 %, meaning that the actual delivered values could lie anywhere between 60 and 80 %. That means potentially significant uncertainty in the actual values the buyer will receive.

Some manufacturers only specify a minimum (GCL, SunPower and Risen), but with no upper bound. The two manufacturers with commercially available n-type bifacial modules specify their coefficients at different levels. LG specifies the minimum at only 65 % which is the same as provided by most p-type bifacial modules. Jolywood offers a 75 % minimum. The only heterojunction module (offered by Risen) provides a minimum 80 % coefficient.

For bifacial gain modeling purposes, it is important to ensure that .pan files (for example) use the minimum guaranteed value, not the nominal value. Otherwise, performance models could produce overly optimistic results which overestimate the actual performance of systems with bifacial modules.

The specified coefficient values are also 'day one' numbers. In other words, a brand-new module should have coefficient values in these ranges. That does not necessarily mean the bifacial coefficient will remain constant throughout the lifetime of the module. Both sides of the module will experience some level of power degradation over time and the degradation rates of both sides may not be the same.

5. Manufacturing

Mismatch may not be avoided

Bifacial solar cells are usually not sorted based on their rear side electrical characteristics. When bifacial cells are combined in a module, the current may be mismatched more than expected, which can lower the energy delivered by the module in the field. Manufacturers should ensure some level of rear side sorting of cells to avoid mismatch.

Coefficients may be infrequently checked

In theory, verifying the bifacial coefficient of an assembled module is easy. The module is turned over on the power (flash) tester in the factory and the rear side of the module is tested under the same conditions as the front. The power produced by the rear is compared to the power produced by the front and the unique coefficient for each module is calculated.

The reality is somewhat different. Most manufacturers will rear side power test only a small fraction of all modules produced. As few as 5 to 10 modules per day in some cases. The testing is often not done in the main production line, but may be done on an offline tester that may or may not have been calibrated. It makes sense, at a minimum, to require the manufacturer to test statistically significant quantities of modules – for example following the sampling rules of ISO 2859.

Bifacial power may not be correctly checked

Testing the power of bifacial modules correctly requires careful attention to detail. For example, if the manufacturer is not careful, light from the flash tester will travel between the cells and reflect onto the back of the module, thus artificially boosting the apparent, measured power of one side. In 25 % of the factory audits conducted by PI Berlin in 2020 (22 out of 87),bifacial coefficients were being incorrectly measured at the factory.

A standard exists that defines how to test the power of bifacial modules correctly – IEC 609045-1 and -2 (Measurement of Current-Voltage Characterization of Bifacial Photovoltaic Devices). Manufacturers should be applying this standard, and third parties should verify that the standard is correctly and routinely being applied.

Flash test data for both the front and rear side of bifacial modules should be captured, and the coefficient calculated. Any modules which do not meet the required coefficient values should be rejected. In addition, the coefficient values should be shared with the buyer (just as front side flash test data values are regularly shared today) so the buyer can see that the specifications are being met and can understand the distribution in actual coefficient values being received.Third party repeat flash testing is also recommended on a sample basis to release batches of bifacial modules for shipment to a buyer. The results of such pre-shipment testing on a variety of bifacial modules is shown Figure 2, demonstrating that several major manufacturers are typically delivering bifacial coefficients on the low end of the specified range, and typically below the nominal specification.

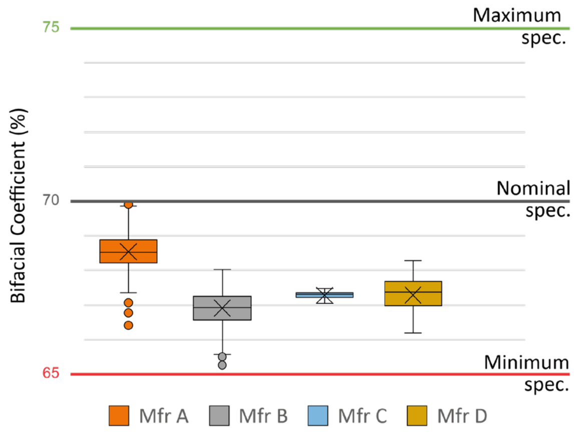

Figure 2: Factory measured bifacial coefficients over a large popula-tion of modules.

Laminating double glass bifacial modules can be challenging

Successfully laminating two pieces of glass, without generating air bubbles within the laminate, can be challenging. Misalignment of the glass may cause a pinch effect on modules which can cause glass to break. Mismatching glass thickness can also cause stress on the cells which may lead to cracks. In addition, laminating two rigid layers to each other can increase mechanical stresses within the module if the glass is not completely flat or each piece of glass has been thermally treated in slightly different ways. Factories producing double glass modules should be checked to ensure high quality lamination is achieved. The glass edges must also be protected against potential impacts. If the modules are framed, adequate sealant should be inserted as a cushion between the glass edge and the metal frame. If the modules are not framed, extreme care must be taken in the field to avoid any impact to the side of the module during handling.

6. Durability and Degradation

Certification has limited value

To certify a bifacial module today, the performance of the rear side of the module is not considered. To understand the durability and reliability of a bifacial module, extended third party testing is highly recommended (or at least incumbent on the buyer to require such testing of the manufacturer).

Bifacial coefficients may decrease over time

Today the basic assumption is that the bifacial coefficient remains constant throughout the lifetime of the module. However extended testing should be conducted on bifacial modules (just as it is on mono-facial modules), with particular attention on how the rear side power and the bifacial coefficient changes over time.

Some manufacturers have already seen that the rear side of a bifacial solar cell may lose more power than the front. In other words, the coefficient may drop over time. For example, the front side power of good

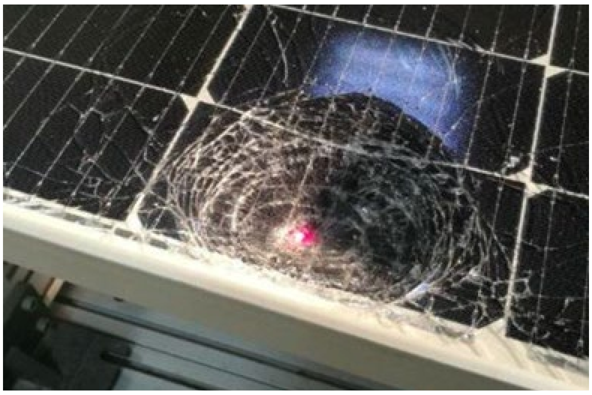

Figure 3: Bifacial module failing the 55 mm IEC Standard Hail Test.

quality modules will typically not drop by more than 5 % after extended stress testing – most modules in fact losing 2 % or less. Manufacturers in contrast will often push to allow up to 8 % rear side power loss.

One of the reasons for this may be the fact the rear side of a bifacial solar cell is more sensitive to silicon quality than the front. If poorer grade silicon is used, it may cause the rear side to lose power at a higher rate than the front side (which may be unaffected by the slight change in silicon quality).

The fact that the front and rear sides of a bifacial solar cell may lose power at different rates also means it is practically impossible for a module manufacturer to guarantee that the coefficient of a bifacial module will remain constant over its lifetime.The most recent data issued by PVEL indicates that rear side power can indeed degrade more than the front side, and that the spread in potential degradation is larger. Results from PID testing show the most potential difference (Figure 4).

Bifacial modules may be more at risk of hail damage

The mechanical strength of double glass type modules should in theory be higher compared to modules constructed with only a single piece of glass and a polymer back sheet. The fact that the double glass module provides a symmetrical structure (if you cut the module right down the middle between both sheets of glass, both sides will look the same) means

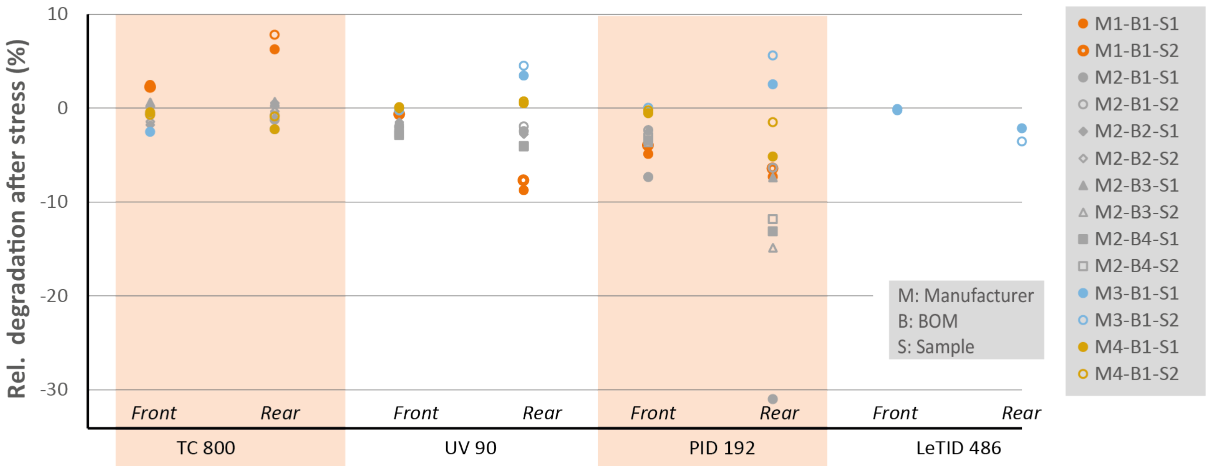

Figure 4: Distribution of degradation (Source PVEL)

that anytime the module bends, the center where the cells lie will not bend. That means the cells are less prone to the risk of cracking.

Since thinner glass is also used on the front (typically 2.0 mm instead of 3.2 mm), they can be more prone to hail related damage. This may be problematic in regions such as the hail belt within the USA. In this region hail larger than two inches in size may be expected every three to five years, whereas most modules are only certified to a one-inch maximum hail size. Testing on bifacial double glass modules has shown that they may not be able to withstand hail up to two inches in size, even though the certification standards allow for hail up to this size to be tested and certified. Manufacturers are aware of this weakness with some announcing they are working on solutions to the problem.

The thinner, not fully tempered back glass is also subject to breaking from rocks or stones that are used below the modules for vegetation mitigation. They can cause the glass to break if they are kicked up by windstorms or mowing. More recently stress has been observed in modules caused by the placement of junction boxes, and holes in the glass that allow the electrical busing to pass through, potentially causing the glass to break.

7. Warranties

Minimal rear side power coverage

Lastly comes the question of warranties. How is the rear side power of bifacial modules typically being protected by manufacturers? In most cases there is no explicit warranty coverage.

The typical 25- or 30-year power warranty only includes the front side power. That means as soon as the buyer takes ownership of the modules, the initial rear side power and coefficient specification is no longer guaranteed. It is therefore incumbent on the buyer to negotiate protection for rear side power into warranties if it is needed.A compiled list of the publicly available warranties regarding rear-side power protection for the rear side can be found in Table 1.

Of the two manufacturers who are publicly providing rear side power protection, Canadian Solar effectively mirrors the power protection provided for the front side, just reduced by the bifacial coefficient. However, the remedy in the event of a loss in rear side power beyond what is warranted is to provide 10 % of the lost power, but as front side power. This assumes that replacement modules cannot be provided with rear side power only and that the rear side typically only produces about 10 % of the front side under real operating conditions.

Trina Solar on the other hand provides a stepped warranty on the rear side power, instead of the more common linear warranty used on the front side. This means that from day one the rear side power is only guaranteed to 85 % of the value specified on the datasheet. That means the rear side power of the module could drop by 14 % on day two and the loss would not be covered by the warranty. The remedy in the event of a loss in rear side power beyond what is warranted is not clearly specified.

Table 1: Warranty coverage of rear-side power

Manufacturer	Rear-side power protection
Boviet	Not referenced
Canadian Solar	Protected against the same rela-tive loss as the front-side power
GCL	Not referenced
HT-SAAE	Not available
JA Solar	Expressly excluded
Jinko	Expressly excluded
Jolywood	Not referenced
LG	Not referenced
LONGi	Not referenced
Risen	Not available
Talesun	Not referenced
Trina	85 % of the initial power guaran-teed until year 10 70 % of the initial power guaran-teed until year 30
Vikram	Not referenced
VSUN	Not available
ZnShine	Not available

The above situation likely comes from the fact that most manufacturers are not taking the rear side performance of the module as seriously as the front side – as evident from specifying through to manufacturing and testing of the modules. Manufacturers may also be uncertain exactly how the rear side power of the modules will degrade in the field based on the lack of any long-term degradation data or sufficient accelerated ageing data. This requires the buyer to assume some caution in bifacial performance estimations.

8. PI Photovoltaik-Institut Berlin AG

PI Berlin is a leading technical advisor, risk manager and quality assurance provider for PV power plants and equipment. With its experienced team of researchers, scientists and engineers, PI Berlin offers a wide range of design, testing and evaluation services with a focus on the risk management and quality assurance of PV equipment and complex PV power plants. PI Berlin has supported 7.5 GW of PV power plants worldwide, with over 300 audits conducted on over 120 PV manufacturers producing more than 67 GW of PV equipment annually.

Contact

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