PV Performance Guarantees: Managing Risks & Expectations

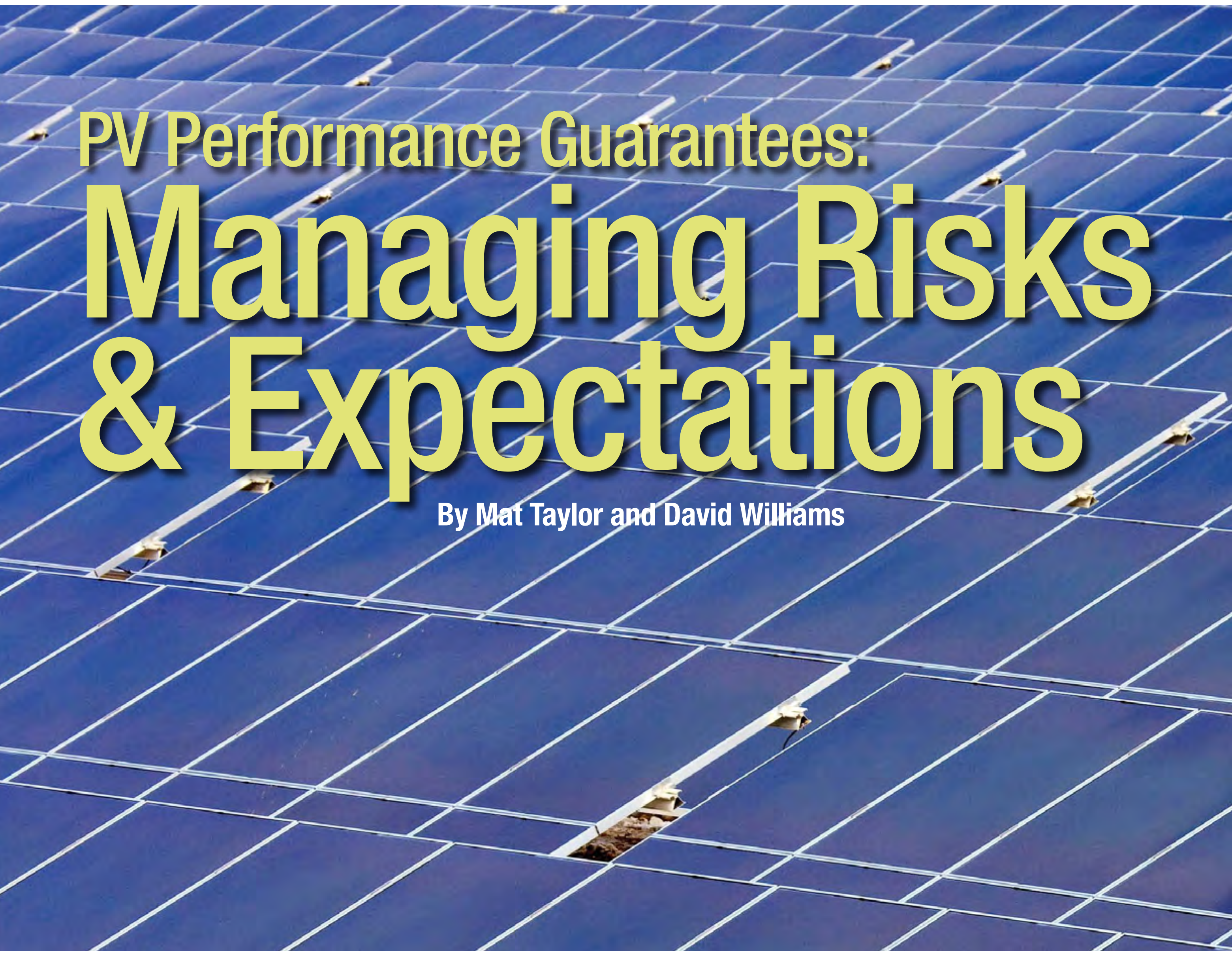
By Mat Taylor and David Williams

PART ONE

CREATING A PERFORMANCE GUARANTEE

Performance guarantees are widely used in the commercial solar industry, yet they are frequently misunderstood. Their purpose, however, is no mystery. To finance and construct a large-scale solar project, there has to be a risk-mitigating mechanism in place to reassure investors, which include large banks and institutional investors. A PV performance guarantee contract is the tool used to give the at-risk owner confidence that the system and investment will perform as expected.

The starting point of the agreement is determining the appropriate contract terms and conditions. There are many competing ideas about what constitutes a good PV performance guarantee, and the debate is often heated. A complex team is required to deliver a large-scale solar project (see sidebar, p. 57). Each involved party—owner, developer, contractor, sponsor and financier—has a distinct point of view. Creating a successful PV performance guarantee is both a multidisciplinary exercise and a balancing act. It requires both a technical and holistic understanding of the factors that affect PV system performance and reliability. It requires financial vision. It requires complex contracts. Given thoughtful and thorough understanding on the part of all stakeholders, a PV performance guarantee



can help make a good project happen and keep it operating properly for the life of the system.

In our current positions, working in project development and construction, we represent two of the protagonists in the PV performance guarantee debate: the project developer and the engineering, procurement and construction (EPC) contractor. We attempt to represent other points of view in this article as well. Together we provide some background and context for understanding this complex topic. We define essential concepts and consider their practical implementation. We describe the current market expectations of the main parties at the negotiating table and examine the obvious tension between the investors' wishes and the EPC contractor's abilities in some detail. While we provide some concrete examples of what might be considered best practices for PV performance guarantees, our intent is not to define a one-size-fits-all solution—which would not be realistic—but rather to elevate the general level of discussion and understanding across the industry.

Courtesy Andy Snow

Why Performance Guarantees? Why Now?

In the construction industry, there are availability guarantees, operations and maintenance (O&M) contracts and product warranties in abundance. However, PV performance guarantees are somewhat unprecedented. What is unique about PV performance guarantee structures is that they percolate a contractor's responsibility through a long-term financial arrangement. They do so because PV systems must predictably perform for many years in order to meet the financial expectations for the project.

Protagonists in the PV Performance Guarantee Debate

The following parties are typically involved in the deployment of large-scale solar projects using PV performance guarantee contracts.

Owner: The owner, or purchaser, is the party who eventually runs, operates and derives revenue from the project. Because revenue is used to service debt, pay investors and so on, the clearest definition of *owner* is the person or people who coordinate and run the project from start to finish.

Developer: The developer, who may also be an investor, helps make the project happen by coordinating commercial and construction contracts. The key distinction between the owner and the developer is the latter's direct tie to project design and construction.

Contractor: The engineering, procurement and construction contractor designs and constructs the project and is the main holder of project risk with respect to the performance guarantee. In most cases, the EPC contractor is the *guarantor* in contract language.

Sponsor: The sponsor is either the developer or the EPC contractor. The sponsor's role is to negotiate and enforce the performance guarantee.

Financier: The financier provides most of the money for the project and the framework for the PV performance guarantee contract. Typically, the financier builds the language of the guarantee to help ensure a cash flow throughout the project life cycle. This role can loosely be defined as the project debt and equity provider. ●

There is significant competition between project developers in search of investment partners. This means that developers seek to prepare a project with the strongest level of guaranteed revenue in order to increase the likelihood of selling the project to debt and equity investment companies. To achieve this, developers tend to ask EPC contractors for comprehensive guarantees. A strong performance guarantee can centralize the responsibility for meeting many of the perceived challenges associated with a big project and make the whole project more attractive to investors. Large-scale solar is big business, and performance guarantees are big business by association. Almost all large-scale PV projects have performance guarantee contracts.

From the developer's point of view, it is easier to ask the contractor for a strong guarantee than to convince equity or debt partners that a comprehensive guarantee is unnecessary.

From the developer's point of view, it is easier to ask the contractor for a strong guarantee than to convince equity or debt partners that a comprehensive guarantee is unnecessary.

After all, the core business of the investor or owner of a large-scale PV system is rarely the generation of solar power. Therefore, the EPC contractor is asked to address the performance risk to help ensure that the system is operational for the long term. At the core of any successful guarantee is the idea that the project must be successful for its lifetime. It may sound simple, but very few construction projects have as much at stake. One of the keys to a successful guarantee is balancing the level of coverage with the cost of coverage.

Level of coverage. It is difficult to generalize about the level of coverage that is sufficient for debt and equity providers. Each unique deal requires an individual analysis. However, investors are generally hesitant to pursue projects that are perceived as risky. The challenge is to provide sufficient risk mitigation while still finding room for all of the stakeholders to make money.

Wrapping the necessary risks while providing a reasonable profit is harder than it sounds. The recent economic slowdown has substantially increased competition for large-scale solar development projects. The combination of investors' growing risk aversion and strong competition for PV projects is shifting the market to where investors insist on very robust guarantees. EPC providers are often left with the dilemma of either offering a strong performance guarantee or simply not doing the job.

Cost of coverage. The true cost of creating and maintaining a performance guarantee is not always disclosed in the EPC contractor's price for services. There are few risk-analysis tools or industry precedents available, so parties on all sides of the negotiating table are most likely guessing. The costs are sometimes rolled into the overall profit margin associated with the EPC contractor's portion of the project. When this is the case, it may appear from an accounting point of view that there are hidden costs in the project proposal. This can be a problem for the owner because hidden costs can negatively impact the project's ROI.

However, too much coverage can also reduce a project's ROI. In this case, the owner is getting too comprehensive a plan to cover the project's needs. One of the challenges is that big EPC providers are not organized to solve the small-scale and relatively high-frequency problems common to large-scale PV systems. Finally, monitoring, maintenance and reporting are not typically central to the business of an EPC contractor. Forcing EPC contractors to take on these risks can be expensive and may set the project up for financial failure.

The True Cost of Performance Guarantees

Pricing a performance guarantee can be very difficult. The challenge is to understand the risks and consequences of the system failing to perform. While large integrators may be able to contractually limit their liability, they may also be forced by the owner for commercial reasons to help resolve problems. A classic example is when a large integrator sells a project to an independent power producer (IPP) or non-utility generator, a transaction that may happen soon after the system is commissioned. The site host or energy off-taker may later tell the EPC contractor that the system is not CONTINUED ON PAGE 60

Brand recognition One challenge for contractors providing performance guarantees is that even if they are able to limit their exposure contractually, they may ultimately feel obligated to go beyond those minimum requirements to protect their reputation and brand.

Courtesy Cupertino Electric

performing as expected and service provided by the IPP is not fulfilling the customer's expectations. Regardless of whether this claim is valid, the EPC provider may feel obligated to help fix a system that it is no longer contractually responsible for.

Consequently, some EPC contractors offer only a 100% guarantee. They may feel that they cannot effectively limit their liability because their reputation is at stake. For example, if a project is extremely underperforming, the value of any damage to the company's brand may potentially be larger than the cost obligated by the guarantee. Therefore, the contractor provides comprehensive coverage regardless of any contractual obligation. This does not come free. In fact, larger EPC contractors may be forced by their internal structures and accounting methods to provide and charge for these larger guarantees.

RISK ASSESSMENT

The concepts of risk and risk mitigation are fundamental to the structure of PV performance guarantees. Risk is what shapes the language of performance guarantees and determines their inherent obligations. To illustrate the intricacies of performance guarantee negotiations, we provide three perspectives on the risks associated with PV projects—the financier's, the project developer's and the EPC contractor's.

The financier. Photovoltaic projects in the US are unique because they require someone to monetize tax benefits to make the projects work. This requires three distinct types of investment: debt (bank financing), tax equity and sponsor equity. A typical utility-scale PV project is financed using 50% debt, 30% tax equity and 20% sponsor equity, as shown in Chart 1. Note that debt and tax equity represent substantially more of the total capital input. This amount of money reduces the amount required from the equity investors, (those investors with an ownership stake in the project), and increases their returns.

As an example, imagine a project that costs $100 and returns $110. If the project is financed with sponsor equity, the equity investors get $10 on a $100 investment, which is a 10% return. However, the math looks quite different if the equity investors get $80 from the bank, and the bank asks for a $4 return. In this case, the bank gets a 5% return, which may be perfectly acceptable provided it is guaranteed to get its money back first. After the debt is serviced, the equity investors get the remaining $6. However, the equity investors put in only $20 ($100 – $80 from the bank), which means they are getting $6 in return for a $20 investment—a 30% return. In this manner, the equity investors are putting in less money and making a higher internal rate or return. In the US today, it is unlikely that PV project returns will be adequate for project sponsors without placing debt and increasing the equity returns.

Bank financing requires a lower rate of return because this debt is senior to sponsor equity, meaning it gets paid off first, and is therefore less risky. This makes debt prices less. Banks also take a much lower risk position by ensuring that there are cash reserves and high debt service coverage ratios. Especially in the wake of the 2008 financial crisis, banks are hesitant to assume unknown risks. Therefore, the bank must have another entity provide adequate coverage to ensure system performance.

The project developer tends to be a smaller, less established player compared to the bank or the EPC contractor. Therefore, the contractor is the natural performance guarantor for the bank. A large balance sheet and the proven ability to fix problems over a period of 5 or more years are essential. Someone must provide a solid and convincing story about the performance of the system to maximize the amount of debt and increase the equity returns. The strength and the structure are highly deal-dependent. While the bank may not be able to give a specific example of the terms required, it knows a good performance guarantee when presented with one.

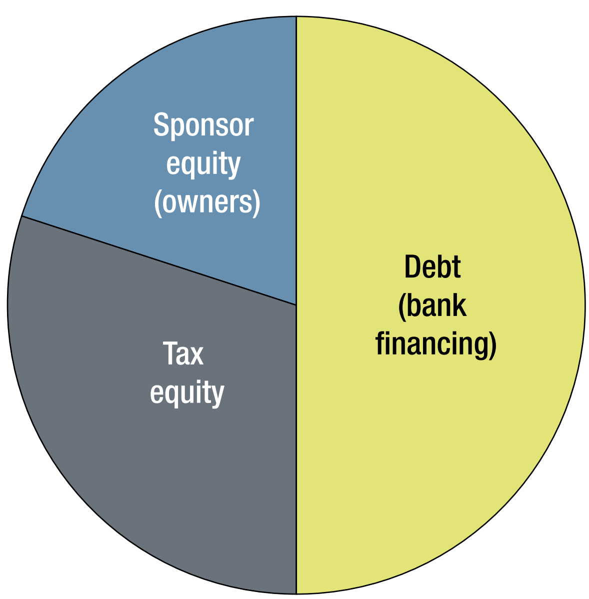


Chart 1 Large-scale PV systems in the US are typically financed using 50% debt (bank financing), 30% tax equity and 20% sponsor equity. Because they are able to put up less money, the equity investors are able to make the higher ROI required to make projects viable.

The developer. The photovoltaic project developer is responsible for bringing together the five essential project pillars: real estate, interconnection, power take-off, permitting and financing. In the process, the developer attempts to assemble a comprehensive CONTINUED ON PAGE 62

package that has a high chance of success with financiers. While large PV projects have some inherent risk, the developer is in a position to apply low-risk bank philosophy to mitigate it.

The developer generally finds it easier to work with the EPC contractor than with the bank. Bank financing tends to be somewhat binary: yes or no. EPC contractors, however, have a level of flexibility. They are motivated to find a performance guarantee that works. After all, if there is no guarantee, there is no project. In addition, EPC contractors are in a good position to own the performance risk. They design, build and commission the project, which limits or controls their exposure.

Performance guarantees need to be provided by an EPC contractor with sufficient experience and a sizable balance sheet. In European PV markets, EPC contractors provide very strong guarantees. This is in part due to the large size of European EPC providers; they can afford to provide strong guarantees. It is also true that EPC contractors are providing increasingly comprehensive performance guarantees as a means of differentiating themselves from the competition. While financiers are not always clear about a guarantee's requirements, a project without a performance guarantee almost certainly fails to find bank financing. A project without debt is simply not viable.

The EPC contractor. As a rule, EPC contractors are intimately familiar with evaluating contracts as they pertain to

> From the EPC contractor's point of view, a PV performance guarantee must be structured so that a relatively simple approach can be taken to assess the risk it is contractually obligated to assume.

getting things built. However, measuring plant performance over a long period of time and assuming responsibility for the possible associated damages is far from the norm.

The typical EPC contract has a definite beginning and end. For large-scale solar projects, this duration is usually a little over a year. PV performance CONTINUED ON PAGE 64

guarantee structures ask the EPC provider to extend contractual obligations for several times that duration. EPC contractors are accustomed to designing solar farms, building them, proving that they operate properly and then moving on to another project. In fact, all of the business structures for an EPC contractor—from design work through commissioning—are organized in this manner: beginning (the notice to proceed), middle (the work), and end (final payment and turnover). The PV performance guarantee is a distinct departure from this simple, predictable model.

While EPC contractors are not afraid of risk, they may not know how to evaluate or estimate it well. When this is the case, they are likely to evaluate project risk on the high side. EPC contractors can mitigate risk associated with system design and construction, but they cannot control the weather. Therefore, contractual conditions that assess damages based on climate data are often unacceptable to them.

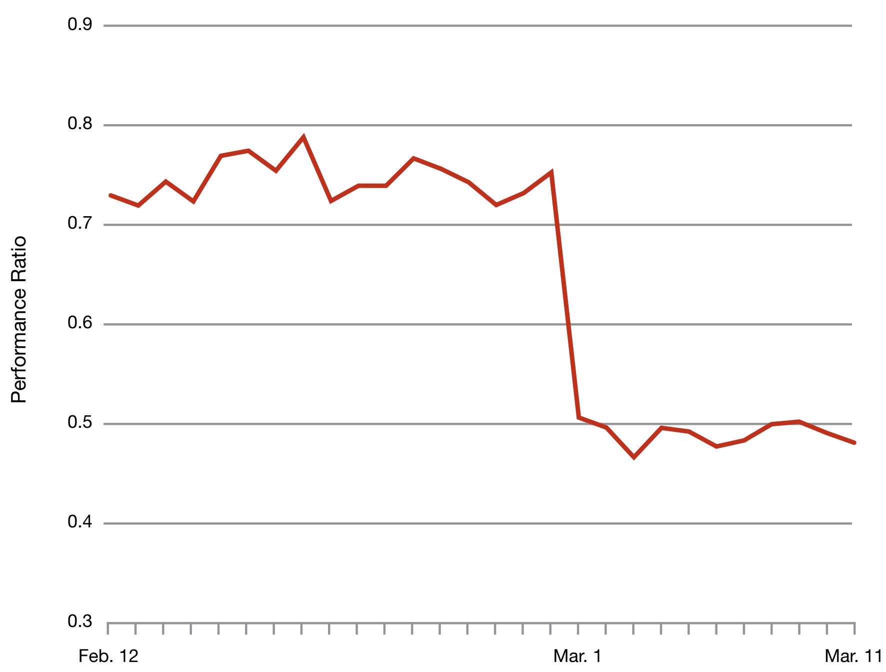
From the contractor's perspective, there is a nearly incalculable risk associated with quantitatively comparing site-measured system output data with historical data. In other words, they avoid putting themselves in the position of having to hit a MWh goal irrespective of the weather. They do not want to do this because they cannot predict the weather. If the assessed liquidated damages have anything to do with a less sunny year than normal, then a prudent EPC contractor is probably going to pass on the project. From the contractor's point of view, a PV performance guarantee must be structured so that a relatively simple approach can be taken to assess the risk it is contractually obligated to assume.

Concepts and Calculations

The complexity of PV performance guarantee approaches can sometimes overshadow the intent of the agreement. Performance guarantees should not be structured to sell projects; they should be structured to ensure that systems work as intended. It is critical that all parties understand their responsibilities. In other words, it needs to be clear what risks are being mitigated and by whom. The keys for successful negotiations are establishing clear rules, formulae and responsibilities; determining consequences of nonperformance; and limiting liability. As a general rule, the parties closest to the risk should be responsible for the risk.

It is also important to understand the constraints of the plant monitoring data. For example, most PV systems have a monitoring system that has technical restrictions on the type, accuracy and granularity of the data collected. This can directly affect the ability to calculate or prove system performance, or the methods used to do so. When making decisions about what to measure and how, it is advisable to get input from all team members responsible for these activities in order to accurately weigh the cost and benefit of monitoring, reporting and measurement validation. The degree to which a plant must be measured is analogous to the expectations of the performance guarantee. Nearly constant monitoring is required to keep everyone informed with the appropriate data. The owner, developer and contractor must know how the asset is performing in order to mitigate having to pay damages.

The duration of the guarantee can help reduce the administrative and payment risks associated with proof of performance. The longer the term, the more flexibility there is to cure or fix the problem; however, a longer term also broadens the contingent liability. It should be clear who requires or prepares documentation to determine if and how payout for damages is to be made. The beneficiary of the guarantee is typically the system owner but not always. Sometimes a third-party investor is the downstream beneficiary.



Performance ratio Because a PV plant's performance ratio is compensated for variables like irradiance, it is useful for comparing systems built in different locations or using different technologies. It can also be used to identify potential instances of or trends toward underperformance, whether occurring suddenly—as shown here—or developing incrementally over time.

Determining meaningful measures of performance is one of the most challenging aspects of contract negotiation. While there are many standard assumptions and models, the global financial markets have continued to tailor the required measures of performance for each set of underwriting needs. These underwriting needs are specific to local incentives, feed-in tariffs or tax equity. For the US, performance guarantees are generally governed by the need to leverage the 5.5 years of potential tax recapture allowed under the Investment Tax Credit and ensure acceptable debt service levels.

One of the first steps in contract negotiations is to establish some common definitions. These definitions ultimately determine the basis of measurement, which can be thought of as the hardware, software and numbers that need to be gathered in order to fulfill the performance guarantee. The most commonly used terms or concepts are specific production, performance ratio, temperature compensation and irradiance compensation.

Specific production. The *specific production* or *specific yield* of a system is a modules-to-meter performance metric. It is the ratio of energy produced by the system (MWh_{AC}) to the nameplate rating of the modules ($MW_{DC\text{-}STC}$), which is usually expressed as MWh/MW. Specific production is a good way to compare various PV technologies because it basically predicts the system output of a specific technology within a given climate. In any case, the predicted result is typically based on hourly PV simulations using known system design parameters. The actual production measurement in the field can be taken at many points throughout the system, but it is typically taken at the production meter, which is located at or near the point of common coupling or utility interconnection point.

A good performance guarantee helps identify and fix problems: When a PV system fails to perform as expected, there can be mutual agreement about the cure, and action can be taken to get it fixed.

The basic formula for specific production is shown in Equation 1:

$$\text{Specific production} = MWh_{AC} \div MW_{DC\text{-}STC} \quad (1)$$

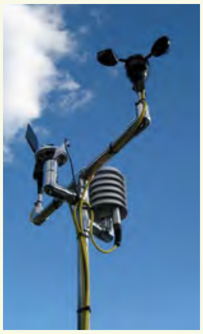
As long as the methods used to determine the numerator and denominator are mutually understood, this index can be a very good starting place for PV performance guarantee negotiations. Of course, specific production is only an indication of relative system performance and depends on a host of parameters. Failing to reach a specific production goal usually indicates a poorly performing system, but it does nothing to help identify or fix problems. Understanding these limitations is key to properly using this index.

Performance ratio. The most widely used and accepted index of PV system performance is the *performance ratio*. This ratio separates out the uncertainty and variability of irradiance and is intended to normalize out weather factors to produce a consistent measure of system performance. It is therefore a useful equivalent for comparing PV plant performance regardless of technology or location. As such, it is CONTINUED ON PAGE 68

Guidelines for a Successful Performance Guarantee

General recommendations:

- Write the terms and conditions with input from all parties.
- Establish a mutually agreeable basis for measurement that identifies the data to be measured, as well as the hardware and software required.
- Identify the monitoring hardware and software needed to ensure equitable measurement.
- Establish co-ownership of plant metrics.
- Design the PV performance guarantee contract to ensure that performance is maintained over the project lifetime.
- Establish firm dates and durations for O&M and guarantee phases.



Shawn Schreiner

Monitoring It is important that all parties engaged in a performance guarantee are in agreement about what data is to be collected, how it is to be collected, and what the limitations are due to measurement accuracy or method. A recalibration schedule should also be part of the agreement.

For the developer or owner:

- Keep the end in mind: It is essential to understand the true risks that need to be managed; those closest to the risk should manage the risk, and that may very well be the owner.
- Do not ask for a performance guarantee for its own sake; it is essential to structure agreements to solve problems, such as plugging gaps in coverage.
- Negotiate with the financier to find a balance for the ownership of risks.
- Keep in mind that managing a PV performance guarantee takes time and money; clear and simple structures work best.

For the financier:

- Take time to understand the terms of the warranties for major components.
- Be willing to pay for the performance guarantee because it adds value.
- Remember that performance guarantees are intended to ensure that systems perform, rather than to provide a mechanism for collecting payout damages.
- Understand that ultimately it is the knowledge, experience and solvency of the EPC and O&M contractors that is being counted on to keep the system producing.

For the EPC contractor:

- Understand the terms of the warranties for major components and fold them into the PV performance guarantee contract terms in full; do not promise more than the manufacturers do.
- Only agree to back up agreements from the manufacturers within the scope of the supply agreement and make sure to have the contractual authority to insist on corrective action.
- Perform accurate, detailed system simulations and agree with the client on the contract terms based on the modeled system.
- Do not guarantee the weather; be careful to avoid contracts that quantitatively tie damages to historical weather data.
- Pursue an arrangement that incentivizes meeting and exceeding performance expectations by trying to write incentives into the contract.

usually expressed as a percentage calculated as shown in Equation 2:

$$PR = (E_{ACTUAL} \div E_{IDEAL}) \times 100\% \quad (2)$$

where E_{ACTUAL} is the amount of energy that passes through the custody meter over a given period of time, and E_{IDEAL} is the amount of energy that would be ideally expected, after correcting for temperature and irradiance.

Like an availability guarantee, which promises system or component uptime, a performance ratio guarantee requires a high level of service response. When both are provided as part of a performance guarantee contract, the EPC contractor ensures that the components work as described and that the system performs at the guaranteed level of effectiveness. The addition of an availability guarantee to a performance guarantee means the PV performance guarantee sponsor (the EPC contractor or developer) takes a more active role in plant management, helping to ensure total system performance even in the event of major component failures. This layered approach works well if there are several sub-metered production obligations or if the overall project includes systems across several sites.

Temperature compensation. Typically, the sponsor and the bank take the weather risk. More sophisticated contracts attempt to account for the performance risk associated with higher-than-average annual temperatures. While this is a more thorough method of assessment, a drastically different average temperature profile is unlikely during the term of a performance guarantee. Temperature fluctuations are typically within a few degrees Celsius. Therefore, the risk of temperature is inconsequential compared to the weight of solar irradiation. It is often expedient to simplify the documentation and limit metrics to include only solar input.

While temperature compensation tends to add complexity, module suppliers and EPC contractors wanting to limit risk may insist on it. In fact, some guarantors take a fundamental position to not guarantee weather impacts. If this is the case, Equation 3 can be used to calculate the temperature-corrected nominal plant power (P_{TC}):

$$P_{TC} = [1 + \gamma \times (T_{MOD} - 25°C)] \times P_{STC} \quad (3)$$

where gamma γ is the thermal coefficient of power from the module specifications, T_{MOD} is the module temperature and P_{STC} is the system capacity value at standard test conditions. Calculating the system capacity value can be as simple as using the nameplate dc system capacity. However, some procurement contracts allow for a wide variation in module power tolerance. Therefore, flash-test data or other factory or field measurements may more accurately reflect the size of the generator installed.

Irradiance compensation. The next challenge is to determine the measurement and verification methods used to account for variable site irradiance. Standard test conditions, of course, are based on an irradiance of 1,000 watts per square meter. In the field, the available solar power (irradiance) in the plane of the array is variable between 0 and perhaps 1,200 watts per square meter and is constantly changing.

While this complicates performance verification, expected PV system output power is directly proportional to solar irradiance, which is the input-power source. Therefore, as measured solar irradiance in the plane of the array changes, the output power of a PV plant should change proportionally. This means that the temperature- and irradiance-corrected expected PV system output power ($P_{EXPECTED}$) can be derived from the temperature-corrected nominal plant power (P_{TC}), as calculated in Equation 3, by multiplying the latter by the normalized solar irradiance, as shown in Equation 4:

$$P_{EXPECTED} = P_{TC} \times (G_{POA} \div 1{,}000\ W/m^2) \quad (4)$$

where G_{POA} equals the measured solar irradiance in the plane of the array.

When managing a large PV asset, verifying power instantaneously is generally less informative than verifying energy production over time. For example, one might want to characterize the daily, monthly or lifetime performance ratio for a PV power plant. As shown in Equation 2, this is a function of the actual energy measured at the revenue meter and the ideally expected amount of energy after temperature and irradiance compensation. This can be accomplished in two steps: determining the available irradiation and solving for the temperature- and irradiance-compensated ideally expected energy.

The first step is to determine the *irradiation,* the solar energy, available at the point of measurement. In *Photovoltaic Systems Engineering,* Robert Messenger and Jerry Ventre explain, "Since energy is power integrated over time, irradiation is the integral of irradiance." In this context, the verb "to integrate" is just a fancy way of saying "to sum up." In other words, available solar energy is the sum of all the little bits of solar energy, which might be measured in 1-second, 1-minute or 15-minute increments, added up over some interval (hour, day, month, year, etc.). While this can be expressed as a sum equation, the integral is shown in Equation 5:

$$H = \int G_{POA}\, dt \quad (5)$$

In this formula, H equals the irradiation or solar energy at the point of measurement. As was CONTINUED ON PAGE 70

the case in Equation 4, G_{POA} is the irradiance or solar power in the plane of the array. This needs to be multiplied by an increment of time in order for power to result in a unit of energy. This increment of time is shown in the equation as dt, which represents a change in time, the smallest increment being measured. It is most common for this to be a 15-minute interval, as this simplifies the math and data collection. The irradiance in the plane of the array is averaged over a 15-minute interval, and then all of these tiny 15-minute bits of energy are added together to determine the total irradiation in the plane of the array over a longer interval of time.

The second step is to use the solution from Equation 5 to solve for the temperature- and irradiance-compensated ideally expected energy (E_{IDEAL}), which might look like Equation 6:

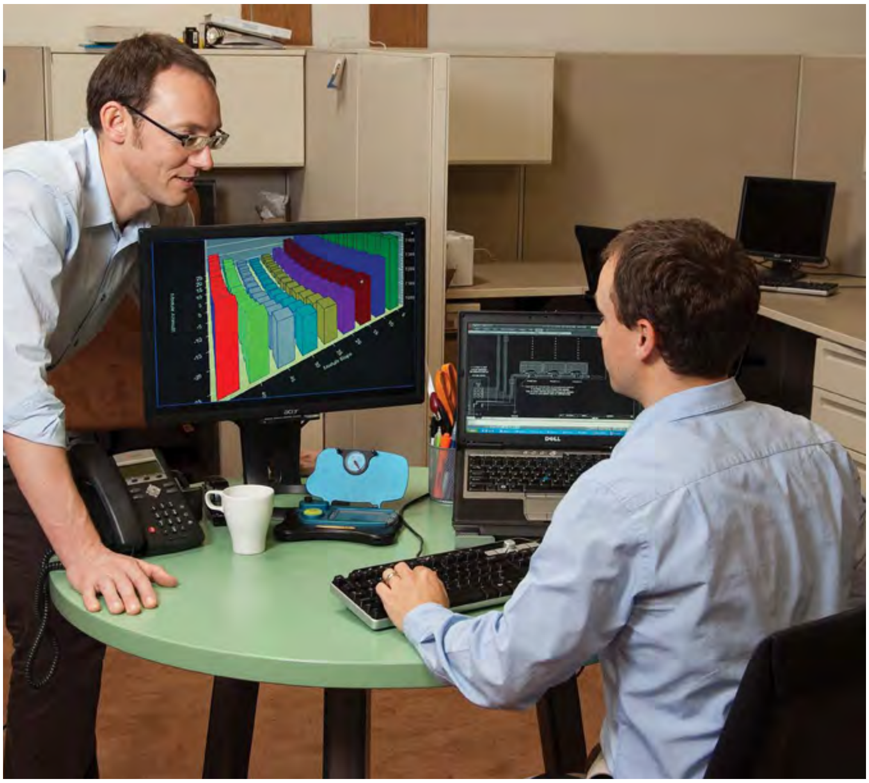
$$E_{IDEAL} = (H \div 1{,}000 \text{ W/m}^2) \times P_{TC} \qquad (6)$$

Dividing the solution found in Equation 6 into the actual measured energy over an identical period of time determines a PV system's performance ratio, as described in Equation 2 (p. 68). This index allows for the comparison of PV plants across different sites, regardless of the PV technology. It is obviously important to choose units and metrics that match the measurement equipment and resolution of data.

These formulae help to give guidance as to who should hold the risk, the EPC contractor or the project sponsor. The key to using these equations is to know their limitations, which are a function of overall project design and measurement accuracy. The results are not intended to be exact, but rather to be very close approximations given the instrumentation options. Furthermore, accurately measuring and correcting for temperature and irradiance is a powerful tool for determining system health. When combined with other plant measurements, temperature and irradiance information are useful as both troubleshooting and revenue-estimating tools.

GUIDELINES FOR MEASUREMENT, ACCURACY AND PROOF

Measurement is the backbone of a solid performance guarantee. Sometimes the performance of the meter and data acquisition system can be more important than the actual system performance. If it matters to the contract, and if it determines assessed damages, then it has to be measured and reported accurately and often. Good plant measurements lessen the challenges associated CONTINUED ON PAGE 72



Fred Speiser

Production modeling The performance assumptions underlying performance guarantee contracts must be supported by accurate and detailed system simulations that all stakeholders have reviewed and agreed on.

with verifying that performance guarantees are met or enforcing the contract terms when they are not.

Instrumentation and accuracy. All performance guarantees have to be definitively measurable. The value of the measurement is directly proportional to all parties' confidence in how it is measured. Instrumentation and accuracy should be explicitly addressed in the contract documents. A rigorous recalibration schedule is also vitally important to the agreement to help mitigate measurement errors.

Measured quantities. All parties have to agree on the measured quantities that ultimately represent the contract terms and conditions. If a contract specifies dc losses, for example, then the equipment needs to be in place to reliably and accurately measure the compliance of the dc system parameters. If there is an inverter efficiency guarantee in place, then third-party monitoring of dc input and ac output at the inverter is required at additional expense.

Identifying low performance. The PV performance guarantee terms must ensure that all relevant aspects of plant performance are quantifiable so that any deliberation as to the claim of low performance can be assessed immediately, beyond a reasonable doubt, and the magnitude of the shortfall can be specifically quantified. In the grand scheme of things, performance guarantees should prevent a PV system from persistently underperforming. Small differences between expected and actual output values are hard to justify, especially when it comes to assessing damages. A good performance guarantee helps identify and fix problems: When a PV system fails to perform as expected, there can be mutual agreement about the cure, and action can be taken to get it fixed.

Administration. Performance guarantee mechanisms always require documentation and proof for damage payment. Unfortunately, this documentation and proof process may incur excessive administrative costs. It is not uncommon for the cost of annual reporting to exceed actual damages. Some of these guarantees with cumbersome administrative requirements have clearly been negotiated with business development teams in isolation from the execution teams that do the actual work. These counterproductive guarantee terms seem to be extending further into the future, which can create decades of form filing that has little to do with keeping systems operational.

Deciding on the Details

In Part 2 of this article, we outline the major approaches to proof of performance. These different warranty or guarantee approaches ultimately determine what PV system performance measurements are required. We discuss the hardware required for the collection of plant metrics, as well as how the variables being measured actually impact plant performance and the verification thereof. We also examine the basic elements of a typical performance guarantee and what to look for when evaluating guarantee structures.

CONTACT

Mat Taylor / Quanta Renewable Energy Services / Greenwood Village, CO / quantarenewable.com

David Williams / dissigno / San Francisco / dave@dissigno.com / dissigno.com

Resources

Photovoltaic System Engineering, Roger Messenger and Jerry Ventre, CRC Press, 2000