Solar Industry

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Inverter Cost Analysis: The Right Metrics For Improved Payback

Evaluating PV performance solely on a dollar-per-watt basis may not be the most effective method, especially for inverter selection.

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In many cases, the U.S.' subsidies for solar energy are being reduced or eliminated, or touted and then delayed. Even the long-term U.S. grant scheme approved by Congress is subject to uncertainty. Therefore, we cannot count on subsidies indefinitely. The quest for grid parity without government incentives is not only healthy for our industry, but essential to its survival.

With grid parity in mind, industry players must assemble technologies and commercial arrangements aimed at lowering the overall cost of energy generation for each project. Modeling tools help developers to optimize site-level designs, but it can be difficult to fully assess trade-offs among various equipment options.

The modeling results are often measured in terms of net present value (NPV), levelized cost of energy (LCOE) or performance ratios. Even with these modeling techniques available, the industry remains anchored in performance metrics that are not fully aligned with the overall cost of energy production.

These metrics include panel energy conversion efficiency, PV dollar-per-watt production cost or selling prices. Evaluating PV performance on a dollar-per-watt basis is the equivalent of a consumer buying a new hybrid vehicle based on maximum horsepower or top speed - not the ideal metric.

Like other PV technologies, central inverters may be evaluated based on incomplete metrics. It is common for inverter users to compare suppliers on a dollar-per-watt basis. This article argues that such a consideration is incomplete and can inadvertently lead to poor decisions. Central-inverter performance perspectives must be driven beyond the unit price, or cost per watt.

A challenge for inverter users is how to organize trade-offs and make appropriate decisions. One approach is to view inverter performance through a life-cycle lens over 20 years to fully account for energy harvests, service expenses and longevity of equipment.

Therefore, inverter contribution to project performance can be grouped into three areas: energy harvest (revenue generation), balance-of-system (BOS) costs (capital investment), and operations and maintenance (O&M) costs (life-cycle service expenses).

Calculating energy harvest

The most obvious metric used to evaluate energy harvest is the inverter power conversion efficiency across load factors ranging from 10% load to 100% load. In the U.S., publicly available data from the California Energy Commission and the California Public Utilities Commission provide this metric.

In Europe, however, the standard of comparison is not as consistent as in the U.S. For example, in the European Union, where indoor inverters are commonly put into enclosures, energy requirements to move or condition ambient air must be deducted from inverter harvest energy.

A 15 kW, nominal air-conditioning load for a 1 MW power station equates to a 1.5% efficiency loss. These overhead energy sinks may not be accounted for in inverter datasheet efficiency figures.

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Uptime is an emerging metric and a substantial consideration for overall PV site performance. The central inverter has been cited as a primary cause of lost production; in years past, inverter uptime was sometimes less than 97%. This is the equivalent of over 10 days of downtime every year - an unacceptable loss.

To combat this challenge, some inverter manufacturers have developed uptime guarantees, whereby developers pay for assured uptime and receive penalty cashflow for downtime - an insurance plan that eliminates one variable in a project's financial model.

Buyers must keep in mind that the uptime algorithm must be precise, yet simple enough to ensure effective implementation. One approach is to measure uptime in terms of availability versus theoretical "sun minutes."

Specifically, if the inverter is available (in standby mode or converting energy), it is up for the following amount of time: uptime = available = (standby + conversion minutes) / (total theoretical sun minutes). This simplicity isolates the inverter from other plant performance factors, such as ground faults, maintenance, and weather or panel issues.

One harvest factor that is sometimes not addressed by industry modeling tools is accounting for BOS accessories and array architectures that affect capital costs and energy harvests. A developer must be sure to calculate all the costs and benefits.

For example, a bi-polar architecture with a remote PV-tie accessory eliminates home-run cabling costs - although, of course, the accessory hardware and installation are not free. However, this approach does eliminate array cabling, and overall energy harvests may increase by 0.3% to 0.5%.

Other mid-array component solutions must be assessed from all angles: harvest, BOS cost and O&M expenses. A supplier's application engineering team should add value by helping developers confidently evaluate all trade-offs. In-depth applications engineering support from the inverter supplier is critical in order to enable the developer to realize maximum performance and evaluate trade-offs on a project-by-project basis.

So, what is the incremental energy harvest worth? Each project is unique, but a simple calculation suggests that the value of just 1% incremental inverter harvest may be worth in the range of $15,000 per 500 kW inverter - a high fraction of a typical inverter unit cost. (Assumptions: incremental harvest of 1% per year, 2,000 sunny hours, $0.20/kWh, 500 kW inverter, NPV based on a 20-year period, 12% discount rate).

> The PV industry will benefit from increased precision of LCOE-oriented evaluation criteria aimed toward grid parity and the life-cycle cost of energy.

Adding BOS costs

Here is where dollar-per-watt calculations are directly tangible and intuitive. Electrical BOS costs are the sum of all up-front equipment and installation costs, including the price of the inverter. Challenges in this area include making sure that all required components are identified correctly and estimating the actual cost of installation, including labor and transportation.

Is the inverter monitoring system included in the unit price? What are the delivery terms? What is the standard warranty period and warranty definition? Is the switchgear included? Can a standard, medium-voltage transformer be used with numerous inverters, or is a special multi-tap winding required (higher unit price, lower efficiency, longer lead time)? These variables can swing the cost per watt by ±15% or more.

The up-front capital investment is also affected by the substation scheme and strategy of the engineering, procurement and construction processes. To accommodate convenient installation, 1 MW and recently introduced 2 MW integrated containers can be trucked to the PV site and quickly installed.

Developers should evaluate the supply chain for these solutions to assess warranties and avoid costly margin stacking. Another approach is to avoid unnecessary and redundant enclosures and utilize outdoor-ready inverters on a pre-fab-skid or concrete pad.

Some approaches can require more on-site labor and planning but may provide a lower landed cost. Decision-making is based on trade-offs, involving labor cost, value of convenience, value of delivery risk, location, and inverter environmental tolerance.

Getting excellent long-term performance from the central inverter requires proactive maintenance and sometimes reactive high-speed service. Thus, evaluation and selection of the ideal inverter must not overlook service factors; a complete project life-cycle perspective is necessary to capture long-term costs.

The inverter standard warranty must be considered carefully up front, as all warranty terms are not the same. In the U.S., a five-year term plus a five-year extension is typical. In Europe, two years' coverage is common.

For any warranty, read the fine print: Does the warranty cover only workmanship and materials, or is it comprehensive? Some warranties exclude wear parts, such as fans or blowers. Extended warranties may also have exclusions. Who pays for technicians to travel to repair, for instance? Does the supplier include product training? How responsive is the supplier?

Service needs

Service speed is related to energy harvest, as it affects uptime, but service also must be evaluated as a downtime expense during the warranty period and for the entire project life. Slow service equals a downtime expense.

Some suppliers may treat service as a burden - under-resourced to save cost - while their prime business is selling hardware. It can be argued that a company alignment of service as a profit center is more likely to perform at high speed and be execution-oriented in order to generate long-term profitable repeat business.

What is the supplier's response time, both to assess and to fix issues? These times should be measured in hours, not days. Does the inverter provider have service programs beyond just their inverter? Some suppliers have expanded service programs to address the entire array, including inverters made by other manufacturers.

Such programs may reduce project costs via fewer truck rolls, and they can ease supplier management and reduce risks by consolidating contracts.

The financial modeling norm for PV projects is to plan a future O&M expense to replace inverters around year 10. This expectation is an embarrassment to the inverter industry, especially to advanced suppliers with products designed for a 20-year useful life.

Depending on calculations and assumptions, the NPV of a long inverter life may be on the order of $20,000. This is a high percentage of the unit price (comparison of 10-year and 20-year 500 kW inverters, assuming longevity maintenance expense years 10-20 and 20-year warranty vs. replacement unit cost, downtime, install, disposal and 12% cashflows discount rate).

Realistic product-life projections depend on the design margins, component selection, qualification rigor, cooling-scheme effectiveness, isolation from contaminants such as dust and moisture, and design for serviceability. Evaluation of these factors can significantly lower O&M expense projections for favorable project LCOE.

Regardless of the specific assumptions and metrics, the PV industry will benefit from increased precision of LCOE-oriented evaluation criteria aimed toward grid parity and the life-cycle cost of energy.

Because inverters are a critical gateway to photovoltaic site performance, suppliers and developers must take an assertive role to fully assess the project life-cycle contribution of the central inverter to progress beyond the dollar-per-watt mind-set.

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