Solar Industry
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How To Integrate PV Monitoring Systems

Photovoltaic project size, data requirements and local environmental conditions will affect monitoring decisions.

AJ Rossman

Selecting the right remote monitoring solution (RMS) - a data acquisition system with a Web-based user interface - is an important step in ensuring that the return on investment for a solar project is maximized. A properly matched and configured RMS should pay for itself many times over during the life cycle of a typical PV system through improved energy production and reduced operational and maintenance costs. The wrong choice, however, can lead to increased expenses and frustration, as well as lost revenue due to suboptimal energy production.

When selecting an appropriate RMS, the project designer needs to balance advanced technical features and system reliability with initial system cost. For a large commercial or utility-scale PV project, a more sophisticated RMS makes economic sense, because failure to detect or pinpoint underperforming assets in a timely manner can be costly, particularly over the entire life of a typical PV project.

Similarly, demonstration projects that require scientifically defensible data sets require more technologically advanced RMS capabilities than small commercial or residential projects do.

For a project of any size, planning for an RMS is best done during the PV system's initial design phase. Just as a scientist defines research objectives before developing a data-collection methodology, PV system designers should outline their data-acquisition requirements before selecting an RMS. Integrating the RMS into the PV system design will save time and money during the installation and commissioning of the RMS and help installers troubleshoot problems. It will also allow an accurate baseline of energy production to be established and allow performance-based incentives to be captured earlier, boosting the project's return on investment.


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Some RMS questions to answer during these planning stages include the following:

- What are the data-reporting requirements that must be met in order to take advantage of performance-based incentives, feed-in tariffs and renewable energy certificates?
- How granular do the data need to be? Is string-level or sub-array monitoring needed to support ongoing maintenance and troubleshooting efforts, or is system-level reporting appropriate?
- Is looking at simple trend data sufficient for proper decision support and troubleshooting, or are performance indexes and other real-time key performance indicators required to meet performance goals?
- To what environmental conditions will the RMS hardware and instrumentation be subjected, and how might these conditions affect the integrity of the data that are reported?
- What is the time horizon for owning and operating the PV system? If it is long-term, what is the expected reliability of the RMS? If it is short-term, will the RMS provide the level of performance data needed to support a successful transfer of ownership?
- What is the value of a continuous data set? What type of redundancy does the RMS need to provide and ensure that data are not lost in the event of a power or communications interruption?
- Is the operator managing a single project or a portfolio of projects around the country or world?
- Is a performance contract or guarantee involved and, if so, will the RMS support defensibly calculated deviances based on the contract language?

Installation costs

Today's large-scale solar power plants are increasingly complex due to the number and spatial placement of inverters. Measuring a single inverter system between 100 kW and 500 kW can be straightforward; however, this task becomes more difficult when multiple inverters, multiple module technologies or multiple installation methods (e.g., rooftop, carport, field, trackers, etc.) are employed. Important considerations when planning a multi-inverter site include equipment placement, communications coordination using one or more gateways, and the level of monitoring required.

Poor up-front RMS design can lead to increased installation costs and limit the operator's ability to remotely troubleshoot future problems as they arise. Integrating the RMS design into the power system design saves on installation costs, because the data and power infrastructure can be installed simultaneously, and installers are not left guessing how best to install the monitoring system. Inadequate documentation and technical support will also hamper the installation process and result in increased costs.

Even though the monitoring system is primarily a low-voltage system, some of the components interact directly with the power system, including the energy meters, smart combiner boxes and recombiner boxes. RMS equipment that includes integrated fusing and safety equipment decreases installation costs and minimizes the possibility of workplace accidents.

Any delay in the installation of the RMS can affect both the installer and the system owner. In most contracts, final payment to the installer is not released until the power system is fully commissioned and validated by the RMS. Similarly, system owners cannot begin receiving incentive-based payments or other revenue until the RMS is fully functional.

An RMS generally includes a data logger or on-site computer, environmental sensors, external energy meter(s), communications devices for inverters and a gateway for moving site data to a remote server. Just as the power system is designed to operate for long periods of time, so should the components used to monitor the power system. The importance of accurate data collection by the monitoring hardware increases over time, because the older the power system gets, the more prone it is to degradation and failure.

Lower-cost components that are not designed to operate in harsh environments are more likely to fail over time when exposed to the elements and can end up costing much more in the long term when field-based repair and replacement costs - along with the potential loss of incentive-based payments - are factored in. In addition, significant hidden costs associated with missing or bad data add up quickly when valuable engineering resources are used to try to reconstruct discontinuous data sets and interpolate missing data resulting from monitoring-system failures.

Most performance-based contracts include some measure of undeliverable energy due to grid outages or other conditions outside of the developer's control. Being able to pinpoint when these events occur and collect the data required to defensibly quantify lost generation is key to minimizing contract disputes.

For these reasons, monitoring systems should include battery backup and on-site data storage in order to minimize gaps in the data sets. Missing or incorrect measurements can call into question the credibility of a data set. The value of a monitoring system and the data it collects is highest when the PV power system or supporting grid is not functioning properly.

Accuracy of field equipment

Establishing an accurate performance baseline allows owners and operators to make more informed decisions regarding the ongoing performance and maintenance of a PV system. An accurate baseline makes possible valid comparisons between actual, real-time performance and initial design assumptions. An accurate baseline also allows for the quantification of system losses due to environmental conditions such as soiling, theft or component failure.

Inaccurate or inconsistent data sets undermine the effectiveness of baseline comparisons and can lead to poor decision-making with respect to the operation and maintenance of a solar system. It is important to remember to budget for data acquisition system maintenance and sensor calibrations to ensure ongoing, accurate baseline performance comparisons.

Many system operators focus on sensor accuracy, because it generally has the highest error rate. However, it is equally important to consider the integrity of the data logger used to measure the sensors. Data loggers must function in harsh environments and are often subjected to extreme temperature fluctuations that can cause short-term temperature-biased measurements and long-term measurement drift. Selecting a data logger that is designed specifically for outdoor usage and includes temperature compensation and self-calibration can mitigate these concerns.

Like the power system itself, the RMS should be commissioned to ensure that it is functioning properly and is accurately measuring components within the PV system. The environmental sensors should be checked on-site to make sure they are installed to industry best practices, and their locations and orientations should be documented.

Measurements reported remotely should be compared to on-site measurements to ensure the fidelity of the RMS. Information collected from inverters and meters should be checked on-site to confirm that equipment is set up properly and that data reported from Inverter 1 is not actually coming from Inverter 2. Some RMS vendors and engineering firms offer commissioning services to validate proper monitoring-system installation.

Knowledgeable, reliable customer service relieves stress and helps keep projects on time and on budget. For hardware platforms, access to qualified personnel means that system operators will not need to waste valuable internal resources trying to troubleshoot problems on their own.

Similarly, contracting with a third party for Web-based services can offer customer support for troubleshooting connectivity issues and keeping the system up and running. Selecting a turnkey solution from a single provider that supports both hardware and Web services, on the other hand, minimizes vendor management.

Data reconstruction

One of the largest hidden costs associated with operating and maintaining a solar power plant is the required time and internal technical resources spent reconstructing missing data. Whether due to RMS component failures, power outages or communications interruptions, lost data can burn up significant internal resources and result in lost revenue due to under-reporting actual energy production.

During the early days of remote monitoring, project technicians and engineers were expected to troubleshoot remote communications for data collection, formatting, validation and analysis. By contrast, today's Web-based interfaces and third-party monitoring solutions provide many of these services for a fee. In addition, some third-party monitoring services offer network operation centers that interpret performance data and dispatch resources to manage solar installations. Such services allow PV system owners and operators to focus on tasks other than having to collect, process, display and analyze remote data from their solar assets.

The granularity in the data collected, along with the sampling frequency, is a function of what the owner and operator feel they need to effectively manage their sites over long periods of time. As one would expect, more data points generally provide more accurate remote troubleshooting, but this level of information comes at a cost. For large projects, this is generally a small percentage of the total project cost and one that can usually be recovered through increased energy production and decreased operations-and-maintenance costs.

The most basic level of monitoring involves relying on an energy meter to tell whether the PV system is on or off. Monitoring inverter communications provides a step above this most basic level by giving operators access to information measured by the inverter, as well as fault and warning codes that are useful for system troubleshooting.

Solar resource and back-of-module temperature sensors provide even more accurate performance data by supporting system modeling that predicts the energy that the system should be producing based on site-specific environmental conditions and power system configurations. This information, in turn, allows the actual production to be compared to expected production based on field conditions, yielding a highly useful calculated performance index.

Data from additional environmental sensors measuring parameters such as ambient temperature and wind speed are sometimes used to further enhance performance models. DC-level monitoring at the sub-array or string level provides information that can be used to remotely isolate maintenance problems in large systems before a service technician is dispatched to a site.

For multi-site projects, a Web interface should display performance metrics on either an aggregate or site-specific basis to support the varying information needs of individual end users. For system owners that need to quickly scan overall system output or review incentive-based reports, an uncluttered dashboard portfolio view will simplify data access and management.

For system operators and maintenance personnel who may need to drill down on site-specific data, having a simple way to access detailed project data will streamline troubleshooting efforts. In addition, an attractive public display optimized for kiosk-type viewing can be a powerful tool for educating and informing stakeholders about a company's commitment to renewable energy and environmental stewardship.

When specifying an RMS, system operators should understand their prospective system vendor's policies. What are the terms and conditions of the warranty for the RMS hardware and instrumentation? What level of field service, if any, is included to support design, installation and commissioning? Are updates and upgrades to the Web-based interface included as part of the contract for ongoing monitoring services, or will these enhancements cost extra? What type of access will be provided to historical data if ownership of the PV system is transferred during the life of the project? What type of security is provided to ensure that confidential project data are backed up and stored in a secure, off-site facility?

There are a number of high-quality RMS solutions offered on the market today. The trick is matching the right monitoring solution to the project based on the requirements of the specific system. If the purchaser performs adequate up-front planning, the RMS should quickly pay for itself through enhanced energy production and lower maintenance and operations costs.

AJ Rossman is founder and chief technology officer of Draker Laboratories, a provider of performance-monitoring solutions for commercial and utility-scale PV power plants. Rossman has over 15 years of experience in renewable energy. He can be contacted at aj@drakerlabs.com.