WHITE PAPER

Best Technology Practices: Effective, Utility-Scale Solar Power Resources

Overview

This white paper presents technology's role in three areas:

- Regulatory compliance
- Operations
- Asset management

Underlying all three of these areas, technology serves to:

- Reduce risk
- Optimize generation
- Maximize profitability
- Deliver power on schedule
- Extend asset life

In utility-scale photovoltaic (PV) power generation, many elements must be synchronized in order to achieve the greatest possible effectiveness. Utility-scale PV developers and resource owners who want to deliver on schedule, reduce risk, meet compliance requirements, and maximize generation must address a wide range of issues that are imperative to a successful development and long-term profitability. This paper discusses the capability of solar generation facilities and their role in providing voltage control and reactive power by coordinating functions of PV inverters and dynamic and static reactive devices to maintain desired voltage at the Point of Interconnection (POI).

Technology plays an essential role in overall effectiveness of PV resources. One consistent approach of effective PV resources is that they treat technology as a strategic imperative – similar in importance to the other six success factors. This paper discusses how monitoring instruments, information systems, and operational control work together to help PV resource owners meet compliance requirements, operate effectively, and fine tune equipment performance.

Consider the sophistication of instruments, intelligent devices, and sub systems installed at a typical PV resource and the dynamic nature of PV power generation operations. The sheer volume of data means that users need management tools to capture the data, put it in context, and analyze. Power-system operators must also be able to quickly analyze data and react accordingly. Your technical systems are essential to your ability to monitor, manage, control, and optimize the resource. Technology systems deliver information that resource owners, balancing authorities, and utilities require to make informed choices about real-time operation and guide decisions about future development.

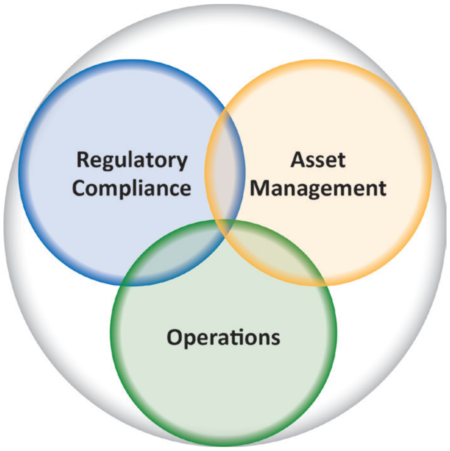
Technology & Compliance

ISOs, balancing authorities, and host utilities establish requirements that resource owners must meet in order to connect to the electric grid and participate in the energy markets.

Requirements addressing business, electrical, environmental, security, and data exchange are typically defined in the interconnection agreement and Power Purchase Agreement (PPA) with a host utility. Additional requirements may also be defined in the business-practices manual of the ISO/balancing authority. It is ultimately the Resource Owner/Developer's responsibility to understand all of the requirements and deploy technology, instruments, and communications networks that comply with these requirements.

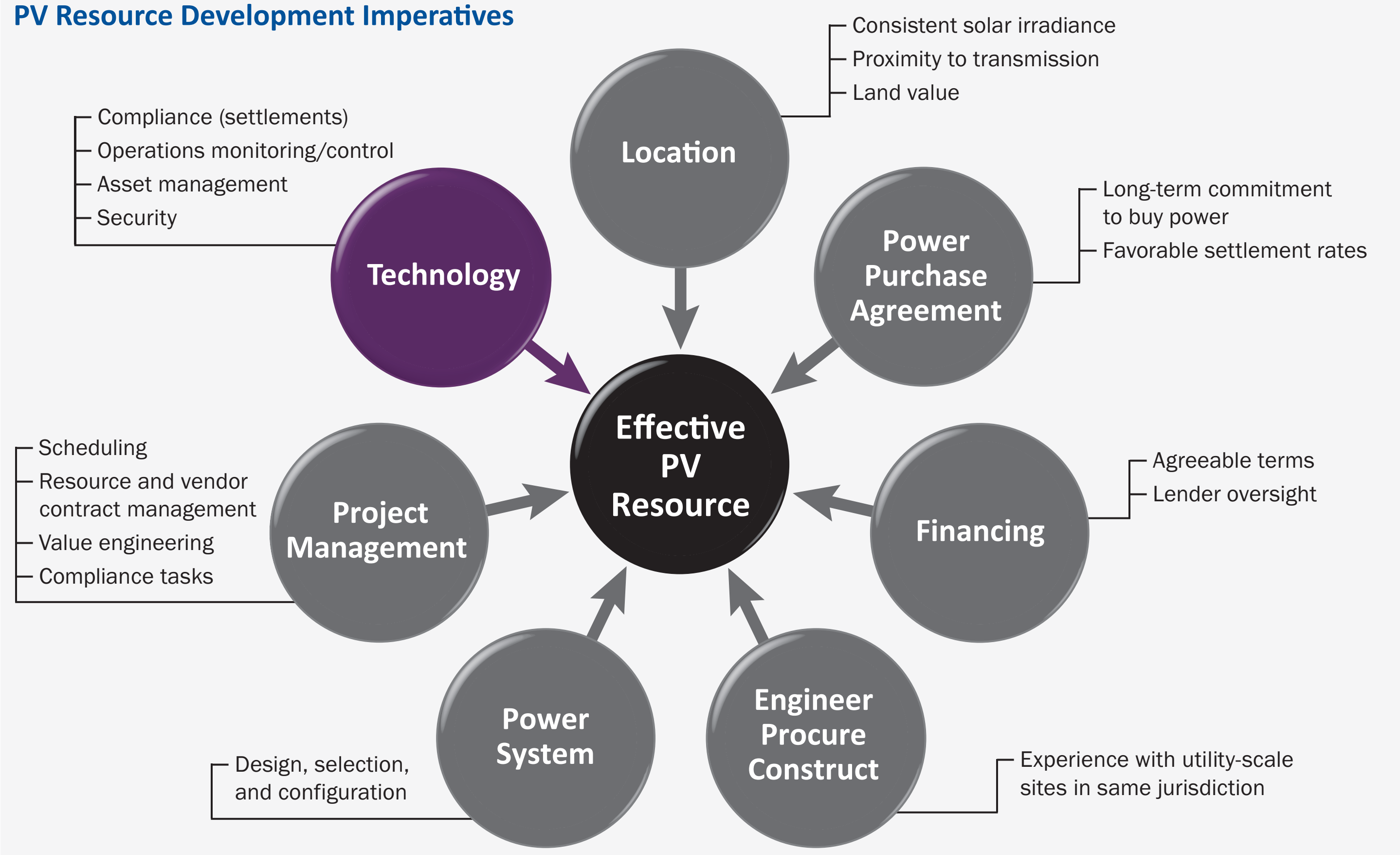
"Using technology to monitor and control your power-generation facility is good for the grid and good for business," says Dean Schoeder, Chief Marketing Officer at Trimark. "That's why ISOs and host utilities demand it – and you should, too."

To avoid delaying their Commercial Operations Date (COD), developers must successfully meet all of the compliance requirements. Failing to deploy mandated technology, in the manner specified, can directly affect grid synchronization – sometimes delaying the start of power generation. Should this occur, it will disrupt your revenue stream and delay profitability.



You need to work with a team that understands the technical requirements and associated schedules required to achieve commercial operations. In the case of compliance, technology and administrative paperwork are inseparable.

PV Resource Development Imperatives



Compliance-related requirements result from business drivers that fall into four general categories:

Ensure Accurate Settlements with Certified Revenue Metering

As the "cash registers" of the electric industry, revenue meters track energy delivered to the grid. The resulting "settlement-quality meter data" is used to document power transactions, so it literally pays to get it right.

"Failing to supply settlement-quality data means you will not be paid," Schoeder explains. "It's that simple."

In some markets, rules require that the resource owner follow a highly prescriptive, multi-step administrative process to attain meter certification. It is essential to acquire appropriate approvals at each step in the process in order to avoid delaying the commercial operations date.

Revenue meters are the primary tool required to ensure accurate settlements. Meters used for utility-scale generation, together with their associated current transformers (CTs) and potential transformers (PTs), typically measure to within 0.3%. Revenue meters must meet the accuracy rating specified by the host utility or balancing authority. Nearly equal in importance is the meter's ability to communicate. Communication options include telephone lines, cellular modems, radio systems, and connection via a secure T1.

"The meter is only one piece of the puzzle," said Dean Schoeder. "The complexity of meter configuration, the fact that meters are typically located in high voltage areas, and the meter certification mean that revenue metering requires trained professionals to complete the job correctly, safely, and with integrity."

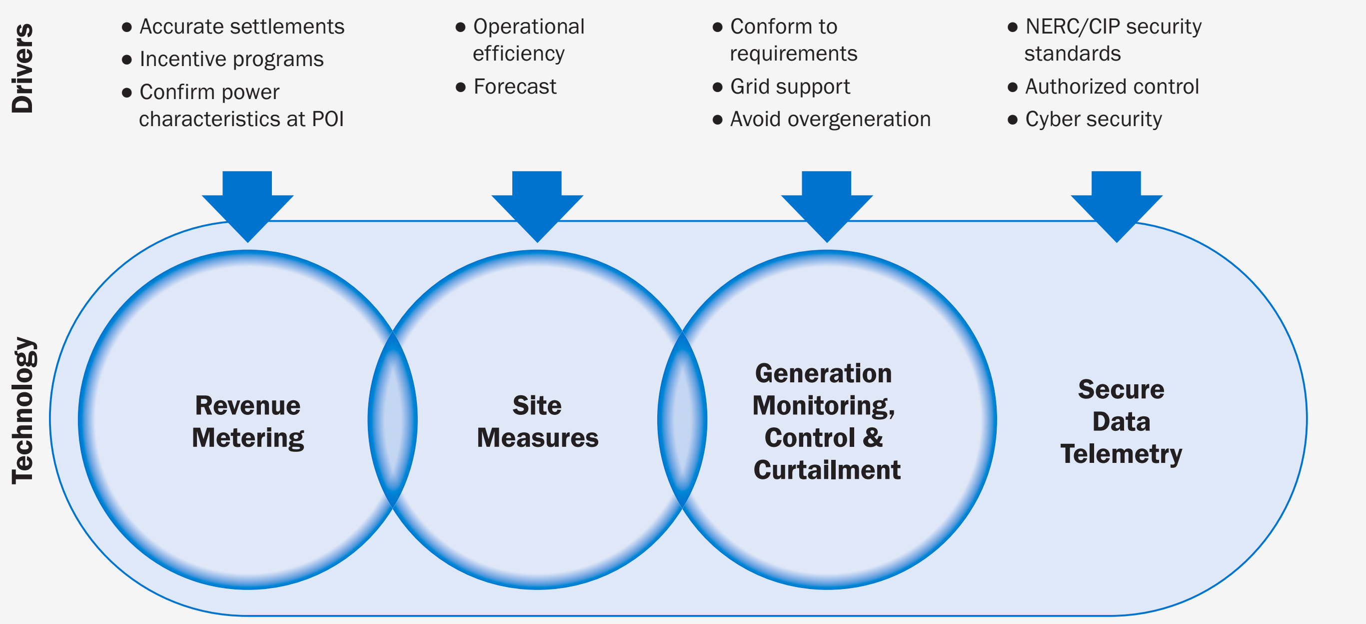
Site Meteorological Data Supports Grid Balancing and Modeling

Balancing authorities require short-term energy forecasts for use in real-time grid management. They use long-term projections to model the impact a planned resource will have on the electric grid. Predicting and managing generation, therefore, requires meteorological (MET) data to:

- Meet PPA requirements
- Model performance of a potential solar site
- Establish a baseline to calculate performance efficiency and assess compliance
- Provide key data required to forecast power production

> ***"Failing to supply settlement-quality data means you will not be paid."***

Compliance Business Drivers and Technology



Meeting a PPA's meteorological requirements can be costly. Some jurisdictions require one MET station for every five MW of generation. Others require irradiance and meteorological sensors at every inverter pad. "Some PPAs also require instrumentation such as rain gauges, rotating shadow bands, and secondary standard irradiance sensors with a heater and ventilation," says Lord Toliao, Trimark Senior Manager. "It's essential that you clearly understand all requirements for instruments in order to comply with the PPA."

Having a reliable, precise meteorological measurement system increases the certainty of forecasting energy production and helps ensure the highest efficiency of solar power generation. "Today, we are seeing many resources that are installing soiling stations in conjunction with their MET instruments as a way to determine the amount of lost generation resulting from dirty PV panels. This helps resource owners make decisions about when to schedule a panel cleaning based on the differential between irradiance and generation," says Toliao.

Grid Management

One imperative for regional electric utilities and balancing authorities is to ensure the stability of the electric grid. At the heart of many compliance issues is the need to ensure that generation resources deliver stable, reliable power at the (POI). With recent growth in variable resources such as solar, this capability is becoming more challenging. In order to support grid stability, utilities have begun to require that generation resources have the ability to curtail generation and be able to control voltage and frequency. Technology systems ensure that this occurs automatically while maximizing the allowable real power output.

Imperatives of Best-in-Class Technology

Monitor:

An effective SCADA system provides reliable information in context of the user's business need. It delivers information to the user when and where he or she needs it.

Measure:

All manner of instruments support real-time measurement: revenue meters, meteorological stations, and the data generated by inverters. Considerations for effective measurement include the method and rate of collection (scan rate), reliability, presentation, and archiving.

Control:

Control systems automate business rules designed to optimize site generation. Considerations include secure data telemetry, enterprise commands, automation, safety, and grid stability. Real-time control based on measurements taken at the POI help ensure stable power characteristics and maximum output.

Automated Curtailment Order Response

In some cases, contracts may require that the resource respond to an authorized set point order sent by a balancing authority or utility. For example, many utilities require PV resources to respond to a curtailment order within minutes. In these cases, automation is the only practical way to comply.

Because many sites operate in an unmanned status, they must be able to validate and execute a curtailment order sent from a central dispatch point such as a Regional Operations Center (ROC).

"Having the ability to unify commands across your operations management system can greatly simplify the response to a curtailment order with the greatest accuracy and lowest strain on resources," explains Bob Wood, Trimark's Chief Technology Officer.

Managing Voltage and Frequency Characteristics

Site control systems help maintain grid stability through automated logic designed to adjust voltage, VARs, frequency and power factor at the POI. They also help protect the resource's interests by creating a historical record of exactly what occurred at every second of connection.

A SCADA system should automatically maintain the target voltage at the POI despite changing conditions – a given in electrical power. These systems must unify command of inverters throughout the array based on measured conditions at the POI. The system must synchronize real-time adjustments across multiple inverters to achieve all desired power attributes.

"Some utilities now require that PV resources provide capacitive or inductive reactive capabilities," says Wood. "Rather than install expensive capacitor banks or other devices to meet these requirements, savvy resource owners can leverage their SCADA system to achieve the target power factor at the POI."

The SCADA system should coordinate and automate real-time adjustments to both capacitor banks and inverters in order to deliver the specified set point at the POI.

Secure Data Telemetry

"Data is a critical element of electrical-grid management and business operations," states Wood. "That means telemetry plays a vital role in both the security of a site and the generation capacity. The telemetry systems must have robust security capabilities to meet the growing needs of solar resources."

It is essential to protect the security of data and commands that are exchanged with the site. Telemetry is used by balancing authorities and utilities to conduct real-time management of the electric grid. These authorities also need to protect the integrity of commands and instructions issued to generation resources. Moreover, the data from a site is essential to supporting accurate settlements, proprietary information that is tightly protected as a trade secret by most resources owners.

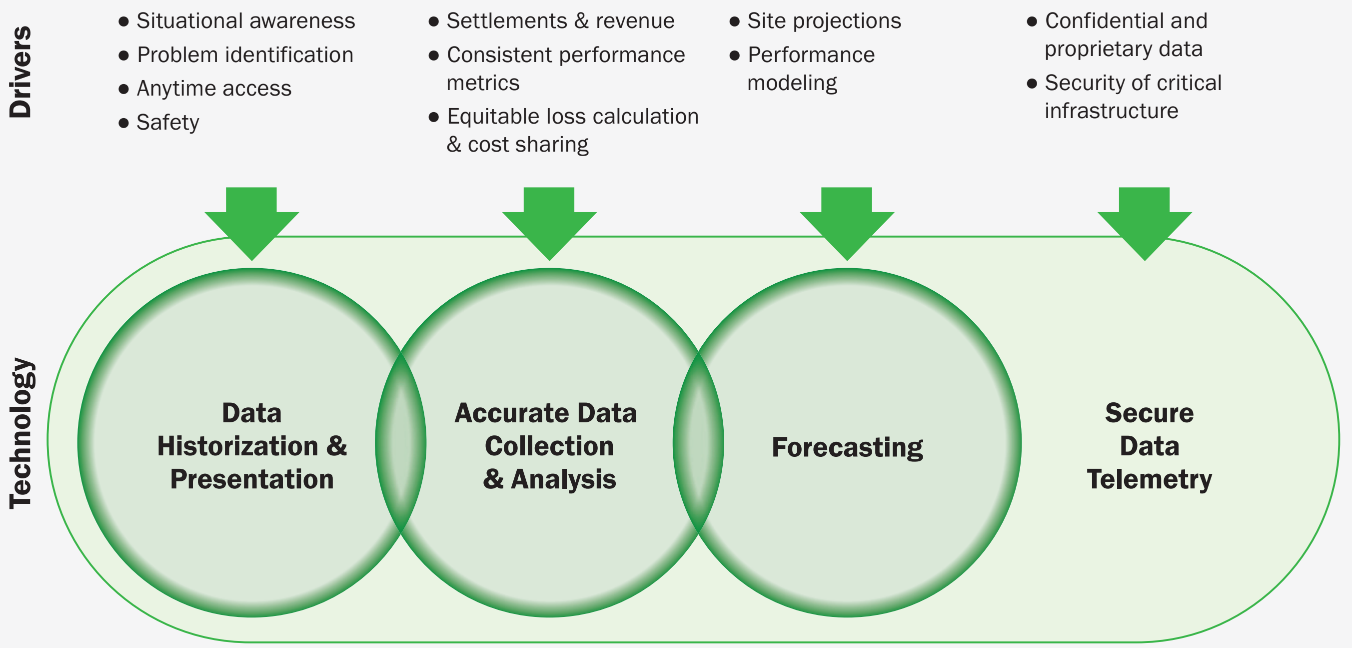
In order to ensure the security and integrity of critical infrastructure, security policies have been established by the National Energy Regulatory Commission (NERC). These policies are deployed through rules and regulations enforced by local entities. The infrastructure requirements to comply with these rules may include a private, secure connection to a dedicated energy network (such as CAISO's ECN). This may also require that telemetry devices utilize security protocols such as DNP and SSL.

Technology & Operation

The primary business objective of utility-scale PV resources is to maximize power generation and income. The related business drivers fall into four general groups:

- Situational awareness
- Accurate settlements of energy transactions
- Forecasting and performance modeling
- Secure data telemetry (See previous discussion).

Operations Business Drivers and Technology



Situational Awareness

The axiom "if you can't measure it, you can't improve it" is particularly relevant to monitoring and maximizing the Performance Index (PI) of a PV resource. Accuracy and timeliness in measuring asset performance is essential to maximizing effectiveness.

"The sooner you know you have an under-performing asset, the faster you can remediate the problem," Schoeder says. "This helps ensure the resource can generate its maximum power potential."

Field instruments including irradiance sensors, back-panel temperature sensors, and meteorological sensors provide key data to determine if the site is performing as expected.

PV-site managers with precise knowledge of their site's real-time and historical performance, meteorological conditions, grid requirements, and market demands have the tools and information required to wring every potential dollar from their operations.

> ***"PV-site managers need precise knowledge of site performance to wring every potential dollar from their operations. "***

Accurate data supports your ability to make reliable plans for maintenance, repairs, and future plant development. For example, you may want to evaluate the performance of inverters provided by Manufacturer A compared to Manufacturer B. Or, you need to look across multiple sites and aggregate data to identify differences and/or long trends. This visibility can be valuable in making informed decisions about the next site you develop.

Many technologies must be integrated to present a complete and accurate picture of site status. The chain of data starts with revenue meters, meteorological stations, back-panel temperature sensors, and inverter data loggers. A SCADA system and associated historian can monitor these instruments, then consolidate and present data.

Turning that data into information requires putting it in a context that is consumable by, and relevant to, specific users and roles. To accomplish this, a SCADA system displays information in an accessible manner, alerts users to an event or anomaly, and supports performance analysis and forecasting.

Accurate Settlements

With millions of dollars at stake, accuracy is critically important in settling accounts. Revenue metering requires configuration, testing, and certification by experienced, impartial meter technicians and inspectors.

Accuracy climbs to another level of importance when resources share a generation tie line to connect with the electric grid. Variability in current and distance can result in fluctuations in line losses and associated effects on settlements. Using static formulas to calculate losses is inadequate because losses vary with changes in line loading. This occurs with changes in current from each resource, temperature changes, and other variabilities.

Advanced metering systems can calculate losses dynamically in near-real time. This advanced approach calculates each resource's portion of the line losses based on actual power delivered to the POI at any point in time. The result is an equitable division of line losses and higher accuracy in settlement values.

Forecasting and Performance Modeling

Projecting site performance is valuable while developing a resource as well as during commercial operations. Accurate projections are important in obtaining financing for development.

Similarly, utilities and balancing authorities need to model how a site will impact the electric grid.

Data required for pre-connection forecasts and modeling is typically gathered using temporary meteorological instruments that collect data for up to a year. Fully commissioned sites gather data from meters, meteorological sensors, back panel temperature sensors, irradiance sensors, and site SCADA. This production data can be used to project actual performance into the future. When the differential between actual and projected performance exceeds a predetermined threshold, a SCADA system can issue an alert that the site is performing below expectations.

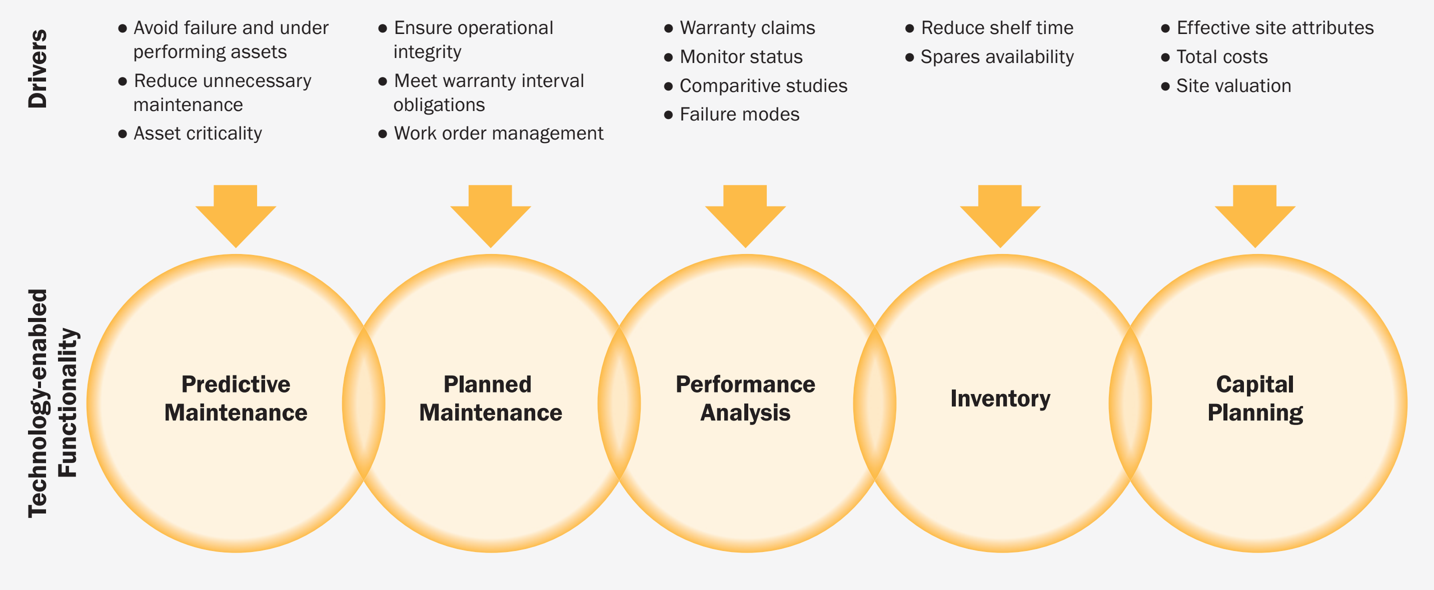
Technology & Asset Management

Information is the foundation of effective asset management. This information is generated by SCADA systems, work-order management systems, inventory systems, and financial systems. In order to present data in context, asset management requires tight systems integration. By sharing data between systems managers, can deploy asset management strategies including performance management, failure mode analysis, warranty management, capital planning, training/certification programs, and scheduling.

Rather than making maintenance decisions exclusively on a schedule, operational data helps identify conditions and trends that are difficult to see in the short term. The site SCADA and historian system can be used to identify leading indicators of wear (e.g. inverter starts and stops or curtailments), failure modes (e.g. increased losses within a device), or indexes that compare data gathered from multiple devices (e.g. deviation from a trend). While predictive-maintenance strategies require reliable data and sophisticated analysis, this approach helps avoid unnecessary and/or emergency service activities.

Early indicators of failure can be detected by analyzing historical data. With information about how many times an inverter has tripped off and reference data on expected asset life and known service issues, you can minimize downtime and outages and manage performance throughout the warranty period. As you continue to collect data and develop more detailed history, data increases in value. It becomes possible to parse out trends long before they would be apparent to the naked eye. Through systems integration between SCADA and the work order system, exceeding a threshold or trend can trigger an alert and initiate a work order. ■

Asset Management Business Drivers and Technology



Summary

The overall effectiveness and resulting profitably of a utility-scale PV resource depend on a number of functional imperatives that are tightly aligned. Your technology platform has an overarching and long-term effect on resource effectiveness.

There are four key practices that every PV resource developer should incorporate into their development efforts to ensure the best possible outcome:

- Integrate information systems into project development from the very start.
- Make data security an imperative.
- Identify ALL technical / instrumentation requirements of your PPA and interconnection agreements.
- Leverage automation to optimize generation.

Ultimately, your technology choice may determine whether the new PV resource is a financial success or failure. It is clear that careful technology selection must be integral to the initial design and made in context of how the technology will support and integrate with all aspects of your resource. Sourcing that technology from an experienced and proven supplier ensures that your PV site will realize its maximum generation and profitability levels.

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