

Solar Photovoltaic Plant Operating and Maintenance Costs

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Solar Photovoltaic Plant Types and Components

Solar cells can be classified into three “generations” which indicate the order in which each became prominent. Currently, research is being conducted on all three types of cells. The first generation technologies accounted for 89.6% of 2009 production

- ◆ *First Generation Photovoltaic (PV) Cells* consist of large area, high quality, single junction devices. First generation technologies involve high energy and labor outputs, preventing any significant progress in reducing production costs
- ◆ *Second Generation PV Cells* have been developed to address energy requirements and production costs of solar cells. The manufacturing costs are lower than first generation, but due to inherent defects, the efficiency is lower
- ◆ *Third Generation PV Cells* or advanced thin-film photovoltaic cells are a range of various alternatives to the first and second generations

A utility-scale solar PV plant is made up of the following*:

- ◆ Photovoltaic panels
 - The PV panels are composed of solar cells that convert the sun’s rays or photons into DC electric power
 - Panel trackers are mechanisms used on some PV systems allowing the solar panels to track the sun throughout the day for optimal power production
 - Trackers can enable the system to produce more power but also require more maintenance than stationary systems
- ◆ The balance of system (BOS) components
 - The BOS components include such things as wires, combiners, junction boxes, mounting equipment, conduit runs, and communications equipment**
- ◆ The inverter
 - The inverter is the unit that conditions or converts the DC electricity produced by the solar cells into AC electric power

*U.S. Department of Energy, 2010, www.doe.gov

**Banke, Bryan. “Solar Electric Facility O&M: Now Comes the Hard Part” three-part series, Oct-Dec 2009, www.renewableenergyworld.com

Estimating Solar Photovoltaic O&M Costs

The number of grid-connected solar PV systems is expected to increase dramatically over the coming decades. This increase in the number of PV units leads to an increased focus by utilities and other solar generating firms on achieving the highest level of performance and reliability from the solar asset. In addition to thinking about up front costs of the solar plant, determining a plan and budget for ongoing operations and maintenance (O&M) expenses is essential in assessing the business case for a PV facility

- ◆ Government incentives and regulations are leading utilities to think about ownership of solar-based generation plants
- ◆ A shift from the current power purchase agreement (PPA) approach to obtaining solar energy assets outright creates a need for utilities to come up with a plan for regular maintenance on these PV plants
- ◆ As a new solar plant nears completion, operation and maintenance (O&M) assumptions must be revisited to ensure that adequate funding is set aside for the reliable operation of the asset
- ◆ Deriving O&M costs of a new solar photovoltaic (PV) plant in the absence of data is a challenge. Working through each cost item will also address many of the operational needs that require attention when bringing a new plant online. Projecting costs should be as much the result of careful process planning as it is an exercise in budgeting

To estimate O&M costs, it is helpful to first have an understanding of the following items:

- ◆ Solar PV plant components
- ◆ The various levels of maintenance and typical maintenance needs
- ◆ The different monitoring types available
- ◆ The plant operational support model
- ◆ Additional considerations for PV O&M costs

Utility-Scale PV Plant O&M Cost Estimates

The table below provides a breakdown of costs across four categories - scheduled maintenance; unscheduled maintenance; inverter/equipment replacement; and insurance, property taxes, and owner's costs – for five conceptual 10 MW PV plants

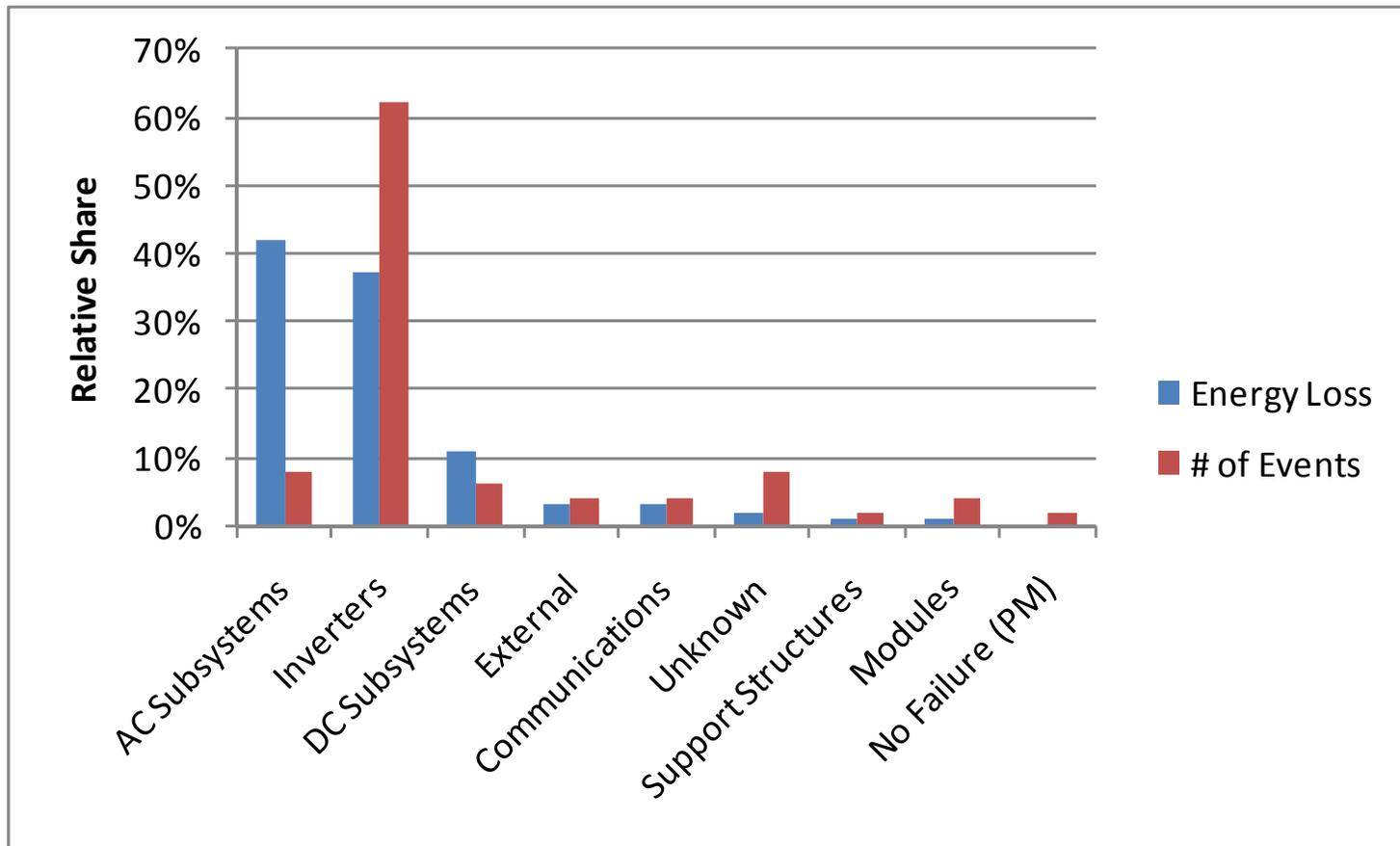
Utility-Scale Solar PV Plant O&M Cost Estimates					
O&M Costs (\$/kW-yr)	Fixed-Tilt c-Si	Fixed-Tilt CdTe	Fixed Tilt a-Si	Tilted Single-Axis Tracking c-Si	Single-Axis Tracking c-Si
Scheduled Maintenance/Cleaning	\$20	\$25	\$25	\$30	\$30
Unscheduled Maintenance	\$2	\$2	\$2	\$5	\$5
Inverter Replacement Reserve	\$10	\$10	\$10	\$10	\$10
Subtotal O&M	\$32	\$37	\$37	\$45	\$45
Insurance, Property Taxes, Owner's Cost	\$15	\$15	\$15	\$15	\$15
Total O&M	\$47	\$52	\$52	\$60	\$60

- ◆ Fixed-Tilt c-Si is defined as polycrystalline modules mounted at a fixed 30 degree tilt facing south
- ◆ Fixed-Tilt CdTe is defined as cadmium telluride modules mounted at a fixed 30 degree tilt facing south
- ◆ Fixed-Tilt a-Si is defined as amorphous silicon modules mounted at a fixed 30 degree tilt facing south
- ◆ Fixed-Tilt c-Si is defined as monocrystalline modules on a north-south axis tracker tilted south at 20 degrees with backtracking
- ◆ Single-Axis tracking c-Si is defined as monocrystalline modules on a north-south axis tracker with backtracking

Source: Electric Power Research Institute, "Engineering and Economic Evaluation of Central-Station Solar Photovoltaic Power Plants, 2010

PV System Failure Areas and Relative Frequencies

The figure below provides the relative frequency of photovoltaic system component failures along with their corresponding outage impacts



Maintenance Strategies and Needs

The various types of maintenance strategies for a PV plant include:

- ◆ *Preventative Maintenance* includes routine inspection and servicing of equipment to prevent breakdowns and production losses
- ◆ *Corrective or reactive maintenance* addresses equipment breakdowns after the occurrence. This “break and fix” method has low upfront costs, but bears the risk of unplanned downtime and higher costs on the back end. This is the current industry standard
- ◆ *Condition based maintenance (CBM)* uses real-time data to prioritize and optimize maintenance and resources

More than one of these maintenance strategies is needed, but a proper strategy can limit the amount of “surprises” and will decrease the amount of unplanned downtime

When establishing a preventative maintenance schedule, it is important to do so based upon each component and system manufacturers’ recommendations. Corrective maintenance procedures should also be established to address items that require immediate repairs and items that can be repaired with routine maintenance visits. Some typical maintenance needs at PV plants include:

- ◆ Over the course of time, dust collects on the PV panels significantly affecting system efficiency. Panels must be cleaned regularly to minimize efficiency loss
 - PV operators and suppliers have found that one to two cleanings per year will adequately serve most plants’ needs
- ◆ System components must go through a thorough maintenance checklist at least once or twice per year. The checklist should include such items as:
 - Checking connections of wires
 - Testing voltage / current through wires and PV modules
 - Inspecting components for moisture
 - Greasing actuator gears and topping off hydraulic fluid on tracker components, if applicable
 - Testing of SCADA and meteorological systems communications
 - Confirming settings on the inverter
 - Resealing of system components
- ◆ Additional maintenance needs include the removal of snow, ice, grass, and vegetation to ensure effective system operation

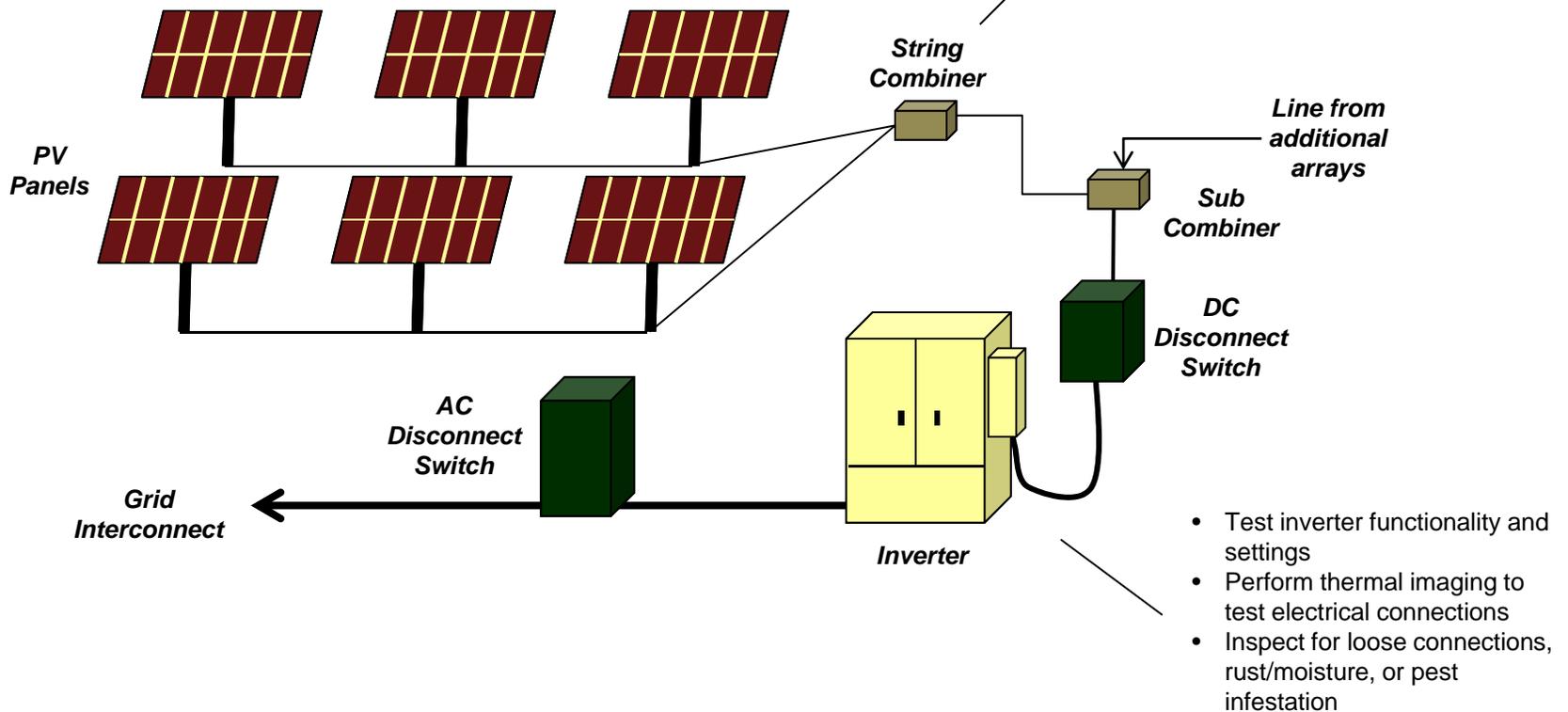
Typical Maintenance Needs

This illustration highlights some of the plant maintenance needs that must be factored into an O&M budget

- Clean panels
- Grease tracker gears and actuators
- Check hydraulics
- Calibrate controllers and sensors
- Remove vegetation, snow, and ice from blocking panels

- Other items:
- Inspect SCADA and meteorological systems communication connection and test signal strength

- Perform thermal imaging to test electrical connections
- Inspect for loose connections, rust/moisture, or pest infestation
- Test string current



* Advanced Energy Global Systems, 2010.

** Banke, Bryan, "Solar Electric Facility O&M: Now Comes the Hard Part" three-part series, Oct-Dec 2009, www.renewableenergyworld.com.

PV Plant Monitoring

PV system monitoring capabilities have advanced significantly over the last decade. Monitoring systems can now offer data at a more granular level. This monitoring capability is especially important given the majority of PV plants are unmanned and supervised off site

“Traditional PV monitoring” and a method widely used simply compares actual energy generation with forecasted generation. If actual compares favorably with predicted, then there is not a problem with the asset. This is a simple and affordable approach. This approach is also fairly reliable, but is more reactive than proactive and a lag often exists between detection and repair. Several new monitoring techniques are currently in the market:

Technology Type	Advantages	Disadvantages
Inverter Monitoring: Inverter Level AC and DC monitoring offers insights into an inverter’s status, adjustable parameters, and historic operating data	<ul style="list-style-type: none"> ◆ Costs are low and value is high given the presence of an inverter at most PV plants ◆ Recognizing inverter problems through performance metrics can identify potential problems and enhance plant production when mitigated ◆ An increasing number of inverter manufacturers are embedding monitoring functionality 	<ul style="list-style-type: none"> ◆ Level of resolution is limited ◆ Information gathering, done either on-site or via remote link, can be time consuming and labor intensive
Array Monitoring: One level deeper than inverter, array monitoring collects information from DC circuits located in sections of a PV array	<ul style="list-style-type: none"> ◆ Provides an additional level of data without too large of an up front investment ◆ It can isolate problems to a specific, though still large, array section 	<ul style="list-style-type: none"> ◆ Limited benefit to cost tradeoff compared to inverter and string level, as a problem might still be detected in a well-advanced stage ◆ A single panel failure might not be detected, but a multi panel one will ◆ Faulty panels will need to be identified by hand from within a group increasing labor cost
String Monitoring: This takes the monitoring one more level down to include individual strings of panels	<ul style="list-style-type: none"> ◆ Capable of determining the status of every string in the array ◆ Root causes in problems are readily apparent and easy to locate in a string ◆ Some third party groups have technology that reduces installation costs 	<ul style="list-style-type: none"> ◆ Additional complexity, which requires special equipment and interface to interpret and organize data ◆ Increased installation cost ◆ Requires multiple communication devices, increasing the likelihood of failure and repair
Micro Inverter Level Monitoring: Micro inverters are installed at the PV module level and provide AC to power panels or to the grid	<ul style="list-style-type: none"> ◆ Efficiency benefits because they directly convert and eliminate DC wire losses and need for parallel communication lines ◆ Panel mismatch losses do not exist 	<ul style="list-style-type: none"> ◆ Not cost competitive ◆ Lack of operating history restricts its financial backing from banks and lending institutions

Source: Electric Power Research Institute, “Addressing Solar Photovoltaic Operations and Maintenance Challenges, July 2010.

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The Plant Operational Support Model

Regardless of what monitoring system or maintenance strategy a firm chooses, the operational support model defines how the new plant will be run on a daily basis -- including who will perform system monitoring, plant repairs, and scheduled maintenance. The model addresses the mechanical and electrical needs of the plant as well as maintaining the grounds and communication systems

- ◆ *In House Staff:* Existing staff may be leveraged when the plant is adjacent to existing generation facilities
 - For example:
 - System monitoring and plant operation may be performed by fossil operators throughout the course of their shift
 - Mechanical engineering not included in the warranty may be handled by onsite fossil maintenance staff
 - Site electrical maintenance may be supported by plant operations crews or transmission maintenance crews
 - The advantages of this system include: better visibility on personnel and equipment issues, greater quality control, ability to use existing personnel and assets, and it will lead to a standard PV O&M process
 - The disadvantages of this system include higher upfront costs, increased risks, and the need to develop an expertise quickly in your work force
- ◆ *EPC Contractor:* The utility may opt to use the Engineering, Procurement, and Construction (EPC) contractor that sold and built the system to oversee an O&M contract
 - This limits the use of multiple contracts and simplifies dealing with warranty-related repairs versus maintenance
- ◆ *Third Party Provider:* Another option for O&M services not covered under the warranty is to use a third party provider which may support multiple PV sites
 - Use of a third party for an organization's first PV plant helps instill best management practices for maintenance schedules and for system repairs
 - One variation of this model is to contract some functions (i.e., mechanical engineering, grounds maintenance, and panel cleaning) to a third party while keeping some tasks (i.e., communication and monitoring, electrical engineering) in-house
 - Advantages of both the EPC and third party option include lower upfront costs and greater flexibility, lower upfront risk, less drain on the current labor force, and potentially greater expertise
 - Disadvantages of the EPC and third party option include less understanding of the O&M process, higher back end cost potential, and that it requires dependence on an outsourced contractor

The Solar PV Plant Operational Support Model

Where tasks are performed internally, cost estimates should be as close as reasonably possible. To derive a total labor cost and to ensure that each support need is addressed, a matrix of tasks can be developed capturing each variable

As illustrated below, an analysis of support costs might include a task description, the organization performing the work, org WBS to which the work is charged, hours for the task, frequency of the task, hourly labor cost, yearly hours, and total yearly cost

Support Tasks	Organization	Org WBS	Hours for Task	Frequency of Task	Hourly Labor Cost	Yearly Hours	Total Yearly Cost
◆ Plant Operation - Perform regular system monitoring, review system reports daily, respond to system alarms, report system failures based on level of severity	Fossil Plant Operations Shift Crew	Dept XYZ	3 hours	Daily	\$ 38.00	1,460 hours	\$ 41,040
◆ Mechanical Repair – Make repairs to non-electrical BOS components including tracker actuators and gearboxes as well as panel mounting equipment							
◆ Electrical Repair – Make electrical repairs to the inverter and BOS components such as combiners, disconnect switches, junction boxes, meter and communications equipment							
◆ Site Maintenance – Perform site maintenance including removal of snow, ice, and grass or other vegetation. Maintain site fencing and signage							
◆ Panel Cleaning – Perform PV panel cleaning according to the manufacturer's instructions at least twice yearly and additionally when requested							

Illustrative

Additional Considerations for PV O&M Costs*

As more utility-scale PV plants come online, more is being learned about system performance and capacity. This includes a better understanding of what to expect with regard to system operation and maintenance, as illustrated in the following lessons learned:

Preventative Maintenance:

- ◆ Focus on design, engineering, and the initial build of the PV plant
- ◆ Target a downtime of 1 percent (3.7 days/year) and prepare for 10 percent downtime (36.5 days/year)
- ◆ Measure system degradation over time and clean panels when the cost of lost power approaches the cost of cleaning
- ◆ Mitigate risk by using multiple smaller inverters rather than one large inverter
- ◆ Perform site visits at least 1-2 times/year
- ◆ Consider transitioning outsourced O&M to in-house staff

Monitoring:

- ◆ Consider monitoring the system at the string level for plants between 250kW to 2 MW and use the data to address maintenance needs
 - Note: larger plants may not see the cost benefit from this level of detail
- ◆ Automate system monitoring and supplement by reviewing system reports multiple times throughout the day
- ◆ Assure good access to historical data
- ◆ Perform simple site analytics once per month
- ◆ Identify core factors that determine the economic tradeoffs of monitoring resolution

Warranty:

- ◆ Make sure warranty terms are clear; avoid vague clauses
- ◆ Perform due diligence before agreeing to a construction contract

Source: Electric Power Research Institute, "Addressing Solar Photovoltaic Operations and Maintenance Challenges," July 2010.

* Banke, Bryan, "Solar Electric Facility O&M: Now Comes the Hard Part" three-part series, Oct-Dec 2009, www.renewableenergyworld.com.

Contact Us

For more information on how we can assist you with determining your solar PV operating and maintenance costs, please contact us

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