Five Years of Operating Experience at the Springerville PV Generating Plant

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ABSTRACT

Tucson Electric Power Company (TEP) currently has 26 crystalline silicon photovoltaic (PV) collector systems, each rated at 135 kWdc, which are installed at the Springerville, AZ generating plant. This 3.51 MWdc facility started operations in 2001 and recently passed the 5-year milestone of continuous operations. These fixed flat-plate systems were installed in a standardized, cookie-cutter approach whereby each uses the same array field design, mounting hardware, electrical interconnection, and inverter unit. Performance, installed costs, and maintenance for these systems were previously documented for operations through 2004 [1]. This paper presents an updated assessment of operating experience through 2006, making this one of the most detailed and complete database of utility-scale PV systems available to the DOE Program.

1. Objective

The objective of this work is to establish benchmark information for large fixed flat-plate reference systems. Development of this information directly supports the DOE Program modeling, benchmarking and database development activity. These performance, cost and reliability data provide validation to system modeling efforts and vetting of Solar America Initiative progress through the Technology Pathway Partnerships. Specifically, this effort contributes to program milestones that address performance/cost model development, data collection for reference systems, and the identification of parameters and architecture for database implementation.

2. Technical Approach

To develop and document actual field experience with PV systems requires access to qualified data. A Sandia/DOE partnership with TEP provides this access to monitor, analyze and assess the field performance of a large number of fixed flat-plate systems in a utility environment.

3. Results and Accomplishments

TEP has installed 26 fixed flat-plate crystalline-silicon systems representing 3.51 MWdc of installed capacity during the period of 2001 through 2006. The utility-scale PV generation effort is centered at the Springerville Generating Station Solar System in eastern Arizona. Shown in Fig. 1, this facility is one of the largest PV generating plants in the world.

Covering 44 acres, this PV generating plant is grid-intertied with a 34.5-kV TEP distribution line. Each of these systems is an identical copy of a standardized array field configuration that utilizes the same hardware components, wiring topology, and structural mounting.

Fig. 1. Springerville PV Generating Plant

The standard system configuration includes ASE Americas (now RWE Schott Solar) ASE-300-DG/50 modules and a Xantrex PV-150 inverter. The arrays are mounted at a fixed tilt of 34 degrees facing due south.

3.1 Performance

The average monthly final yields for all systems over the past 3 years are presented in Fig. 2.

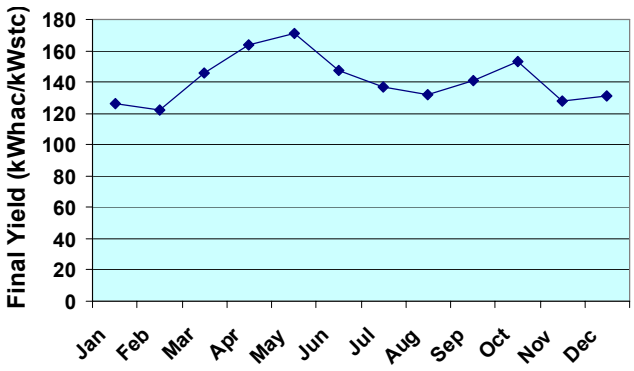

Fig. 2. Average Monthly Final Yield

The average annual final yield for all systems over the past 3-year period is 1707 kWhac/kWdc. The average final yields for 2004, 2005 and 2006 are 1720, 1669 and 1731 kWhac/kWdc, respectively.

The average annual reference yield over this operating period is 2138 sun-hours. The annual reference yields for 2004, 2005 and 2006 are 2175, 2054 and 2185 sun-hours, respectively.

The average monthly performance ratios for all systems over the past 3-year operating period are

presented in Fig. 3. The performance ratio reflects the system losses going from aggregate nameplate dc power to annual average ac power of the system.

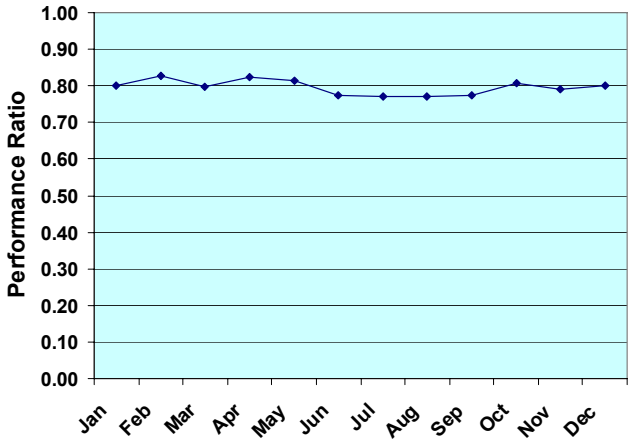

Fig. 3. Average Monthly Performance Ratio for All Systems

The average annual performance ratio for all systems over this operating period is 0.79. The average annual performance ratios for all systems in 2004, 2005 and 2006 are 0.78, 0.81 and 0.79, respectively.

3.2 Operation and Maintenance

An unscheduled maintenance events results in a loss of generating capacity that affects one or more systems and requires human intervention to restore the system(s) to full operational capacity. Through January 1, 2007, the 26 crystalline silicon Springerville systems had provided 1206 system-months of continuous operation since installation. Over that same period, a total of 156 unscheduled maintenance events were recorded which provides a mean time between unscheduled services per system of 7.7 months of operation.

Table 2 lists the annual maintenance cost, both scheduled and unscheduled, as a percentage of the cumulative capital investment by year. The average annual maintenance costs since the initial Springerville installations are 0.12% of initial capital cost.

Table 2. Maintenance Cost as a Percentage of Capital Investment

Year	Scheduled %	Unscheduled %	Total %
2002	**0.08**	**0.01**	**0.09**
2003	**0.07**	**0.22**	**0.29**
2004	**0.06**	**0.04**	**0.10**
2005	**0.06**	**0.01**	**0.07**
2006	**0.04**	**0.03**	**0.07**

The distribution of unscheduled maintenance costs by system category is presented in Fig. 4.

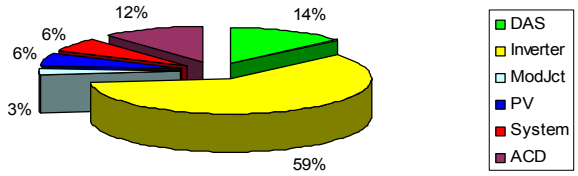

Fig. 4. Unscheduled Maintenance Costs by Category

3.3 Impact on Utility Operations

The PV Generating Plant is located next to the coal-fired Springerville Generating Station and is intertied to the same transmission line that feeds power back to Tucson. TEP is observing that PV generating intermittencies associated with short timescale events, such as cloud passage and storms, are in fact swinging the controls of a 420 MW coal fired unit at the generating station. These impacts bring into question the capacity value of solar in the utility plant operations and emphasize the need to stabilize PV power output, perhaps through storage or inverter modifications, in the utility environment.

4. Conclusions

The energy data, maintenance experience and costs with the Springerville crystalline silicon systems provide a treasury of information that establishes a benchmark for current utility-scale fixed flat-plate PV systems technology. This operating assessment has identified a number of findings, including:

- Average annual ac system energy output is 1707 kWhac per kWdc of array.
- Average annual ac system power is 0.79 of the array dc nameplate rating.
- Average annual O&M cost is 0.12% of initial system installed capital cost, not including rebuild/replacement cost of the inverter.
- The mean time between unscheduled maintenance services per system is 7.7 months of operation.
- Solar generating intermittencies are observed to have significant impact on capacity value to the utility and require hardware/control system modifications.

ACKNOWLEDGEMENTS

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REFERENCES

1. L. Moore and H. Post, "Photovoltaic Power Plant Experience at Tucson Electric Power," Energy Conversion and Resources Journal v.2005, p.387-394