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JOINT DOE/INDUSTRY PHOTOVOLTAIC SYSTEM RELIABILITY PROGRAM*

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The U.S. Department of Energy and several industry groups including the Utility PV Group, Ascension Technology, and the Sacramento Municipal Utility District are cooperating to obtain and analyze data on the reliability and life-cycle cost of several PV grid-tied and grid-independent systems.

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To achieve the lowest life-cycle cost (LCC), photovoltaic (PV) systems must have the optimum mix of low first cost, low operation and maintenance (O&M) cost, and high availability. Additionally, the long-term health of the photovoltaic (PV) industry requires that PV systems work as expected. Although PV modules now enjoy high reliability due to a significant multi-year effort by both the U.S. Department of Energy (DOE) and industry, the same is not always true of PV systems. Even for systems that do operate reliably, customers, suppliers, and manufacturers can benefit from knowing what O&M expenses to expect. This knowledge will reduce technology risk to the customer and improve likelihood of commitment to PV projects. System integrators and utilities may benefit from O&M cost information to improve system designs, to properly price service agreements and warranties, and to optimize maintenance strategies. The DOE and component manufacturers may benefit from identifying cost drivers to optimally focus research and quality assurance resources to improve product reliability.

There are five tasks in the present project effort.

Task 1 - Quantify System Reliability and Life-Cycle Cost
Task 2 - Improve Specifications
Task 3 - Improve Inverter Reliability
Task 4 - Improve Battery System Reliability
Task 5 - Continuously Communicate the Result to Industry and Project Participants

This paper will discuss the first task, quantifying system reliability and life cycle cost by collecting, analyzing and reporting data on PV system reliability and cost. Industry participants collect the necessary O&M data on systems they are monitoring. Sandia provides support in the form of assistance identifying data that needs to be collected, helping develop forms or databases to collect the data, and analyzing the data. Sandia uses a software package called WinR, developed by Sandia for the semiconductor industry. This package is commercially available, runs on a Windows PC, and enables powerful statistical analysis of failure rate and time-to-repair data to quantify system reliability and its cost.

The DOE and several representatives of the PV industry are cooperating to obtain data on the reliability and O&M cost of several PV systems currently in operation or planned for the near future. These systems span the range from small to large, and include grid-connected and grid-independent projects. Ascension Technology is funded by the Utility PhotoVoltaic Group (UPVG) to monitor the performance and reliability of 110 small, medium, and large grid-connected systems being installed as part of UPVG's Round 1 and Round 2 *TEAM-UP* program. Ascension is monitoring 12 systems ranging from 2-kW residential to 35-kW utility systems. The Sacramento

Municipal Utility District (SMUD) has installed 350 grid-tied residential and 74 commercial system at 21 locations over 3 years as part of its PV-Pioneer program. SMUD has modified its O&M collection database to include data needed to quantify the cost and availability of its systems. Both are sending O&M reports to Sandia periodically for analysis.

The Georgia Institute of Technology (GIT) is participating by collecting data on its natatorium PV system. This is a large (350-kW) grid-tied system. A number of grid-independent systems are included in the program as well. About 100 water pumping and a dozen residential systems deployed by the PV Service Network (PSN) at member utilities are being monitored by PSN. With assistance from Sandia, the Colorado Energy Office is monitoring over 40 small (1 to 4-kW) dc lighting and water pumping systems installed throughout Colorado parks, and the Bureau of Land Management (BLM) is monitoring the performance of 16 small (400W) power systems at scattered sites. Several large grid-independent systems such as the Dangling Rope Marina, Pinnacles, China Lake, and Mt. Home hybrid systems operated by the Park Service and the Department of Energy are being monitored as well.

Data collection for most of these systems has begun, and the first periodic reports are in preparation on some of these systems. One report has been completed. It analyzes the reliability of eight 4-kW grid-tied systems which were installed by Ascension Technology under contract to the U.S. Environmental Protection Agency. A reliability analysis has been completed and results on mean time between failure, availability, sensitivity and uncertainty were found. These systems were modeled using a fault tree whose top event is "No power output from the system" in order to find all failures which cause the system to not output power. The analysis used logged maintenance information to establish failure rate and repair rate distributions as input to the model. Figure 1 shows the mean time to failure distribution for the systems that were studied--based on 12 hour days, the median MTBF is equivalent to about 168 days.

Figure 2 shows the distribution of times required to repair a system failure. Due to the remote operation of these systems, maintenance actions normally needed a week's time to make even the simplest repair. These downtimes could also be exacerbated by long waiting times for repairs requiring returns to manufacturers.

Figure 3 shows which failures crop up the most and take the PV systems down. Looking only at failures within the PV system, inverter-related failures (items 4 through 10) dominate this chart and even overshadow the frequency of blown fuses in the disconnect. The mean, 5th, and 95th percentile ranges of the distribution are shown for each failure mode.

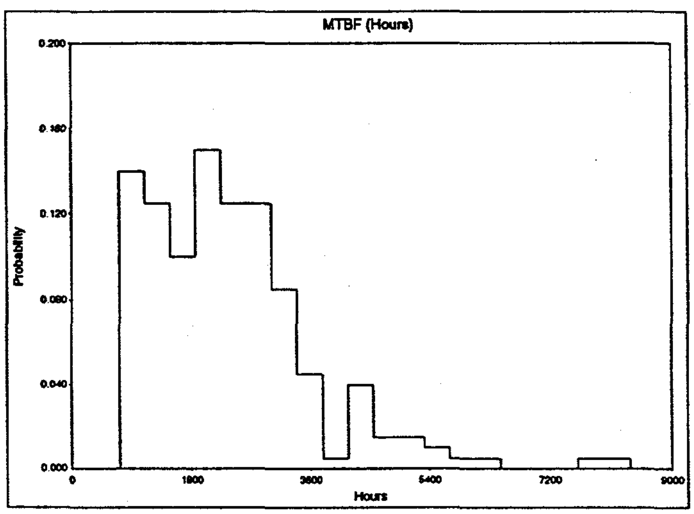

Figure 1. Mean time between failure

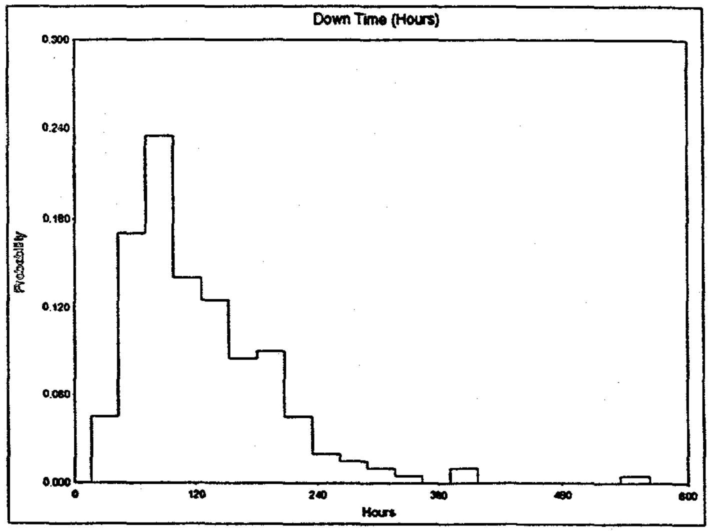

Figure 2. Downtime

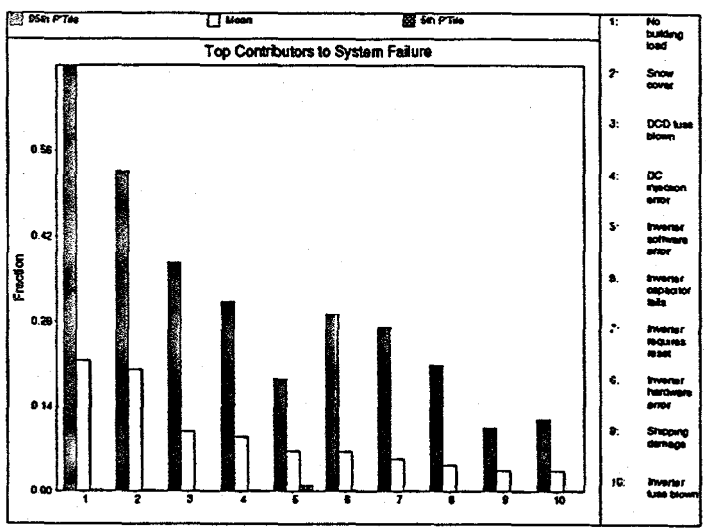

Figure 3. Top Failure Modes Contributing to System Failure