Information Sharing via the DER Lab Network. Sandia has joined with Oak Ridge National Laboratories and the National Renewable Energy Laboratory to form the DER Lab Network. The DER Lab Network was formed to support the DER Program of DOE by sharing of testing information and coordination of testing results. This provides a mechanism whereby DETL results can be shared with the wider DER community.

Modeling

Using Sandia internal funding in the form of a laboratory-directed R&D project, computer simulation capability is being enhanced and emphasized in the Sandia power electronics evaluation laboratory. Development of laboratory-validated models is necessary to provide reliable analytical tools for a variety of PV inverter issues.

Anti-islanding Controls. Islanding has been chosen as the issue on which to focus modeling activities. As has been emphasized in this report, effective anti-islanding is critical to utility acceptance of both PV and other DER. Development of a laboratory-validated model of PV inverter anti-islanding controls may potentially limit the number of utility-requested multi-inverter tests such as those recently performed by Sandia and others. This modeling capability will have application throughout a wide range of DER because of the similarities among inverters.

To enable these investigations, models of sources are being developed in conjunction with Electrotek, a major power systems analysis consulting company. The circuit simulations are being performed using PSCAD, a graphical program capable of both transient and steady state simulations. PSCAD is similar to a number of graphical variants of EMTP, a program that has been widely used and accepted within the utility community. The first DER to be modeled is a grid-tied PV inverter manufactured by Xantrex. Xantrex will be actively involved in the development of this model. Participation by the manufacturer is particularly critical in accurately describing the anti-islanding algorithm used.

Protection Issues with High Penetration. As discussed earlier, utility distribution system planners will require validated analysis tools when a critical level of DER penetration is reached. Because power system analyses have historically been based on rotating machine behavior, it is desirable to characterize PV and other DER inverters in an analogous manner. Classes of problems include harmonic analysis, fault current calculations, voltage regulation, and coordination of system relay protection. Different levels of model complexity are required for different classes of problems. The approach that is being used is to develop the more complete model first in order to address the anti-islanding issue, to validate it in the laboratory, and then to simplify it as appropriate.

Related activities (i.e., developing models that are compatible with utility power system analysis methods) are underway within the DOE Distributed Power Program and at EPRI. Sandia modeling results will be coordinated with these efforts.

Grid Characteristics. One issue that is a subset of PV anti-islanding is the effect of local power system characteristics on the behavior of grid-tied PV inverters. The electrical characteristics of the grid connection into which a PV inverter attempts to supply power depend upon a number of factors. Usually the most important of these are the characteristics of the local distribution transformer. Because it has been shown that some types of inverter anti-islanding controls may be sensitive to local grid conditions, it is important to quantify and understand this sensitivity with respect to transformer characteristics. This is being done experimentally, as described earlier, using actual distribution transformers provided by PNM, our utility partner. This problem is complicated by the fact that transformers of similar ratings may have significantly different characteristics, depending upon core material, core geometry, core lamination thickness, winding geometry, etc. Analysis by circuit modeling may be a more effective use of resources than testing the broad spectrum of transformers.

Evaluation of a PV Battery Charger Using a Maximum Point Tracker

The RV Power Products Solar Boost 3048 maximum power point tracker (MPPT) PV charge controller was evaluated using a 768-Wp Solarex MSX-64 module array. The RV Power Products MPPT Solar Boost 3048 charge controller is relatively new and available for PV systems with a maximum charging current of 30 amps. Input array voltage can be set for 24 or 48 volts to charge 24-volt batteries. The Solar Boost was tested to measure MPPT efficiency and performance at both 24- and 48-volt array inputs for 24-volt batteries only; calculations were also performed. The results indicate that MPPT can provide an increase in available energy from the PV array is possible over the year. The boost in energy output in many cases can justify the added cost of the MPPT controller.

Test Summary. The effectiveness of the MPPT was evaluated by momentarily replacing the MPPT charge controller with an IV curve tracer. The curve tracer accurately measures the maximum power available and then the experimenter compares these measured parameters to the same parameters while the MPPT is operating. The test equipment included the Daystar DS-100 portable IV curve tracer and a Campbell data acquisition system. Array IV curves were obtained at 30-to-60-minute intervals. Data was plotted as a function of the time of day. The difference in the two power measurements was used to calculate the MPPT efficiency. Below the MPPT performance measurements and calculation results are summarized.

1. The 700+ Watt multicrystalline Solarex MSX-64 array V_{mp} was calculated to be as low as 27.5 volts during hot summertime use. The low summertime voltage limits the MPPT energy advantage when battery regulation voltage is set at 28.8 volts or above. In this case, array MPPT energy gain under typical operating temperatures of between 35° to 48°C resulted in an 8% energy gain at the 24/24 voltage setting and a 4% energy gain at the 48/24 voltage setting.

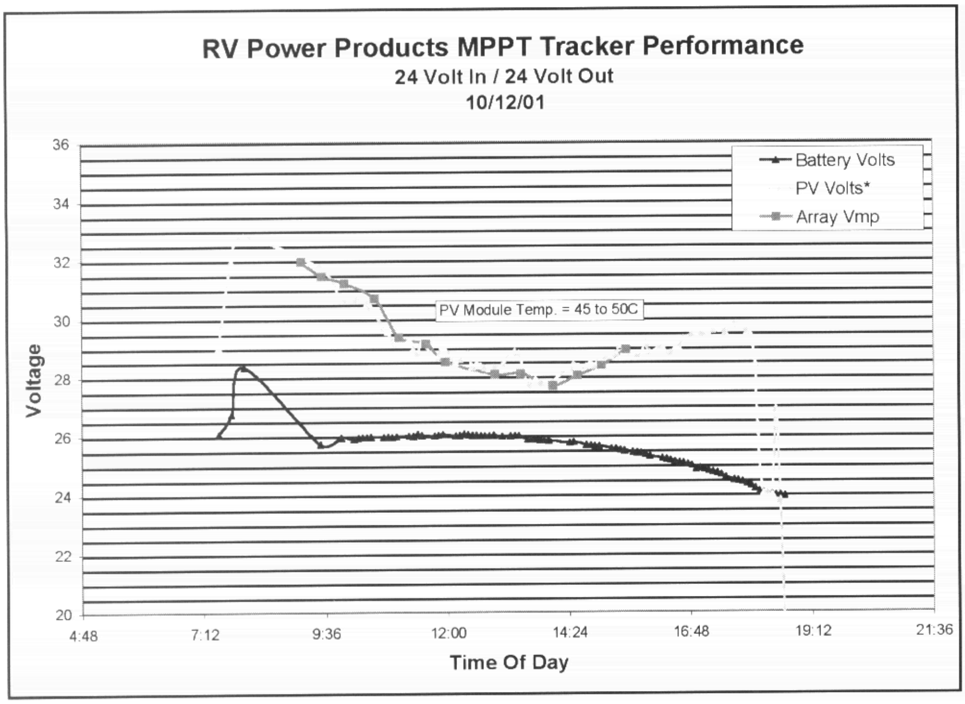

Figure 9. Demonstration that MPPT functions properly.

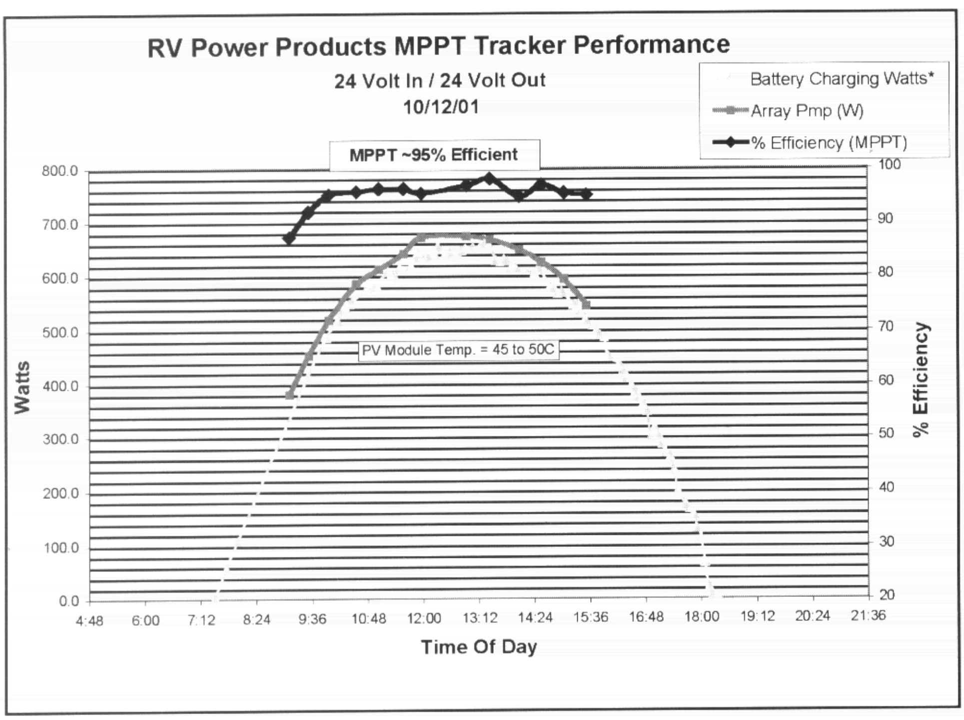

Figure 10. Solar Boost 3048 MPPT 24 volt performance and efficiency.

2. Based on our array modeling for Albuquerque, most 36-cell multicrystalline and crystalline PV modules can provide up to 15% to 20% more energy bulk charging over the year as a result of MPPT. Because charge controller regulation voltage disables the MPPT function, the actual yearly MPPT energy gain will vary depending on system use and design.

3. Figure 9 illustrates that the MPPT is working-as-designed in the 24-volts-in/24-volts-out configuration. The array V_{mp} line is the series of point measurements taken with the IV curve tracer; it plots the voltage at the maximum power point for each measurement. The PV volts trace shows the value of voltage input to the MPPT. The fact that these two traces overlap demonstrates that the MPPT is functioning properly.

4. The conversion efficiency as a function of time of day of the RV Power Products MPPT for the 24-volts-in/24-volts-out configuration is shown in Figure 10. The results show a MPPT efficiency that starts out near 87% at about 9:00 AM and rapidly increases to 95% by 10:00 AM. Efficiency was measured at between 95% and 98% until 3:30 PM. Similar data was obtained for the 48-volt-in/24-volt-out configuration with the efficiency ranging from 87% to 94%.

5. The typical MPPT current gain for a 24-volts-in/24-volts-out voltage setting and the calculated energy gain from MPPT using the Solarex MSX-64 array is shown in Figure 11. A 2-amp gain in charge current occurs initially, but as the array temperature increases and the charge voltage increases, the MPPT current drops to the same value as the PV array. The magnitude of the MPPT energy gain is dependent on the array V_{mp} and array temperature. In this case calculations show an energy gain of 0.04 kWh per 1 kWh/m^2 of solar resource was obtained from MPPT.

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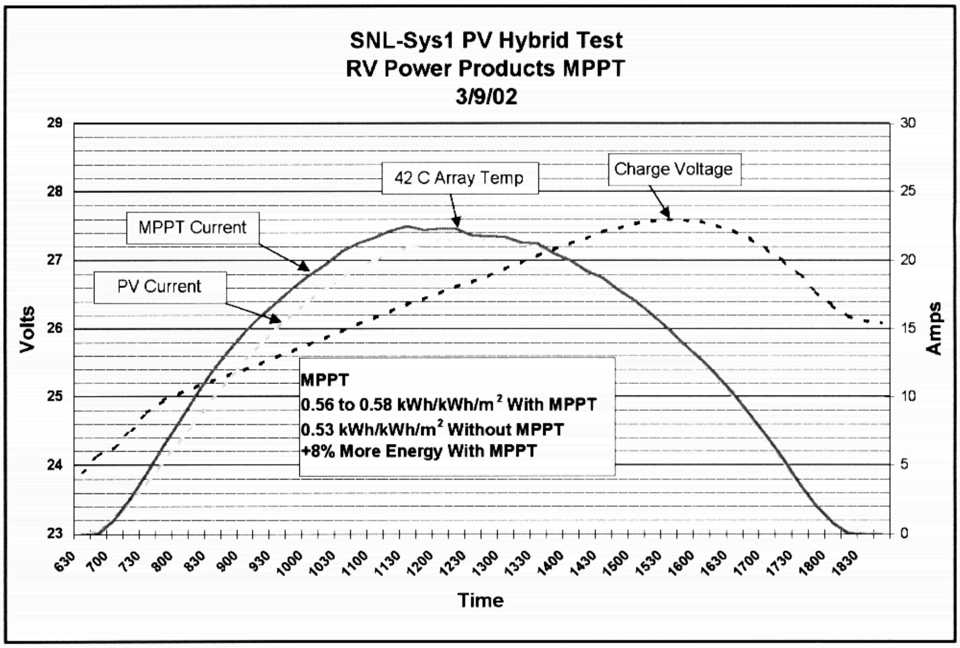

Figure 11. MPPT current gain at the 24/24 voltage.

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