Solar Sentry Alpha Test Site

Introduction

Solar Sentry's 'Alpha Test Site' is the first demonstration of our PV monitoring and diagnostic technology in an 'end-to-end' field test.

The PV system under test consists of twelve Mitsubishi 170 Watt solar panels, south facing at about 45^o tilt and wired in a series string that is connected to an SMA Sunny Boy 2kW grid-tied inverter.

The lower row includes Panels 1-6 in order from left to right. The string then continues with panel 7 in the upper right and concludes with panel 12 in the upper left. It is in a residential neighborhood with mature trees, resulting in shading both morning and afternoon. The afternoon shading is quite serious from tall trees to the near southwest.

Installation of Monitoring & Diagnostics

The installation was a 'retrofit' accomplished by attaching prototype Panel Sentry Adapters to each of the panels. Each panel was then plugged into its Panel Sentry Adapter, where the monitoring device is located. The monitoring device consumes about 0.1 W and the rest of the power is 'passed through' to complete the 'power loop' just as it was before. Each monitoring device measures the voltage of its solar panel, the temperature inside the box and the voltage of the next solar panel in the string. The system, as originally installed, had a 'junction box' behind Panel-12 in the array, and we mounted our prototype 'Smart String Combiner' near it. Again, the string power passes through the Smart String Combiner where the voltage and current is measured before it is routed through to the original junction box. Also in our enclosure is a small embedded computer to collect Panel Sentry data and take additional measurements and a DSL modem to communicate the data over the internet. Data is sent to the Solar Sentry Server every six minutes where it is recorded. Mounting and wiring the Panel Sentries took about two hours and installing the 'Smart String Combiner' took about an hour. Installation was completed on May 5, 2008, and on May 6 we collected our first full day of data.

First Look at the First Day's Data

Weather

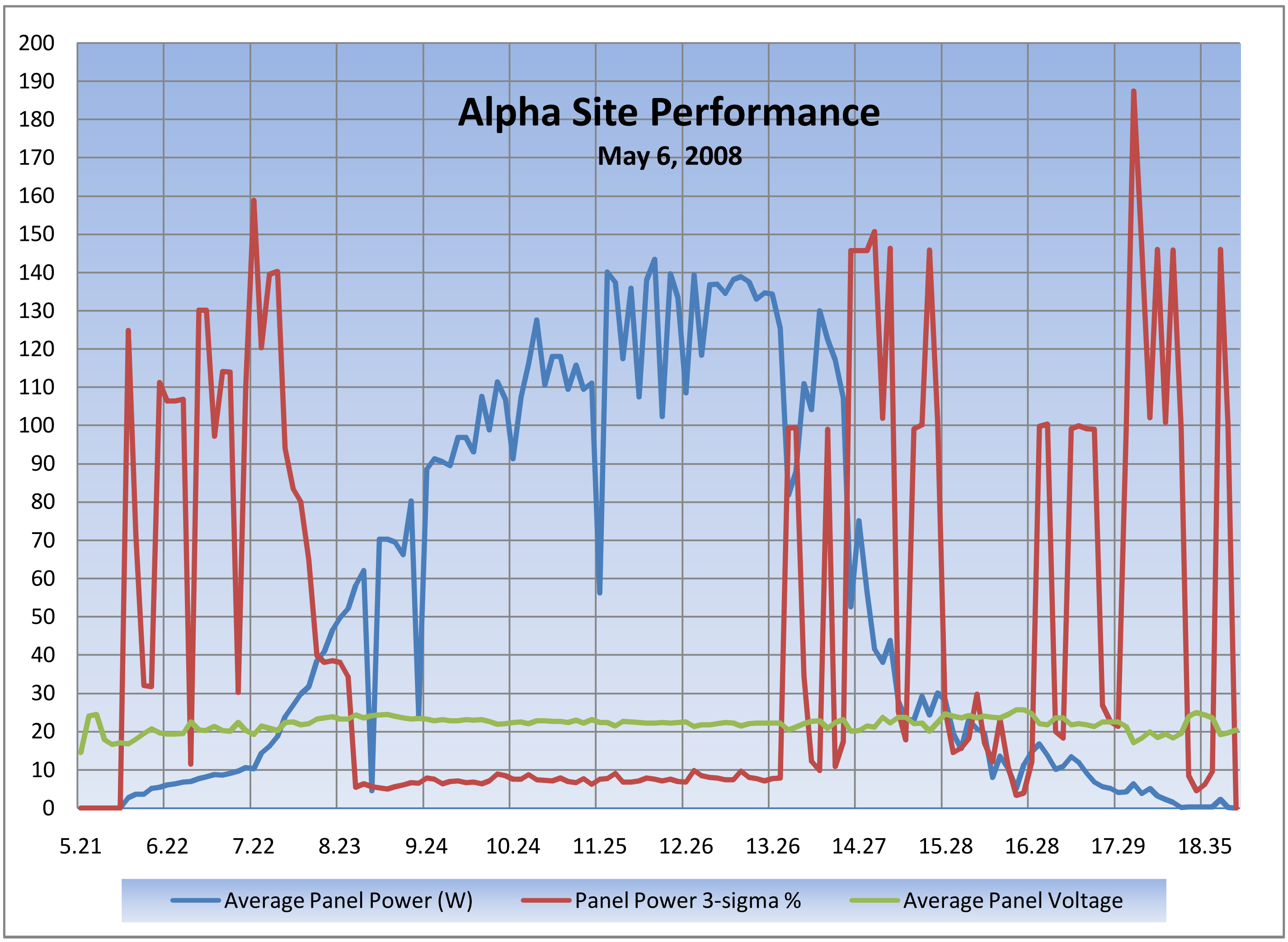
At our location, May 6 started out sunny and cool. The temperature in the Panel Sentry boxes was in the high 40s Fahrenheit. The temperature in the string combiner started in the high 60s F. That box is currently unvented and while the embedded computer in it operates on about 1W of power, the business-class DSL modem appears to use about 3.5W. It remained mostly sunny until late morning with clouds accumulating by noon. By 9:00 AM the temperature in the Panel Sentries had climbed to the low 70s and the combiner box was in the mid 80s. By noon, the Panel Sentry temperatures were in the high 80s and the combiner in the mid 90s. The ambient temperature, taken from the record of a nearby weather station climbed from the 40s in the morning to the high 60s by early afternoon. We saw highs in the Panel Sentries in the high 80s and about 100^o F in the string combiner.

Performance

Site Output, Clouding and Shading

The blue trace in the graph below indicates average solar panel power output from 5:21 AM to 6:35 PM EST. The red trace represents a '3-sigma' statistical calculation of solar panel output power consistency as a percentage of power produced. Note that between the hours of 8:30 AM and 1:30 PM the solar panel outputs were very consistent with one another with the '3-sigma' calculation between 6% and 10%. This is consistent with the solar panel factory specifications and represents a period when there was NO SHADING of solar panels in the site. Note that outside of that time period, when there was shading, the '3-sigma' value rose dramatically. This is a very good indicator that all the solar panels are operating properly within expected factory specifications for output power consistency, i.e., no shading and no soiling.

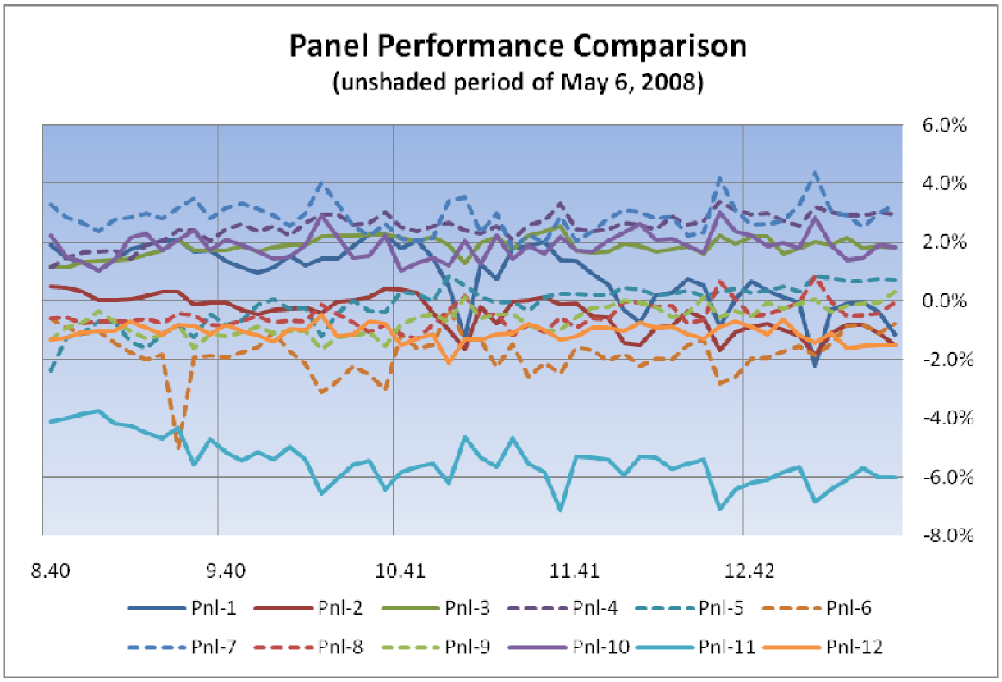
Also note that in the morning hours there were three downward spikes in the average power produced which we believe were caused by clouding because of the continued consistency of solar panel output power during the event. On the other hand, the downward spike between 13.26 and 14.27 was accompanied by shading, as determined by looking at the raw data for each panel, and also observing the '3-sigma' calculation, which spiked to 100%. The second spike in the '3-sigma' calculation during that period correctly indicates shading; however the shading would not have been discernable by looking at the average panel power output of 122W.



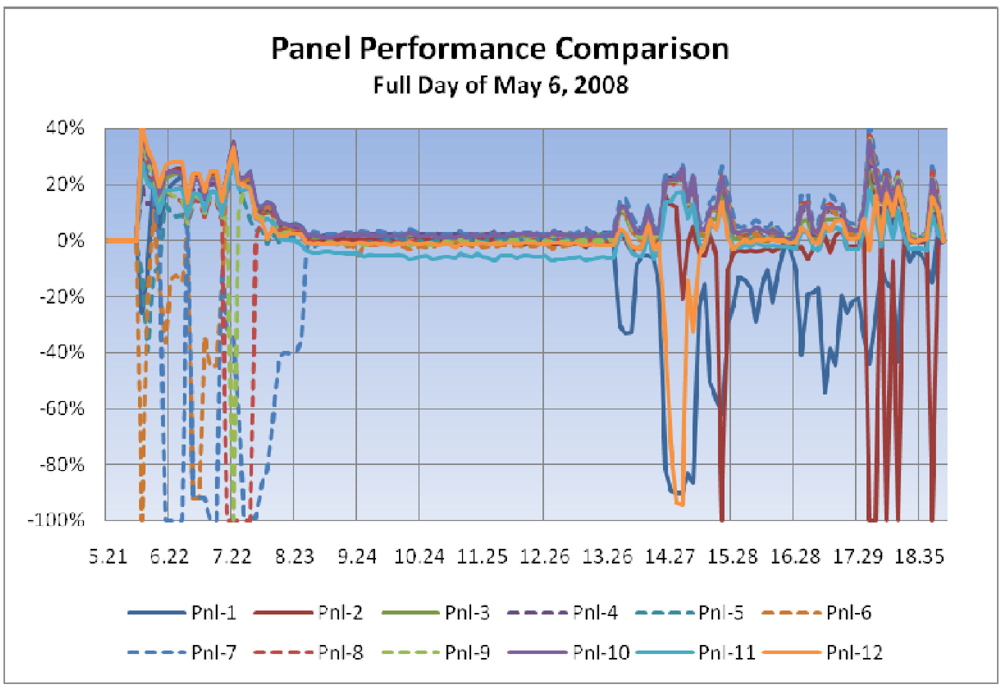
Solar Panel Consistency

As previously noted, power out of individual solar panels was very consistent during the unshaded operating hours, within expectations for clean solar panels meeting factory specifications.

A comparison of individual outputs is shown at right. Note that performance is essentially in three bands: a group of solar panels performing 2-4% above average, a group performing from average to 3% below average, and one solar panel performing 4-7% below average. They would all be considered 'within the factory specification' for variability which is typically +5% to -10%. Also note that our analysis approach is comparative and makes no attempt to ascertain absolute performance.



When considering the morning hours, it is clear to see that panels at the East side of the array (dotted lines) are shaded. Similarly, panels at the West side of the array are shaded in the afternoon. Furthermore, the afternoon shading is more severe, with the first shading event (Panel-1) occurring at about 1:35PM EST. On the other hand, the last shading event in the morning ended at about 8:AM EST (3.5 hours before noon).



Conclusions

The day's events and subsequent analysis show that having power measurements for individual solar panels provides the ability to easily distinguish between cloudiness, that affects all panels, and shading events, that affect only some of the panels. ***This has implications far beyond shading that encompass virtually all forms of solar panel underperformance including soiling, failure, partial failure, connection failure, and defective bypass diodes.*** *Of course, since data is collected every six minutes, intermittent failures of any kind are also identified, as are blown fuses or connection failures anywhere in the system. Together this information provides the owner with detailed assurance as to proper operation of their solar power site during the day.*