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## Field Performance Summary Report

### Sun Tie<sup>ä</sup> - ST Series



#### Version History

Version	Date	Author	Comments
I	6-24-00	T .Booth	First Draft
A	7-24-00	T. Booth	Released Version



## Table of Contents

1	Summary .....	3
2	Variances .....	3
3	Comprehensive Assessment .....	3
3.1	PVUSA .....	4
3.2	SMUD: Orangevale Community Center.....	6
3.3	SMUD: Krause Residence .....	8
3.4	FSEC: Lakeland Elementary .....	10
3.5	Trace Engineering: Test Array .....	11
4	Evaluation .....	13
5	Planned Activities.....	13
6	Approvals and Certifications.....	13



## 1 Summary

This field performance data is made available to demonstrate Trace Engineering's Sun Tie™ — ST Series inverter operations under real world conditions. In short, the ST Series inverters are the most versatile, yet the simplest photovoltaic power conditioning units available today for utility interconnection.

The following sites have been monitored to complete this field performance evaluation:

Site Name	Location	STC Array Size	Module Type
1. PVUSA	Davis, CA	3612 W	Solarex Millennia MST43
2. SMUD: Orangevale	Sacramento, CA	2580 W	EPV 40
3. SMUD: Krause Residence	Sacramento, CA	2580 W	EPV 40
4. FSEC: Lakeland Elementary	Lakeland, FL	1800 W	Siemens SP75
5. Trace Engineering	Arlington, WA	720 W	Siemens M75

The following data has been selected as typical data for each site. Additional raw data can be provided from several of the sites upon request.

## 2 Variances

The PVUSA and both SMUD sites utilize Phase One ST2500 versions. Phase One inverters use alternate heat sinks, fan controls, inverter enclosures and an earlier software version than current production ST2500 units.

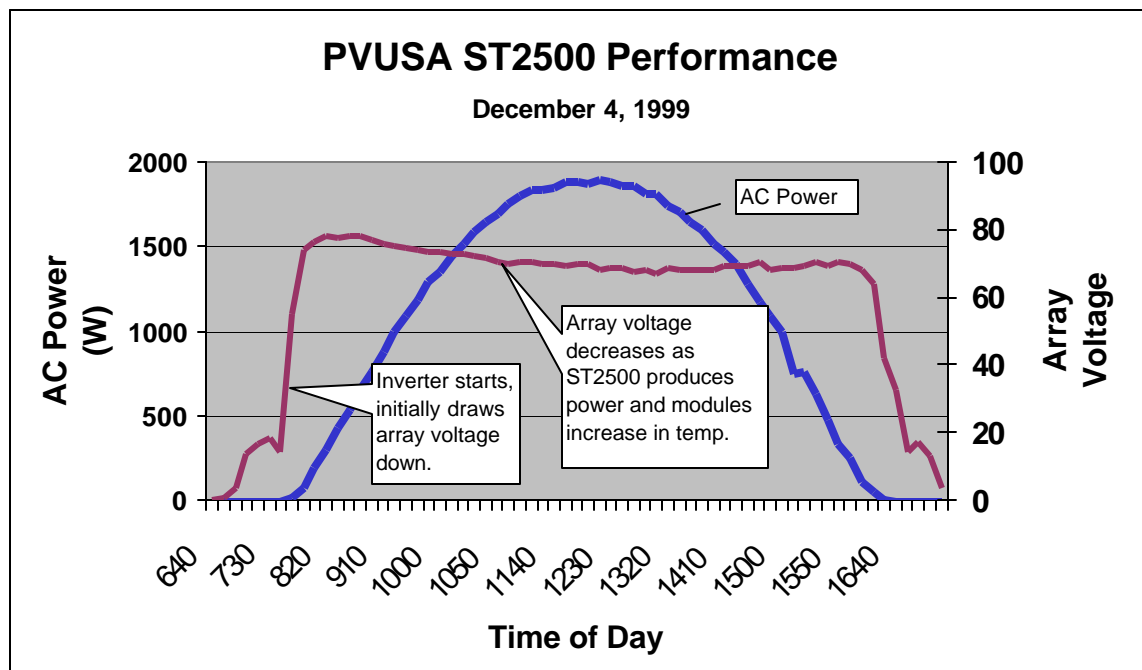
## 3 Comprehensive Assessment

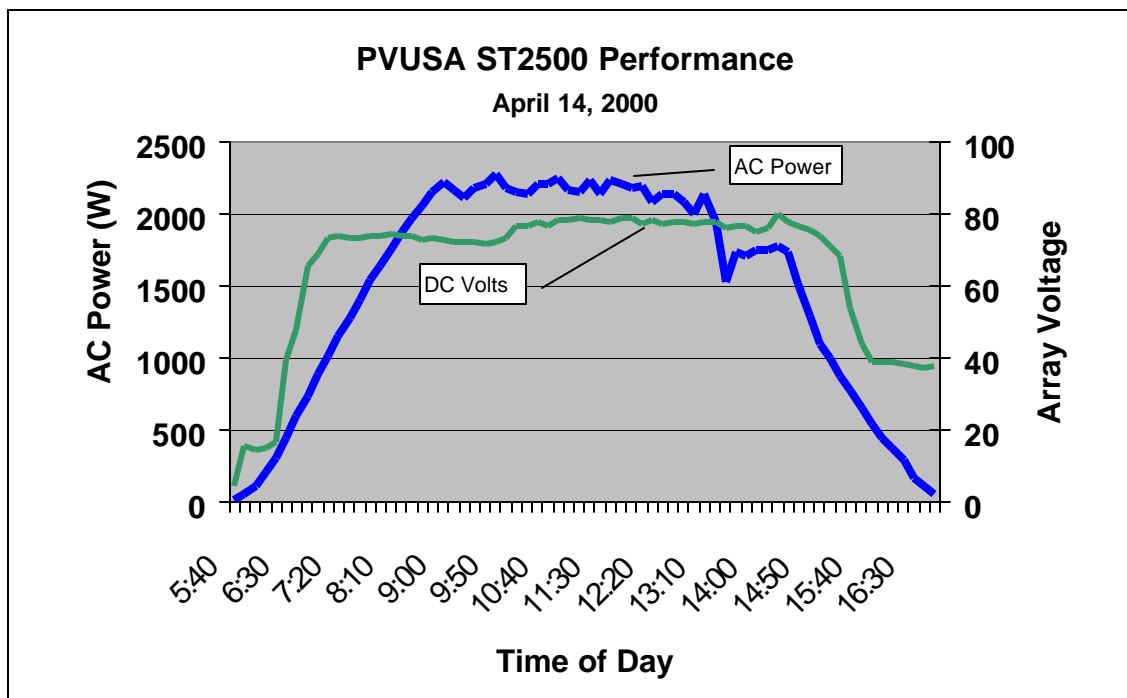
ST2500 performance has been evaluated in five locations where specific unique conditions made the sites desirable for performance testing. A comprehensive inverter performance assessment is presented herein to fully demonstrate the versatility of the ST Series in a wide range of environments using various PV arrays. Field testing began in November of 1999 and continues today at the 5 sites.

### 3.1 PVUSA

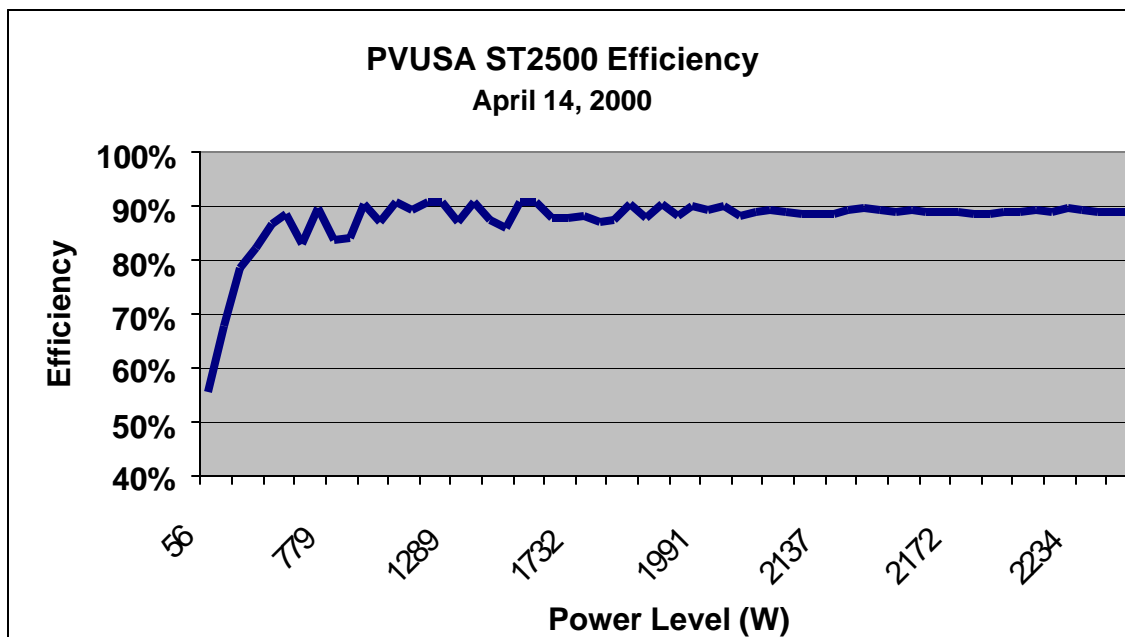
<b>Location:</b>	Davis, California
<b>Module Type:</b>	Solarex Millennia, MST43
<b>Array Size:</b>	3612 watts STC
<b>Array Orientation:</b>	True South
<b>Data Acquisition:</b>	Campbell Scientific CR10, measures AC/DC watts, AC/DC volts, module temp, inverter temp, ambient temp, wind speed, irradiance
<b>Test Dates:</b>	November 1999 – May 2000
<b>Current Status:</b>	System remains in operation, data acquisition has been decommissioned

The inverter wake-up voltages and power tracking operational windows were optimized during this testing phase. Trace inverter development engineers performed various testing at PVUSA during the development of the ST Series. The presented test data was collected by Endecon Engineering on a periodic basis. The following data illustrates the inverter's power production versus array voltage for two significantly different days and an efficiency curve over the 2500 watt power range.





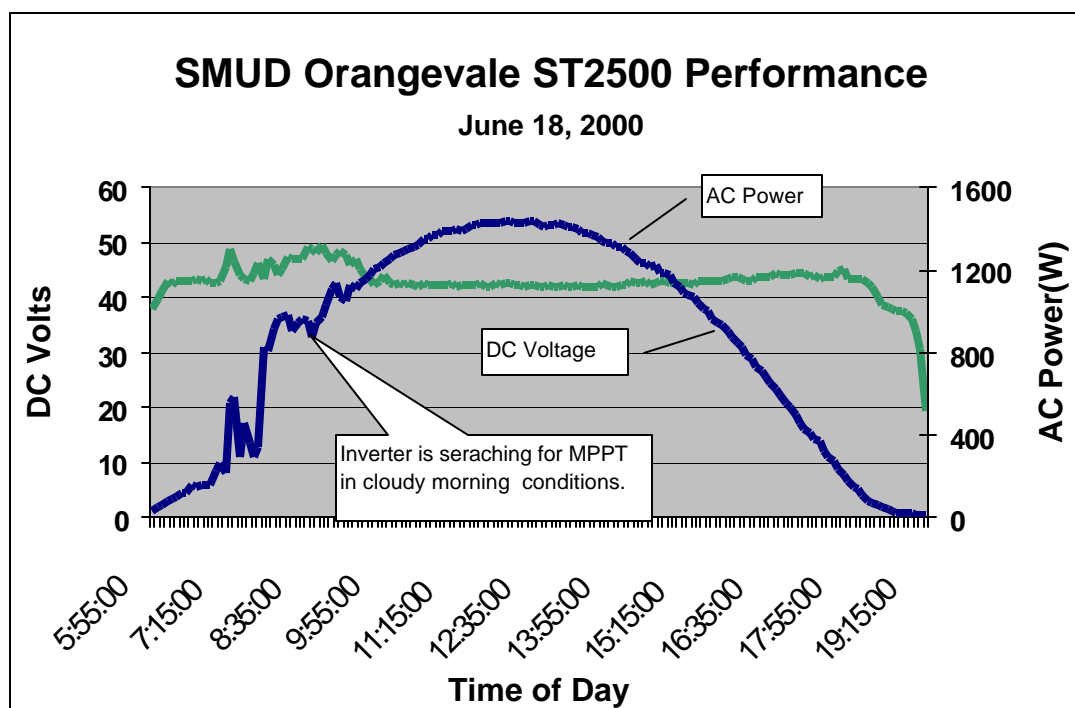
The following inverter efficiency data illustrates the high efficiency over a wide range of power levels. The ST2500 achieves an overall inverter efficiency of 90% or greater above 500 watts in the laboratory. The 6 minute interval data below illustrates real-world efficiencies over the power range during 35 to 45 °C ambient temperatures and varying sunlight.

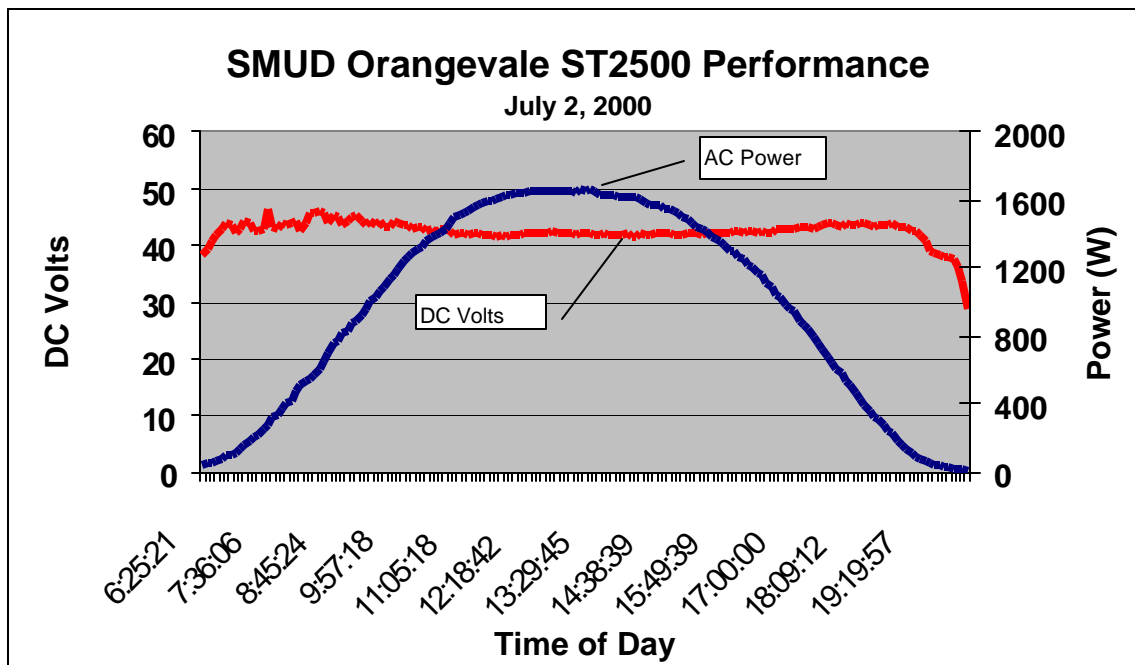
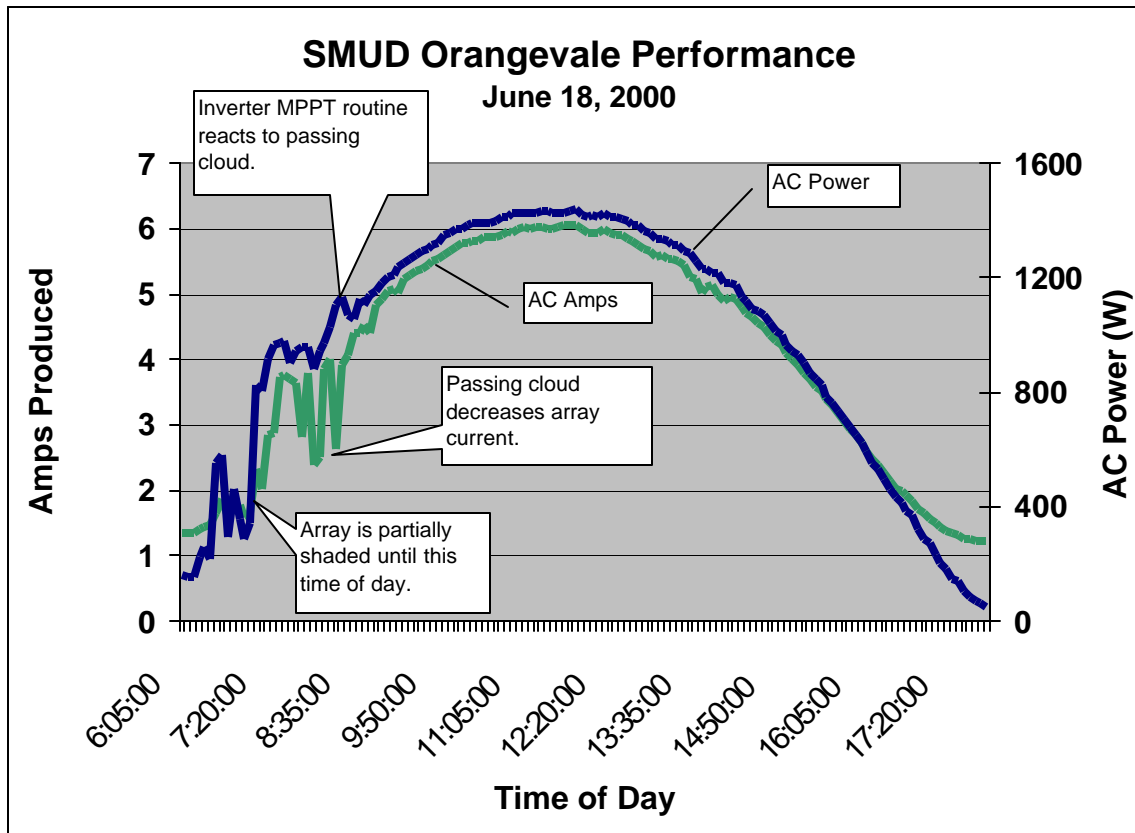


### 3.2 SMUD: Orangevale Community Center

<b>Location:</b>	Sacramento, California – Orangevale Community Center
<b>Module Type:</b>	Dunasolar/EPV, EPV 40
<b>Array Size:</b>	2580 watts STC
<b>Array Orientation:</b>	West of South, 27° tilt angle, shading from adjacent rooftop in morning hours
<b>Data Acquisition:</b>	Trace Engineering Power Tracer, measures AC/DC volts, AC amps, watts, watt hours, power factor
<b>Test Dates:</b>	May 2000 – current
<b>Current Status:</b>	System remains in operation, data logging is available on demand

The module manufacturer's specifications state  $V_{oc} = 62.2\text{ V}$  and  $V_{mp} = 44.8\text{ V}$  are the voltage parameters for these modules. After several months of stabilization, we found  $V_{mp}$  to be closer to 42 V for these modules. The module performance data is evident in the power production graphs and also illustrates significant voltage drop as the panels continue to absorb the sun's heat as the day continues. This site was desirable to test the low voltage limits for the ST2500 hardware and software combination and verify proper inverter maximum peak power tracking with lower voltage producing modules. The following graph illustrates power and current production for June 18, 2000. Notice how AC current and power production correspond with the changing PV array voltage.

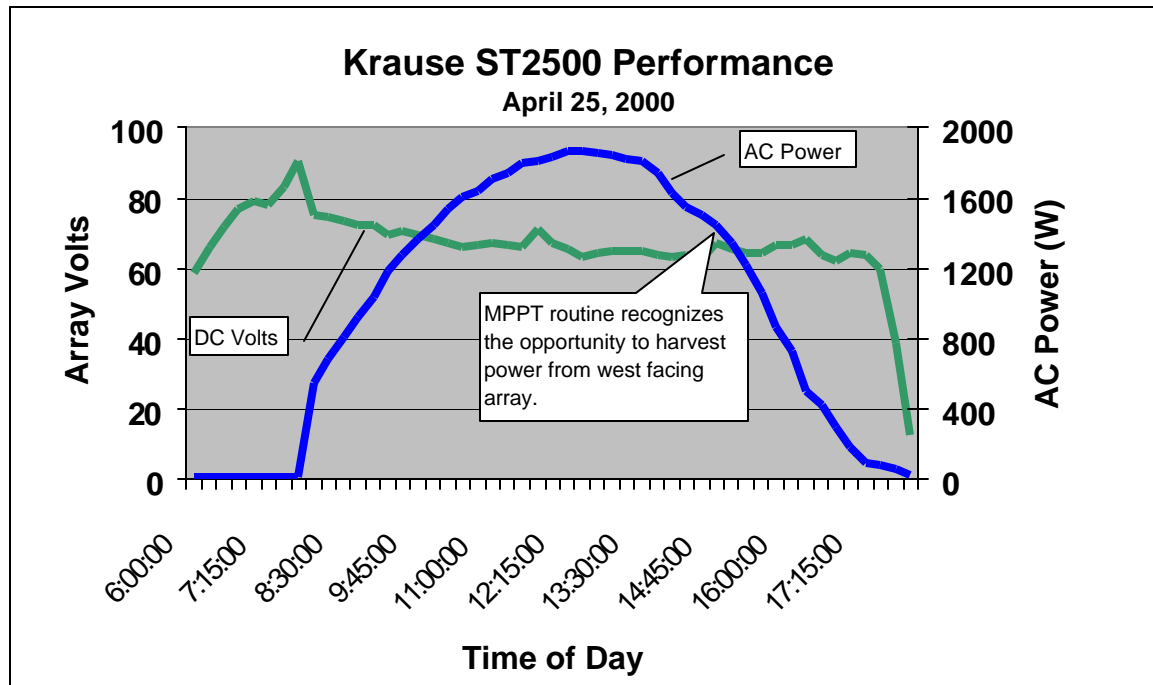




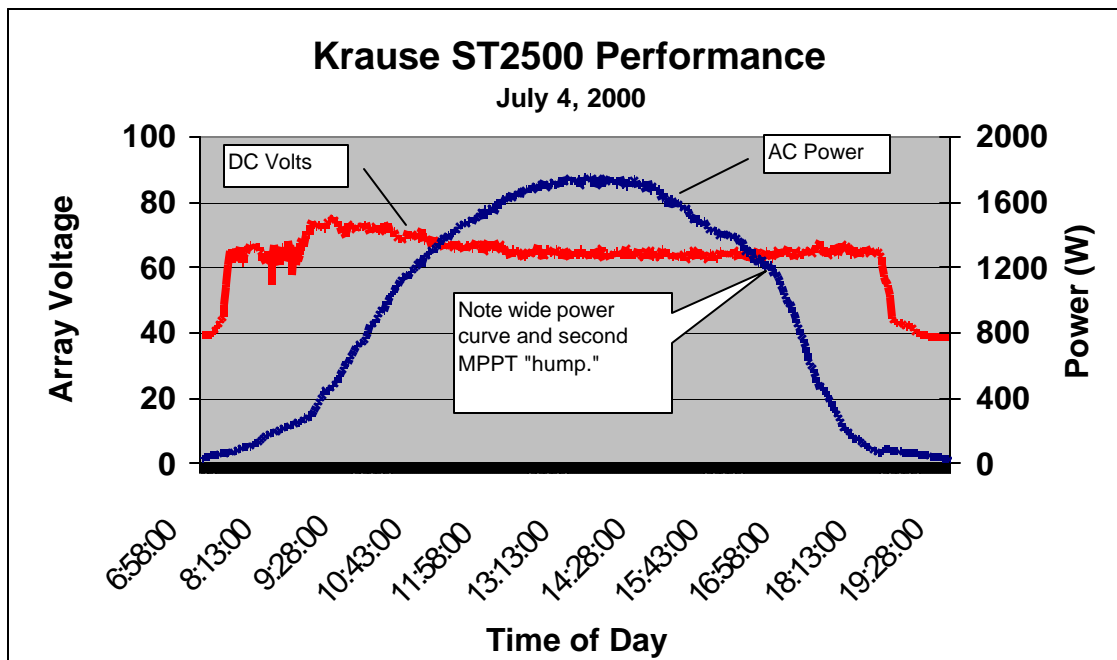
### 3.3 SMUD: Krause Residence

<b>Location:</b>	Sacramento, California – Krause Residence
<b>Module Type:</b>	Solarex Millennium, MST43
<b>Array Size:</b>	2580 watts STC
<b>Array Orientation:</b>	22.5° tilt, ½ array faces 2 degrees east of true south ½ faces 2 degrees south of due west
<b>Data Acquisition:</b>	Trace Engineering Power Tracer, measures AC/DC volts, AC amps, watts, watt hours, power factor
<b>Test Dates:</b>	January 2000 – current
<b>Current Status:</b>	System remains in operation, data logging upon demand

The Krause home is of particular interest because the inverter has essentially two arrays to peak power track. It is noticeable that the inverter is attempting to peak power track the west facing array in the afternoon. This “second hump” is more noticeable during the summer when long afternoon sunsets are more prominent in California. See July 4<sup>th</sup> data where the west facing array assists in producing significantly more energy (kWh) throughout the day. The April 25<sup>th</sup> graph uses 5 minute sampling intervals while the July 4<sup>th</sup> graph uses 1 minute sampling intervals. The shorter sampling resulted in more detailed data and “smoother” curves.







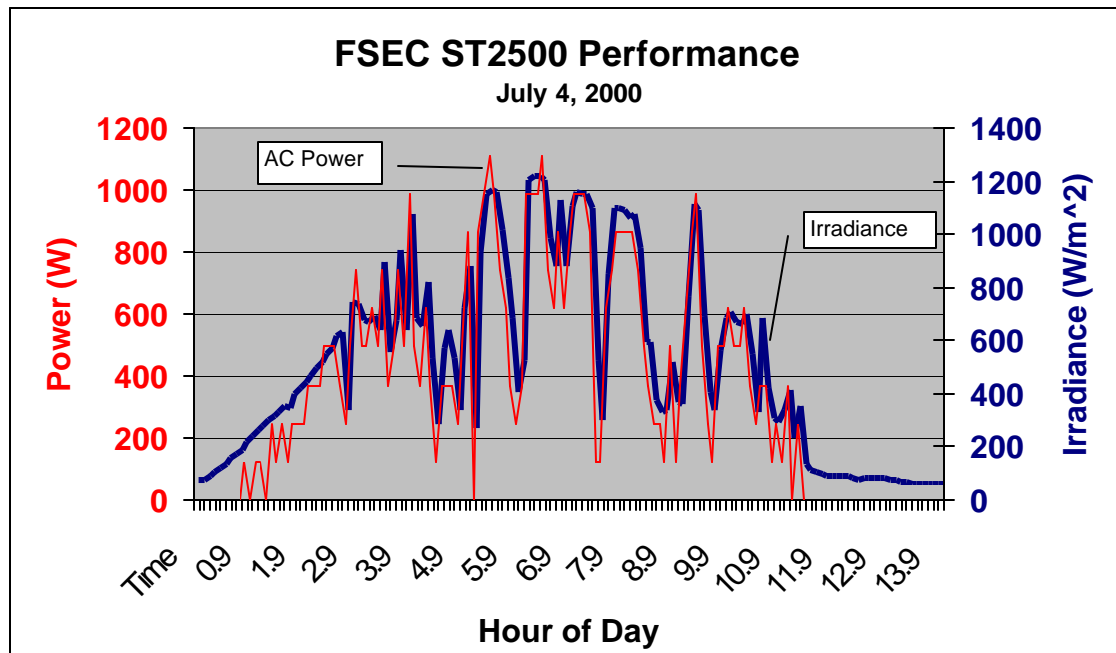
### 3.4 FSEC: Lakeland Elementary

<b>Location:</b>	Lakeland, Florida – Lakeland Electric and Water Company Solar School Site
<b>Module Type:</b>	Siemens, SP75
<b>Array Size:</b>	1800 watts STC
<b>Array Orientation:</b>	Array faces close to true south
<b>Data Acquisition:</b>	Campbell CR10, measures AC/DC watts, AC/DC volts, module temp, inverter enclosure temp, inverter heat sink temp, ambient temp, wind speed, irradiance
<b>Test Dates:</b>	June 24, 2000 – current
<b>Current Status:</b>	System remains in operation, data logging ongoing

This PV crystalline system is in the hot, sunny and humid Florida climate. This inverter has been commissioned to begin operation during the rainy season



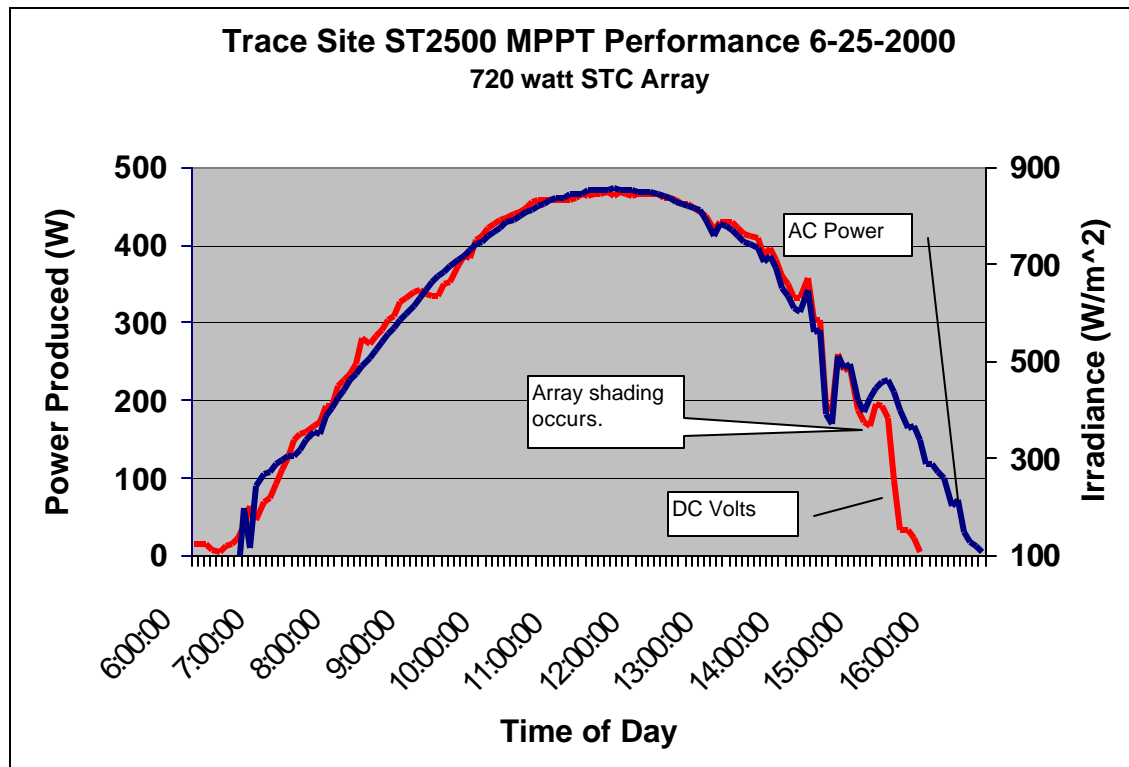
in Florida when lightning storms and tropical hurricanes commonly push through. Testing the inverter during this time of year has been useful for verifying accurate maximum peak power tracking functionality in quickly changing climate conditions. The performance data below, collected by Florida Solar Energy Center, occurs on a warm, muggy and intermittent sun day in central Florida.



### 3.5 Trace Engineering: Test Array

<b>Location:</b>	Arlington, Washington – Trace Engineering facility
<b>Module Type:</b>	Siemens, M75
<b>Array Size:</b>	720 watts STC, estimated at 500 watts with all losses
<b>Array Orientation:</b>	Array faces close to true south, approximately 50° tilt angle
<b>Data Acquisition:</b>	Trace Engineering Power Tracer, measures AC watts, AC/DC volts, ambient temp, wind speed, irradiance
<b>Test Dates:</b>	June 19, 2000 – current
<b>Current Status:</b>	System remains in operation, data logging ongoing

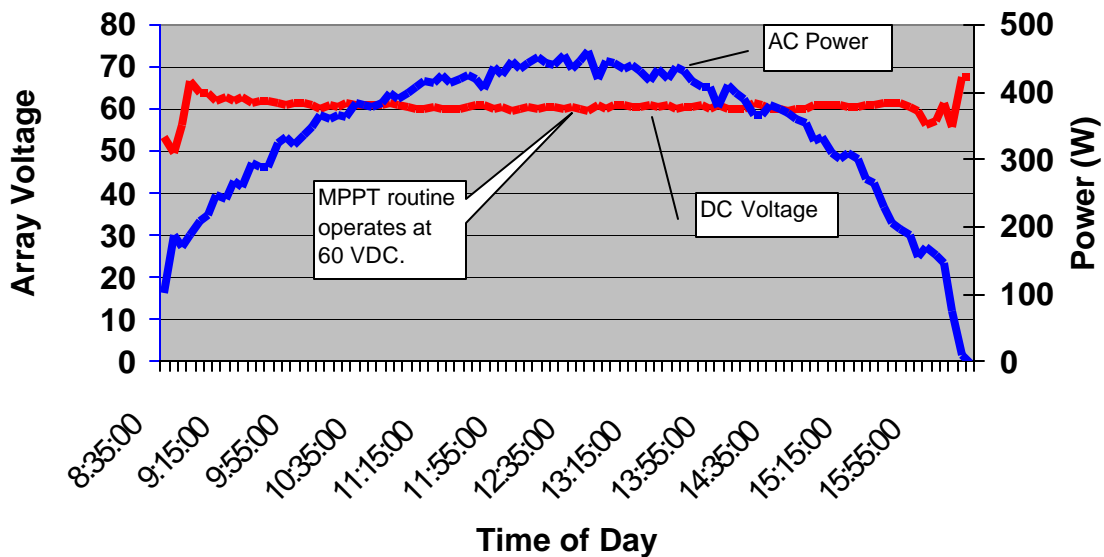
The Trace Engineering test array is excellent for testing the ST2500 in a variety of panel configurations and varying weather conditions. Our MPPT routine is constantly monitored with this in-house test array. Gathering consistent weather and inverter performance data has helped to optimize the inverter for the variety of PV modules available today. The array was used with three modules in series and four modules in series to simulate the characteristics of some commonly available PV panels. This inverter has remained stable through horizontal rain, intermittent clouds, and long warm and sunny northwest days at the Trace Engineering test site.



### Trace ST2500 Performance

#### 4 Modules in Series

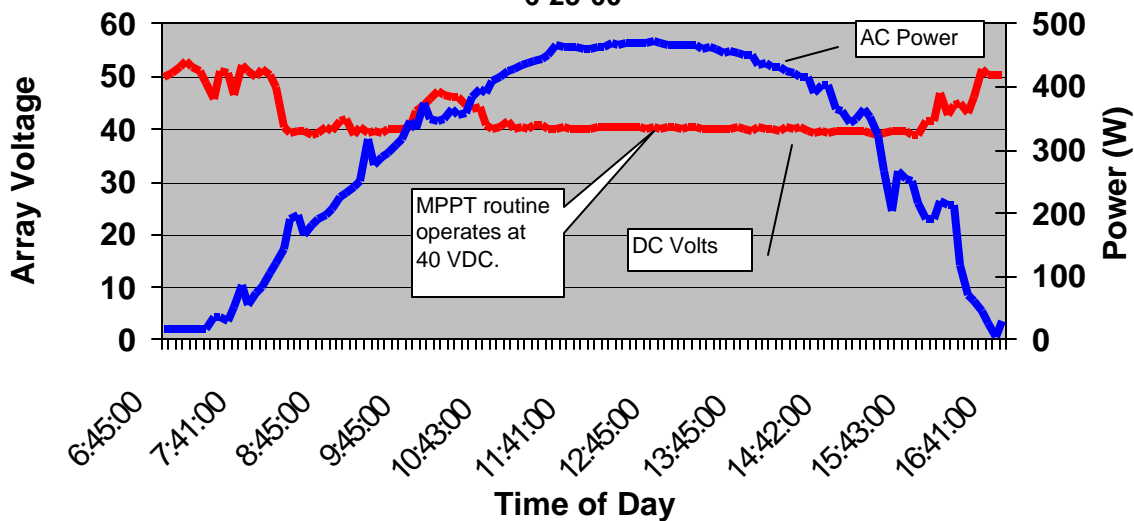
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### Trace ST2500 Performance

#### 3 Modules in Series

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## **4 Evaluation**

ST Series inverters are field proven as versatile machines for various modules on the market and extremely efficient in maximizing solar array power production. The proof is illustrated in the Orangevale and PVUSA data which show the ST2500 producing 1100 watts of power at  $V_{mp} = 42$  VDC (EPV thin film) and 1300 watts of power at  $V_{mp} = 70$  VDC (Solarex thin film). The ST2500 is flexible enough to harvest energy from a wide range of modules, plus efficiently maximize the output of these arrays.

## **5 Planned Activities**

The Trace and Florida sites will be continuously monitored for performance over the coming months. We plan to continue testing for maximum peak power tracking windows, module wake-up voltages, power tracking effectiveness and other software controls. Further ongoing testing will include using other module types and array configurations.

## **6 Approvals and Certifications**

The Trace Engineering ST Series (ST1000, ST1500, ST2000 and ST2500) is listed by Underwriters Laboratories under standards UL1741 1<sup>st</sup> edition (file #E187916) for sale in the U.S., and under CSA 22.2 #107.1-95 (file #E186797) for sale in Canada.