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Field Performance Summary Report

Sun Tie - ST Series

Version History

Version	Date	Author	Comments
1	6-24-00	T .Booth	First Draft
A	7-24-00	T. Booth	Released Version

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1 Summary

This field performance data is made available to demonstrate Trace Engineering's 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.

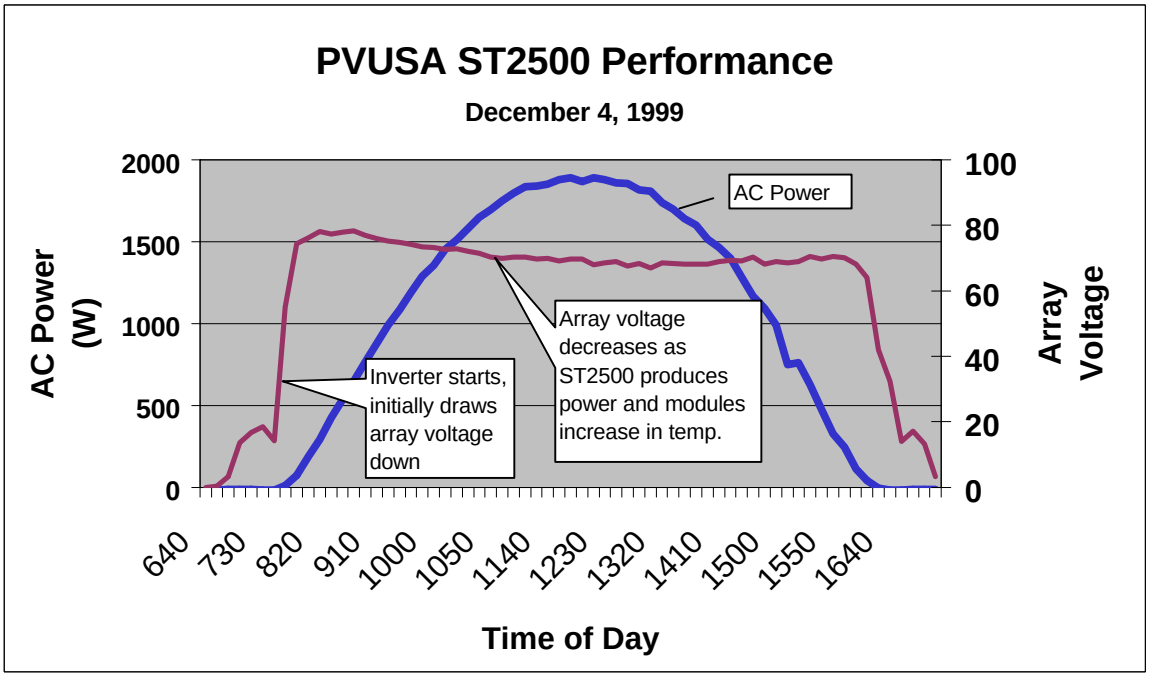
3 Comprehensive Assessment

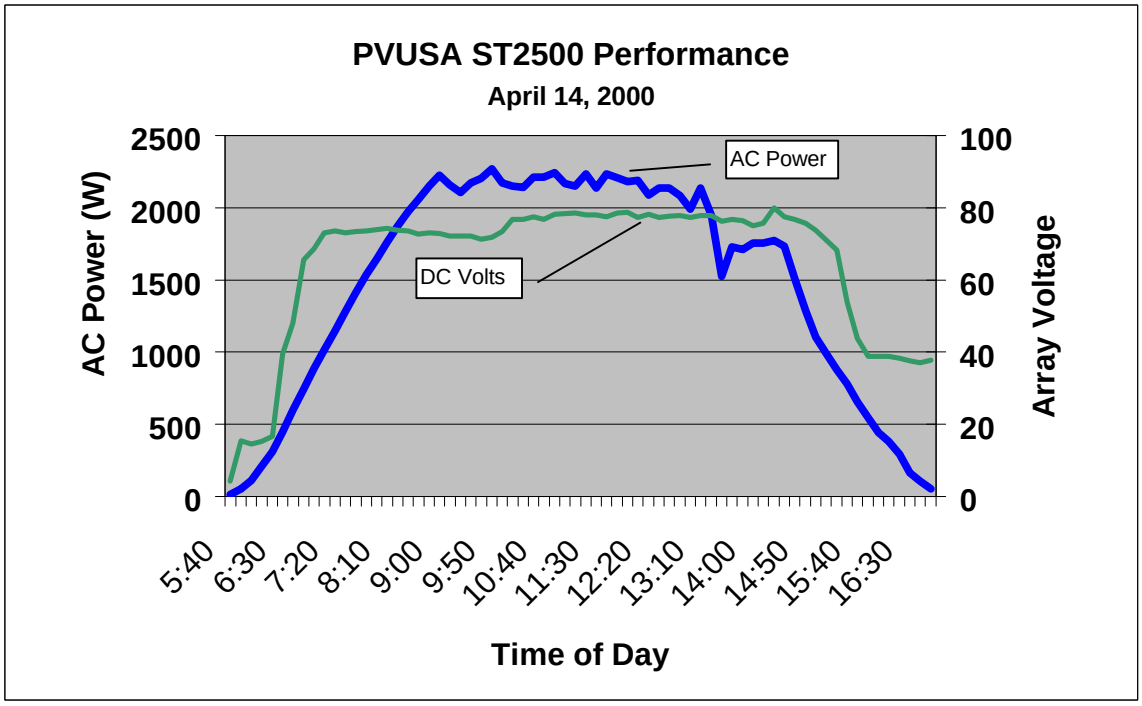
ST2500 performance has been evaluated in five locations where specific unique conditions made the sites desirable for performance testing. A comprehensive inverter performance assessment is presented herein to fully demonstrate the versatility of the ST Series in a wide range of environments using various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

3.1 PVUSA

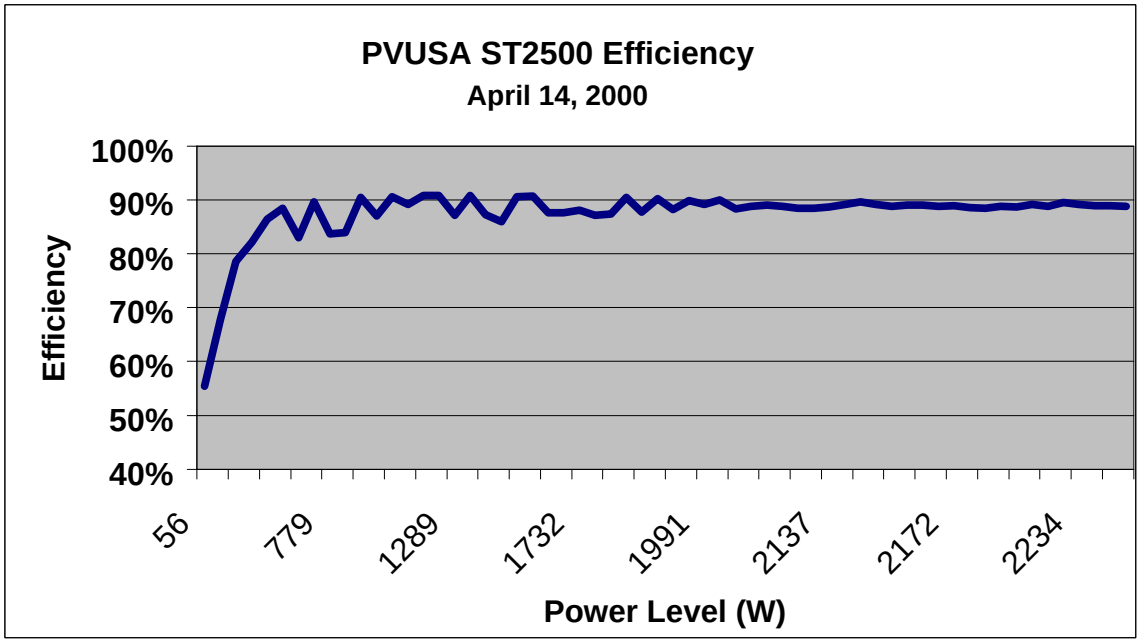
Location:	Davis, California
Module Type:	Solarex Millennia, MST43
Array Size:	3612 watts STC
Array Orientation:	True South
Data Acquisition:	Campbell Scientific CR10, measures AC/DC watts, AC/DC volts, module temp, inverter temp, ambient temp, wind speed, irradiance
Test Dates:	November 1999 – May 2000
Current Status:	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.





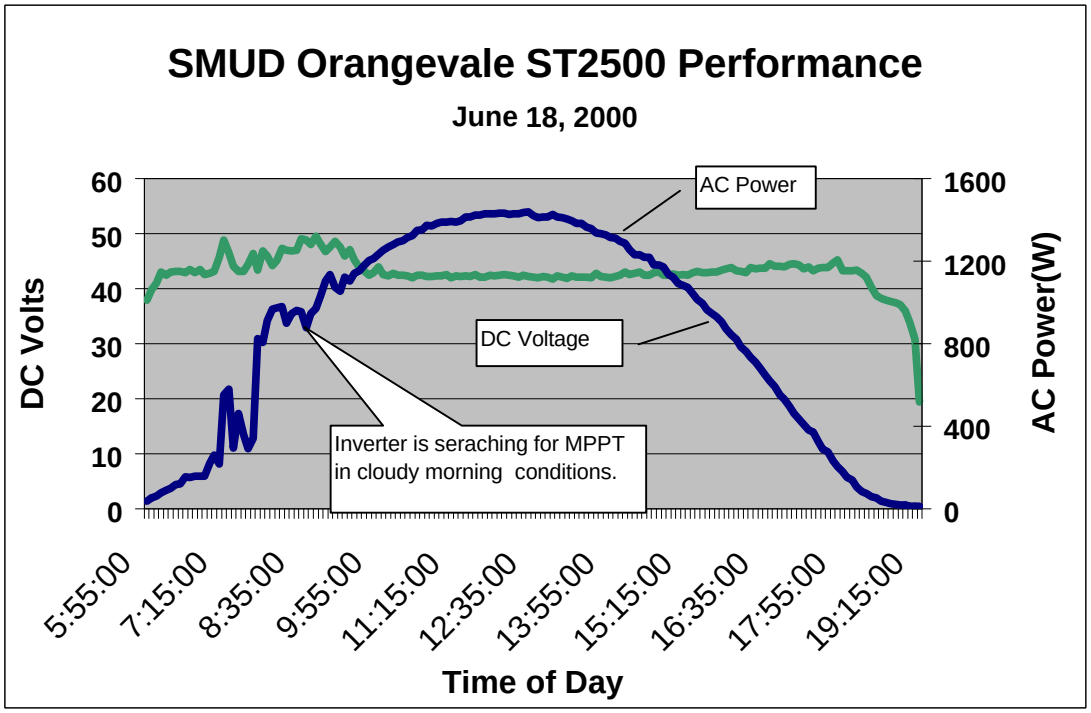
The following inverter efficiency data illustrates the high efficiency over a wide range of power levels. The ST2500 achieves an overall inverter efficiency of 90% or greater above 500 watts in the laboratory. The 6 minute interval data below illustrates real-world efficiencies over the power range during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

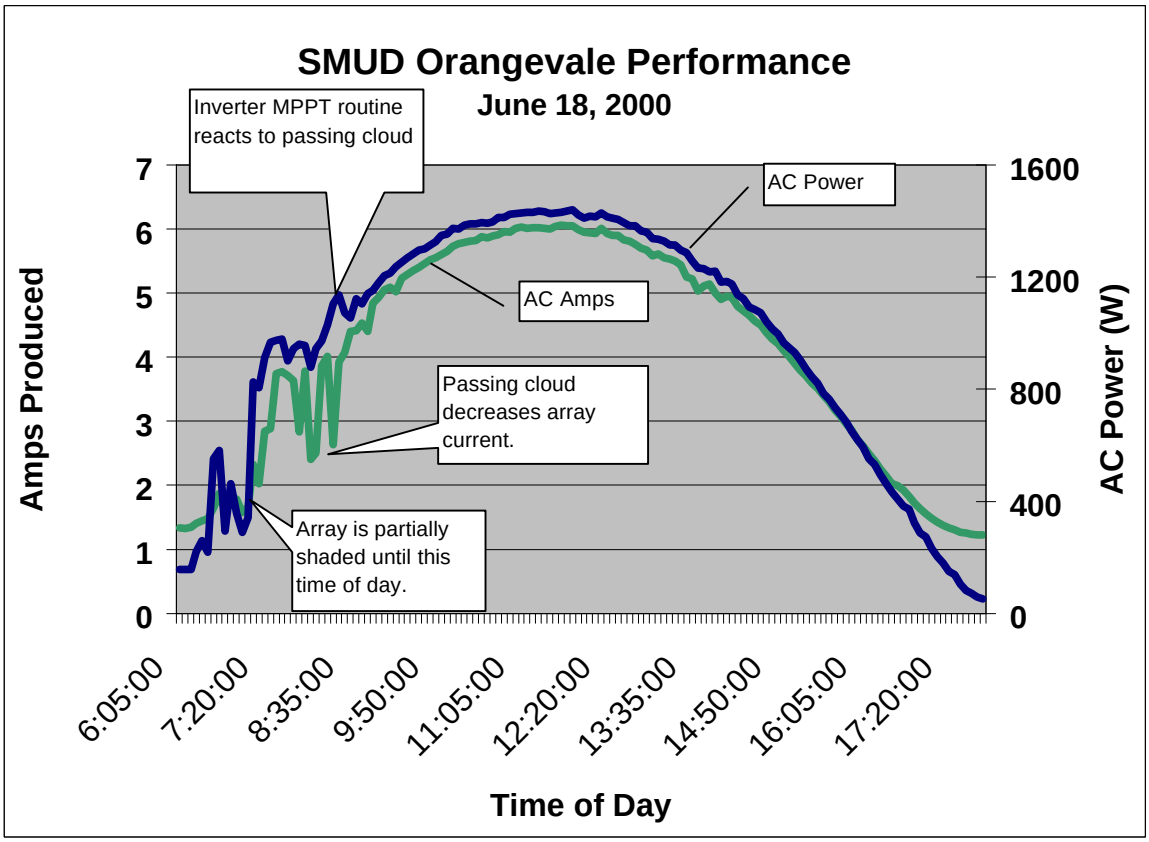


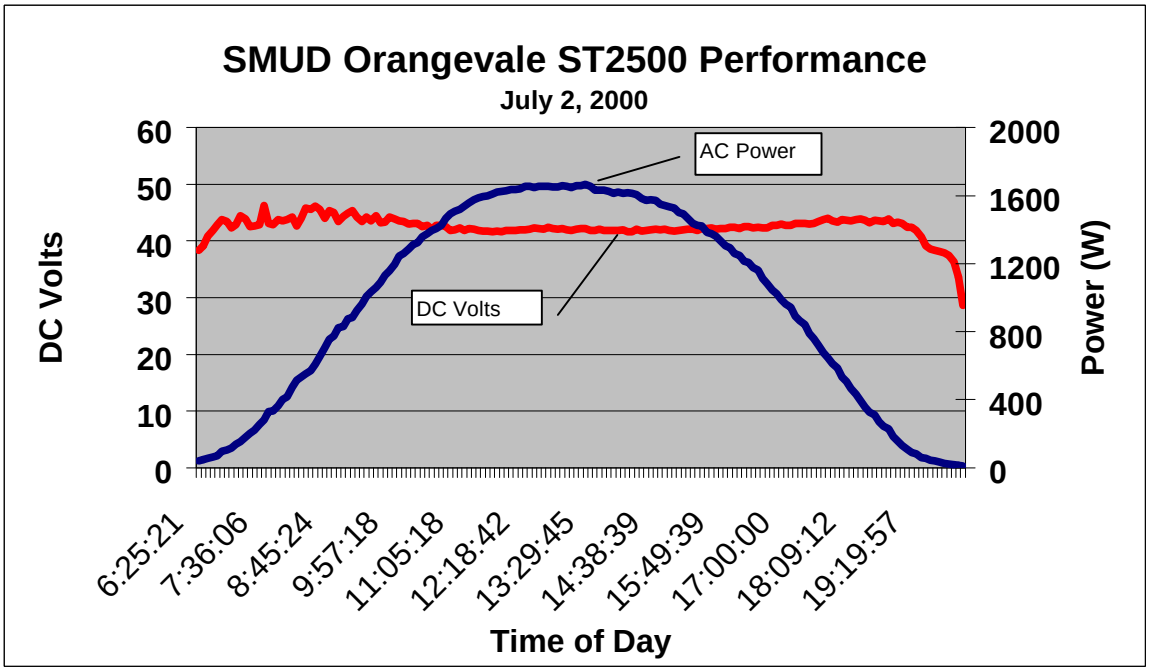
3.2 SMUD: Orangevale Community Center

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

The module manufacturer's specifications state Voc = 62.2 V and Vmp = 44.8 V are the voltage parameters for these modules. After several months of stabilization, we found Vmp 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.



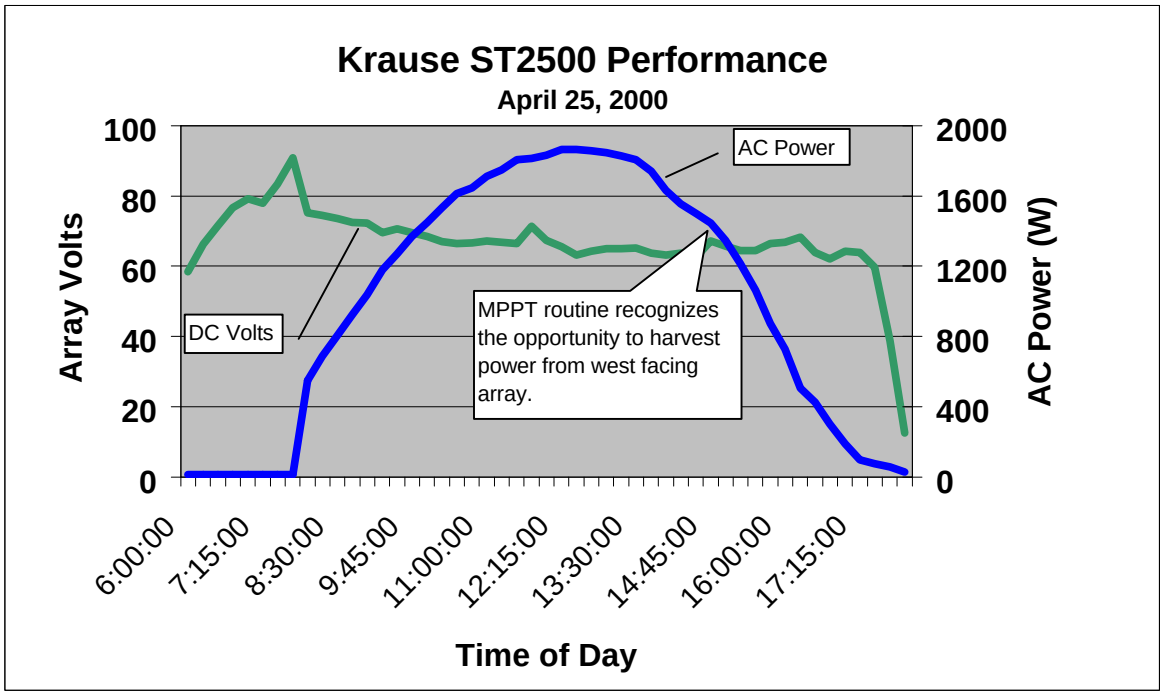

SMUD Orangevale Performance
June 18, 2000
Inverter MPPT routine reacts to passing cloud
AC Power
AC Amps
Passing cloud decreases array current.
Array is partially shaded until this time of day.
Amps Produced
AC Power (W)
0
1
2
3
4
5
6
7
0
400
800
1200
1600
6:05:00
7:20:00
8:35:00
9:50:00
11:05:00
12:20:00
13:35:00
14:50:00
16:05:00
17:20:00
Time of Day

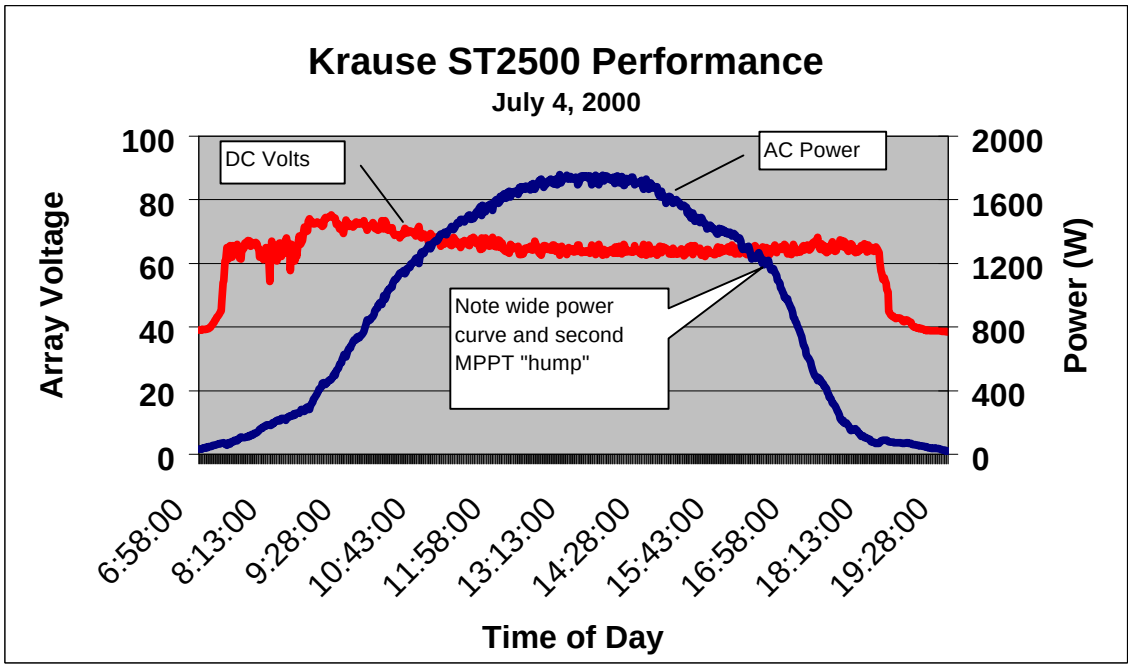

SMUD Orangevale ST2500 Performance
July 2, 2000
AC Power
DC Volts
DC Volts
Power (W)
0
10
20
30
40
50
60
0
400
800
1200
1600
2000
6:25:21
7:36:06
8:45:24
9:57:18
11:05:18
12:18:42
13:29:45
14:38:39
15:49:39
17:00:00
18:09:12
19:19:57
Time of Day

3.3 SMUD: Krause Residence

Location:	Sacramento, California – Krause Residence
Module Type:	Solarex Millennium, MST43
Array Size:	2580 Watts STC
Array Orientation:	22.5° tilt, ½ array faces 2 degrees east of true south ½ faces 2 degrees south of due west
Data Acquisition:	Trace Engineering Power Tracer, measures AC/DC volts, AC amps, watts, watt hours, power factor
Test Dates:	January 2000 – current
Current Status:	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 4th data where the west facing array assists in producing significantly more energy (kWh) throughout the day. The April 25th graph uses 5 minute sampling intervals while the July 4th graph uses 1 minute sampling intervals. The shorter sampling resulted in more detailed data and "smoother" curves.

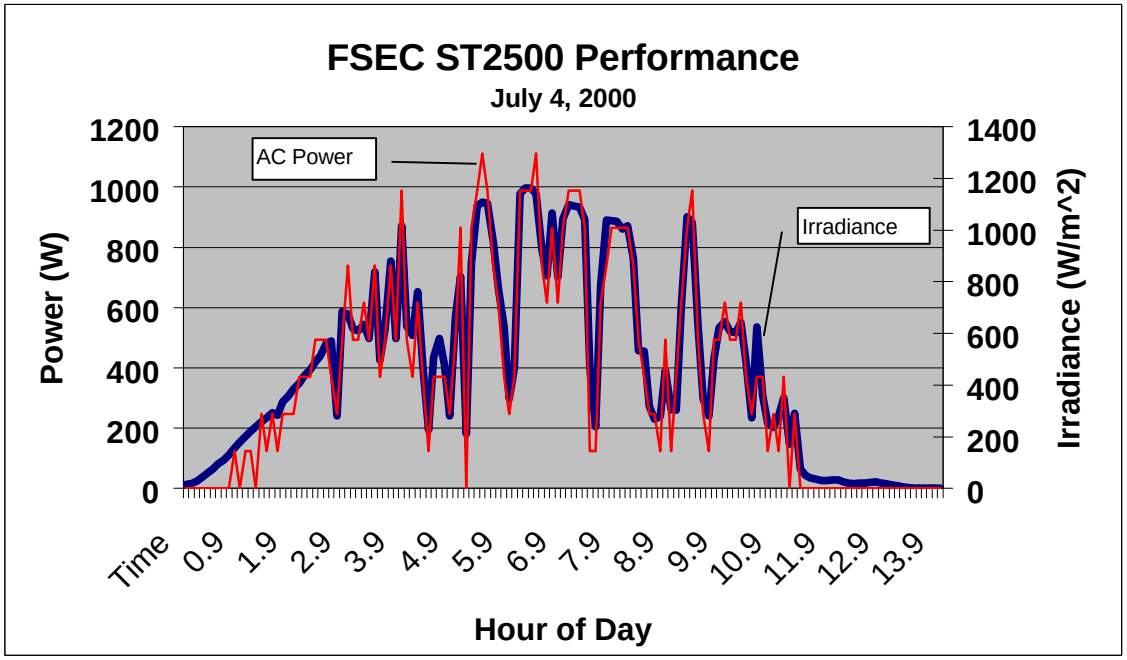



Krause ST2500 Performance
July 4, 2000
Array Voltage
Power (W)
100
80
60
40
20
0
2000
1600
1200
800
400
0
DC Volts
AC Power
Note wide power curve and second MPPT "hump"
6:58:00
8:13:00
9:28:00
10:43:00
11:58:00
13:13:00
14:28:00
15:43:00
16:58:00
18:13:00
19:28:00
Time of Day

3.4 FSEC: Lakeland Elementary

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

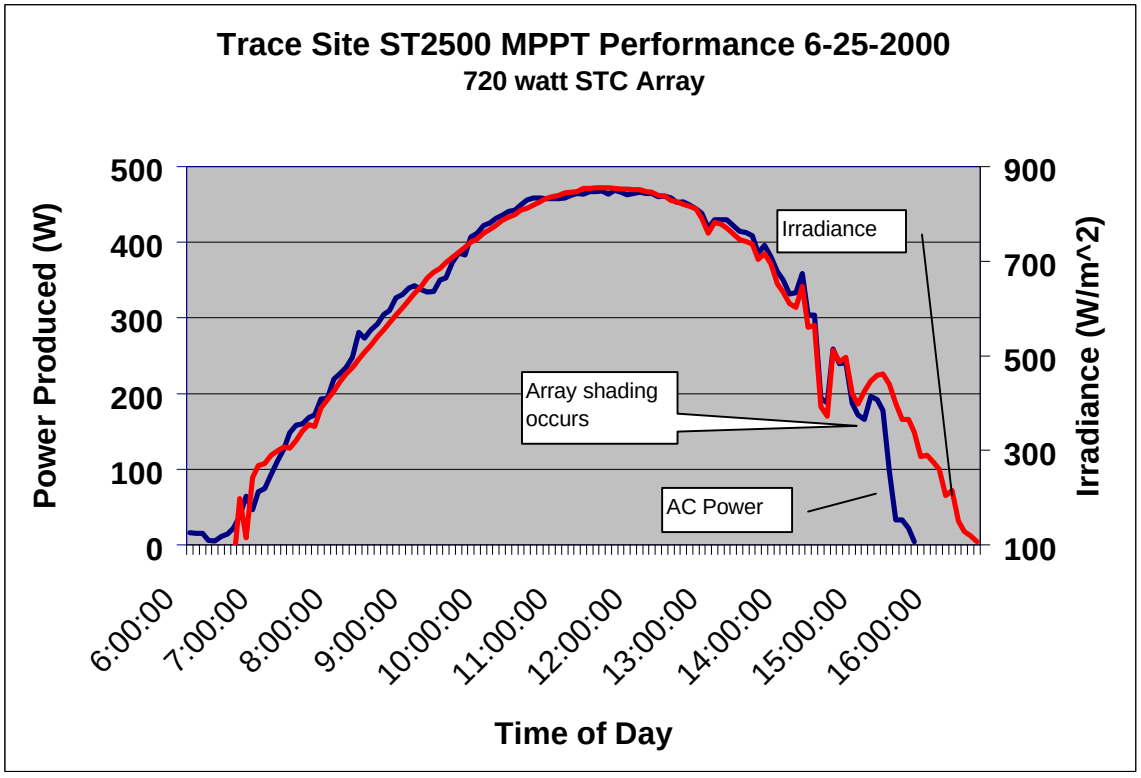
This PV crystalline system is in the hot, sunny and humid Florida climate. This inverter has been commissioned to begin operation during the rainy season in Florida when lightning storms and tropical hurricanes commonly push through. Testing the inverter during this time of year has been useful for verifying 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.

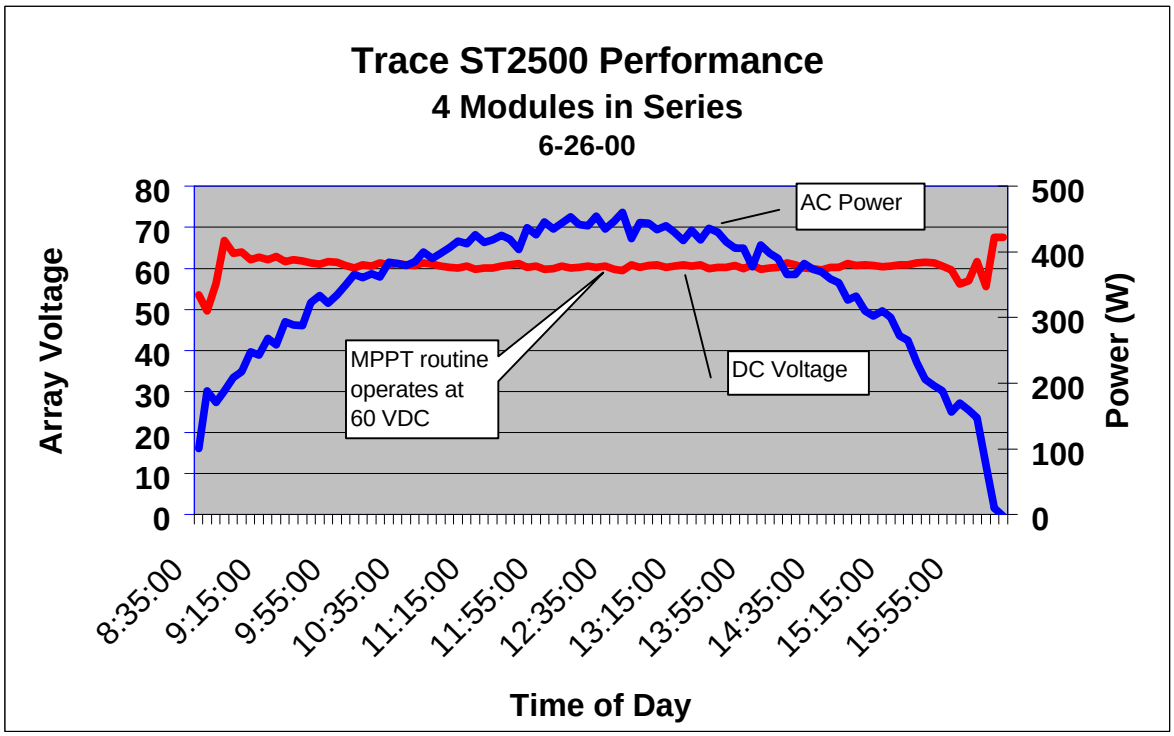


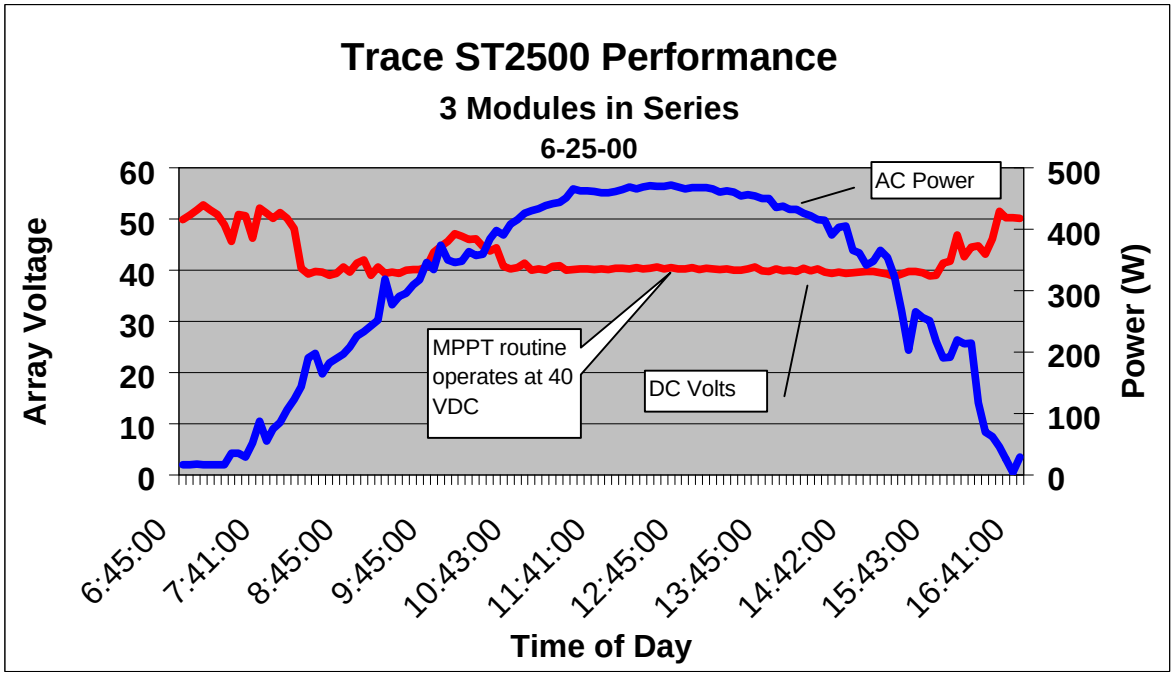
3.5 Trace Engineering: Test Array

Location:	Arlington, Washington – Trace Engineering facility
Module Type:	Siemens, M75
Array Size:	720 Watts STC, estimated at 500 Watts with all losses
Array Orientation:	Array faces close to true south, approximately 50° tilt angle
Data Acquisition:	Trace Engineering Power Tracer, measures AC watts, AC/DC volts, ambient temp, wind speed, irradiance
Test Dates:	June 19, 2000 – current
Current Status:	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
6-26-00
Array Voltage
Power (W)
AC Power
DC Voltage
MPPT routine operates at 60 VDC
80
70
60
50
40
30
20
10
0
500
400
300
200
100
0
8:35:00
9:15:00
9:55:00
10:35:00
11:15:00
11:55:00
12:35:00
13:15:00
13:55:00
14:35:00
15:15:00
15:55:00
Time of Day


Trace ST2500 Performance
3 Modules in Series
6-25-00
Array Voltage
Power (W)
AC Power
DC Volts
MPPT routine operates at 40 VDC
60
50
40
30
20
10
0
500
400
300
200
100
0
6:45:00
7:41:00
8:45:00
9:45:00
10:43:00
11:41:00
12:45:00
13:45:00
14:42:00
15:43:00
16:41:00
Time of Day

4 Evaluation

The 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 Vmp = 42 VDC (EPV thin film) and 1300 watts of power at Vmp = 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 approved for use by Underwriters Laboratories standard UL174 under file number E187916 and E186797. The ST Series is also approved for use in Canada by the Canadian Standards Association, under CSA standard 22.2 #107.1-95.