PHASE II -- PHOTOVOLTAICS FOR UTILITY SCALE APPLICATIONS (PVUSA)

SECOND TECHNICAL REPORT 1995

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I. SUMMARY

PVUSA is summarizing 1995 system performance and major project activities by way of two Technical Reports and a final Progress Report. The first report covered the January-April period, this report covers May-August, and the final four months will be discussed in the 1995 Progress Report.

Principal activities during the second four months of 1995 included:

- Confirming the transfer of project management from PG&E to a joint CEC/SMUD team beginning next year and initiating several transition tasks
- Installing a 225-kW Kenetech replacement PCU for the IPC US-1 Omnion PCU at Davis
- Mobilizing and completing much of the installation of the Amonix EMT-3 array at Davis
- Installing the remaining BOS equipment for the Solar Cells EMT-3 array at Davis
- Hosting a two-day PCU, DAS, and System Rating workshop at the Davis site
- Rating three host systems—SMUD UPG @ 207 kW, NREL IPC @ 12.9 kW, and CSW UPG @ 98 kW
- Issuing the 1994 Progress Report and three major topical reports, and delivering papers and presentations at four conferences and workshops.

Except for the inoperative VEPCO site, data were collected for 17 other completed systems with a combined capacity of 1,800 kW. Combined, these systems generated nearly 1 million kWh during May through August, including a project monthly high of 0.29 million kWh during June. For the year, over 1.6 million kWh have been generated, about the same energy used by 400 homes over the same period. The project's cumulative generation now stands at 6.4 million kWh. Key May-August and cumulative 1995 results are listed in the following table. The locations of systems other than Davis are noted alongside the supplier's name.

Emerging Module Technologies 1995 cumulative = []	Efficiency %	Capacity Factor %	Performance Index ¹ %
AstroPower	5.4 [5.6] dc	27 [21]	96 [94]
ENTECH	10.3 [10.5] dc	31 [21]	84 [80]
Solarex	7.5 [7.8] dc	24 [19]	95 [94]
Sovonics	2.8 [2.6] dc	23 [16]	97 [90]
Sovonics (Maui, HI)	3.2 [3.3] dc	20 [20]	100 [98]
SSI	9.5 [9.9] dc	23 [18]	90 [90]
UPG	2.8 [2.8] dc	21 [17]	82 [87]
Utility Scale Systems 1995 cumulative = []			
APS	2.6 [2.9] ac	17 [14]	71 [78]
ENTECH (Fort Davis, TX)	9.1 [cumulative n/a]	20 [n/a]	n/a [n/a]
IPC	6.9 [7.4] ac	8 [10]	19 [32]
IPC (Austin, TX)	7.3 [7.5] ac	21 [17]	76 [75]
IPC (Farmingdale, NY)	7.7 [7.8] ac	19 [10]	71 [45]
IPC (Maspeth, NY)	3.2 [3.0] ac	13 [11]	82 [83]
SSI	6.9 [7.2] ac	24 [18]	57 [62]
SSI (Kerman, CA)	7.6 [8.4] ac	16 [15]	41 [53]
UPG (Fort Davis, TX)	7.4 [8.2] ac	20 [21]	60 [67]
UPG (Sacramento, CA)	10.0 [10.2] ac	34 [23]	88 [80]

¹ Defined as the percentage of actual to expected generation. The expected generation adjusts for ordinary differences between actual and rated output caused by variations in insolation and temperature, as well as shortfalls related to scheduled outages, long-term degradation, and BOS limitations.

II. PROJECT MANAGEMENT

1. Schedule Analysis

Overall, the project continued with plans for a January 1, 1996 transfer of project management duties from PG&E to a joint CEC/SMUD team. The present scheduling emphasis is to complete outstanding PV-related contracts and major technology transfer activities before the end of the year to help the transition go smoothly. In addition to several transition tasks, work in progress at this time includes: resolving a few punch list, DAS, and dc source circuit problems on the recently re-powered Kenetech/IPC US-1 system, finishing the Amonix and Solar Cells EMT-3 array installations that are presently underway and on schedule, and supporting host site installation activities at CSW (ENTECH), DOD/Yuma (UPG), and PSCC. Unfortunately, as this report was being prepared, PVUSA learned that VEPCO has canceled its plans to operate their AstroPower EMT-2 host array and is closing down their PV site. Major technology transfer activities remaining for 1995 include issuing three more topical reports (DAS, Procurement/Acceptance/Rating, and PCUs/Power Quality) and attending an IEEE PV Standards meeting in New Mexico in November.

Pending contracts are listed in the following table. The status of PSCC's undetermined system is unchanged from the previous report. In June, UPG was awarded a contract to supply a 375-kW PV/battery hybrid stand-alone system for the DOD's Yuma site. CSW's ENTECH system is now considered complete and is no longer shown on the table. After over six months of start-up efforts, this system reached full power operation in July (although a few DAS-related items such as instrument calibrations and unreliable communications remained unfinished as of the end of August). VEPCO's system has also been deleted. Earlier this year, PVUSA expressed its interest in supporting Golden Photon's CdTe/CdS module qualification testing if the work could be completed by October 1, 1995. Unfortunately, Golden Photon was unable to follow this schedule and PVUSA notified them on August 3 that it would not be able to fund the qualification tests this year.

Systems to be installed:	Original Estimated Completion Date	Current Forecast Completion Date
<i>Davis site</i>		
Solar Cells	September 1995	September 1995
Amonix	September 1995	September 1995
<i>Host sites</i>		
PSCC (APS)	December 1994	TBD
DOD (UPG)	October 1995	August 1996

2. Cost Analysis and Funding Activities

June data are the latest available for this report, as PG&E's accounting status is only reported quarterly. In April, the project received \$320,000 of the \$1,100,000 requested from the DOE, although the funding was not posted in time to be included in the first interim report for 1995. Indications are that total DOE funds for 1995 will only reach \$970,300. New invoicing to DOE over the April-June period amounted to \$571,000, and another \$300,000 was invoiced to EPRI. The project's total funding stood at \$32.6 million through June, and is forecast to reach \$34.5 million by the end of 1995.

Project expenditures over the second quarter were about \$483,000, with no significant lump sum payments made. Through the first half of the year, project expenses were less than half of the 1995 budget of \$2,720,000, but large payments to Kenetech, Amonix, and Solar Cells are anticipated in the second half of the year, and the annual budget estimate is still accurate.

The Defense Contractor Audit Agency initiated their audit on behalf of DOE on August 1. The audit covers from inception through 1994 and is expected to be completed this fall.

3. Principal Activities

Principal activities over the May-August 1995 period are detailed below for the Davis, Kerman, and host sites, and for general project activities. The focus for this section is on procurement, engineering, construction, and planning activities. Maintenance activities for operating systems are discussed in Sections III (Davis systems) and IV (Kerman and hosts).

Davis

The AstroPower EMT-2 array rating (17.1 kW dc) was released in May, triggering final payment to AstroPower.

PVUSA issued a purchase order in May for a 225-kW Kenetech PCU to replace the IPC system's original PCU. In July, Kenetech's factory assembly and PVUSA's field preparations began. The unit arrived on August 15 and began start-up tests on August 28. The unit was operating successfully, but as of the end of the month, a few minor punch list items remained, along with more significant troubleshooting on several corrupted DAS signals that were believed to be affected by PCU noise.

Installation of the Amonix EMT-3 250x concentrator array began in July. Scientific Engineering, Amonix' principal subcontractor, modified the old EPRI assembly pedestal and array mounting pad, installed a new array pedestal, and completed most of the array assembly by the end of August. PVUSA moved a spare EMT-2 DECC/Helionetics PCU to the Amonix array location and began PCU tests using the ENTECH array as a temporary dc power source.

Collins Electric completed the BOS equipment (such as source circuit junction boxes, disconnect switches, sub-array wiring, and PCU hook-ups) installation for the Solar Cells EMT-3 CdTe/CdS array in August. Module delivery and installation was on schedule for a September completion date.

Kerman

The landmark Kerman case study evaluation was issued in June as the topical report titled "The Value of PV in the Distribution System - The Kerman Grid-Support Project." A key finding of the Kerman project is that the value of a PV system can double when its distributed, or non-traditional, benefits are considered. The tools developed for this study will be useful for evaluating distributed resources at other locations. The Kerman study also found a good correspondence between plant output and feeder loads, with the PV plant operating at an equivalent dispatchable capacity of 77% of its rated capacity, even though its annual capacity factor was 25% (July 93-Jun 94).

The Kerman system saw significant downtime this summer, generating only 41% of the energy that it was expected to over the past four months (and only 53% through the first eight months of the year). Accordingly, many of the activities reported over the past four months were maintenance-related issues. These are discussed in Section IV.2.

Hosts

PVUSA used June data to establish PTC ratings for three systems. SMUD's 1-axis tracking system at their Hedge substation in Sacramento, CA was rated at 207 ± 6 kW. NREL's fixed 10° tilt rooftop IPC system in Maspeth, NY was rated at 12.9 ± 0.7 kW, and CSW's 1-axis tracking UPG system at their Solar Park near Fort Davis, TX was rated at 98 ± 2 kW. Detailed reports were issued for each system. In addition, CSW informed PVUSA in September that the South West Technology Development Institute had calculated a PTC rating of 82.6 kW for the ENTECH system using about one month of data from mid-July on. Unfortunately, CSW also

indicated that an August lightning storm ruined five ENTECH modules and three ground fault protection devices and adjacent module wiring on their UPG system. Repairs were pending as of the end of August.

General

A proposal developed by the CEC and SMUD for continued DOE funding of PVUSA was submitted to SMUD management for review in May. SMUD's Board of Directors approved the proposal at the beginning of June, in time for PVUSA's June TRC and SC meetings in Dallas. The TRC and SC confirmed their earlier conditional approval of the new CEC/SMUD management team for PVUSA, and SMUD submitted the proposal to DOE later that month.

In July, PVUSA issued an informational bulletin announcing the new management plan to all PVUSA *UPDATE* recipients. Under the new management structure, the CEC is assuming ownership of PVUSA's assets, and SMUD will have primary responsibility for daily operations. PG&E will remain active as a participating utility. The bulletin also notes that DOE funding for FY 1996 is anticipated this fall, and that the CEC and SMUD will give final consideration of the transfer once notification of funding is received from the DOE. An early emphasis of the new management team will be to develop a long-range plan and to encourage greater utility participation.

In August, a draft transfer agreement was submitted to the CEC for review. Also that month, PG&E contracted for an environmental assessment of the Davis site for lease termination purposes. The contractor found no adverse effects by PVUSA on the site.

4. Technology Transfer Activities

Publications, Conferences, and Meetings

May:

The topical report "Emerging Photovoltaic Module Technologies at PVUSA - A Five-Year Assessment" was distributed. The report summarizes experiences in procuring, installing, and operating the EMT-1 arrays at Davis and Maui.

Walt Stolte presented a paper titled "Inverter Performance Comparison at PVUSA" at the 13th NREL PV Program Review Meeting in Lakewood, Colorado.

June:

PVUSA TRC and SC meetings were held at CSW's offices in Dallas.

The topical report "The Value of PV in the Distribution System - The Kerman Grid-Support Project" was issued.

Nineteen participants attended a PVUSA workshop on PV Power Conversion, Data Collection, and System Rating at the Davis site.

Chuck Whitaker attended the SCC 21 Standards Meeting at NREL in Golden, CO.

July:

PVUSA presented two papers: "PVUSA Experience with Power Conditioning Units," and "Acceptance Testing and Rating Grid-Connected PV Systems: Experience at PVUSA" at the ASES Solar '95 conference in Minneapolis.

Brian Farmer gave a presentation on PVUSA and U.S. experience with interconnection requirements at the Grid Connection of PV Systems Workshop, sponsored by the Centre for PV Devices and Systems at the University of New South Wales in Australia.

The 1994 PVUSA Progress Report was issued.

The topical report "Photovoltaic Balance-of-System Designs and Costs at PVUSA" was issued.

Site Tours

During the second four months of 1995, PVUSA hosted 37 tours of the Davis site for a total of 126 visitors, including visits by an Australian group led by the Honorable Colin Barnett, Leader of the House in the Australian Legislative Assembly, and a visit by a Chinese delegation sponsored by NREL.

III. TECHNICAL ANALYSIS - DAVIS SITE

1. System Performance

General

Performance data are listed in Table III.1 for nine Davis systems, including six EMT arrays and three US systems. Overall, the PV systems operated under normal seasonal conditions, although there were some extremes of high winds, high irradiance, and high temperatures in June. On June 5-6, winds up to 40 mph caused outages and transients on the PG&E system, tripping PVUSA off line and causing some fuses to blow. An unseasonal storm on June 14-15 included brief periods on the 15th when cloud-enhanced conditions resulted in irradiance levels as high as 1,503 W/m², the highest ever observed at the Davis site. One week later, a series of days exceeding 100 °F, including one day that reached 107 °F, again resulted in widespread power outages on the distribution system and two PCU trips at Davis (it is unknown whether the trips were caused by temperature or transients).

After the June storms, the site received no more precipitation through August. The arrays were visibly soiled in July and August. One array (SSI EMT-1) was washed in late August, increasing its output by about 12%. It is estimated that over the four-month period, soiling reduced site generation by at least 5% but probably less than 10%.

In Table III.1, dc efficiencies are listed for the EMT arrays and ac efficiencies are listed for the US systems. The insolation totals differ in this table, even for arrays of the same orientation. They differ primarily because this quantity is integrated only when the PCU is on, and the hours of PCU operation vary between arrays. In addition to the instrument uncertainty (typically $\pm 3\%$), there are also small differences in the field of view from each array. Background data for the performance index calculations are listed in Appendix A.

Energy

Figure III.1 tracks the monthly energy supplied by the Davis site EMT systems over the past 16 months. Figure III.2 shows the same information for the US-1 systems, including start-up and testing energy delivered prior to system completion. The right scales refer to insolation measured at the site weather station (integrated over all hours). On both plots, the 30° tilt insolation is shown as a reference trend for the fixed tilt systems. On Figure III.1, the 1989-94 monthly average 30° tilt insolation is also included, and on Figure III.2, the horizontal N-S 1-axis insolation is included as a reference trend for the IPC and SSI 1-axis tracking systems.

The monthly energy production patterns generally follow the insolation trends, except that the array energy production also reflects outages, limited operation during installation and startup, and seasonal efficiency variations. The most notable departure from the expected trends on Figure III.1 is the UPG array's low output in June. On June 9, several wires and blocking diodes in the array's dc collection cabinet were damaged by a fire of unknown cause, reducing array output by about 50%. The array was turned off until repairs were completed on June 29.

On May 9, the ENTECH array's tracker drive and motor were replaced, and the system has worked flawlessly since the change was made. Its monthly output was lower than expected in May and August. The dip in May was caused partly by a PCU synchronization error over a weekend and partly by poor tracker operation during the first week of the month. The dip in August resulted from using the array for three days to test-power the Amonix array PCU. (To avoid an unfair penalty in its performance index calculation, the system's downtime in August was considered to be a scheduled outage.)

The Utility Scale systems' generation trends on Figure III.2 are generally less distinct than those of the EMT arrays, partly because these systems use different orientations and also because their capacities differ widely. More significantly, these systems have been interrupted often by various PCU failures. The APS PCU's four inverters suffered blown fuses on four occasions. One inverter suffered several failed components and could not be reset after a July 15 transient. PVUSA's troubleshooting efforts were unsuccessful, and the unit was not restarted until APS' engineer Dick Lenskold was called in to service it in September.

The SSI system's one active Dickerson PCU, Unit "B," began to trip more often upon trying to start in the morning. By the end of August, it was requiring manual resets nearly every day and was sometimes idled for longer periods, such as weekends. The IPC system's Omnion PCU was also unreliable, continuing a several-year trend of tripping off line with various control board failures. In May, PVUSA decided to end its efforts to continue repairing the unit since a replacement Kenetech PCU was planned. The unit tripped several times between May and July and was able to be reset manually, but in July, a transient caused numerous component failures and the unit was shut down. The new PCU was installed in August.

Table III.1
PVUSA Davis Systems: Performance Summary

Characteristics	SSI EMT-1	Sovonics	UPG	Solarex	ENTECH	AstroPower	APS	IPC	SSI US-1
Orientation (fixed flat plate, tracking)	30° ffp	30° ffp	30° ffp	30° ffp	2-ax trk.	30° ffp	30° ffp	1-ax trk.	1-ax trk.
Initial rating, kW	18.7 dc	17.3 dc	15.7 dc	15.7 dc	16.5 dc	17.1 dc	479 ac	196 ac	67 ac
Installation date	1/89	6/89	12/89	10/90	3/91	11/94	9/92	6/93	5/94
Module area, m ²	169	497	477	182	172	292	11520	2443	845

System	Quantity	1994	cumulative '95	Jan-Apr '95	May-Aug '95
SSI	AC kWh	30141	18707	6420	12287
	Performance Index %	88	90	88	90
EMT-1	DC eff. %	10.0	9.9	10.6	9.5
	AC cap.fac. %	19.1	17.8	12.4	23.1
	Insol. kWh/m ²	2016	1275	416	859
Sovonics	AC kWh	24350	15146	4366	10780
	Performance Index %	88	90	75	97
EMT-1	DC eff. %	2.6	2.6	2.2	2.8
	AC cap.fac. %	17.7	16.3	9.5	23.0
	Insol. kWh/m ²	2076	1297	426	871
UPG	AC kWh	26537	14701	5520	9181
	Performance Index %	95	87	97	82
EMT-1	DC eff. %	2.8	2.8	2.9	2.8
	AC cap.fac. %	20.1	16.7	12.7	20.6
	Insol. kWh/m ²	2083	1155	430	725
Solarex	AC kWh	25915	16394	5609	10785
	Performance Index %	90	94	92	95
EMT-1	DC eff. %	7.8	7.8	8.3	7.5
	AC cap.fac. %	19.6	18.6	12.9	24.2
	Insol. kWh/m ²	2055	1309	430	879
ENTECH	AC kWh	27258	18898	4554	14344
	Performance Index %	67	80	71	84
EMT-1	DC eff. %	10.7	10.5	11.3	10.3
	AC cap.fac. %	19.9	20.8	10.1	31.2
	Insol. kWh/m ²	1523	1113	250	863
AstroPower	AC kWh	1803	19538	6513	13025
	Performance Index %	81	94	90	96
EMT-2 (start 11/18/94)	DC eff. %	6.0	5.6	5.9	5.4
	AC cap.fac. %	10.6	20.8	14.0	27.4
	Insol. kWh/m ²	112	1284	408	876
APS	AC kWh	650555	389359	149839	239520
	Performance Index %	83	78	92	71
US-1 (92 data based on 3 1/4 mos.)	AC eff. %	3.2	2.9	3.3	2.6
	AC cap.fac. %	15.5	13.9	10.9	16.9
	Insol. kWh/m ²	1757	1190	394	796
IPC	AC kWh	168742	108788	65117	43671
	Performance Index %	31	32	64	19
US-1 (93 data based on June start)	AC eff. %	7.8	7.4	7.7	6.9
	AC cap.fac. %	9.8	9.5	11.5	7.6
	Insol. kWh/m ²	843	605	346	259
SSI	AC kWh	98995	71563	24870	46693
	Performance Index %	60	62	73	57
US-1 (Quantities reflect intermittent pre-June -94 start-up power)	AC eff. %	7.5	7.2	7.9	6.9
	AC cap.fac. %	16.3	18.3	12.9	23.6
	Insol. kWh/m ²	1022	1171	373	798

PVUSA DAVIS EMT SYSTEMS RECENT OUTPUT and INSOLATION

Figure III.1

PVUSA UTILITY SCALE SYSTEMS RECENT OUTPUT and INSOLATION

Figure III.2

Efficiency

Figures III.3 and III.4 show monthly average efficiency histories for the EMT arrays and US systems, respectively. DC efficiencies are reported for the six EMT arrays, and ac efficiencies are reported for the three US systems. Except for the ENTECH array, the efficiencies are calculated as the ratio of monthly energy produced to monthly plane-of-array insolation during hours when the PCU was operating. The ENTECH array, which uses a 22X concentrating lens and two-axis tracking structure, shades portions of itself and its pyrheliometer during the early and late hours of the day. Therefore, its efficiency calculations are based on the hours between 9 a.m. and 3 p.m. PST, when shading does not occur at any time of the year.

Except for the two a-Si EMT arrays, the other four EMT arrays experienced similarly declining efficiencies over each of the past four months. The trend is believed to be caused by steady increases in both temperatures and soiling. The a-Si arrays are less sensitive to temperature, and in the case of the Sovonics array, tend to improve anyway during the summer as a result of more favorable spectral conditions, thermal annealing, or both. The UPG array did show a dip in June as a result of the junction box fire noted earlier.

Figure III.4 shows the US system efficiencies. Unlike the a-Si EMT arrays, the a-Si APS system experienced declining monthly efficiencies. Much of the drop was actually caused by a loss of one-fourth of the array during part of July and all of August due to an inverter failure. A gradual increase in soiling is also believed to be responsible for the declining efficiency trend. The SSI system's efficiency remained fairly steady at just under 7%, although it is not clear why this was the case. The array operated at progressively warmer temperatures and became visibly soiled throughout the summer. A transformer tap change in July moved the array nearer to its optimum voltage, and this change may have improved the system's output enough to offset the other loss factors. The IPC system's efficiency trend was more erratic because there were several periods when it operated with fewer than its normal 11 source circuits on line. It was also off line for all of August.

**PVUSA DAVIS SITE
EMT array dc efficiencies**

Figure III.3

**PVUSA DAVIS SITE
US system ac efficiencies**

Figure III.4

2. Solar/Weather Data

Table III.2 lists several solar radiation, temperature, and wind speed statistics for 1994 and 1995. The global horizontal insolation over the second four months was just 1% below the long-term seasonal average. The average ambient temperature of 21.4 °C, while higher than the long-term seasonal average of 20.7 °C, was not unusually high, and was actually slightly lower than the past six-year average of 21.7 ± 1 °C ($\pm$ is one standard deviation). The 1.4" of rain was twice the normal amount for the same period, although none occurred in July or August. The average wind speed of 3.0 m/s was moderately milder than the site's six-year seasonal average of 3.2 ± 0.1 m/s ($\pm$ is one standard deviation).

Table III.2
Solar/Weather Summary

Insolation, kWh/m ² ; Peak Irradiance, W/m ²	1994	cumul '95	Jan-Apr '95	May-Aug '95
LT-Avg. global horizontal insolation	1838	1412	469	943
Global horizontal insolation	1872	1323	393	931
Peak 10-min. avg. irradiance	1156	1186	1079	1186
Global 30° tilt insolation	2122	1357	454	903
Peak 10-min. avg. irradiance	1297	1209	1185	1209
Global normal insolation	3052	1950	559	1391
Peak 10-min. avg. irradiance	1321	1232	1187	1232
Horizontal 1-axis tracking insolation	2748	1901	549	1352
Peak 10-min. avg. irradiance	1233	1236	1149	1236
Direct normal insolation	2289	1470	381	1089
Peak 10-min. avg. irradiance	983	1007	1007	993
Minimum T _{ambient} , °C	-2.5	-1.3	-1.3	4.6
LT-Avg. T _{ambient} , °C	15	15	10	21
Avg. T _{ambient} , °C	15.1	16.5	11.5	21.4
Maximum T _{ambient} , °C	40.5	41.8	28.9	41.8
Avg. wind speed, m/s	2.9	3.3	3.7	3.0
Max. wind speed, m/s (sustained 10-min.)	14.2	17.8	17.8	13.5

3. Operation and Maintenance

Table III.3 summarizes PVUSA's Davis O&M activities. The activities are identified as either preventive maintenance (including planned outages), failure-related (including forced outages), or research activities. This summary does not include Data Acquisition System (DAS) O&M activities. Host system activities are described along with host system performance in the following section of the report.

Table III.3
May - August 1995 O&M Summary

O&M Type	Event	Date; Force x Time (default is 1 person)
Preventive	<p><u>Site-BOS:</u> Read meters and report to PG&E Control Dept. Check fire extinguishers, emergency lights, security system, site vehicle maintenance, lubricate sump pumps. Conduct weed control, site mowing. Check field safety boxes and perimeter fence. Calibrate 12-kV trip relays. Clearance on switch #20013 for calibrations of 12-kV trip relays. Calibrate meteorological station. Relocate sump microswitches. Non-routine maintenance; lamps, doorstops, sheetmetal roofing. Repair Sea-Van storage room doors. Clean mud from sump. Blade roads and reshape ditches.</p> <p><u>APS:</u> Clean PCU filters, test emergency lights. Adjust PCU operating limits. Clearance for 12-kV trip relay calibration. Inspect array and test PCU smoke detectors.</p> <p><u>IPC:</u> Clean PCU filters, set tracker clock, check MOV fuses, adjust startup voltage. Clearance for 12-kV trip relay calibration. Replace tracker oil in winch. Tension tracker cable. Lubricate tracker bearings.</p> <p><u>SSI:</u> Clearance for 12-kV trip relay calibration. Tap change and associated clearances.</p> <p><u>ENTECH:</u> Inspect array, check tracker alignment, check battery. Check tracker gear oil, lube bearings.</p>	<p>Monthly; 0.5 hr Monthly; 3.7 hrs</p> <p>Quarterly; 6.5 hrs + \$1,760.00 Quarterly; 0.5 hr 5/2; 10 hrs 5/2; 1.25 hrs 5/8; 2 hrs + \$70.00 7/13; \$671.25 7/14; \$962.39 8/1; 1 hr 8/1; \$1,324.00 8/10; \$1,110.00</p> <p>Monthly; 0.7 hr Quarterly; 0.25 hr 5/2; 0.25 hr 5/18; 2 hrs</p> <p>Monthly; 0.80 hr</p> <p>5/2; 0.25 hr 7/6; 1.5 hrs 7/27; 16 hrs 7/31; 3 hrs + \$26.00</p> <p>5/2; 0.25 hr 7/6; 3.3 hrs</p> <p>Monthly; 0.5 hr Quarterly; 0.5 hr</p>

Table III.3 continued
May - August 1995 O&M Summary

O&M Type	Event	Date; Force x Time (default is 1 person)
Failure-related	<u>Site-BOS:</u> (0.2 hr total) Reset plant after loss of site power.	6/6; 0.2 hr
	<u>APS:</u> (24.7 hrs total) Replace broken module.	7/24; 4 hrs + \$200.00
	PCU #1 failed, diagnose and test.	7/25; 2 hrs + \$52.00
	Troubleshoot PCU #1 via telecon with subcontractor.	7/26; 1 hr
	PCU #1 failed; replace REC fuses, megger power circuits, SCRs.	8/1; 5 hrs + \$180.00
	PCU #3 failed, replace dc contactor bridge and F8 fuses.	8/9; 1.5 hrs + \$6.00
	Swap boards between PCU #1 and #2.	8/9; 6 hrs
	Reset PCU and replaced fuses.	4 occurrences; 2.5 hrs total + \$578.00
	Reset PCU after misc. shutdowns.	15 occurrences; 2.7 hrs total
	<u>IPC:</u> (21.3 hrs total) Installed new e-prom, reseated socketed U-2 chips.	5/3; 0.5 hr
	Replaced I/O module in tracker controller.	5/4; 0.5 hr
	Removed 15 bridge control boards.	5/10; 3 hrs
	Replaced 15 repaired bridge control boards.	6/1; 3.5 hrs
	Cleaned ribbon cable connectors.	6/2; 2 hrs
	Closed dc circuits rows #1, #2, and #3.	6/27; 0.1 hr
	Final inverter failure, not reset.	7/17; 0.5 hr
	Repaired failed datalogger.	7/28; 2 hrs
	DC ground faults identified in rows #1 and #11.	8/1; 4 hrs
	Investigate cause of dc ground faults in rows #1 and #11.	8/21, 8/22; 1.25 hrs total
	Reset PCU and opened dc circuits.	4 occurrences; 1 hr total
	Reset PCU after misc. shutdowns.	17 occurrences; 2.35 hrs total
	Reset tracker.	2 occurrences; 0.6 hr total
	<u>SSI:</u> (2.7 hrs total) Reset PCU "B" after misc. shutdowns.	27 occurrences; 2.7 hrs total
	<u>EMT-1 ENTECH:</u> (0.4 hrs total) Warranty installation of new tracker motor and drive	5/8-9; 8 hrs.
	Reset PCU due to line disturbance (auto reset).	6/6; 0.05 hr
	Reset PCU due to sync error shutdown.	2 occurrences; 0.35 hr total
	<u>EMT-1 SSI:</u> (2.1 hrs total) Replaced shattered module.	8/21; 1 hr
	Reset PCU after misc. shutdowns.	12 occurrences; 1.1 hrs total
	<u>EMT-1 Solarex:</u> (0.1 hr total) Reset PCU after line disturbance.	6/6; 0.1 hr
	<u>EMT-1 Sovonics:</u> (1.1 hrs total) Install logic card from Solar Cells PCU.	5/17; 0.5 hr
	Reset PCU after misc. shutdowns.	7 occurrences; 0.6 hr total
	<u>EMT-1 UPG:</u> (9.2 hrs total) Fire in dc collection box.	6/9; 0.2 hr
	Inspect burnt dc collection box.	6/22; 2 hrs
	Repair burnt dc collection box.	6/29; 6 hrs + \$58.00
	Reset PCU and replace fuse.	2 occurrences; 0.8 hr total
	Reset PCU after misc. shutdowns.	2 occurrences; 0.2 hr total
	<u>EMT-2 AstroPower:</u> (0.4 hr total) Replaced 1 amp fuse in PCU.	6/12; 0.2 hr + \$1.25
	Reset PCU due to synch. error shutdown.	3 occurrences; 0.2 hr total
Research Activities	Install and calibrate new e-prom in tracker controller.	7/25; 0.8 hr
	Test Amonix PCU using ENTECH array.	8/29; 1.5 hrs
	Troubleshoot peak power tracking problem at Amonix PCU.	8/30; 4.5 hrs
	Solar Cells PCU powered from Solarex array.	8/31; 0.5 hr

IV. OTHER PVUSA SITES

1. Summary

Figure IV.1.a shows the location and lists basic information about PVUSA's various sites. In addition to the Davis and Kerman sites within PG&E's service territory, host systems are operating in Kihei, HI, Austin, TX, Farmingdale, NY, Maspeth, NY, Sacramento, CA, and Fort Davis, TX. As this report was being prepared, VEPCO indicated it was closing down its PV site and ending its participation in PVUSA. Accordingly, this EMT-2 array has been deleted from the figure, leaving 16 systems totaling 1.8 MW in the PVUSA network. Two more host systems are planned, including a 375-kW system at the DOD's site in Yuma and a recently-proposed 25- to 30-kW system in Colorado to be installed by PSCo.

At a glance, Figure IV.1.b compares how much insolation the various sites have been receiving—and how well their systems have been using it. Two key statistics are presented: this year's cumulative global horizontal insolation, expressed as an average daily quantity; and this year's cumulative performance index.

Through August, the Maui and Fort Davis sites continued to receive a higher average global horizontal insolation than the other sites, although the gap generally narrowed over the past four months. Maui and Fort Davis have averaged about 6 peak hours equivalent per day, while the Davis, Kerman, Austin, and Sacramento sites have averaged about 5 peak hours per day, and the Maspeth and Farmingdale sites have averaged about 4 peak hours per day.

Five of PVUSA's 16 systems with data available have generated at least 90% of the energy expected from them so far in 1995. Only one of these, Maui, was at a site other than Davis. Six of the remaining eleven systems have generated from 70% to 90% of their expected amounts, four have operated in the range of 40% to 70%, and one system, at Davis (IPC), has only generated about 30% of its expected amount. Performance data were not yet available for the CSW ENTECH system. Performance index data are listed in Appendix A.

A key host site activity over the summer was establishing ratings for three systems: UPG systems at SMUD (207 kW) and CSW (98 kW) and an IPC system at NREL's Maspeth site (12.9 kW). Ratings still need to be calculated for two other systems. One of these, CSW's ENTECH system, has operated intermittently all year and was not accepted until after the end of August. CSW had the Southwest Technology Development Institute (SWTDI) rate the system in February and then again in July-August; their ratings of 88 kW in February and 82.6 kW in July-August will be considered preliminary until PVUSA can confirm a final value. A rating has yet to be established for the NYSERDA system because long-standing PCU, tracker, and DAS problems have prevented NYSERDA from accepting the system. A temporary rating of 17.9 kW, identical to the Austin system, will be used until NYSERDA accepts the system.

The following subsections include detailed performance information for operating sites.

PVUSA SITE DATA Thru 8/95: 17 sys. totaling 1.8 MW

Figure IV.1.a

PERFORMANCE INDEX and INSOLATION January - August 1995

Insolation: global horizontal
Performance Index: actual/expected generation (exp. gen. considers actual insolation, scheduled outages, temperature, BOS losses, and degradation)

Figure IV.1.b

2. Kerman

Tables IV.2.a and IV.2.b summarize 1994 and 1995 PV system, solar insolation, and weather data for the Kerman site. The plant's poor May-August performance index of 41% was principally due to recurring array, PCU (often flagged as "regulator or crowbar faults"), and operator problems. Unfortunately, these problems kept the system from operating during many peak hours, including on the afternoon of August 2, when this year's peak feeder load occurred.

Despite previous attempts in 1993 and 1994 to modify the Omnion PCUs to avoid cloud-enhanced irradiance trips, both units continued to trip this year, although some of the conditions seemed extraordinary. On May 1, the site measured 5-second-average irradiances as high as $1,520 \text{ W/m}^2$. To combat the trips, one source circuit from each PCU was disabled on May 5. However, similar trips occurred several more times over the next month. In June, the array field developed a voltage imbalance. Although a ground fault, open fuse, and burnt module junction box were located and fixed, a smaller imbalance continued to persist in the morning hours.

PG&E Fresno maintenance staff replaced a control fuse in PCU #1 on July 5. The unit then tripped on July 11 and would not reset. Despite several troubleshooting attempts and a few brief periods of successful operation, the unit was not repaired until August 23. During one troubleshooting trip on July 26, the local PG&E crew, with phone assistance from Omnion, concluded that a utility outage, coupled with a failure to replace a programmable logic controller (PLC) on schedule, resulted in a loss of logic memory. The battery was replaced and the PLC reprogrammed, but the unit tripped shortly after being reset on August 1. After being repaired on August 23, it experienced two more "nuisance" trips by the end of the month.

PCU #2 had its air conditioning fail in June, limiting its operation to a few of the cooler hours each day until repairs were made on July 5. On July 6, the unit tripped and would not reset, but this was because the unit had inadvertently been left on local, rather than remote, control. The unit would not reset after a trip on July 14. Although a troubleshooting trip on July 26 found a failed source circuit fuse and the unit was restarted OK, it tripped again on August 2 and remained down until August 23, when both units were restarted. On August 28, PCU #2 could not be reset, and it remained down through the end of the month.

In July, one passive tracker actuator was observed to be malfunctioning. It was replaced on August 1. Reliable data for the site's 1-axis reference tracker were not available for parts of June and July. For these months, the site's global horizontal insolation has been scaled up by the long-term average ratio of 1-axis/horizontal insolation given in NREL's Solar Radiation Data Manual. The reference tracker was reset in July and has operated properly since then.

Other key activities related to the Kerman system, such as procurement and technology transfer, are discussed in Section II.3.

Table IV.2.a
Kerman Performance Summary

SSI system characteristics	
Rating:	498 kW ac
Installation date:	6/93
Total module area:	5210 m ²
Orientation:	Horiz. N-S single axis trkr.

Quantity	1994	cumulative 1995	Jan-Apr '95	May-Aug '95
Performance Index %	85 (89 [*])	53	81	41
AC kWh (incl. '93 start-up)	1016118	442715	207240	235475
AC eff. %	9.0	8.4	9.3	7.6
Cap. fac. %	23.3	15.2	14.4	16.0
Max. ac kW	533	498	493	498
Wtd. avg. T _{module} °C	43	41	35	46
POA insol. (PCU on) kWh/m ²	2162	1114	519	595

* updated 1994 value, consistent with 1995 calculation that now includes a 5% PCU low-load loss allowance.

Table IV.2.b
Kerman Solar/Weather Summary

Quantity	1994	cumulative 1995	Jan-Apr '95	May-Aug '95
1-axis insol. kWh/m ²	est. 2534	est. 1841	est. 549	est. 1292
Horiz. insol. kWh/m ²	1835	1346	423	923
LT-Avg. horiz. insol. kWh/m ²	1899	1437	490	947
Peak 1-axis irradi. W/m ²	1221	1131	1125	1131
Peak horiz. insol. W/m ²	1205	1158	1048	1158
Min. T _{amb} °C	-2	2	2	3
Avg. T _{amb} °C	18	20	15	24
LT-Avg. T _{amb} °C	17	18	12	25
Max. T _{amb} °C	42	43	31	43
Avg. wind speed m/s	2.6	2.9	2.7	3.1
Max. wind speed m/s	11.4	12.4	12.4	10.6

3. Maui

Table IV.3.a summarizes 1994 and 1995 performance for the Maui Sovonics array. Table IV.3.b summarizes solar/weather data. The system's performance index over the second four months of 1995 was nearly 100% (rounded). Unfortunately, this result must be somewhat inaccurate because the array was known to have operated at a 15% reduced level on two occasions totaling about 6 weeks over the four-month period. The two instances were likely both module junction box failures, although no report has been received from Maui Electric. A rough estimate suggests the P.I. should not have been greater than 95%, as the "lost" generation from operating at 85% of normal for 6 of 17 weeks would have amounted to about 5% of the expected four-month total. A 5% error could be caused by the combined effect of several instruments' calibrations drifting with time, as only the PSPs have been maintained regularly over this system's six years of operation.

The two failures this period increased the total number of module/junction-box failures to 51 out of 1200 modules (7 in 1995, 9 in 1994, 6 in 1993, 5 in 1992, 11 in 1991, and 13 in 1990).

Table IV.3.a
Maui Performance Summary

Sovonics array characteristics	
Rating:	18.5 kW dc, 17.6 kW ac
Installation date:	10/89
Total module area:	497 m ²
Orientation:	22° tilt, south facing

Quantity	1994	cumulative 1995	Jan-Apr '95	May-Aug '95
Performance Index %	92 (97*)	98	95	100
AC kWh	30760	20603	10100	10503
DC eff. %	3.3	3.3	3.3	3.2
Cap. fac. %	20.0	20.1	19.9	20.2
Max. ac kW	18.9	18.9	18.9	17.4
Wtd. avg. T _{module} °C	45	43	41	45
POA insol.(PCU on) kWh/m ²	2008	1359	655	704

* updated 1994 value, consistent with 1995 calculation that now includes a 5% PCU low-load loss allowance.

Table IV.3.b
Maui Solar/Weather Summary

Quantity	1994	cumulative 1995	Jan-Apr '95	May-Aug '95
POA insol. kWh/m ²	2146	1412	705	707
Horiz. insol. kWh/m ²	2065	1438	639	798
LT-Avg. horiz. insol. kWh/m ²	2008	1409	600	809
Peak POA irradi. W/m ²	1226	1218	1218	1196
Peak horiz. irradi. W/m ²	1257	1291	1169	1291
Min. T _{amb} °C (Jun-Jul '93 n/a)	13	15	15	17
Avg. T _{amb} °C (Jun-Jul '93 n/a)	27	27	26	28
LT-Avg. T _{amb} °C	24	24	23	25
Max. T _{amb} °C (Jun-Jul '93 n/a)	43	42	40	42
Avg. wind speed m/s	3.2	3.8	4.0	3.5
Max. wind speed m/s	14.4	12.4	11.3	12.4

4. Austin

Table IV.4.a summarizes 1994 and 1995 performance for the Austin IPC system. Table IV.4.b summarizes solar/weather data. The Austin site's performance index over the middle four months of the year was 76%, similar to its index of 73% over the first four months. Unlike earlier this year, when PCU problems limited system operation, a malfunctioning tracker reduced system output considerably in both July and August. The problem was corrected in August by replacing a rotational sensor on the winch drum. For the purpose of performance index calculations, the POA insolation for July and August has been estimated by multiplying the (actual) horizontal insolation by the long-term-average ratio of tracking/horizontal insolation from NREL's Solar Radiation Data Manual. Austin has also identified two modules that are still operating but need to be replaced. There were no significant problems with the PCU.

Table IV.4.a
Austin Performance Summary

IPC system characteristics	
Rating:	17.9 kW ac
Installation date:	7/92
Total module area:	212 m ²
Orientation:	Horiz. N-S single axis trkr.

Quantity	1994	cumulative 1995	Jan-Apr '95	May-Aug '95
Performance Index %	84 (88*)	75	73	76
AC kWh	26209	17412	6365	11047
AC eff. %	8.2	7.5	7.9	7.3
Cap. fac. %	16.7	16.7	12.4	20.9
Max. ac kW	19.8	17.6	17.6	16.8
Wtd. avg. T _{module} °C	40	45	38	48
POA insol. (PCU on) kWh/m ²	1522	1100	386	714

* updated 1994 value, consistent with 1995 calculation that now includes a 5% PCU low-load loss allowance.

Table IV.4.b
Austin Solar/Weather Summary

Quantity	1994	cumulative 1995	Jan-Apr '95	May-Aug '95
POA insol. kWh/m ²	1847	est. 1427	521	est. 906
Horiz. insol. kWh/m ²	1525	1148	420	728
LT-Avg. horiz. insol. kWh/m ²	1790	1294	507	787
Peak POA irradi. W/m ²	1171	1096	1069	1096
Peak horiz. irradi. W/m ²	1181	1129	1041	1129
Min. T _{amb} °C	-2	1	1	15
Avg. T _{amb} °C	21	24	18	31
LT-Avg. T _{amb} °C	20	21	15	28
Max. T _{amb} °C	43	45	37	45
Avg. wind speed m/s	1.8	1.8	1.8	1.7
Max. wind speed m/s	9.2	8.0	7.1	8.0

5. NYSERDA

Table IV.5.a summarizes the system's 1994 and 1995 performance. Table IV.5.b summarizes solar/weather data. Although it began operating in mid-1993, NYSERDA has yet to accept the system from IPC, as it has been limited by PCU, tracker, and DAS problems from its first days of operation. Several temperature and insolation values have been estimated using data from the nearby Maspeth host site and from NREL's Solar Radiation Data Manual. Also, the POA and horizontal insolation values over the first four months of 1995 have been revised since the previous report. NYSERDA is charting a plan with the help of its suppliers to remedy problems and complete acceptance of the system.

Table IV.5.a
NYSERDA Performance Summary

IPC system characteristics	
Temporary rating:	17.9 kW ac
Installation date:	8/93
Total module area:	212 m ²
Orientation:	Horiz. N-S single axis trkr.

Quantity	1994	cumulative 1995	Jan-Apr '95	May-Aug '95
Performance Index %	66 (69*)	45	5	71
AC kWh	19270	10383	426	9967
AC eff. %	8.4	7.8	8.6	7.7
Cap. fac. %	12.3	10.0	0.8	18.8
Max. ac kW	23.4	20.2	18.2	20.2
Wtd. avg. T _{module} °C	30	est. 37	27	est. 38
POA insol. (PCU on) kWh/m ²	1079	634	24	610

* updated 1994 value, consistent with 1995 calculation that now includes a 5% PCU low-load loss allowance.

Table IV.5.b
NYSERDA Solar/Weather Summary

Quantity	1994	cumulative 1995	Jan-Apr '95	May-Aug '95
POA insol. kWh/m ²	1505	est. 1355	522	est. 833
Horiz. insol. kWh/m ²	1366	est. 1063	395	est. 668
LT-Avg. horiz. insol. kWh/m ²	1460	1112	399	713
Peak POA irradi. W/m ²	1310	988	988	n/a
Peak horiz. irradi. W/m ²	1246	1267	1170	1267
Min. T _{amb} °C	n/a	n/a	n/a	n/a
Avg. T _{amb} °C	n/a	n/a	n/a	n/a
LT-Avg. T _{amb} °C	13	13	4	22
Max. T _{amb} °C	n/a	n/a	n/a	n/a
Avg. wind speed m/s	1.6	1.7	1.8	1.7
Max. wind speed m/s	12.4	10.4	10.4	7.7

6. NREL/NYPA

Table IV.6.a summarizes the system's 1994 and 1995 performance. Table IV.6.b summarizes solar/weather data. An updated PTC rating of 12.9 ± 0.7 kW was calculated using June data. This corresponds to a degradation of nearly 25% over its first two years, compared to the system's initial rating of 17 kW calculated by NREL. The updated rating has been accounted for in the performance index calculation as a degradation adjustment factor of $12.9/17 = 0.759$. As with other systems, the original rating has been retained for capacity factor calculations. The adjustment factor has also been applied retroactively to the index calculations for the first four months of 1995. The previously reported index of 68% over the Jan-Apr period now stands at 83%. The performance index over the May-August period was 82%, keeping the overall index for the year at 83%.

No maintenance activities were reported by NYPA or the New York Transit Authority. In August, PVUSA reported a PCU outage to the Transit Authority. Data indicated a ground fault had occurred. The system was down for about 10 days, but a manual PCU reset was all that was required.

Table IV.6.a
NREL/NYPA Performance Summary

IPC/Uni-Solar system characteristics	
NREL Installed Rating:	17.0 kW ac
Installation date:	7/93
Total module area:	413 m ²
Orientation:	Fixed 10° tilt, south-facing

Quantity	1994	cumulative 1995	Jan-Apr '95	May-Aug '95
Performance Index %	83 (87*)	83	83	82
AC kWh	19478	10753	4241	6512
AC eff. %	3.3	3.0	2.8	3.0
Cap. fac. %	13.1	10.8	8.7	13.0
Max. ac kW	17.7	15.0	14.5	15.0
Wtd. avg. T _{module} °C	35	38	28	45
POA insol. (PCU on) kWh/m ²	1420	890	367	523

* updated 1994 value, consistent with 1995 calculation that now includes a 5% PCU low-load loss allowance.

Table IV.6.b
NREL/NYPA Solar/Weather Summary

Quantity	1994	cumulative 1995	Jan-Apr '95	May-Aug '95
POA insol. kWh/m ²	1448	1044	407	639
Horiz. insol. kWh/m ²	1298	943	347	596
LT-Avg. horiz. insol. kWh/m ²	1460	1112	399	713
Peak POA irradi. W/m ²	1163	1174	1174	1168
Peak horiz. irradi. W/m ²	1050	1071	1064	1071
Min. T _{amb} °C	-17	-13	-13	9
Avg. T _{amb} °C	14	16	7	25
LT-Avg. T _{amb} °C	13	13	4	22
Max. T _{amb} °C	39	44	26	44
Avg. wind speed m/s	3.2	3.1	3.4	2.9
Max. wind speed m/s	10.9	10.5	10.5	9.9

7. SMUD

Table IV.7.a summarizes the system's 1994 and 1995 performance. Table IV.7.b summarizes solar/weather data. The 1994 totals are based on a partial year of data collection beginning in mid-August. A final PTC rating of 207 ± 6 kW was calculated using June data, replacing the October 1994 interim rating of 213 kW. The final rating has been applied retroactively to all of the capacity factor and performance index calculations shown in the table.

The system's performance index from May-August was 88%, raising its overall 1995 index from 61% over the first four months to 80% after eight months. The system experienced just one long outage of about 10 days early in May due to a PCU trip, but in general, PCU availability has improved since Omnion enabled the unit to restart automatically following minor line disturbances. In mid-May, UPG was on site to remedy a tracker controller program error. Tracker performance improved significantly after the program change.

Table IV.7.a
SMUD Performance Summary

UPG/SSI system characteristics	
PTC Rating:	207 kW ac
Installation date:	4/94
Total module area:	2043 m ²
Orientation:	Horiz. N-S single axis trkr.

Quantity	8/16-12/31 94	cumulative 1995	Jan-Apr '95	May-Aug '95
Performance Index %	66 (69 [*])	80	61	88
AC kWh	99399	273477	64306	209171
AC eff. %	9.4	10.2	10.8	10.0
Cap. fac. %	14.5	22.6	10.8	34.2
Max. ac kW	196	240	233	240
Wtd. avg. T _{module} °C	40	41	31	45
POA insol. (PCU on) kWh/m ²	515	1305	286	1019

* updated 1994 value, consistent with 1995 calculation that now includes a 5% PCU low-load loss allowance.

Table IV.7.b
SMUD Solar/Weather Summary

Quantity	8/16-12/31 94	cumulative 1995	Jan-Apr '95	May-Aug '95
POA insol. kWh/m ² [1-axis insol. est. from Davis]	657	1627 [1798]	477 [528]	1150 [1270]
Horiz. insol. kWh/m ²	513	1252	378	874
LT-Avg. horiz. insol. kWh/m ²	532	1375	453	922
Peak POA irradi. W/m ²	1048	1143	1072	1143
Peak horiz. irradi. W/m ²	1018	1135	1001	1135
Min. T _{amb} °C	-1	1	1	7
Avg. T _{amb} °C	16	18	13	22
LT-Avg. T _{amb} °C	16	17	11	22
Max. T _{amb} °C	41	44	29	44
Avg. wind speed m/s	2.0	2.9	3.0	2.8
Max. wind speed m/s	12.7	18.3	18.3	11.8

8. Central and South West Services (CSW)

Both of CSW's systems at their Solar Park site in Ft. Davis are now complete. Only limited data are available for the ENTECH system, as some signals have not yet been verified. Tables IV.8.a-c are filled in as completely as

possible, but phone line interference has prevented PVUSA from regularly downloading the site's weather and PV system data, with some data missing or corrupted.

Ratings

A final rating of 98 ± 2 kW was established for the UPG system using June data. This rating has been applied to performance data for the first four months of the year as well as the current period. Through August, PVUSA had yet to rate the ENTECH system because CSW had not yet accepted it. CSW informed PVUSA in October that the system had been accepted, and that the Southwest Technology Development Institute (SWTDI) had updated an earlier 88 kW rating with a new rating of 82.6 kW, using data from July and August. These ratings will be considered preliminary until PVUSA can confirm a final value using a July-August data set.

UPG

Performance data are summarized in Table IV.8.a. Although it rarely tripped off line, the system's PCU often shed one of the array's five source circuits to avoid overpowering the unit, reducing system generation.

The principal maintenance activities during the May-August period concerned tracking and ground fault protection components. In June, CSW first noted a failure of the tracker Programmable Logic Controller (PLC). Similar failures occurred on three other occasions through August. It was determined that the PLC's sensitivity to transients and over/under voltage conditions was causing it to shut down. The problem was resolved by adding a ferroresonant transformer to the PLC's ac input line at the same time as several other maintenance activities were being performed in September.

The PLC and several PVX2000 ground fault disconnect devices were also damaged by two lightning strikes, one in July and another in August. The first strike short-circuited one source circuit and burned a hole through a panel adjacent to one of the PVX2000 boxes. UPG was able to restore the system to 80% capacity after the July strike. The second strike in August damaged two more disconnect device boxes, and CSW and UPG decided to replace all of the ground fault detection units with disconnects and 60 Adc fuses. These changes were made in September, along with other repairs, including replacing tracker motor ac fuses and the PLC's output module, and reprogramming the PLC to correct an error that had also existed on the Sacramento host system's tracker controller.

For the P.I. calculations, the 1-axis insolation has been estimated by multiplying the measured global horizontal insolation by the ratio of the El Paso long-term-average ratio of global 1-axis insolation to global horizontal insolation (from NREL's Solar Radiation Data Manual).

ENTECH

After over six months of start-up efforts, this system reached full power operation in July. Between May and August, ENTECH replaced several modules and retrofitted the system's tracker roll drive. The August lightning strike ruined five modules, increasing the total to 19 failed modules since start-up activities began early this year. Some of the modules have suffered cracked lenses and others have developed ground faults where the receiver cell string's Tefzel insulating tape has failed.

ENTECH also worked on improving tracker performance. As with the Davis system, the tracker roll drive was upgraded to use a larger, 1500 pound ball screw jack. This modification required changing the motor rotation counter's reed switch, adding an external east limit switch, and adding east and west limit mechanical stops. ENTECH also corrected a software error that had been allowing the roll angle to drift up to 0.75 degrees during the day.

Table IV.8.a
CSW UPG Performance Summary

UPG/SSI system characteristics	
PTC Rating:	98 kW ac
Installation date:	11/94
Total module area:	1021.5 m ²
Orientation:	Horiz. N-S single axis trkr.

Quantity	cumulative 1995	Jan-Apr '95	May-Aug '95
Performance Index %	67	76	60
AC kWh	120231	61344	58887
AC eff. %	8.2	8.9	7.4
Cap. fac. %	21.0	21.7	20.4
Max. ac kW	105	105	105
Wtd. avg. T _{module} °C	39	31	47
POA insol. (PCU on) kWh/m ²	1453	674	779

Table IV.8.b
CSW ENTECH Performance Summary

ENTECH system characteristics	
Interim Ratings:	Feb: 88, Aug: 82.6 kW ac
Installation date:	2/95
Total module area:	907 m ²
Orientation:	2-axis trk. concentrator

Quantity	cumulative 1995	Jan-Apr '95	May-Aug '95
Performance Index %	n/a	n/a	n/a
AC kWh	60967	13235	47732
AC eff. %	9.1	n/a	9.1
Cap. fac. %	19.6	n/a	19.6
Max. ac kW	97	97	92
Wtd. avg. T _{module} °C	n/a	n/a	n/a
POA insol. (PCU on) kWh/m ²	n/a	n/a	578

Table IV.8.c
Fort Davis Solar/Weather Summary

Quantity	cumulative 1995	Jan-Apr '95	May-Aug '95
UPG POA insol. kWh/m ²	1798	801	997
[1-axis insol. est. from El Paso]	[1986]	[867]	[1119]
Direct normal insol. kWh/m ²	n/a	n/a	n/a
LT-Avg. dir. nrml. insol. kWh/m ²	1726	801	925
Horiz. insol. kWh/m ²	1447	609	838
LT-Avg. horiz. insol. kWh/m ²	1553	631	922
Peak 1-axis irr. W/m ²	1349	1288	1349
Peak dir. nrml. irr. W/m ²	1018	n/a	1018
Peak horiz. irr. W/m ²	1232	1093	1232
Min. T _{amb} °C	-8	-8	7
Avg. T _{amb} °C	17	11	22
El Paso LT-Avg. T _{amb} °C	19	11	26
Max. T _{amb} °C	37	28	37
Avg. wind speed m/s	3.2	3.4	3.1
Max. wind speed m/s	17.1	17.1	13.7

APPENDIX A. 1995 Performance Index Worksheet

PERIOD	SYSTEM	KWH	TOTAL INSOL	SCH.OUTG INSOL	Tmod pwr-wtd-av	Tmod PTC	Beta	ORIGINAL AC RATING	RATING IRR kW/m2	DA	TA	BOSA	SA	P.I.
Jan-Apr	SSI-	6420	456.4	5.9	32	47	-0.0045	18.1	1.000	0.898	1.0675	0.93	1.00	88.5
May-Aug	Davis EMT	12287	903.0	0.0	47	47	-0.0045	18.1	1.000	0.898	1.0000	0.93	1.00	90.2
Sep-Dec					47	47	-0.0045	18.1	1.000	0.898		0.93	1.00	
Annual		18707	1359.4	5.9	42	47	-0.0045	18.1	1.000	0.898	1.0232	0.93	1.00	89.6
Jan-Apr	Sovonics-	4366	462.2	5.9	32	44	-0.0027	15.9	1.000	0.836	1.0324	0.93	1.00	74.8
May-Aug	Davis	10780	903.0	0.0	46	44	-0.0027	15.9	1.000	0.836	0.9935	0.93	1.00	97.0
Sep-Dec					44	44	-0.0027	15.9	1.000	0.836		0.93	1.00	
Annual		15146	1365.2	5.9	42	44	-0.0027	15.9	1.000	0.836	1.0047	0.93	1.00	89.6
Jan-Apr	UPG-	5520	455.0	5.9	31	51	-0.0010	15.1	1.000	0.881	1.0200	0.93	1.00	97.3
May-Aug	Davis EMT	9181	903.0	0.0	48	51	-0.0010	15.1	1.000	0.881	1.0028	0.93	1.00	81.9
Sep-Dec					51	51	-0.0010	15.1	1.000	0.881		0.93	1.00	
Annual		14701	1358.0	5.9	42	51	-0.0010	15.1	1.000	0.881	1.0093	0.93	1.00	87.0
Jan-Apr	Solarex	5609	458.2	5.9	31	43	-0.0045	15.1	1.000	0.907	1.0540	0.93	1.00	92.2
May-Aug		10785	903.0	4.6	45	43	-0.0045	15.1	1.000	0.907	0.9915	0.93	1.00	94.9
Sep-Dec					43	43	-0.0045	15.1	1.000	0.907		0.93	1.00	
Annual		16394	1361.2	10.5	40	43	-0.0045	15.1	1.000	0.907	1.0129	0.93	1.00	94.0
Jan-Apr	ENTECH-	4554	380.9	6.0	42	61	-0.0045	15.6	0.850	1.000	1.0855	0.86	1.00	71.3
May-Aug	Davis EMT	14344	1089.4	30.4	55	61	-0.0045	15.6	0.850	1.000	1.0293	0.86	1.00	83.9
Sep-Dec					61	61	-0.0045	15.6	0.850	1.000		0.86	1.00	
Annual		18898	1470.3	36.4	51	61	-0.0045	15.6	0.850	1.000	1.0428	0.86	1.00	80.5
Jan-Apr	AstroPower-	6513	459.7	5.9	30	44	-0.0045	16.1	1.000	1.000	1.0630	0.93	1.00	90.1
May-Aug	Davis	13025	903.0	0.0	44	44	-0.0045	16.1	1.000	1.000	0.9996	0.93	1.00	96.3
Sep-Dec					44	44	-0.0045	16.1	1.000	1.000		0.93	1.00	
Annual		19538	1362.7	5.9	39	44	-0.0045	16.1	1.000	1.000	1.0207	0.93	1.00	94.1
Jan-Apr	APS	149839	425.4	9.5	32	49	-0.0027	479.0	1.000	0.835	1.0459	0.93	1.00	92.5
May-Aug		239520	903.0	3.9	47	49	-0.0027	479.0	1.000	0.835	1.0049	0.93	1.00	71.2
Sep-Dec					49	49	-0.0027	479.0	1.000	0.835		0.93	1.00	
Annual		389359	1328.4	13.4	41	49	-0.0027	479.0	1.000	0.835	1.0207	0.93	1.00	77.9
Jan-Apr	IPC-	65117	548.6	10.6	32	48	-0.0045	196.0	1.000	1.000	1.0720	0.90	1.00	63.8
May-Aug	Davis US	43671	1351.9	21.7	51	48	-0.0045	196.0	1.000	1.000	0.9888	0.90	1.00	18.8
Sep-Dec					48	48	-0.0045	196.0	1.000	1.000		0.90	1.00	
Annual		108788	1900.5	32.3	39	48	-0.0045	196.0	1.000	1.000	1.0386	0.90	1.00	31.7
Jan-Apr	SSI-	24870	548.6	14.0	31	44	-0.0045	67.0	1.000	1.000	1.0585	0.90	1.00	72.7
May-Aug	Davis US	46693	1351.9	5.9	44	44	-0.0045	67.0	1.000	1.000	1.0000	0.90	1.00	57.4
Sep-Dec					44	44	-0.0045	67.0	1.000	1.000		0.90	1.00	
Annual		71563	1900.5	19.9	39	44	-0.0045	67.0	1.000	1.000	1.0203	0.90	1.00	61.7
Jan-Apr	Sovonics-	10100	704.6	0.0	41	44	-0.0027	17.6	1.000	0.892	1.0081	0.95	1.00	95.3
May-Aug	Maul	10503	707.0	0.0	45	44	-0.0027	17.6	1.000	0.892	0.9981	0.95	1.00	99.8
Sep-Dec					44	44	-0.0027	17.6	1.000	0.892		0.95	1.00	
Annual		20603	1411.6	0.0	43	44	-0.0027	17.6	1.000	0.892	1.0030	0.95	1.00	97.6
Jan-Apr	IPC-	6365	521.3	0.0	38	46	-0.0045	17.9	1.000	1.000	1.0360	0.90	1.00	73.0
May-Aug	Austin	11047	906.0	0.0	48	46	-0.0045	17.9	1.000	1.000	0.9892	0.90	1.00	76.3
Sep-Dec					46	46	-0.0045	17.9	1.000	1.000		0.90	1.00	
Annual		17412	1427.3	0.0	45	46	-0.0045	17.9	1.000	1.000	1.0063	0.90	1.00	75.0
Jan-Apr	SSI-	207240	546.7	0.0	35	44	-0.0045	498.0	1.000	1.000	1.0405	0.90	1.00	81.1
May-Aug	Kerman US	235475	1292.2	0.0	46	44	-0.0045	498.0	1.000	1.000	0.9928	0.90	1.00	40.8
Sep-Dec					44	44	-0.0045	498.0	1.000	1.000		0.90	1.00	
Annual		442715	1838.9	0.0	41	44	-0.0045	498.0	1.000	1.000	1.0151	0.90	1.00	52.8
Jan-Apr	IPC-	426	522.0	0.0	27	48	-0.0045	17.9	1.000	1.000	1.0945	0.90	1.00	4.6
May-Aug	Farmingdale	9957	833.0	0.0	38	48	-0.0045	17.9	1.000	1.000	1.0455	0.90	1.00	70.8
Sep-Dec					48	48	-0.0045	17.9	1.000	1.000		0.90	1.00	
Annual		10383	1355.0	0.0	37	48	-0.0045	17.9	1.000	1.000	1.0475	0.90	1.00	45.3
Jan-Apr	IPC-	4241	405.5	0.0	28	53	-0.0010	17.0	1.000	0.759	1.0250	0.95	1.00	83.3
May-Aug	Maspeth	6512	638.8	0.0	45	53	-0.0010	17.0	1.000	0.759	1.0080	0.95	1.00	82.5
Sep-Dec					53	53	-0.0010	17.0	1.000	0.759		0.95	1.00	
Annual		10753	1044.3	0.0	38	53	-0.0010	17.0	1.000	0.759	1.0147	0.95	1.00	82.8
Jan-Apr	UPG-	64306	528.5	0.0	31	44	-0.0045	207.0	1.000	1.023	1.0585	0.90	1.00	61.5
May-Aug	Sac'to US	209171	1270.3	0.0	45	44	-0.0045	207.0	1.000	1.000	0.9969	0.90	1.00	88.4
Sep-Dec					44	44	-0.0045	207.0	1.000	1.000		0.90	1.00	
Annual		273477	1798.8	0.0	41	44	-0.0045	207.0	1.000	1.000	1.0113	0.90	1.00	80.5
Jan-Apr	UPG-	61344	867.0	0.0	31	43	-0.0045	98.0	1.000	1.000	1.0540	0.90	1.00	75.9
May-Aug	Ft. Davis US	58887	1119.1	0.0	47	43	-0.0045	98.0	1.000	1.000	0.9838	0.90	1.00	60.5
Sep-Dec					43	43	-0.0045	98.0	1.000	1.000		0.90	1.00	
Annual		120231	1986.1	0.0	39	43	-0.0045	98.0	1.000	1.000	1.0196	0.90	1.00	67.1
Jan-Apr	ENTECH-	13235	n/a	0.0	n/a	n/a	-0.0045	82.6	0.850	1.000	n/a	0.86	1.00	n/a
May-Aug	Ft. Davis US	47732	n/a	0.0	n/a	n/a	-0.0045	82.6	0.850	1.000	n/a	0.86	1.00	n/a
Sep-Dec					n/a	n/a	-0.0045	82.6	0.850	1.000	n/a	0.86	1.00	n/a
Annual		73865	n/a	0.0	n/a	n/a	-0.0045	82.6	0.850	1.000	n/a	0.86	1.00	n/a

P.I. = [kWh x Rating Irrad.] / [(Total Insol. - Sched. Outage Insol.) x Orig. Rating x TA x DA x BOSA x SA]

note: Total Insol. based on appropriate reference for each system's fixed or tracking orientation.

TA = (1 + Beta x (Tmod - Tmod,rated))

DA = Present / Original ratings

BOSA = 0.86 (concentrator), 0.90 (1-axis tracking), 0.93 (fixed tilt arrays at ≥30°), 0.95 (other fixed arrays)

note: BOSA includes effects of non-ideal tracking, reduced PCU efficiency at low loads, and shading.