

PV-HYBRID SYSTEM FIELD-TEST MONITORING AT STAR



Bob Hammond

*Principal Investigator
Arizona State University*

*FY2001 ENERGY STORAGE SYSTEMS PEER REVIEW
NOVEMBER 14-15, 2001*

ACKNOWLEDGEMENTS



- DOE, SNL: Garth Corey
- Arizona Public Service:
 - Bryan Hill and Herb Hayden
- EECI: Dr. Phil Symons
- Spencer Everingham, Co-author

OVERALL GOALS



- **Develop a Partnership With a Progressive Electric Utility with Mutual Interests [i.e. APS]**
- **Develop a Renewable Generator & Storage (RGS) Operational Strategy To Improve Battery Life Cycle Costs for Off-Grid Hybrid Systems**
- **Support the Development of a New Technique to Equalize Individual Strings of a Battery Bank**

PROJECT HISTORY

- **Dec. 1996: APS Hybrid Test Facility Completed**
- **Q1 1997: SNL-APS “Partnership” Formed**
- **Jun. 1997 - Jun. 2000: First Hybrid System**
- **May 1998 - SNL-ASU Contract**
- **Jul. 1999: San Juanico, Mexico; Fishing Village**
 - **17 kW PV, 10 10-kW Wind, 80 kW Diesel, 70 kW Trace, L16 Bat.**
- **Jan. 2000: YPG, 105 kW, ABS IIP,**
- **Jan. - Aug. 2001: Dangling Rope Sys. at STAR**
- **Aug. 2001 -Present: AES Inverter Evaluation**
- **Jan. 2001 - Support Alternative Configuration**

THE SITE - STAR



**Dedicated
Jan. 1988**

THE SITE -STAR



*Ocotillo
Power
Plant*

HYBRID “EXPERIENCE”, CSM



Installed
Oct.
1995

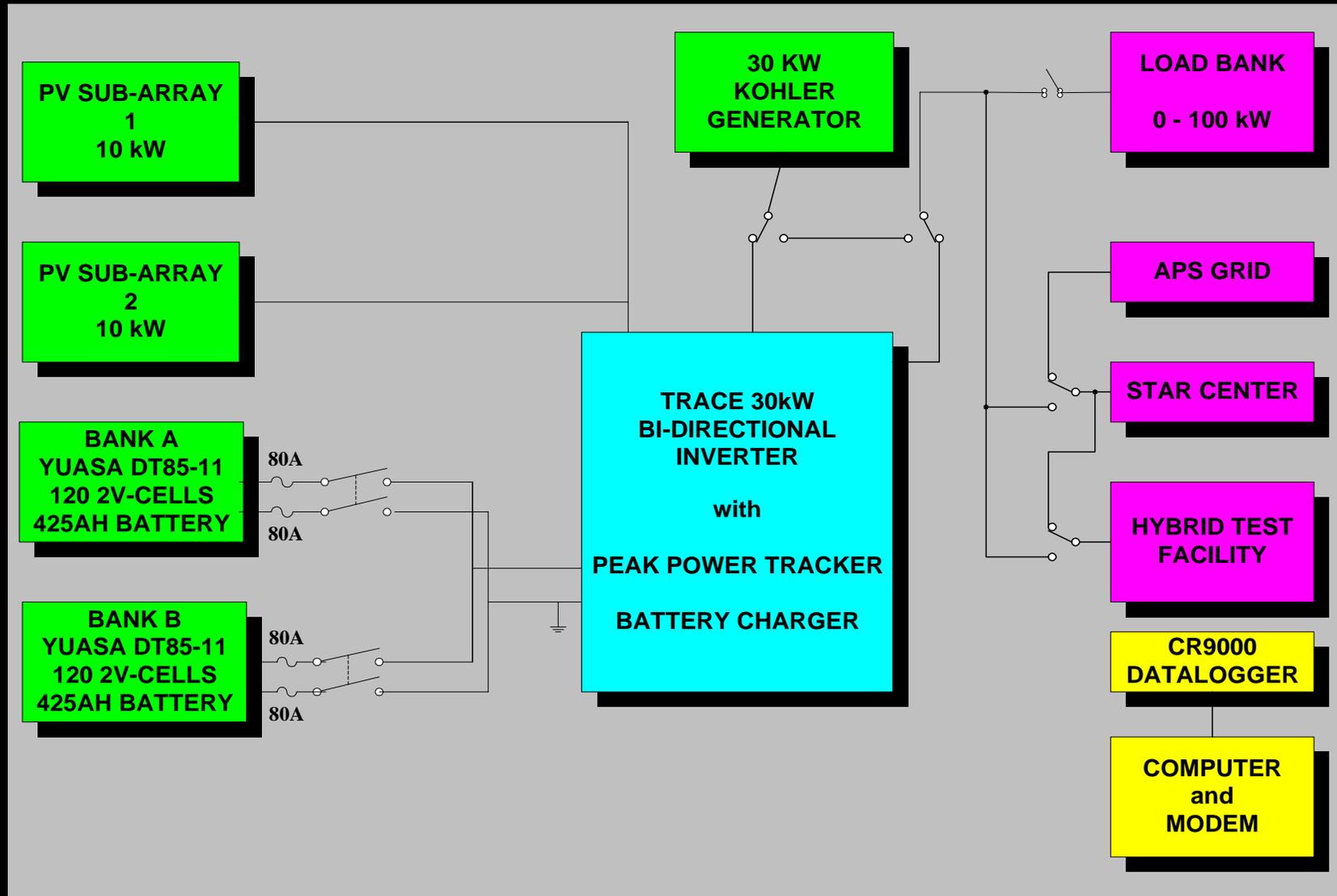
Abacus
Inverter,
S/N #1

THE HYBRID TEST FACILITY



Completed
Dec.
1996

YUASA EVALUATION: JUNE 1997 - JUNE 2000



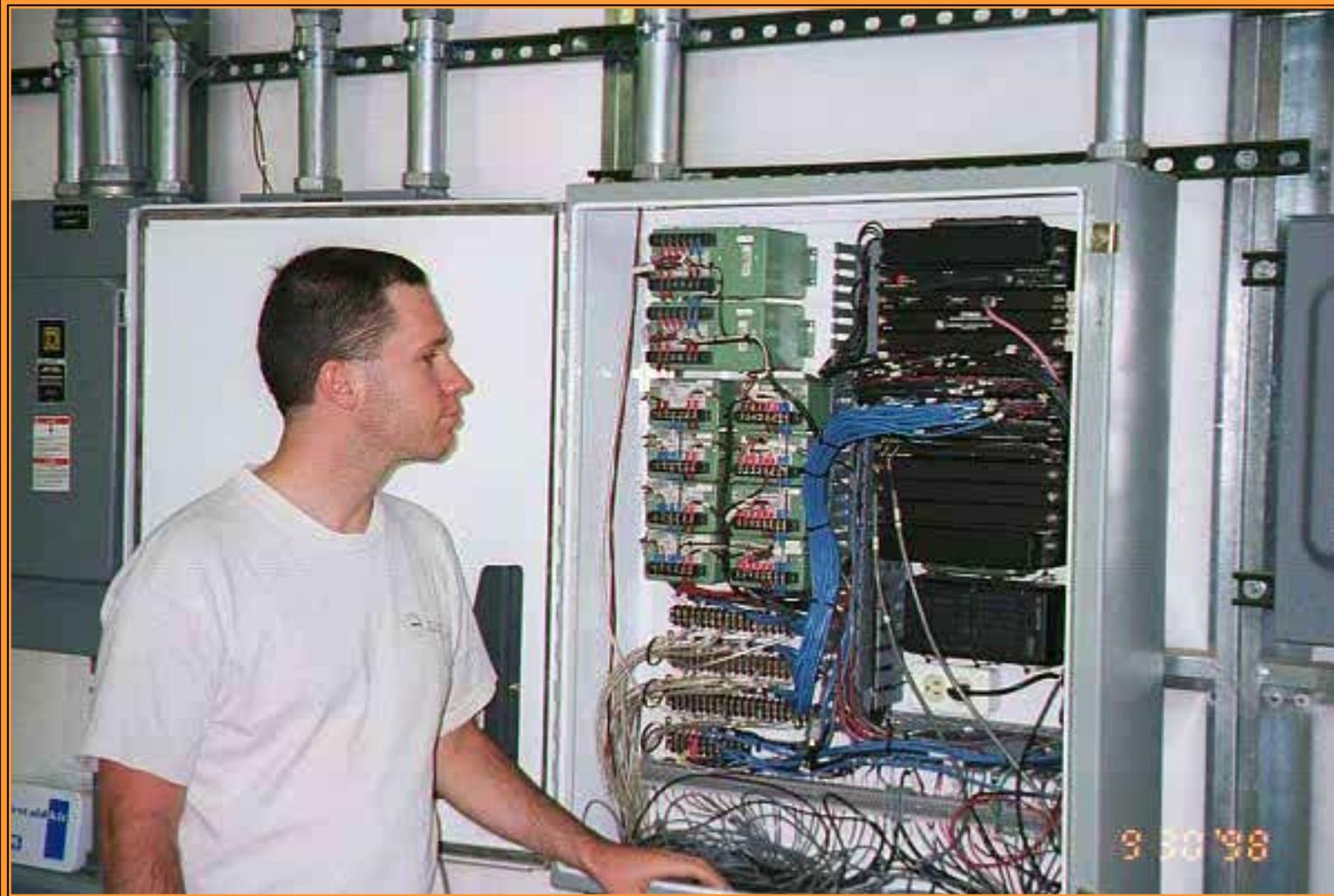
YUASA VRLA GEL



FY2001 ESS 11-14-01

10

CR9000 DAS



FY2001 ESS 11-14-01

11



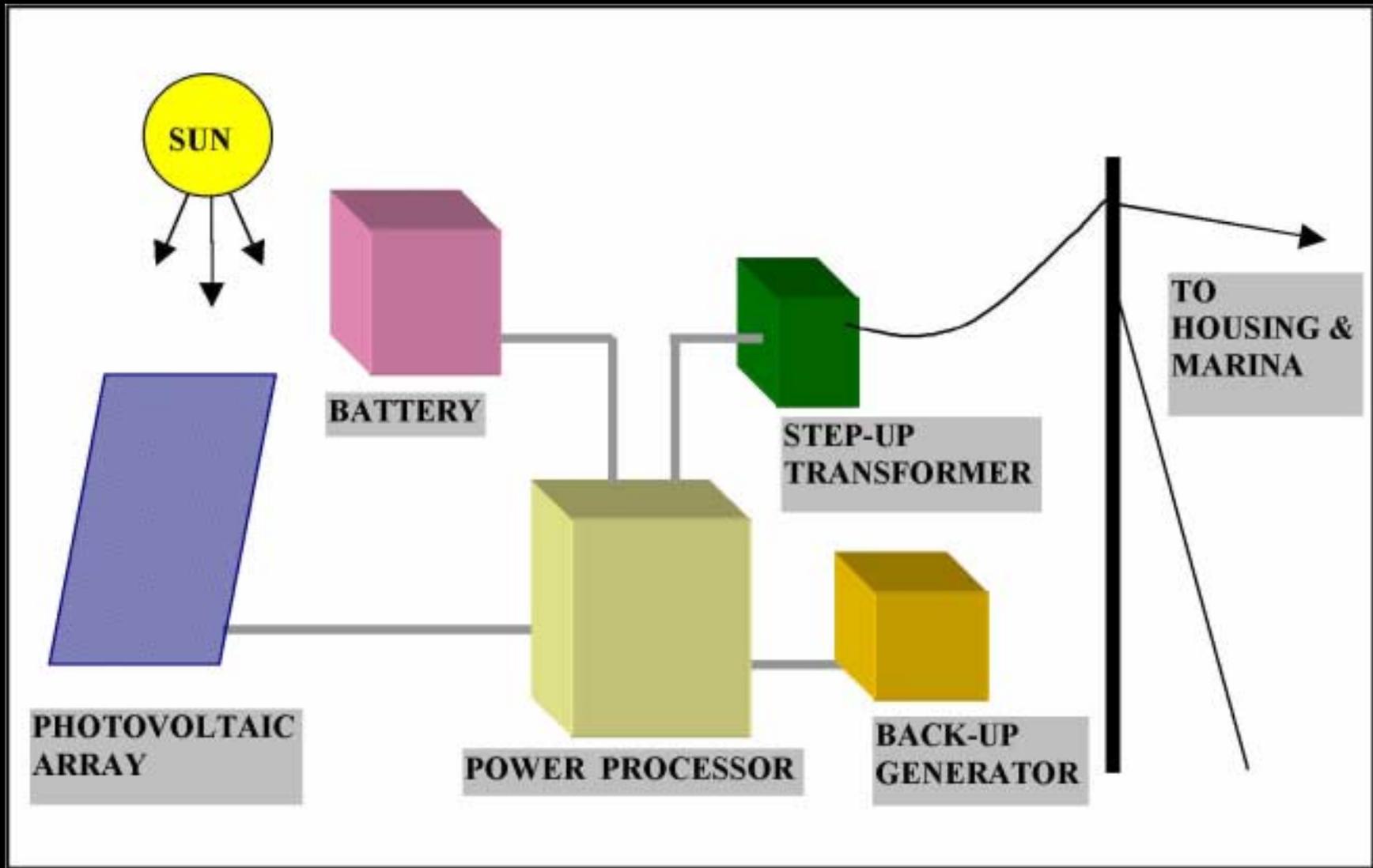
*CR9000 DAS
SIGNAL
CONDITIONERS*

DANGLING ROPE MARINA

Dedicated Aug. '96



DANGLING ROPE MARINA SYS.



DANGLING ROPE MAJOR COMPONENTS: 1996

- **PV: 115 kW**
- **Gensets: 2 - 255 kW LP Caterpillar Generators**
- **Batteries: 2.4 MWh, C&D, 396 Vdc nominal**
 - **792 C&D 6-C125-25, in 40 Steel Cases**
 - **4 parallel strings, 396 Vdc - nominal**
- **Inverter: 250 kW, 3 phase 480 Vac**
 - **Kenetech/Trace**

DANGLING ROPE INVERTER

Kenetech/Trace 250 KVA



DANGLING ROPE BATTERIES



*Photo
9-18-98*

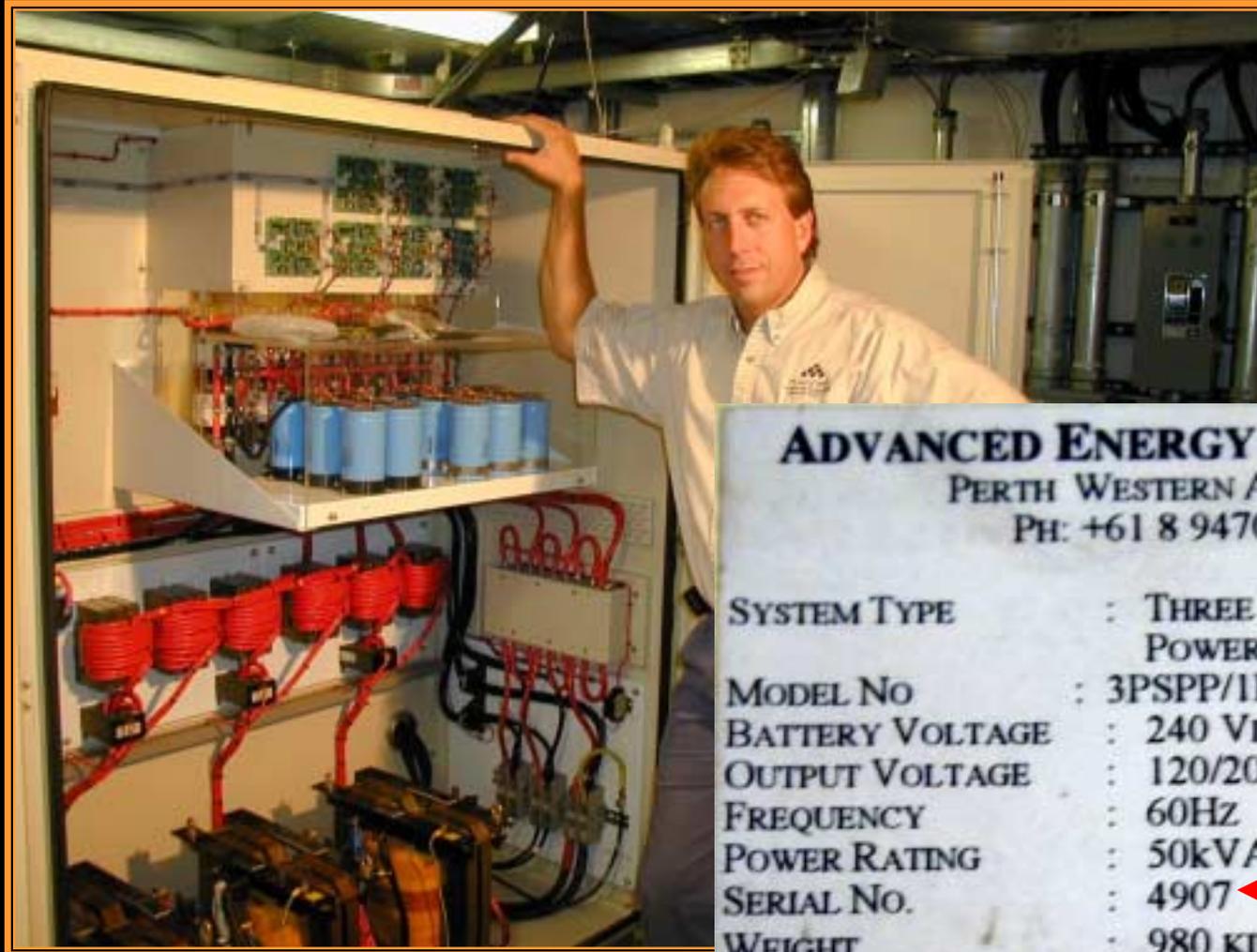
DANGLING ROPE: MAJOR LOADS

- **Park Service maintenance shop.**
- **Residence housing for 40 people.**
- **Water and sewer system.**
- **Boat sewage pump-outs.**
- **Boat parts and repair shop.**
- **Boater's supply store.**
- **Fuel docks/pumps.**
- **Large ice barge freezers.**
- **Convenience store with food and beverage coolers and food freezers.**
- **Public Restrooms**
- **Business and Park Service offices.**

D.R. TEST BATTERIES AT STAR



AES INVERTER EVALUATION



*Aug.
2001*

ADVANCED ENERGY SYSTEMS LTD
PERTH WESTERN AUSTRALIA
PH: +61 8 9470 4633

SYSTEM TYPE	: THREE PHASE STATIC POWER PACK INVERTER
MODEL NO	: 3PSPP/1D/50K/120/60/240/50K
BATTERY VOLTAGE	: 240 VDC
OUTPUT VOLTAGE	: 120/208 VAC
FREQUENCY	: 60Hz
POWER RATING	: 50kVA
SERIAL NO.	: 4907 ←
WEIGHT	: 980 KILOGRAMS

ALTERNATIVE CONFIGUTATION

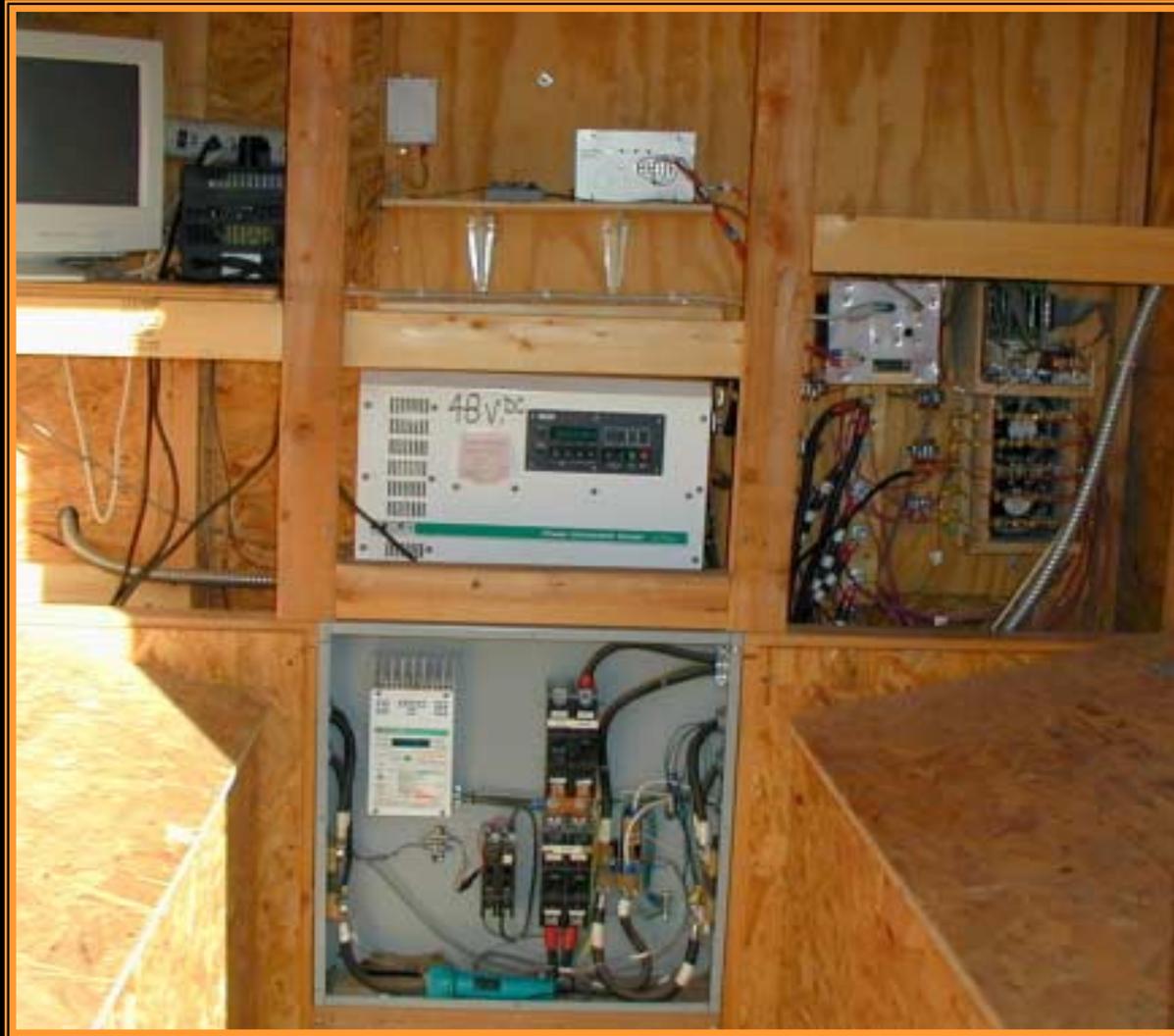


- **Support the Development of a New Proprietary Technique to Equalize Individual Strings of a Battery Bank**
 - **Test site located at the APS STAR Center**
 - **Support via data collection, data quality control, data processing and on-site system management as required by:**
 - **Dr. Phil Symons (EECI) and**
 - **Mr. Garth Corey (SNL Program Manager)**

ALTERNATIVE CONFIGURATION Equipment Building



ALTERNATIVE CONFIGURATION



A.C., MONITOR

Secs	StrA U	StrA A	StrB U	StrB A	StrC U	StrC A	StrD U	StrD A
23	48.89	0.1	48.96	0.0	48.90	0.1	48.92	-0.2
19	48.89	0.1	48.96	0.0	48.89	0.1	48.92	-0.2
15	48.89	0.1	48.96	0.0	48.89	0.1	48.92	-0.2
11	48.89	0.1	48.96	0.0	48.89	0.1	48.92	-0.2
7	48.89	0.1	48.96	0.0	48.89	0.1	48.91	-0.2
3	48.88	0.1	48.95	0.0	48.89	0.1	48.91	-0.2
59	48.88	0.1	48.95	0.0	48.88	0.1	48.91	-0.2
55	48.88	0.1	48.95	0.0	48.88	0.1	48.91	-0.2
51	48.88	0.1	48.95	0.0	48.88	0.1	48.91	-0.2
47	48.88	0.1	48.95	0.0	48.88	0.1	48.91	-0.2
43	48.88	0.1	48.94	0.0	48.88	0.1	48.90	-0.2
39	48.87	0.1	48.94	0.0	48.88	0.1	48.90	-0.2
35	48.87	0.1	48.94	0.0	48.87	0.1	48.90	-0.2
31	48.87	0.1	48.94	0.0	48.87	0.1	48.90	-0.2
27	48.87	0.1	48.94	0.0	48.87	0.1	48.90	-0.2
23	48.87	0.1	48.94	0.0	48.87	0.1	48.89	-0.2
19	48.86	0.1	48.93	0.0	48.87	0.1	48.89	-0.2

15:55:34 on 10-31-01

DisCharging All started 05:39 on 10-30

1 to halt, 9 to exit program.

String finished this cycle: D

StrA Ah: PrevCh:	0.00	PrevDis:	15.64	ThisCh:	0.00	ThisDisch:	6.44
StrB Ah: PrevCh:	0.00	PrevDis:	15.48	ThisCh:	0.00	ThisDisch:	6.71
StrC Ah: PrevCh:	16.88	PrevDis:	30.51	ThisCh:	0.00	ThisDisch:	6.36
StrD Ah: PrevCh:	0.00	PrevDis:	12.94	ThisCh:	16.90	ThisDisch:	21.00

A.C., LOAD SHACK - EXTERIOR



FY2001 ESS 11-14-01

25

A.C., LOAD SHACK - INTERIOR



A.C., CHECKLIST

Alternate Configuration Project Checklist.

11-Oct

12:00

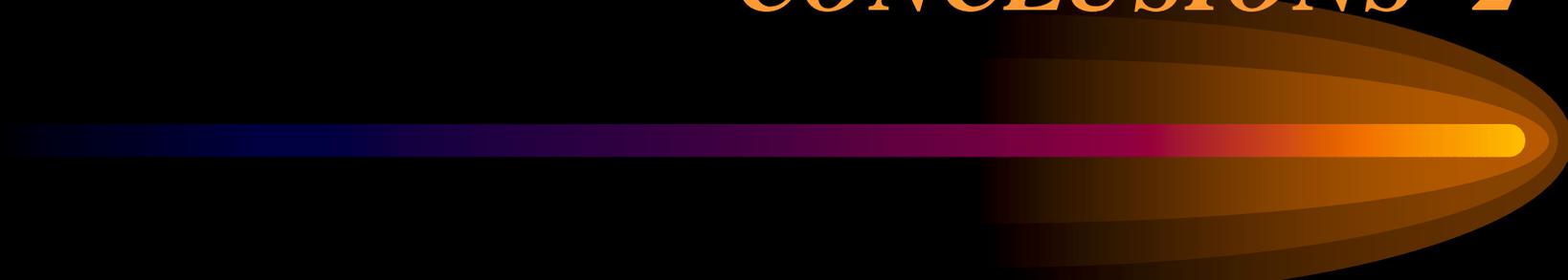
Are the lights ON (Timer: 6-9 PM)?	N
Is the refrigerator running?	Y
Is the swamp cooler running?	N
Is the load shed door latched?	N
Is the battery shed door closed?	Y
What is the generator state? [ON or OFF]	Off
What is the fuel level in percent of full?	78%
Does the monitor turn on?	Y
Are the fans running?	Y
What is the start time of the current battery cycle?	10/10/01 17:40
What is the state of the battery?	Discharge
If in FINISH CHARGE, are charger lights active?	N/A

CONCLUSIONS - 1



- Medium to large hybrid systems (>10 kW) installed prior to 1996 were a valuable (but painful) **learning experience**.
- Factory Tests and Laboratory Tests of Inverters were not able to ensure proper and reliable field performance.
- It is prudent to fully test most hybrid systems with all associated components before installing the system in the field.
- It is not prudent to send Inverter **Serial #1** to the field.

CONCLUSIONS -2



- Interface issues between Inverter / Generator / Battery / PV (under a full range of operating conditions) must be resolved before installing hybrid systems in the field.
- The partnership between APS and DOE/SNL/NREL is an excellent way to leverage the resources of these organizations to quickly improve function and reliability of hybrid systems - and to reduce costs

MAIN ACCOMPLISHMENTS, FY 01



- Supported SNL-DOE Partnership
- Continued support of Hybrid Data Acquisition at STAR-Hybrid facility
- Established and maintained program to monitor Alternative Configuration

PLANS FOR THE FUTURE



- Business as usual

BIBLIOGRAPHY

1. Hammond, R., et. al., *Photovoltaic Hybrid Test Facility: System Evaluation of Yuasa VRLA/GEL Batteries*, EESAT 2000 Conference: September 18-20, 2000, Orlando, FL.
2. Bryan Hill, *Pinnacle West & Y Dangling Rope Solar Hybrid System*, Pinnacle West, October 2001
3. Rosenthal, A., *Dangling Rope Marina: A Photovoltaic-Hybrid Power System*, SNL Quarterly, Volume 1, 1998
4. Rosenthal, A., *Dangling Rope Marina: Preliminary Results*, Photovoltaic Performance and Reliability Workshop, Las Cruces, NM, 1997
5. Thomas, M. and Post, H., *Photovoltaic Systems Performance and Reliability: Myths, Facts, and Concerns - A 1996 Perspective*, PV Performance and Reliability Workshop, 1998
6. Post, H. and Thomas, M., *Photovoltaic Systems Costs for Stand-Alone Systems with Battery Storage*, PV Performance and Reliability Workshop, 1998
7. Newmiller, J. and Farmer, B., *PVUSA Operations Experience With Trace Technologies PV Inverters*, 26th IEEE PVSC, Anaheim, CA, Sep. 29- Oct. 3, 1997