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
• EECl: 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
- 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

- **PV SUB-ARRAY 1**
  - 10 kW

- **PV SUB-ARRAY 2**
  - 10 kW

- **BANK A**
  - YUASA DT85-11
  - 120 2V-CELLS
  - 425AH BATTERY

- **BANK B**
  - YUASA DT85-11
  - 120 2V-CELLS
  - 425AH BATTERY

- **Load Bank**
  - 0 - 100 kW

- **APS Grid**

- **Star Center**

- **Hybrid Test Facility**

- **CR9000 Datalogger**

- **Computer and Modem**

- **30 kW Kohler Generator**

- **Trace 30kW Bi-Directional Inverter**
  - With
  - Peak Power Tracker
  - Battery Charger

- **80A** connections

FY2001 ESS 11-14-01
YUASA VRLA GEL
DANGLING ROPE MARINA

Dedicated Aug. ‘96
DANGLING ROPE MARINA SYS.

Diagram showing the components of the system:
- SUN
- PHOTOVOLTAIC ARRAY
- BATTERY
- POWER PROCESSOR
- STEP-UP TRANSFORMER
- BACK-UP GENERATOR
- TO HOUSING & MARINA
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

Serial #
250-001
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

Type: 1CPV1770
100 HR. 17.7A 1.90V
10-00 H  OP 10376
# AES INVERTER EVALUATION

**Aug. 2001**

![AES Inverter Image](image)

## Advanced Energy Systems Ltd

**Perth, Western Australia**

**Phone:** +61 8 9470 4633

### Technical Specifications

<table>
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<tr>
<th>Specification</th>
<th>Details</th>
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<td>System Type</td>
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<td>Model No</td>
<td>3PSPP/1D/50K/120/60/240/50K</td>
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<tr>
<td>Battery Voltage</td>
<td>240 Vdc</td>
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<tr>
<td>Output Voltage</td>
<td>120/208 Vac</td>
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<td>Frequency</td>
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<td>Power Rating</td>
<td>50kVA</td>
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<td>Weight</td>
<td>980 Kilograms</td>
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ALTERNATIVE CONFIGURATION

• 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

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<th>Secs</th>
<th>StrA V</th>
<th>StrA Ah</th>
<th>StrB V</th>
<th>StrB Ah</th>
<th>StrC V</th>
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</tbody>
</table>

15:55:34 on 10-31-01
1 to halt, 9 to exit program.

DisCharging All started 05:39 on 10-30
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: 21.08
A.C., LOAD SHACK - EXTERIOR
A.C., LOAD SHACK - INTERIOR
## Alternate Configuration Project Checklist

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


