PV-HYBRID SYSTEM FIELD-TEST MONITORING AT STAR

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- Arizona Public Service: Herb Hayden
- EECI: Dr. Phil Symons
- Spencer Everingham, Co-author
OVERALL GOALS

- Enhance a Partnership With a Progressive Electric Utility [APS] with Mutual Interests
- Support the Development of the “Alternative Configuration” to Equalize Individual Strings of a Battery Bank
- Monitor Batteries in Large Remote Hybrid PV Systems
- Evaluate Battery Test Equipment
- Support IEEE SCC21 Energy Storage Subsystem Working Group
WHY

- Reduce the Life-Cycle Cost of Remote Hybrid Systems
- Increase the reliability, durability and confidence in Remote Hybrid Systems
- Make above information available to users (e.g., via IEEE Standards)
- Determine which battery test equipment can best predict battery failure
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

Ocotillo Power Plant
HYBRID “EXPERIENCE” - CSM

Installed Oct. 1995

Abacus Inverter, S/N #1
New Battery: GNB ABS IIP, 05/13/02

05/16/02
CSM Cell Voltage Reads

Carol Springs Mountain Battery
String 3 Jar Voltage Comparison
Midtronic vs Cell Corder Reads

- Midtronic Jar Voltage (May 16, 2002)
- Sandia Cell Corder Jar Voltage (May 16, 2002)
CSM Cell Resistance Reads

Carol Springs Mountain Battery
String 3 Jar Resistance Comparison
Midtronic vs Cell Corder Reads

Jar Number

Cell Resistance, micro-ohms

- Sandia Cell Corder Jar Resistance (May 16, 2002)
- Cell Corder #2 Jar Resistance (May 13, 2002)
- Midtronic Jar Resistance (May 16, 2002)
CELLTRON VS. CELLCORDER
# CELLTRON VS CELLCORDER

## SPECIFICATION COMPARISON

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>MIDTRONICS CELLTRON CTM-300</th>
<th>ALBER CELLCORDER</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Application</strong></td>
<td>2, 4, 6, 8, 10, 12 V Jars</td>
<td>2V, 6V, and 12V Batteries</td>
</tr>
<tr>
<td><strong>Voltage Accuracy</strong></td>
<td>2%</td>
<td>0.1% of reading +/- 1 LSD</td>
</tr>
<tr>
<td><strong>Voltage Resolution</strong></td>
<td>10 mV [20 mV actual]</td>
<td>1 mν</td>
</tr>
<tr>
<td><strong>Memory</strong></td>
<td>252 Test Results</td>
<td>1792 Test Results</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7 Strings of 256 Cells</td>
</tr>
<tr>
<td><strong>Weight (tester)</strong></td>
<td>1 pound (500 grams)</td>
<td>8.5 pounds, not including leads or carry case</td>
</tr>
<tr>
<td><strong>Size</strong></td>
<td>9” x 4” x 2.5” w/case</td>
<td>11” x 10” x 4”</td>
</tr>
<tr>
<td><strong>Ease of use (10 = easiest)</strong></td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td><strong>Data collection &amp; storage time</strong></td>
<td>55 seconds</td>
<td>40 seconds</td>
</tr>
<tr>
<td><strong>Battery Life</strong></td>
<td>1 hour</td>
<td>6 hours</td>
</tr>
<tr>
<td><strong>Cost (including software)</strong></td>
<td>$4935</td>
<td>$5400</td>
</tr>
<tr>
<td><strong>Software sold separate</strong></td>
<td>Yes, $620</td>
<td>No</td>
</tr>
<tr>
<td><strong>Ability to predict battery failure</strong></td>
<td>UNKNOWN</td>
<td>UNKNOWN</td>
</tr>
</tbody>
</table>
THE HYBRID TEST FACILITY

Established
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

30 KW KOHLER GENERATOR

TRACE 30kW BI-DIRECTIONAL INVERTER
with
PEAK POWER TRACKER
BATTERY CHARGER

LOAD BANK 0 - 100 kW

APS GRID

STAR CENTER

HYBRID TEST FACILITY

CR9000 DATALOGGER

COMPUTER and MODEM

FY2002 11-19-02
CR9000 DAS, SIGNAL CONDITIONER
D.R. TEST BATTERIES AT STAR
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/repair as required by:
    • Dr. Phil Symons (EECI) and
    • Mr. Garth Corey (SNL Program Manager)
ALTERNATIVE CONFIGURATION
Equipment Building
ALTERNATIVE CONFIGURATION
GENSET STARTING BATTERY
A.C., LOAD SHACK - EXTERIOR
<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</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>

2. IEEE P1561/D5. Recommended Guide For Optimizing the Performance and Life of Lead-Acid Batteries In Hybrid Remote Systems
IEEE 1561: USER QUESTIONS

CAROL SPRINGS MOUNTAIN
REMOTE HYBRID SYSTEM

1. For a nominal load, what is the relationship between State of Charge (SOC) and Vbb?
2. What methodology should be used to measure SOC? AmpHour counting? Vbb? Both?
3. What is the recommended charging technique? Equalization frequency?
4. For the Remote Solar Electric System (RSES), how should those batteries be managed?
5. Temperature compensation – charge set points only? Discharge set points?
6. VRLA/CSM: How do the battery characteristics change with age.
7. CSM: Equalization frequency? Finish charge every two weeks? 5% Overcharge (Ah)?
8. Why is there not a smart controller that can anticipate daytime PV availability and decide when to start the genset?
GRAY WOLF HYBRID REMOTE SYSTEM

1. How does load affect genset start/stop and Low Battery cutoff (LBCO) set points? How do we compensate for the effects of load?
2. What is an authoritative reference for temperature compensation of Charge and Discharge set points?
3. Equalization: How often? Procedure?
4. Where do you measure Temperature, Voltage, Current? How do you measure these parameters?
5. How are above answers affected by battery age?
6. How is battery resistance measured?
7. How effective is Amp-hour counting? Pros and cons? Procedure? When is counter reset?
IEEE STANDARDS: P1561

CHARGE ACCEPTANCE AT 40C (FLOODED LA BATTERY)

Source: Figure 5.7, pg 147: Rand, D., R. Woods and R.M. Dell, Batteries for Electric Vehicles, John Wiley & Sons, Inc., New York, 1998
CONCLUSIONS - 1

• Lead-acid Battery Technology is Mature. Battery Management in PV Systems is still in the early stages of development.
  – Need charge controllers that include amp-hour counting
  – The Alt. Config. management system is a major step forward

• Proper Battery Management Information is not readily available to the System Integrator/User.
  – System Integrators still have more questions than answers
CONCLUSIONS -2

- The Alber Cellcorder has 20 times greater voltage resolution than the Midtronics Celltron. Time will tell which instrument is better at predicting battery failure.

- The partnership between APS and DOE/SNL is an excellent means of leveraging the resources of both organizations in order to improve function and reliability of hybrid systems, and to reduce the costs of hybrid systems.
PLANS FOR THE FUTURE

• CONTINUE TO SUPPORT:
  – Alternative Configuration Development
  – STAR, Hybrid Test Facility
  – STAR, CSM Battery Management/Optimization
  – Battery Standards
  – On site Liaison between APS and DOE/SNL
THANK YOU

QUESTIONS
BIBLIOGRAPHY


