Alternative Configurations to Optimize Lead-Acid Batteries for Renewable Generation and Storage (RGS)

DOE Program Review, 10/20/2005

ACONF R&D and US Coast Guard Implementation

Philip C. Symons

Symons/EECI, 623-476-7336, pcsymons@earthlink.net

Work performed under contract with Sandia National Labs
Project Managers: Stan Atcitty (R&D) and Garth Corey (USCG)

Paul Butler of SNL also collaborates on the project

Sandia is a multi-program laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

ACKNOWLEDGMENTS

- Funded in part by the Energy Storage Systems Program of the U.S. Department Of Energy (DOE/ESS) through Sandia National Laboratories (SNL).

ACONF Headlines for FY05

- **USCG to have ACONF unit installed at Duke Island NDS site, because testing at SNL DETL showed >20% fuel savings in simulated NDS operations**
- **Testing of two improved 100kW ACONF units continued in preparation for final development push; APS continues to be interested in using at Gray Wolf site**
- **Communications for remote sites with ACONF units successfully developed**
- **ACONF for Standby/UPS battery systems patent applied for (Atcitty, Butler, Corey, Symons)**

ACONF FY05 Work: Topics

- Overview of ACONF Technology
- Work for USCG National Distress System sites
- Development of 100kW class ACONF units
- Finish charging technologies for ACONF
- ACONF Communications at remote sites
- ACONF for Standby/UPS battery systems
- Concluding Remarks, Future Plans

Alternative Configurations to Optimize Lead-Acid Batteries for RGS

Project Goal

To conceive, develop, and promote implementation of, alternative configurations for renewable generation and storage systems that will improve reliability, enhance component performance, and lower life-cycle-costs

Secondary Goal

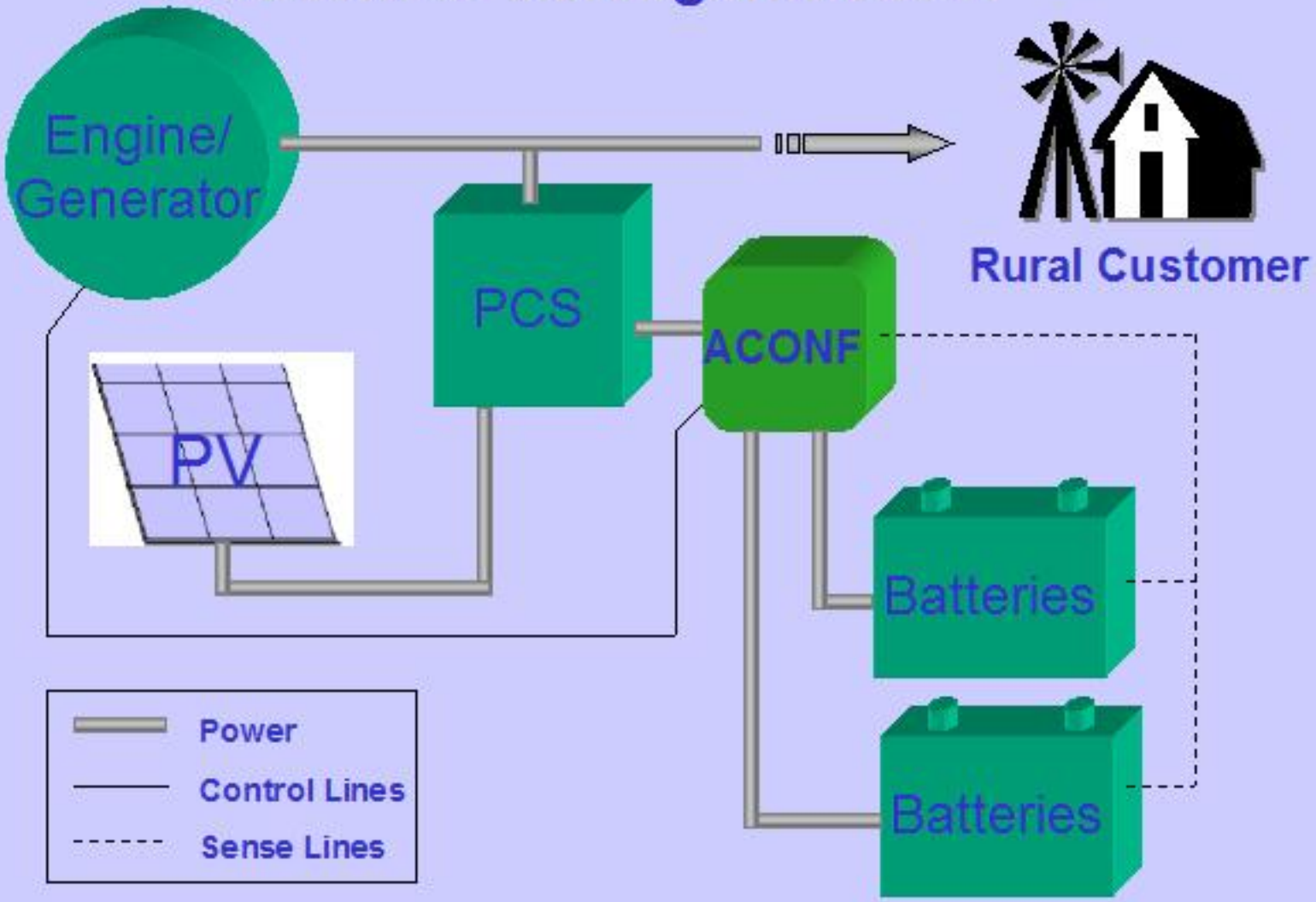
To facilitate communication between battery manufacturers and RGS users, using the alternative configurations developed, so that batteries might be used to their best advantage without compromising system performance

What are Alternative Configurations?

- **Added circuitry between each string of the battery and the DC terminals of the AC-DC-AC converter**
- **Hardware and software to control the currents to and from the strings through the additional circuitry**

String currents are controlled on basis of measured parameters and characteristics of battery modules used in each specific installation

What are RGS Battery Alternative Configurations?



Project History

- **FY98: Conceptualized solutions to RGS problems**
- **FY99-00: Developed alternative configurations (ACONF) with modeling then lab testing**
- **FY00-01: Identified user field test site; refined hardware and software; fabricated breadboard and tested in lab and then at field test site**
- **FY02: Patent issued. Identified implementer and performed joint engineering development of 10kW (Type A) unit; built several Type A prototypes and operated at field test site**
- **FY03: Continued and expanded Type A field site testing; developed 100kW class (Type B) unit**
- **FY04: Began testing Type A unit for USCG; improved 100kW class units and began testing at SNL and STAR**

Benefits of Alternative Configurations For RGS Solar Hybrid Systems

- Overcharge and over-discharge avoided
- Battery finishing charge & generator “de-coupled”
- Can utilize PV for and while finish charging
- Easily made smart relative to expected load & solar
- In advanced ACONF units:
  - Module voltage and/or temperature controls operations
  - Generator will start for weakest module(s)
- Opportunity to maximize battery and system life, performance, and to minimize life-cycle-cost

FY05 Progress: Work for USCG

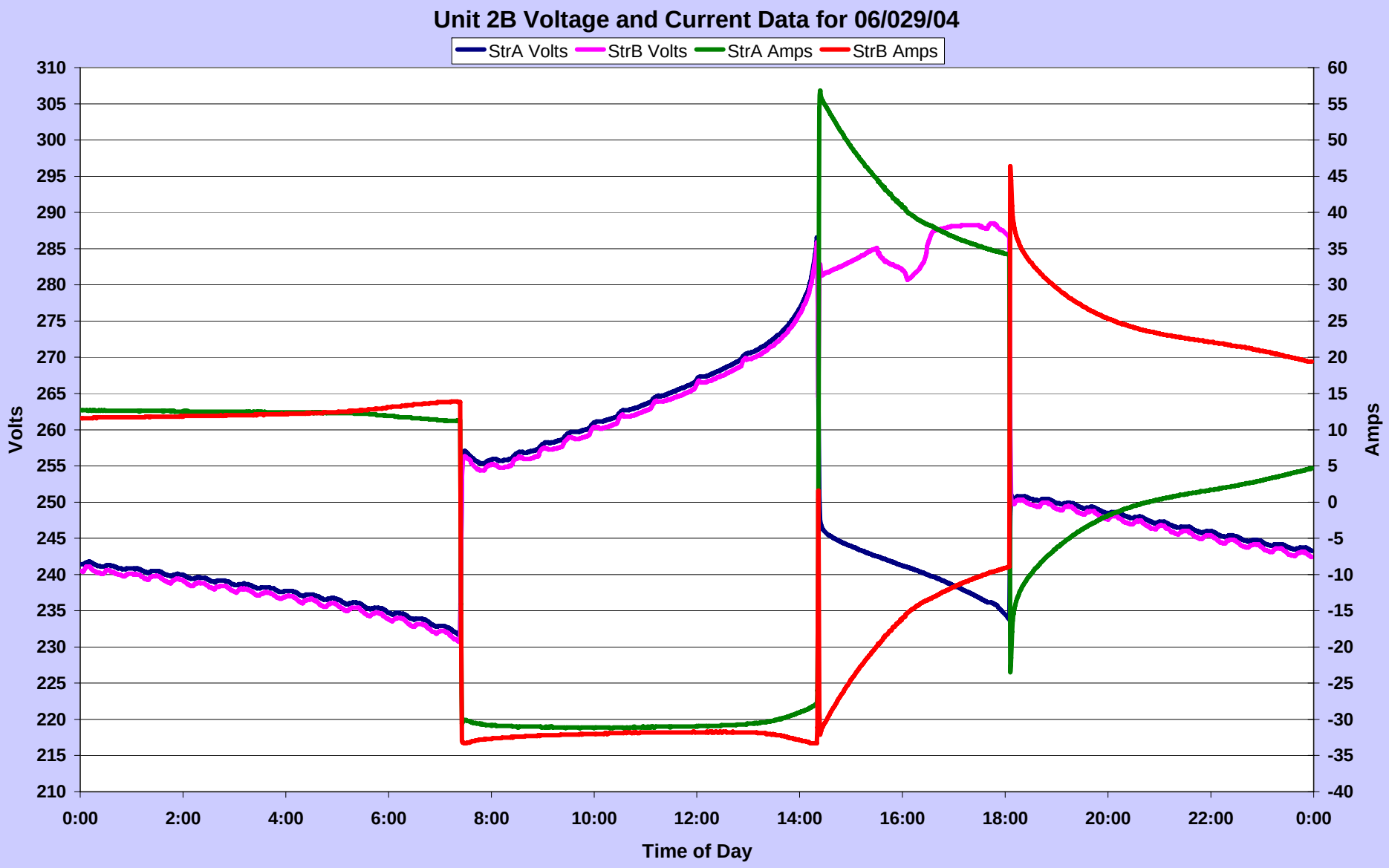
- **Results of testing reported on by Garth Corey in EESAT paper, so no details here to avoid repetition**
- **Symons/EECI work this year involved:**
  - **Supply and factory testing of two Type A ACONF units, together with three Bypass Switches**
  - **Modifications to ACONF software as necessary, and providing revised set points to minimize fuel consumption**
  - **Development of improved, higher efficiency upverter for finish charging, see below**
  - **Development of communications package for retrieval of data from remote sites, see below**
  - **Analysis of data from various USCG units**
  - **Support to SNL personnel in preparing for installation at Duke Island site**

FY05 Progress: Further Improvement of 100kW Class (Type B) Unit

- ACONF unit sized for 33kW/string (100kW for 4-string unit)
- Utilizes innovative (low-cost) finish charge technology
- Many changes and modifications made in FY05 to give more reliable operations
- Two units under test, Unit 2B at Sandia DETL and Unit 3B at APS STAR Facility

FY05 Progress: Unit 2B at DETL

- 2-string, 425Ahr/string, 240V Yuasa Gel VRLA battery
- Trace (Xantrex) 30kW converter connected to grid for charging; solar arrays also available but not used in FY05 testing
- Battery and converter had been previously tested at STAR
- Variety of load banks can be connected to Trace output
- Little testing during FY05 due to demands on DETL personnel from other programs


Unit 2B Voltage and Current Data for 06/029/04
StrA Volts
StrB Volts
StrA Amps
StrB Amps
Volts
Amps
Time of Day
310
305
300
295
290
285
280
275
270
265
260
255
250
245
240
235
230
225
220
215
210
60
55
50
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
0:00
2:00
4:00
6:00
8:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
0:00

100kW Class Unit 3B in Hybrid Building at STAR

FY05 Progress: Unit 3B at STAR

- 2-string, 1000Ahr/string, 240V C&D flooded lead acid battery
- AES 30kW converter, with 50kW propane-fueled generator for charging
- Solar arrays, up to 20kW, are also connected
- Variety of loads can be connected to AES output
- Some testing during FY05, but testing currently suspended because APS needs facility for other testing
- Testing early in FY05 work (May) exposed software/hardware problem; testing continued successfully after repairs/modifications made

FY05 Progress: ACONF Finish Charge Technologies

- **Sub-contractor to Symons/EECI (FWR, Flagstaff, AZ) uncovered alternative upverter topology**
- **As first implementation, a higher efficiency, more reliable upverter has been developed for the USCG project**
- **Technology may be applicable to 100kW class systems, but development costs make implementation impossible at this time (more than entire amount spent on ACONF R&D in FY05)**
- **Battery-based finish charger, with MOSFET-based controls, appears to be working reliably for 100kW class units at STAR and DETL, and is inexpensive compared to upverter at present time**

FY05 Progress: ACONF for Standby/UPS Battery Systems

- For some years, our group have been trying to devise ways to expand ACONF technology to Standby/UPS applications; finally, about two years ago, Atcitty, Butler, Corey and Symons figured out how to do this
- After some debate within SNL, it was decided to file a patent application; this was done during the past year
- The patent application is based on similar principles as ACONF for RGS, but differs from our original ACONF patent in many ways
- Successful implementation should improve the assurance that Standby/UPS batteries will deliver energy and power as needed
- Since this is a patent application in process, we cannot say more at this time

Summary Conclusions

- Continuing progress on R&D on 100kW class units; two Type B units under test and being readied for major updates
- 1st phase of USCG testing so successful that CG ordered ACONF unit for installation at Duke Island NDS site; installation scheduled for Nov 14,
- Development of ACONF components, e.g., communications software, improved Type A upverter, proceeding well

Next Steps

- Continue testing and improvement of ACONF 100kW class (Type B) prototypes as sites, personnel and funding allow, to allow possible field test later in FY06
- Perform analyses on ACONF data from USCG Duke Island site, and from tests of parallel systems at SNL DETL; arrange for improved Type A units to be supplied to USCG; continue contacting other potential US Government users
- Begin process of porting ACONF software to a better language on a better operating system than Professional Basic on DOS 6.22, probably in C on a Linux operating system