Li Ion Battery Energy Storage System (BES)

Saft America
Advanced Battery Systems Div.
Dr. S. Oweis

salah.oweis@saftamerica.com

And

SatCon Power Systems
V. Scaini and Leonard Lansing

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Demonstration System

- Funded by DoE and administered by Sandia National Labs
- Particular interest in high power Li-Ion technology
- Developed : "480V high power Li-Ion battery / 100 kW SatCon PCS System"
- Two (2) Systems to be Delivered:
  - * 1st System: Southern Services Co.
  - * 2nd System: AEP

"SAFT 100 kW Li-Ion Battery / SatCon PCS" System

Battery

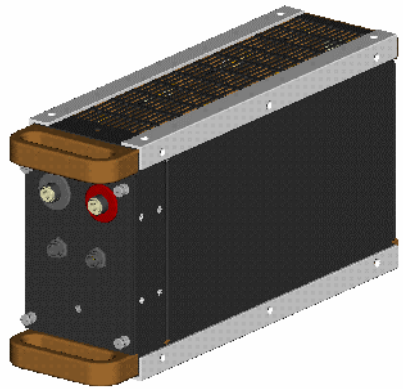
PCS

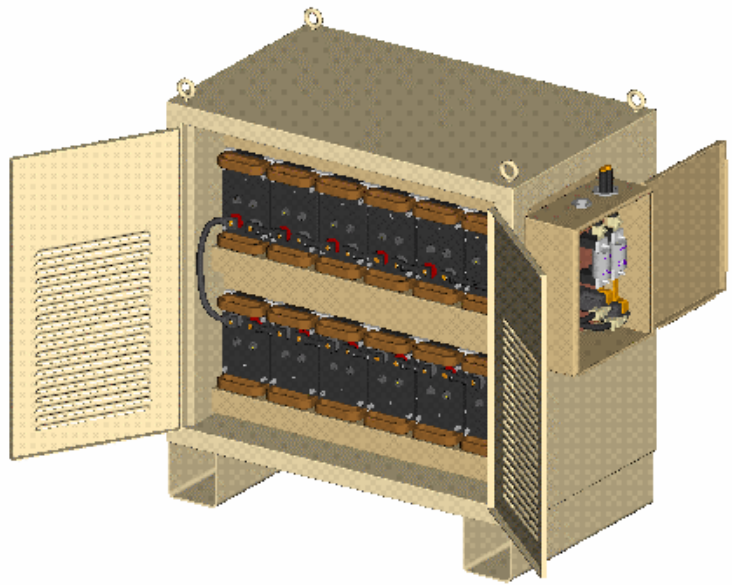
System Functionality

- Distributed Generation (DG), e.g. Microturbine, configured for grid-connected operation Normally in standby mode
- PCS senses loss of ac line and provides seamless transition to 'island' operation
- Battery carries critical loads for a period, then microturbine starts up automatically
- Battery also provides or absorbs excess power during load shifts

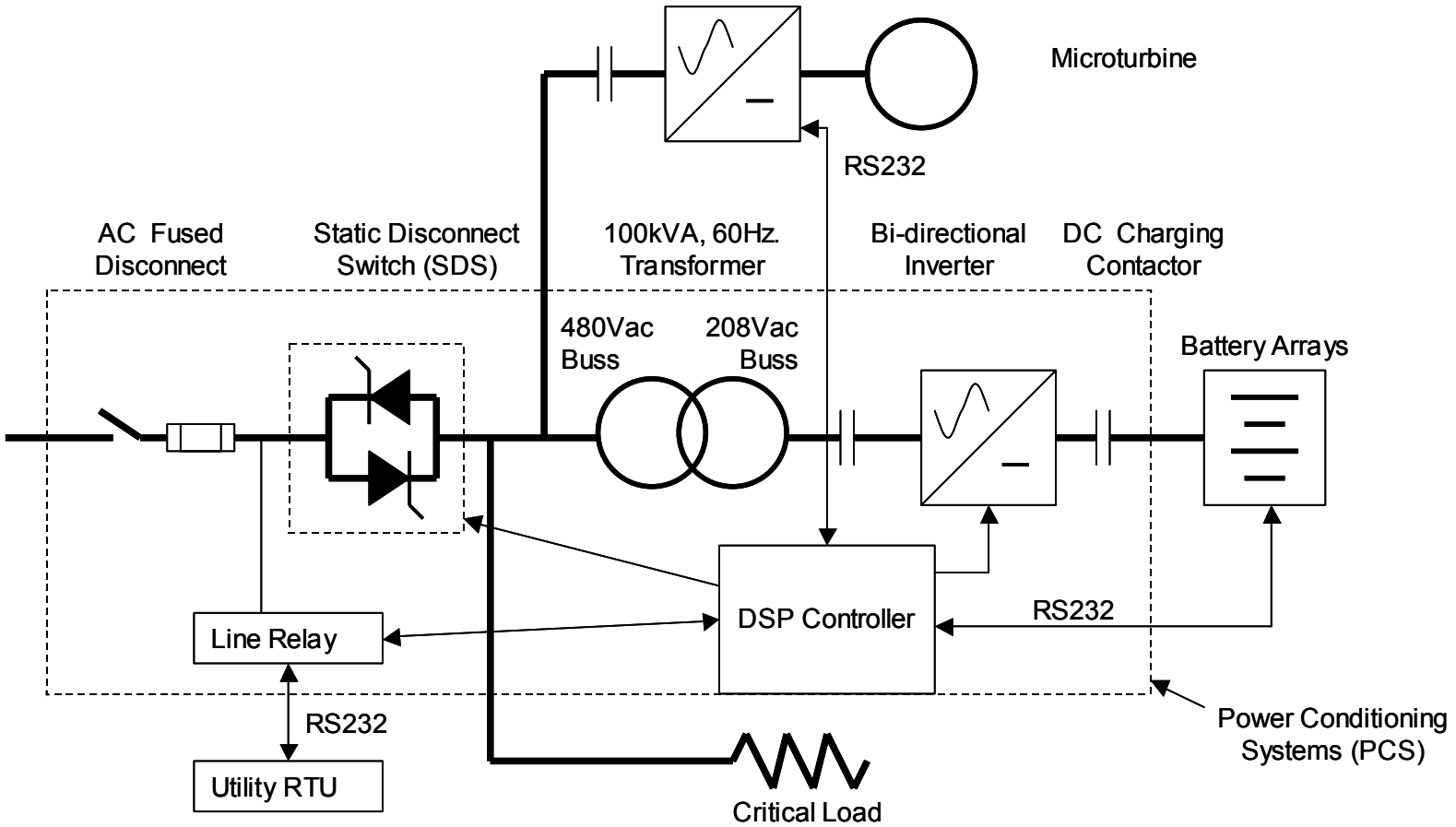
System Overview

- Nominal 480V high power lithium ion battery
  - 132 cells Saft HP30
  - 11 modules of 12 cells
  - Battery management system
- System capabilities
  - 100 kW / 1 minute
  - 15 kWh
- Can operate as standalone UPS system
- Also configured to interact with Capstone 60kW microturbine
- 100 kW SatCon PCS





One-Line Diagram



Battery Electrical Specifications

Power:	**100 kW/1 minute**
Energy:	**15 kWh**
Voltage Window:	**515/ 405 VDC no load/full load**
Typical Operating Mode:	**Floating with occasional power pulse.**
Operating Environment:	**Humidity: non-condensing. Temperature Range: (Estimated between -30°C and 50°C)**

Battery Physical Specifications

- **Overall Battery Dimensions:**
  - **Width:** 50.38 in (1280mm)
  - **Height:** 45.00 in (1143mm)
  - **Depth:** 28.50 in (724mm)
- **Total Weight (including modules):** 1100 lbs (500kg)
- **Battery Modules:** 11 each (series connected)
- **BMS Modules:** 1 each
- **High Voltage Junction Box:** 1 each
- **Forced Air Cooling:** 1600 CFM (Filtered)
- **Front doors and high voltage box door are moisture sealed**

The Look of The High Power LiON Battery

Battery cabinet with high voltage box.

Battery with modules

All Power and communication connections are front mounted for easy service.

Battery Management System (BMS)

LiON High Voltage Battery Protection & Control Requirements:

- OVERCHARGE PROTECTION
- OVERDISCHARGE PROTECTION (OPTIONAL)
- OVERTEMPERATURE PROTECTION
- OVERCURRENT PROTECTION
- GROUND FAULT DETECTION
- INTERNAL BATTERY FAULT DETECTION
- WATCHDOG TIMER - LOSS OF COMMUNICATION WITH VEHICLE CAUSES DROPOUT OF CONTACTORS BY BMS
- SAFETY INTERLOCK TO CAUSE DROPOUT OF CONTACTORS IN THE CASE OF ABUSE CONDITIONS CONTROLLED BY I-BMS
- CELL BALANCING

ELECTRONIC SYSTEM CONFIGURATION

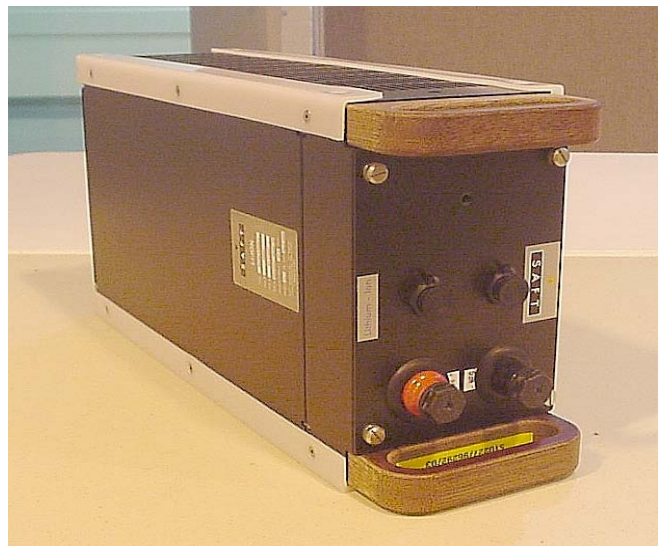
- **The Basic Structure of the Saft Electronic System:**
  - High speed, distributed, cell level protection & balancing processing
  - Synchronous voltage data gathering telemetry
  - 3 Safety Interlocks as needed (Discharge, Charge, & Redundant Overcharge)
  - Optical isolation connection to I-BMS with inherent in-line safety
  - Inter-Module & Intra-Module Balancing under I-BMS computer direction

- **Internal BMS Components:**

  BMS Circuit Board
  110VAC to DC Power Supply
  110VAC Fan relay
  CanPro Power Relay

Battery Module

- Ruggedized Construction
- 12 high power HP30 cells (series connected).
- DC power terminals and communication terminals front mounted for easy serviceability.
- CANProbe circuitry monitors cell voltages and module temperature.
- Battery module weight: 45.5 lbs
- Dimensions:
- W: 5.75in , H: 10.00in , Depth: 19.56in



"SAFT 100 kW Li-Ion Battery / SatCon PCS " System

PCS AC Parameters – Grid Connected / Stand Alone:

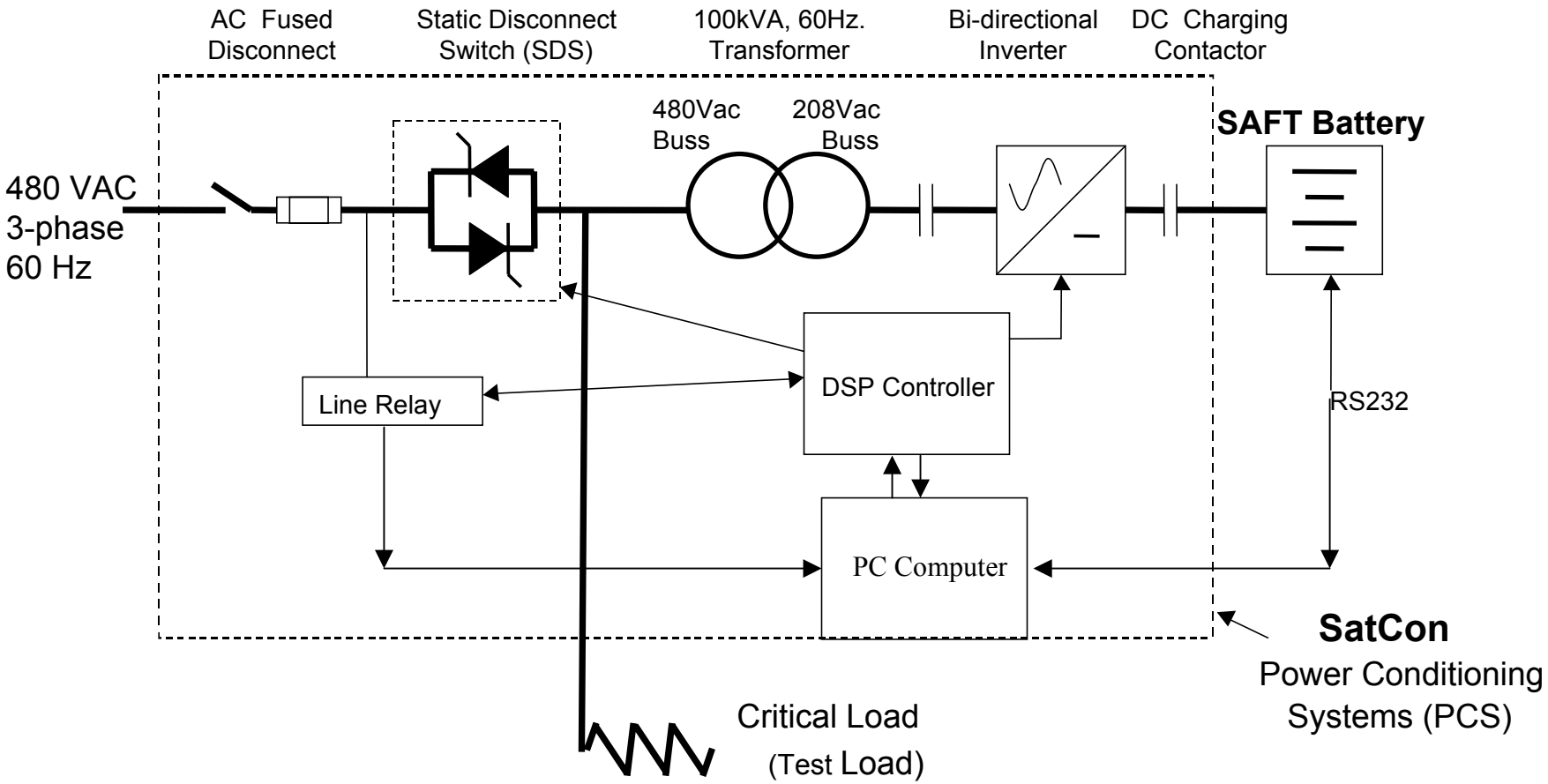
Rated Output Power	*:100kW/100kVA 110% overload*
Frequency, Rated	*: 60 Hz*
Rated AC output voltage	*: 480 V AC*
Operational range of line linkage voltage	*: Rated voltage+10%/- 12%*
Operational range of line linkage frequency	*: Rated frequency ± 1%*
Efficiency of power conversion	:>95%Without Transformer :>93% With Transformer
Power factor	:0.8 lead to 0.8 lag Programmed ramp
Power Real and Reactive Accuracy	: ± 1%
Output current harmonics Grid Connected	:THD ≤ 5%, Each ≤ 3%

System Integration at SatCon

PCS

System Integration at SatCon

PCS / Battery test setup



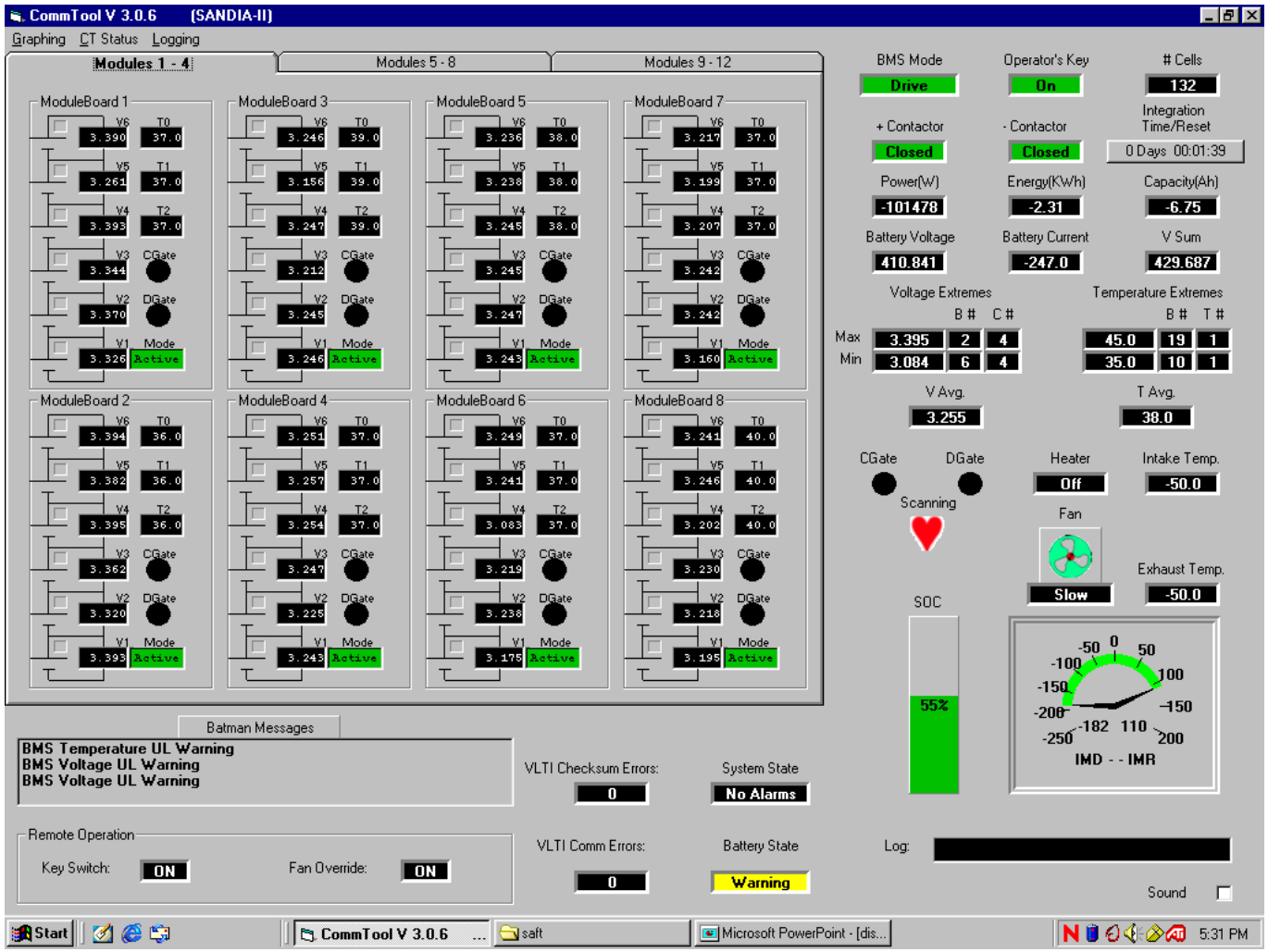
PCS Efficiency Measurements

SA 50%	Bat DC Voltage 441V	Bat DC Current 118.9A	Pdc = 52.4 kW	Pac = 49.07kW	Efficiency = 93.6 %
SA 100%	Bat DC Voltage 432V	Bat DC Current 249.0A	Pdc = 107.5kW	Pac = 100.5 kW	Efficiency = 93.5 %
LL 50%	Bat DC Voltage 442V	Bat DC Current 121.0A	Pdc = 53.5 kW	Pac = 50.0 kW	Efficiency = 93.4 %
LL 100%	Bat DC Voltage 436V	Bat DC Current 246.4A	Pdc = 107.5kW	Pac = 100.0 kW	Efficiency = 93.0 %

Battery discharge characteristics at different power levels

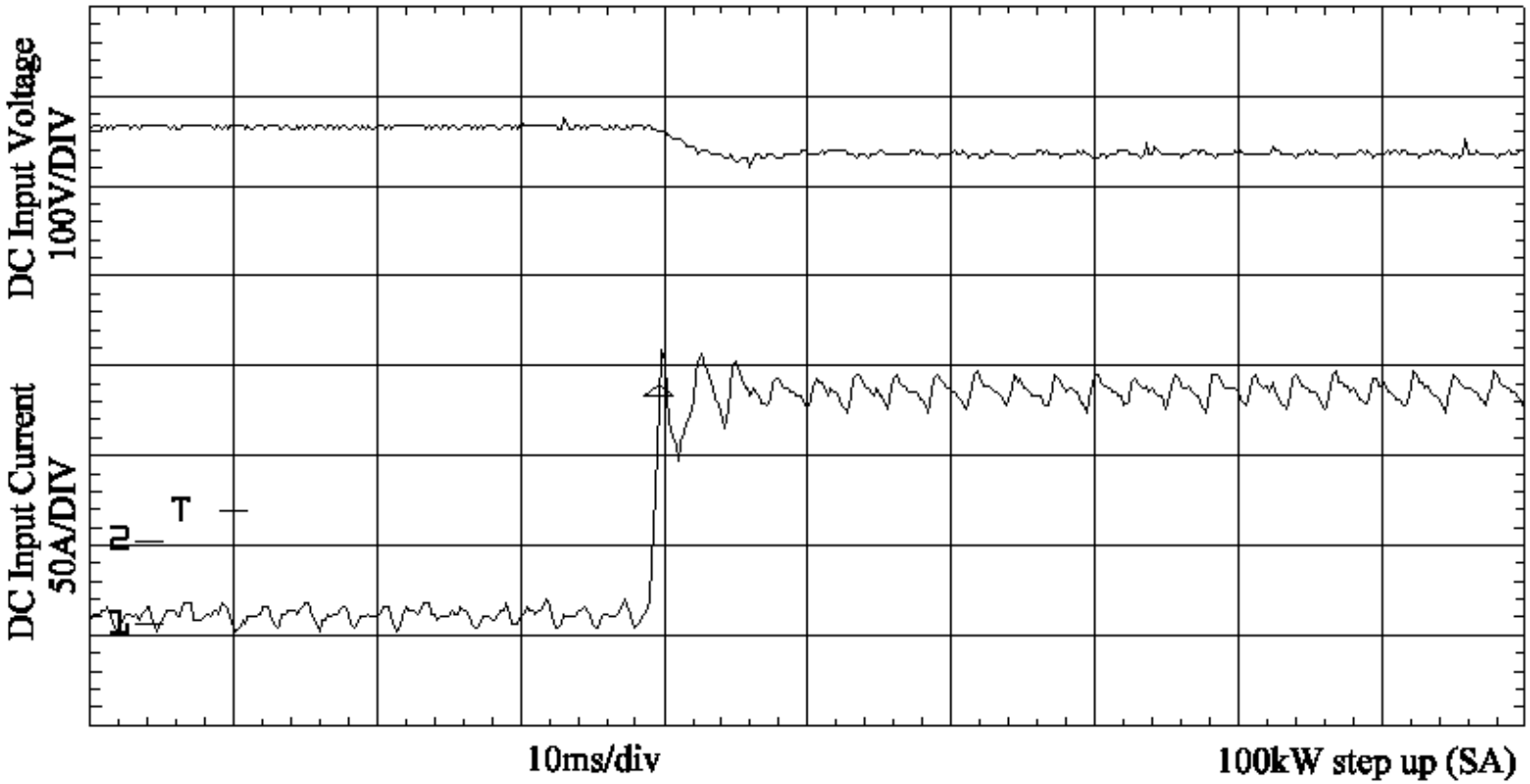
Saft Battery Discharge Test (Oct. 4, 2002)								
Status before discharge: SOC=64%, Cell Vmax=3.9V, Cell Vmin=3.6V								
Status after discharge are the followings								
Load (kW)	Output Current (A)	Battery Current (A)	Discharge time (min)	Cell Vmax (V)	Cell Vmin (V)	SOC (%)	Vsum (V)	Stopped by Warning
10	13	25	26min 37sec	3.6	3.2	29	464	Low SOC
25	31	56	11min 30sec	3.5	3	29	453	Low SOC
50	62	115	5min 38sec	3.5	2.9	31	440	Low Cell Vmin
75	93	180	3min 28sec	3.4	2.7	42	432	Low Cell Vmin
100	124	247	1min 39sec	3.4	3	55	429	Over Temp

Battery display status at end of 100 kW discharge

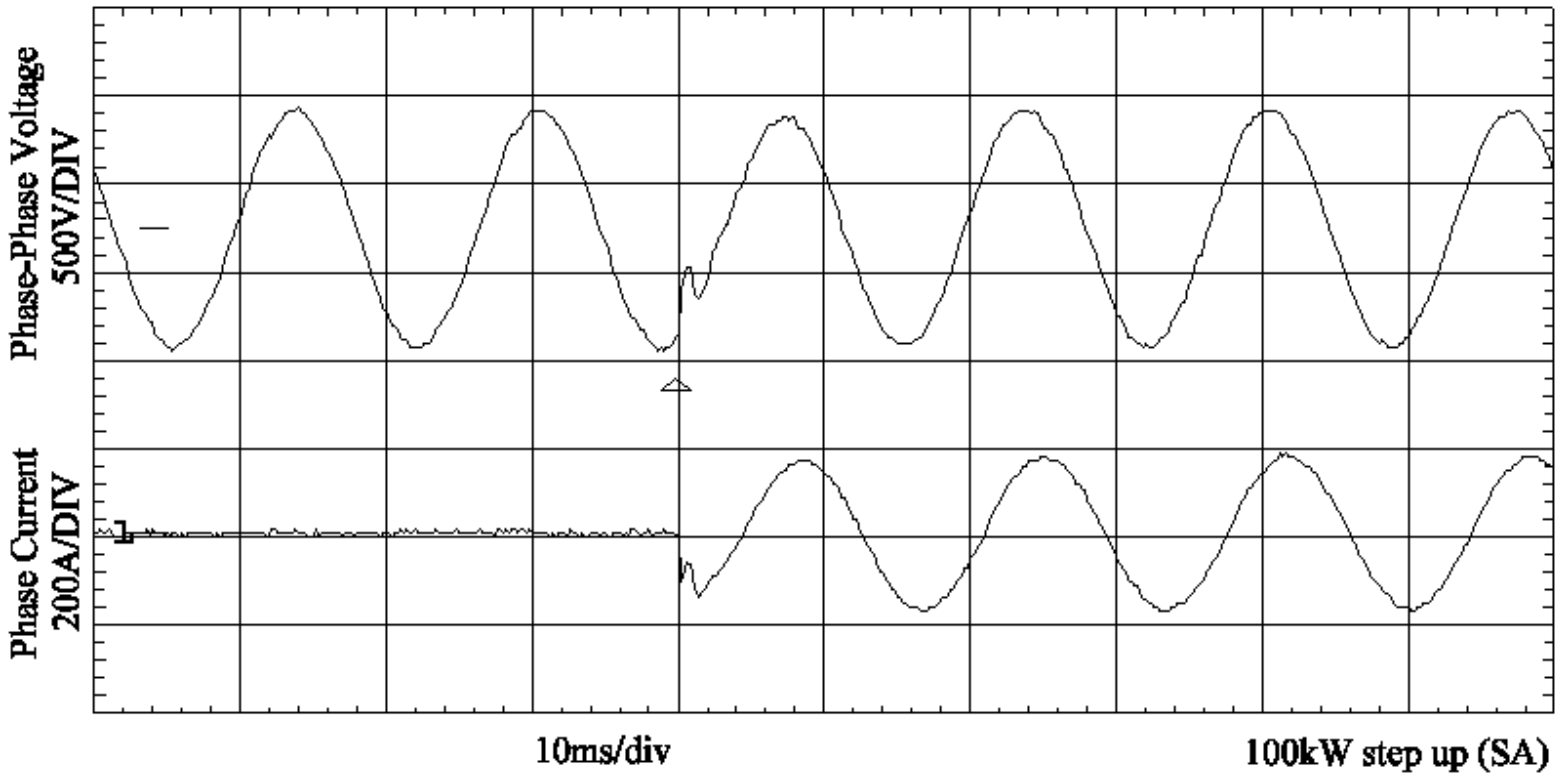


DC voltage and current waveform in 100 kW AC step load

In stand alone mode



AC phase voltage and current waveform in 100 kW AC step load In stand alone mode



Line Harmonics measurements

	Input Power KW	Input Power KVA	Frequency Hz	Voltage Vl-n	Voltage THD	line Current Amps	Current THD
Stand Alone mode	101.9	101.9	60	278.4	1.10%	122	1.10%
Stand Alone Mode	52	52.12	60	276.9	1.10%	62.1	2.10%
Line Link Mode	80	100	60	276.9	0.70%	122	1.10%

1st 100 kW Li-Ion Battery/PCS System

- System Integration tests are complete at SatCon.
- System is ready to ship to Southern Services Co. after demonstration on Nov. 26, 2002.

2nd 100 kW Li-Ion Battery/PCS System

	2nd 100 kW P C S	2nd 100 kW Battery
Finishing Assembly	Nov. 18, 2002	Jan. 03.2003
Factory Acceptance Test	Dec. 02,2002	Jan. 10, 2003
Battery Integration Test (using the 1st battery)	Dec. 12, 2002	N/A
Ready for Shipping to AEP	Dec. 16, 2002	Jan. 13, 2003

Summary

- Storage for supporting Distributed Generation (DG) expected to be mainly high power devices

- Lithium ion expected to be a major contender in this area

Acknowledgement

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