Northern

Northern Power

EnergyBridge™ UPS

Status Update

September 29, 2008

DOE Peer Review – Washington, DC

This project is part of the Energy Storage Collaboration between the California Energy Commission (CEC) and the Energy Storage Systems Program of the U.S. Department of Energy (DOE/ESS) and managed by Sandia National Laboratories (SNL). 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
Project Objectives

- Maintain high power quality on protected loads at all times
- Provide power to protected load in event of a utility sag or outage
- Meet the ITI (CBEMA) curve during power quality events
- Resynchronize with backup power or grid as necessary
Palmdale Water District
Clearwell Site

EnergyBridge™ EB 450

- Ultracapacitors
- Static switch
- Power conversion

Hydro
250 kW

NG Genset
200 kW

ATS

Clearwell Protected Loads
~400 kW

Clearwell Other Loads
~350 kW

Diesel Back-up
800 kW

SCE Utility Grid

Legend

M
Utility meter

PQM
Power quality meter

ATS
Automatic transfer switch

M
Circuit breaker
**One Line Diagram**

**Sub-system 1: Series Components**
- Isolation Breaker CB1
- Series Inductance Ls
- Fast Switch S1
- Isolation Breaker CB2

**Sub-system 2: Shunt Power Conversion**
- Bi-directional Inverter
- Bi-directional DC to DC Converter
- Electrolytic Capacitor Bank
- DSP Controller

**Sub-system 3: Energy Storage**
- Ultracapacitor Bank

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To Utility Grid

To Critical Loads
EnergyBridge™ UPS System at PWD
Project Status Milestones

• Factory Witness Test September 2007
• System Installed in December 2007
• System Commissioned March 2008
• On Site Acceptance Test May 2008
EnergyBridge™ UPS Project

• Aggressive Goals:
  ▪ Develop a production-ready prototype 450kW Ultracapacitor based uninterruptible power supply
    o New hardware design for power converter
    o New control architecture design using distributed control
  ▪ Demonstrate prototype with motor + process control loads
• Significant underestimation of problem size and inherent challenges for UPS grade operation
On Site Acceptance Test

- Test performed with high standards
- Test procedures designed to test system performance based on original UPS grade design goals
- Each test performed only once, no “do-overs”
- Demonstrable outliers still scored as failures
Project Successes

- Demonstrated successful system operation for limited loads
- Demonstrated power quality improvement for all loads
- Ultracapacitor interface and control demonstrated
- Demonstrated system operation for generator and grid source
- Demonstrated proper operation and capability of hardware
Load Support From / To Grid

- Mostly satisfactory for large and medium loads
  - Requires load dependent controller settings
  - Marginal control stability results in “random” faults
- Possible, but unsatisfactory for no / low load
- Hardware capable of performing goal
- Control algorithms require significant additional development work to meet UPS grade operation
200hp PWD Load Grid Power Quality

- Input displacement power factor corrected
- Compensating harmonic current injection to grid
Voltage Waveforms, 200hp PWD Load

Note: These actual waveforms were acquired with a low sampling frequency. Therefore the non-sinusoidal appearance is a measurement artifact.
• Series switch open (zero grid current)
• Load supported by power converters & ultracapacitors
Ultra-Capacitor Control

- Control algorithms fully functional
- Charging and discharging of ultra-capacitors well behaved
- Modular and autonomous operation of capacitor strings demonstrated
- Future work is refinement and cost reduction
Bus Voltages & Ultracapacitor Currents
200 + 150 hp PWD Load Support

dc Bus Voltage and Capacitor Voltage & Current

Grid Connected
Recharge Ultracapacitors
Isolated Load Support

Grid Connected
Northern Power Corporate Status

• Northern Power now a private company owned by new investors as of August 2008
  ▪ Publicly traded Distributed Energy (old owner) filed Ch. 11 on 04 June 2008 and sold the Northern Power asset

• Northern Power focused on wind turbine technology
  ▪ Northwind® 100 wind turbine is present commercial product
  ▪ Developing 2.2 MW wind turbine
  ▪ Power electronics (PE) in support of wind secondary focus
    o MW Wind power converter
    o Other PE systems to further enable wind sales
• Limited testing on demonstration system going forward
• Northern pursuing energy storage solutions for wind-diesel applications
  ▪ Northern is seeking an energy storage partner for commercializing an energy storage product that operates with our Northwind 100 wind turbine
• Evaluating wind-energy storage for utility grids
Future Opportunities for EnergyBridge™ Technology

• Increase wind penetration in isolated wind-diesel grids
  ▪ *Real, identified* customer driven market in Alaska (AVEC)
  ▪ *Potential* market for rural agricultural pumping
  ▪ Present solution not satisfactory
    ◦ Secondary load to handle load sheds / wind gusts
    ◦ Doesn’t handle load increases / wind lulls
    ◦ Limited ability to utilize dump load

• Load Leveling in Grid Connected Wind Farms
  ▪ Same concept as above, only much larger scale
  ▪ Large *potential* market including locations in Palm Springs, Altamont and Tehachapi
Wind-Diesel System Architecture

Northwind® 100 Wind Turbine