Northern

Northern Power EnergyBridge™ UPS Status Update

September 29, 2008
DOE Peer Review – Washington, DC

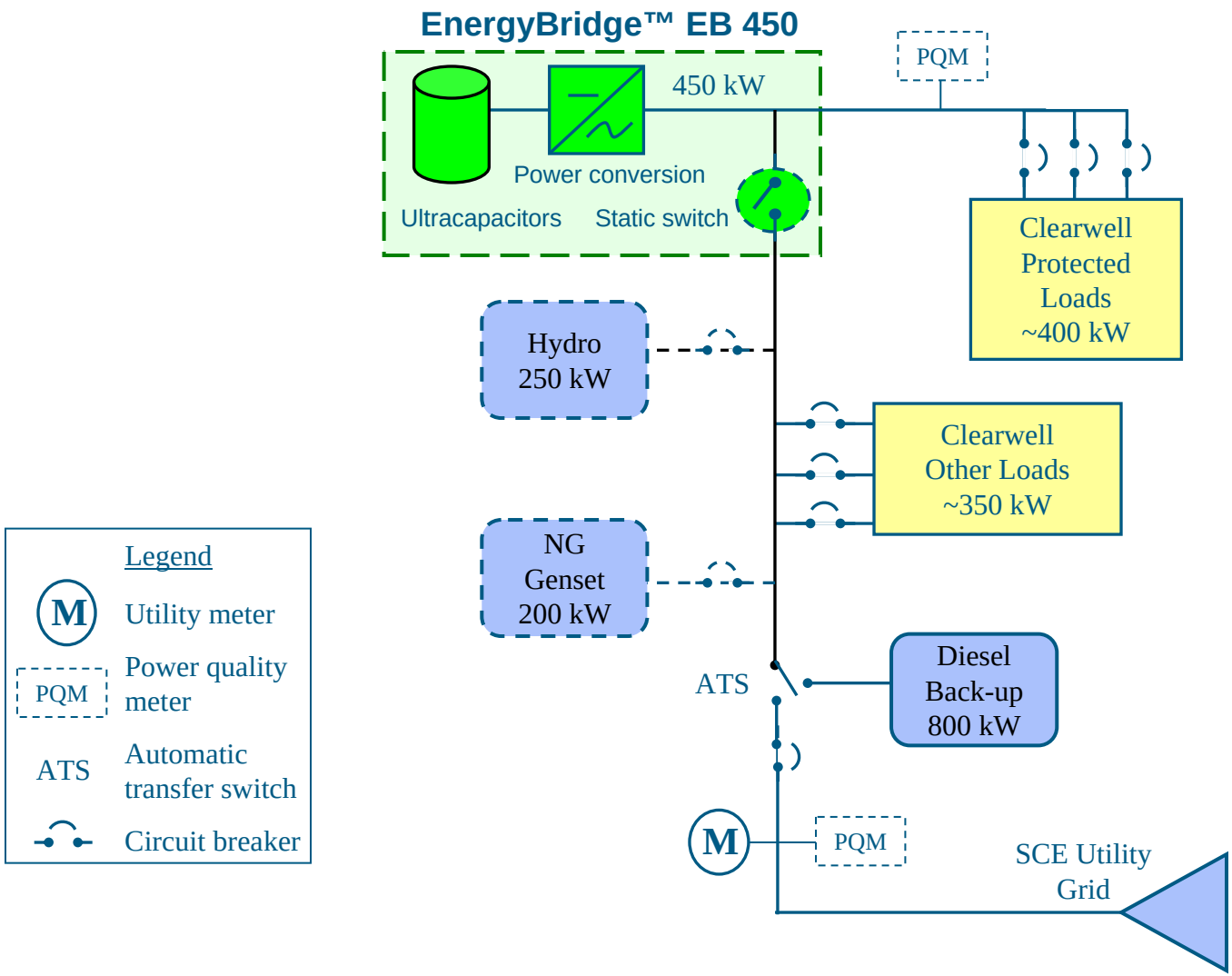
This project is part of the Energy Storage Collaboration between the California Energy Commission (CEC) and the Energy Storage Systems Program of the U.S. Department of Energy (DOE/ESS) and managed by Sandia National Laboratories (SNL). Sandia is a multi-program laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration, under contract DE-AC04-94AL85000

Project Objectives

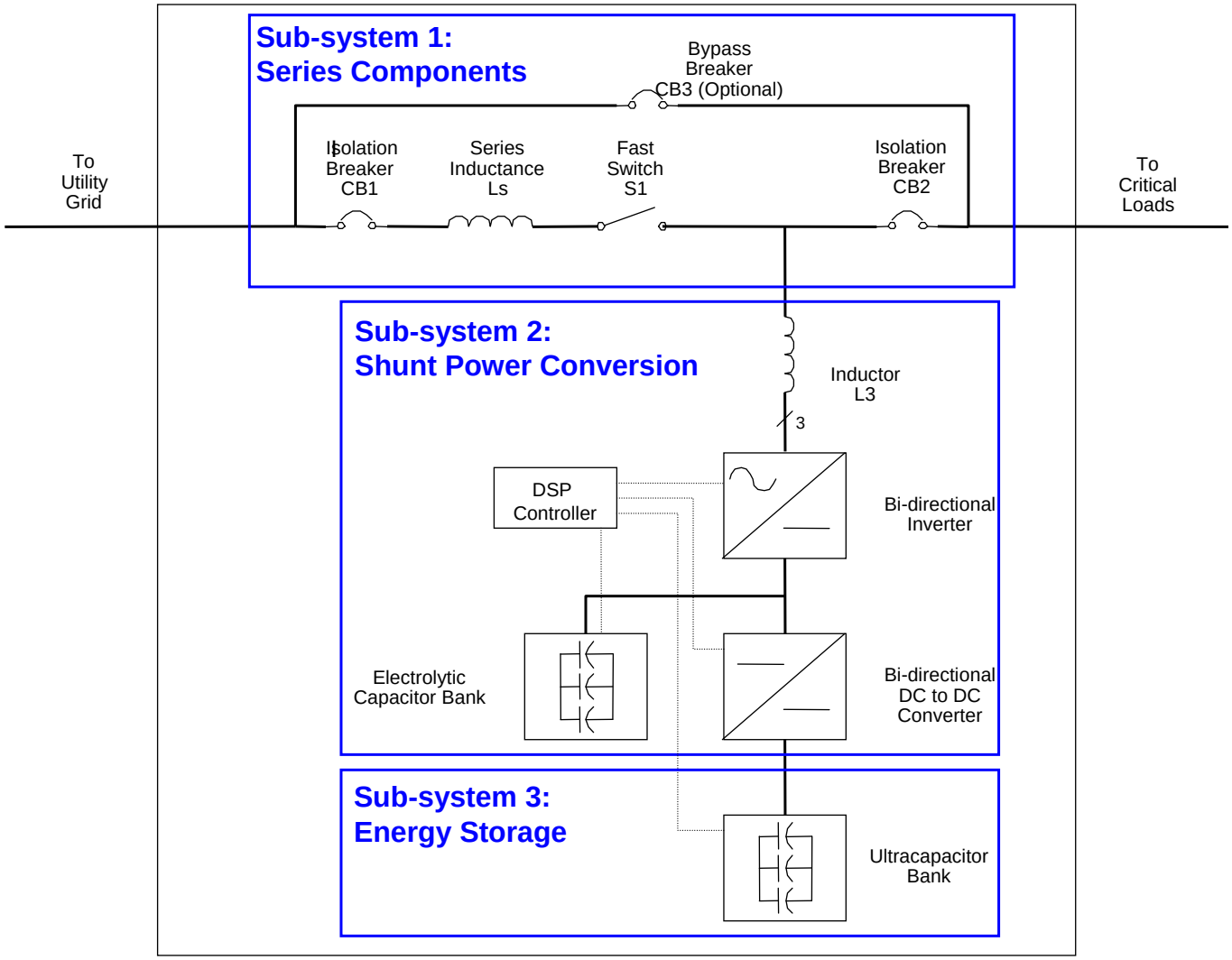
- Maintain high power quality on protected loads at all times
- Provide power to protected load in event of a utility sag or outage
- Meet the ITI (CBEMA) curve during power quality events
- Resynchronize with backup power or grid as necessary

Palmdale Water District

Clearwell Site



One Line Diagram



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
    - New hardware design for power converter
    - 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

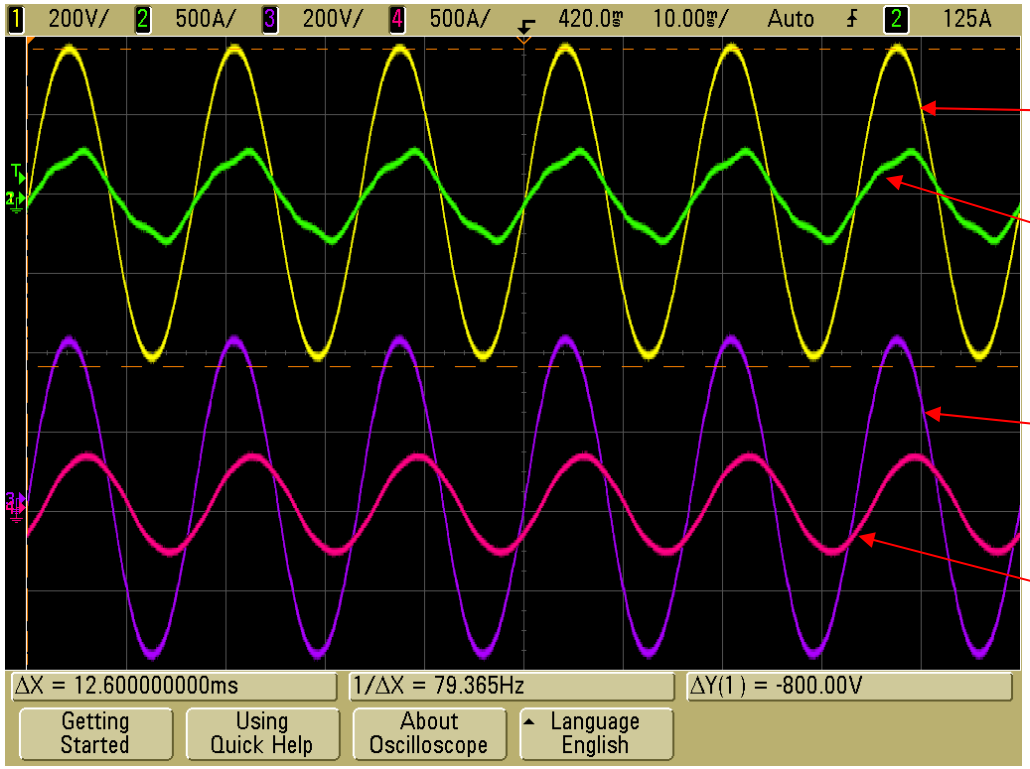
Project Successes

- 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



Grid Voltage

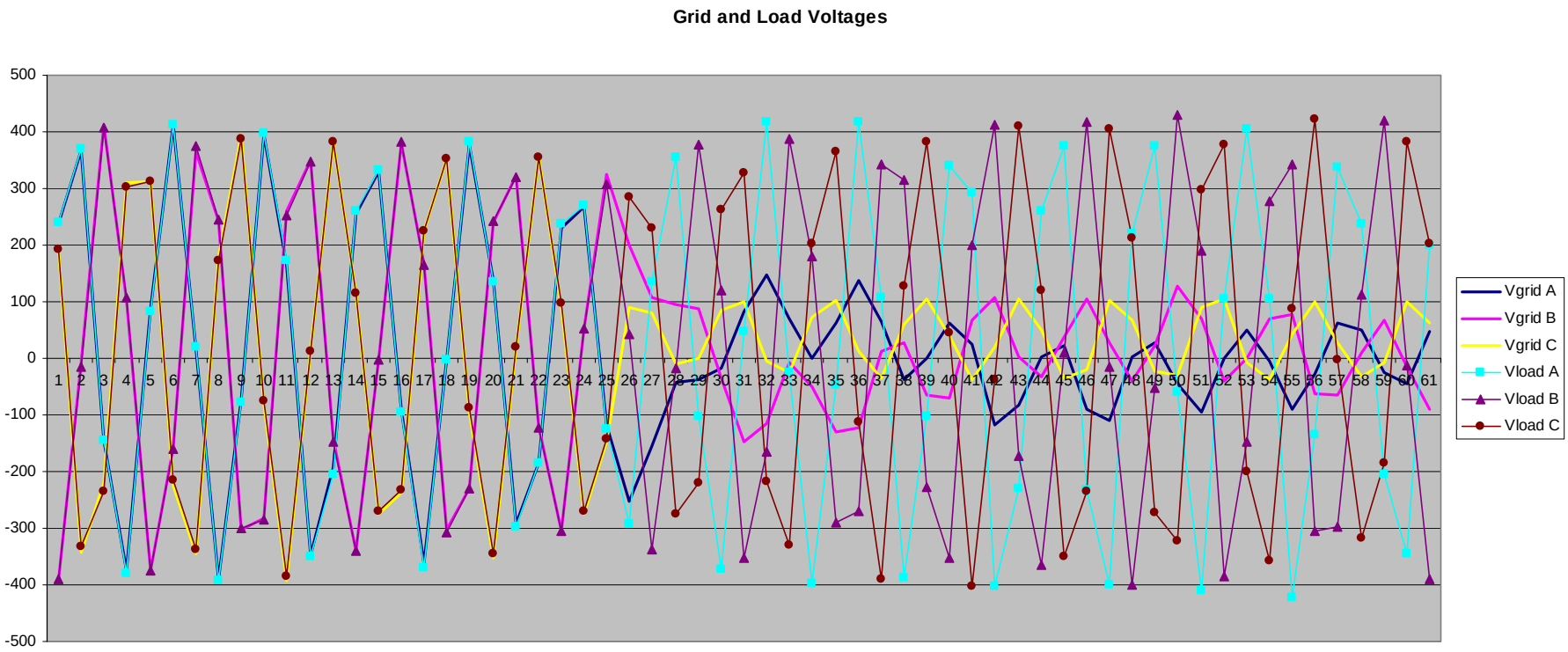
Grid Current

Load Voltage

Load Current

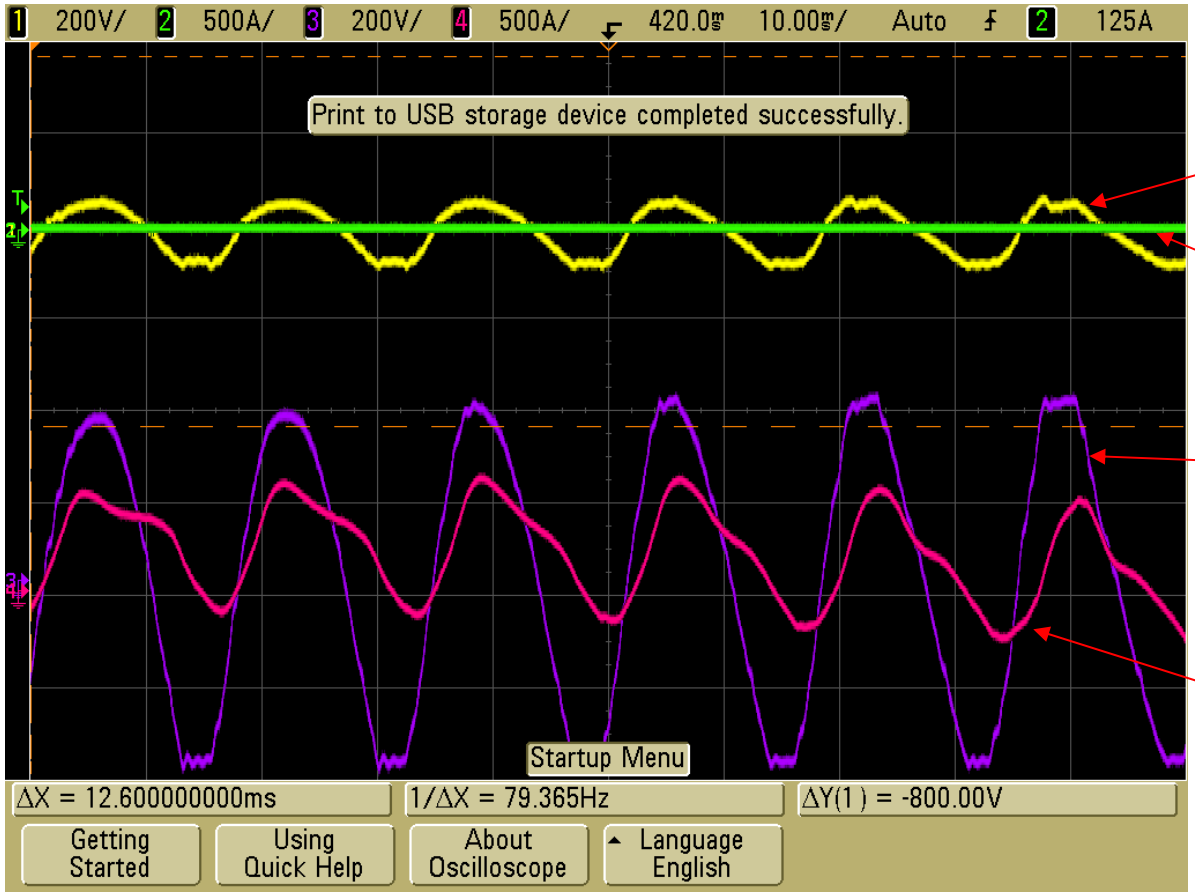
- Input displacement power factor corrected
- Compensating harmonic current injection to grid

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.

200hp PWD Load Support V & I

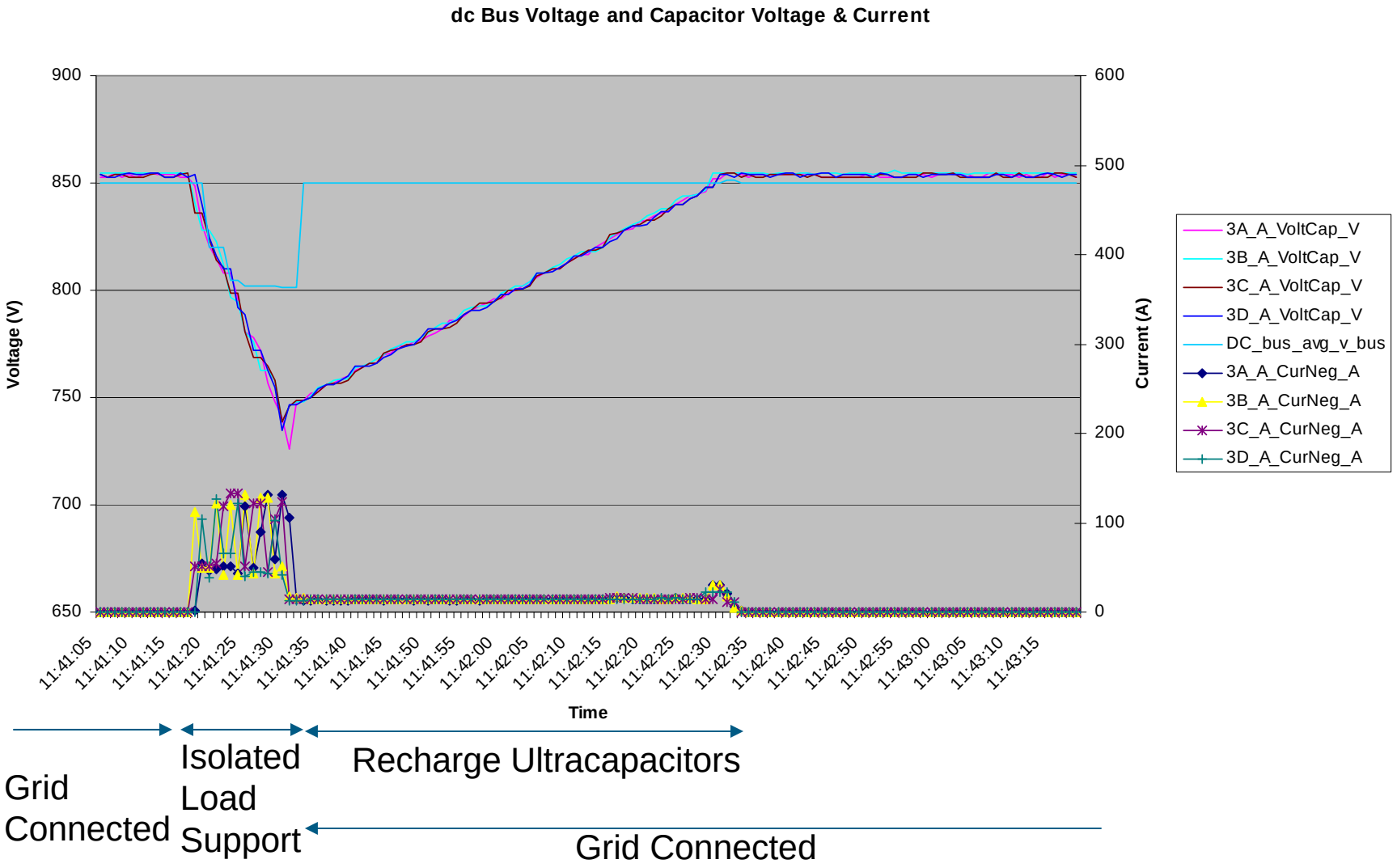


- Series switch open (zero grid current)
- Load supported by power converters & ultracapacitors

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



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
    - MW Wind power converter
    - Other PE systems to further enable wind sales

EnergyBridge™ UPS Project Future Status

- 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