



The Power to Control.



**Richard Jennings**  
Software Engineering Manager  
Xtreme Power, Inc

NIWeek 2011

# Xtreme Power, Inc.

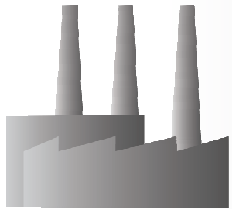
## Company Overview

### Developer and manufacturer of Dynamic Power Resources™

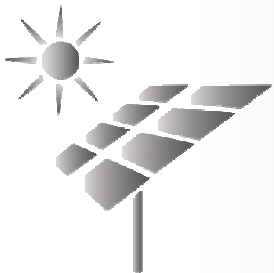
- Founded in 2004 in Austin, Texas
- 20+ years of R&D in our technology
- Projects operating, contracted, and in final negotiations: >70 MVA, > 60 MWh
- US-based manufacturing
  - Oklahoma and Texas
- Over \$50 MM in funding: SAIL VP, Bessemer VP, Dow Chemical, Fluor, Dominion Power, BP, POSCO, Skylake Incuvest
- Utility industry leadership on our Board – Pat Wood, Foster Duncan

# The 21<sup>st</sup> Century Grid

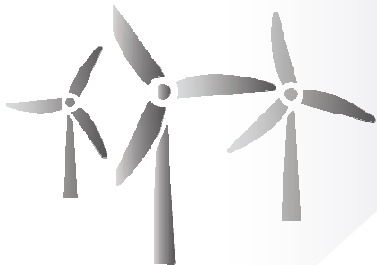
## Energy Production



Traditional Power Generation



Solar Generation



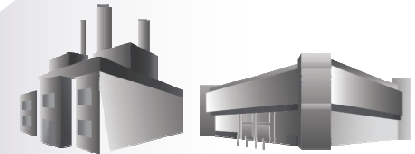
Wind Generation

## Energy Delivery



Ancillary Services

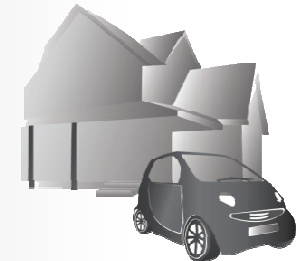
## Energy Consumption



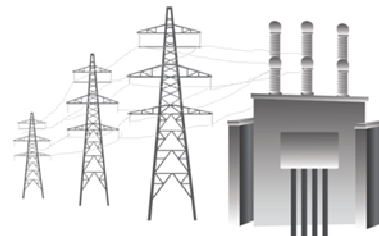
Commercial and Industrial



Load Centers



Residential



Transmission & Distribution

# Target Segments

## Renewable Integration



Ramp Control

Curtailment  
Mitigation

Firming/Shaping

Interconnection  
Compliance

Grid Services

## Transmission & Distribution Providers



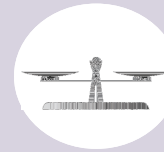
T&D Deferral

Voltage Support

Power Quality

Grid Reliability  
Enhancement

## Ancillary Service Providers



Frequency  
Regulation

Voltage  
Regulation

Responsive  
Reserves

## Commercial & Industrial



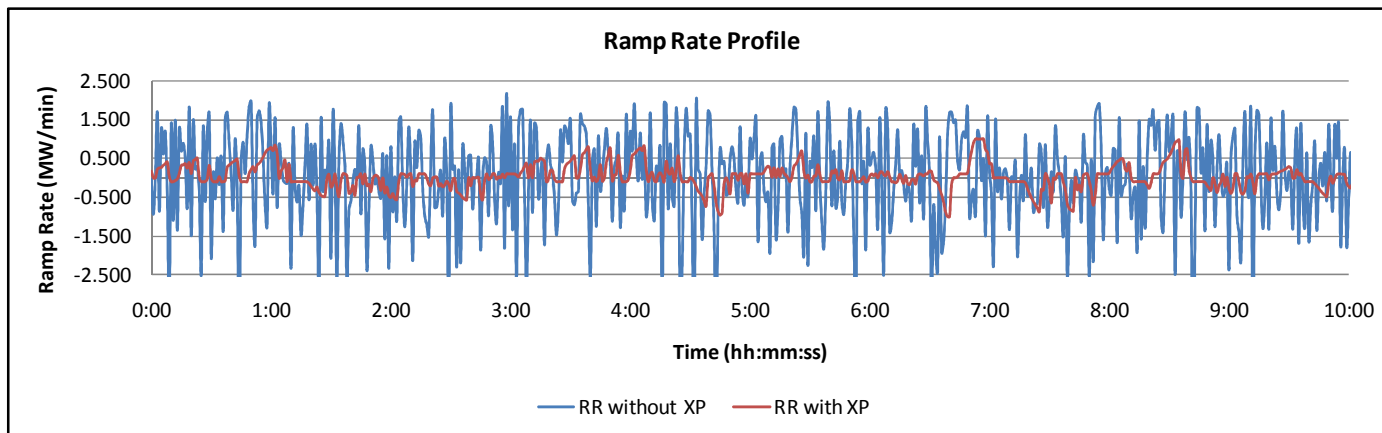
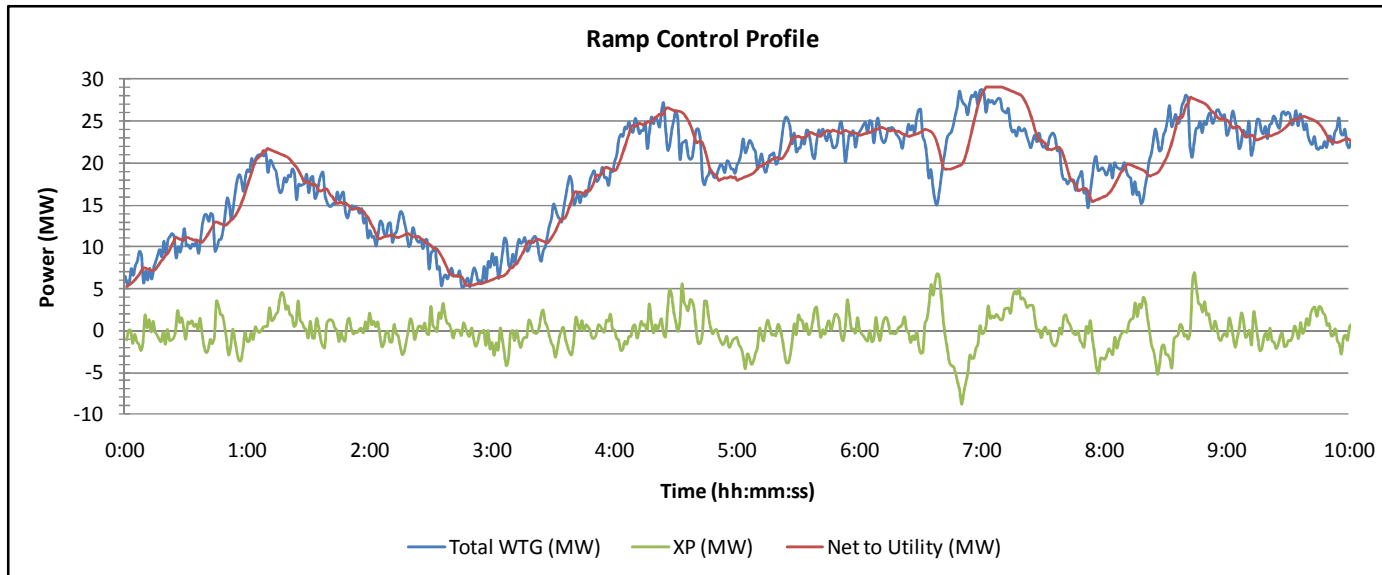
Peak Shaving

Load Leveling

Power Quality



# Proof of Performance

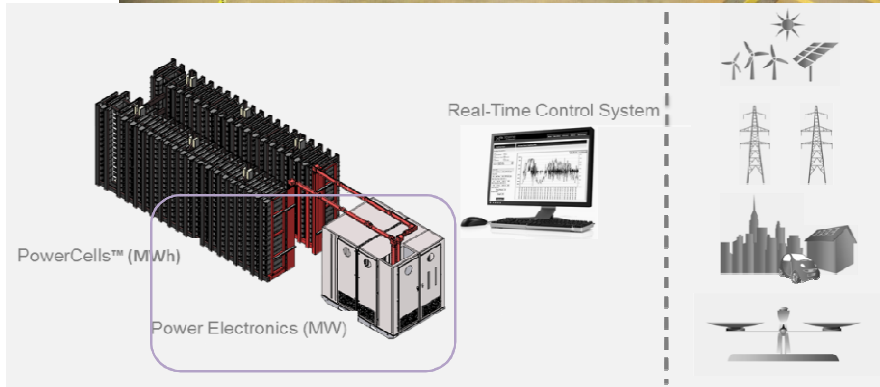


# Xtreme Power Technology

## Power Electronics

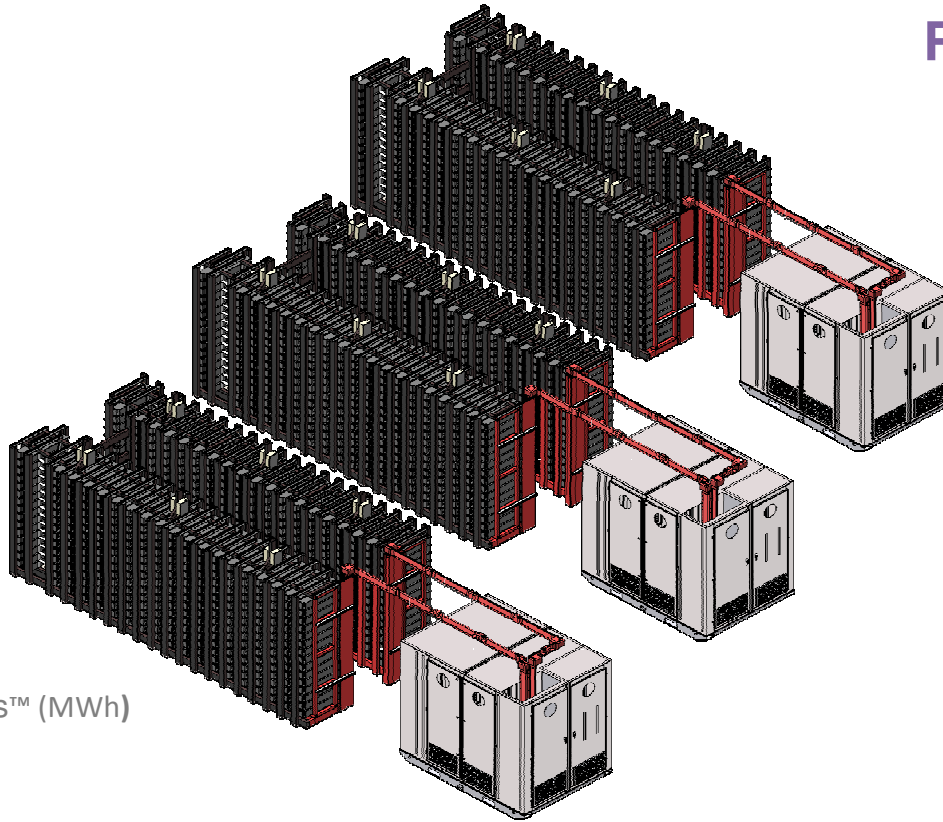


- Bi-directional inverter/charger technology
- Full four quadrant performance, managing real & reactive power requirements
- Solid State
  - Microsecond response
  - Nominal O&M
- Closed-Loop Water Cooled
- Switch from + 1.5 MW to – 1.5 MW in <80 ms



# Xtreme Power Technology

## Real-Time Control System



PowerCells™ (MWh)

Power Electronics (MW)



Real-Time Control System

- Dynamic Power Resource contains 1 or more Dynamic Power Modules
  - DPM is Inverter / PowerCell combo with sbRIO integrated controller.
- One RT Controller can control multiple DPM



# Xtreme Power Technology

## Real-Time Control System

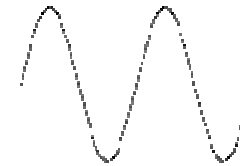


Web Server  
mySQL database  
LabVIEW User Interface

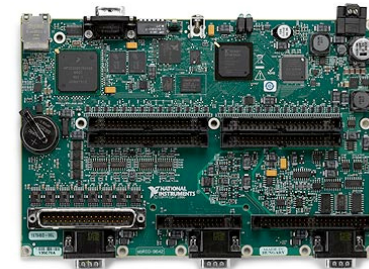
NI PXI-1042 Chassis  
NI PXI-8110 RT Controller  
NI PXI-7854R FPGA  
NI 9151 Expansion Chassis  
NI 9225 PT Input  
NI 9239 CT Input



Continuous power quality  
measurements at 100 Hz.



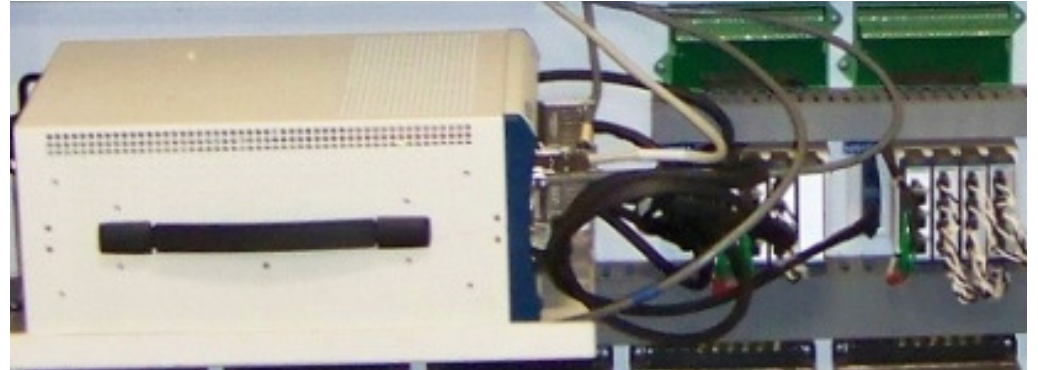
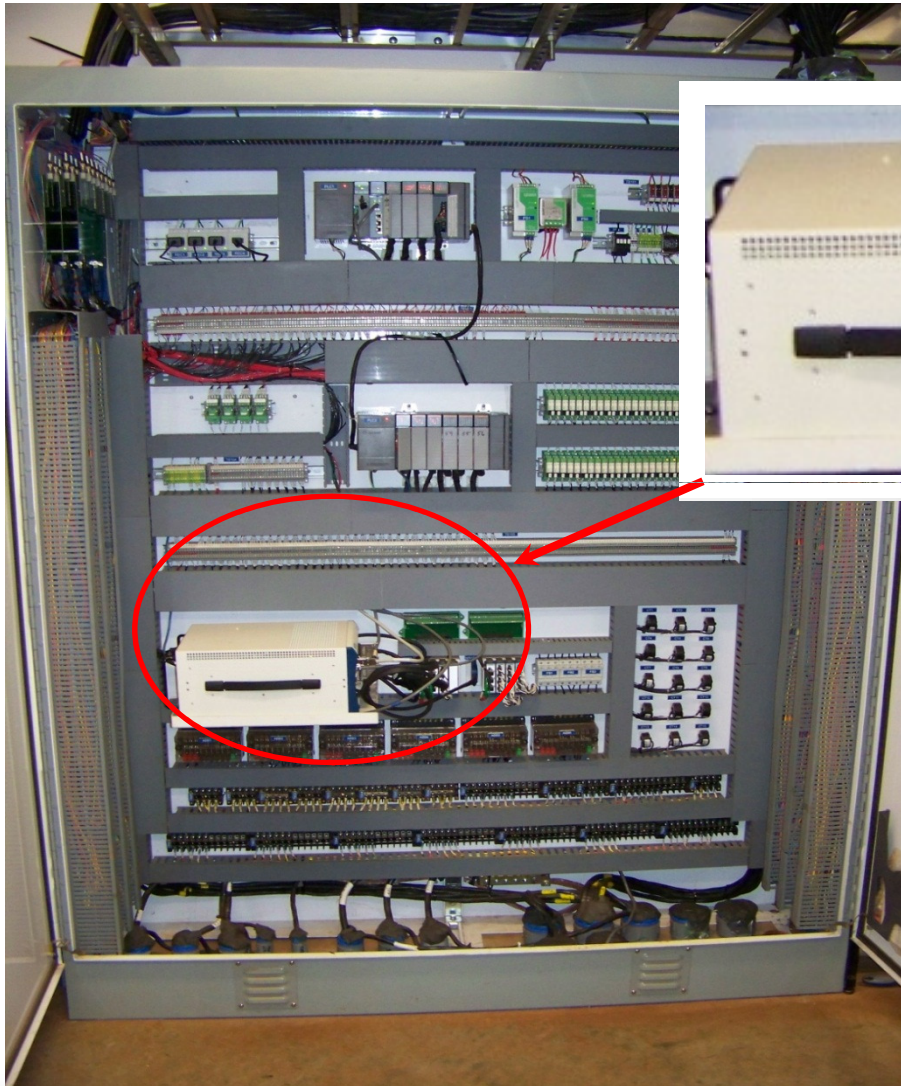
NI-9642 sbRIO  
Inverter Control  
PowerCell Management





# Xtreme Power Technology

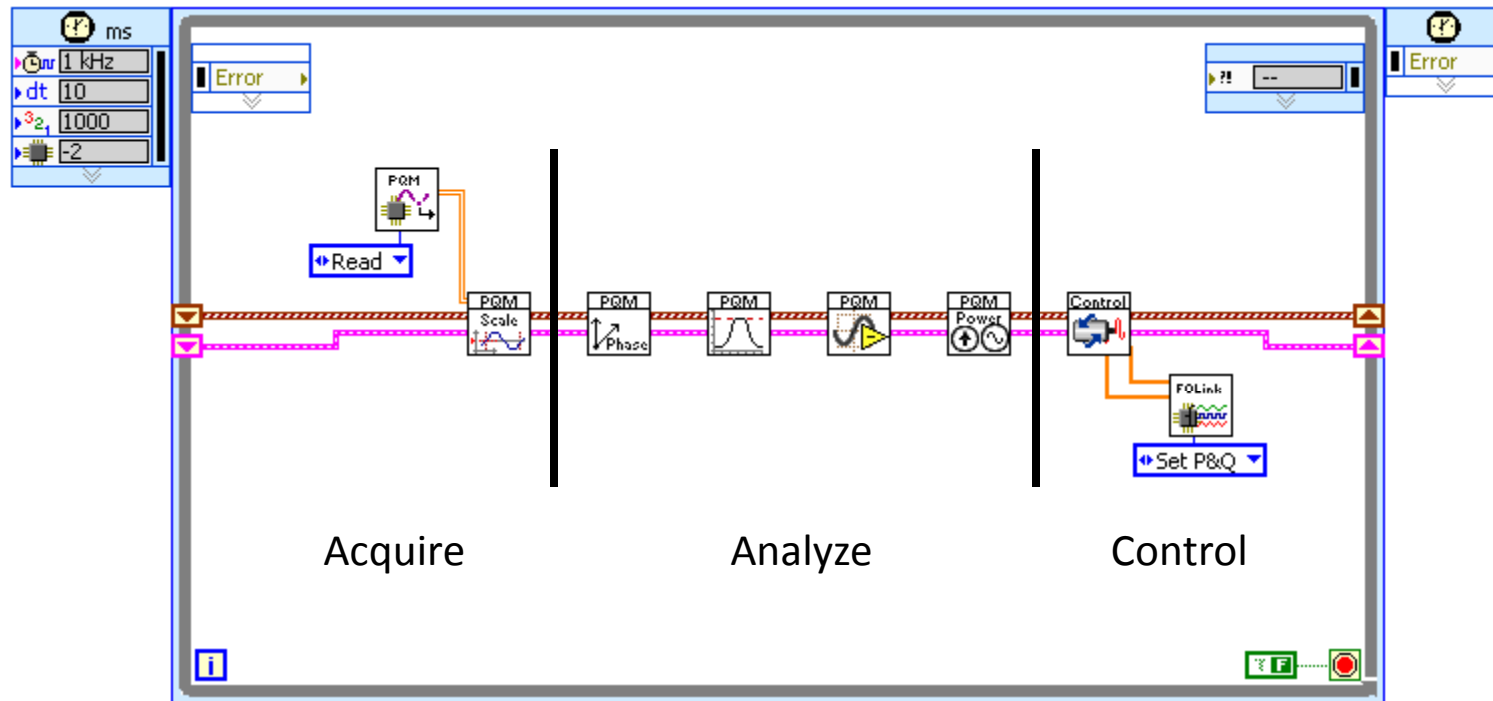
## Real-Time Control System



Control cabinet with RT PXI controller.

System acquires PT and CT voltages from NI-9225 and 9239 analog input modules.

Main RT processing loop runs at 100 Hz.

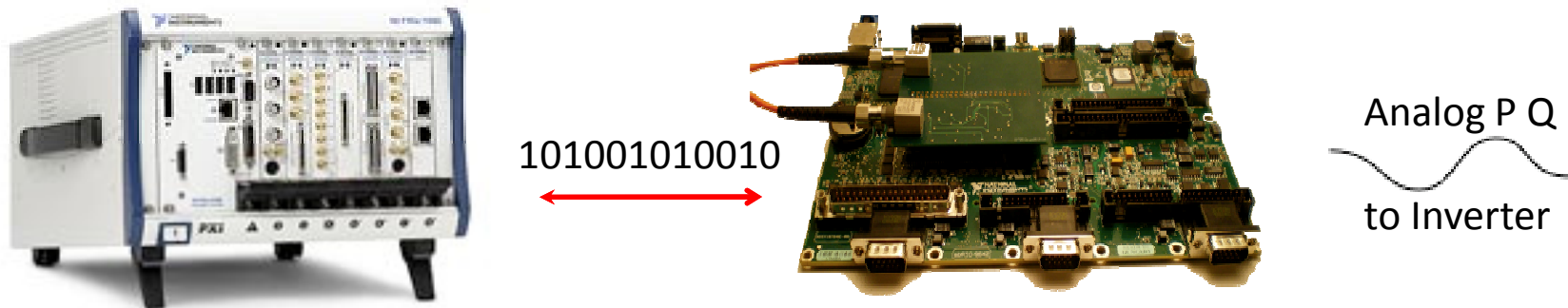


## Sub-Cycle Control

# Xtreme Power Technology

## Real-Time Control System

UDP command packets and data sent over non-real-time Ethernet.



High speed fiber-optic link updates P and Q setpoints for each DPR in parallel.

Bidirectional FPGA <-> FPGA communication provides deterministic real-time control.

sbRIO FPGA converts digital commands into analog outputs.

sbRIO FPGA closes the control loop by sending operating parameters back to PXI.

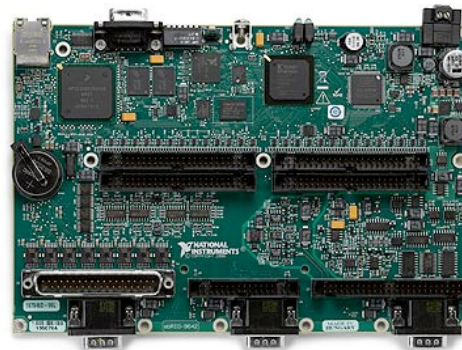
# NI sbRIO Real-time Controller

## Master controller for DPM

- Receives commands from the PXI Master.
- Manages inverter/charger
- Manages the PowerCells (SOC, VMax, VMin, Temp.)
- Monitors over 200 data points.

## NI9642 sbRIO

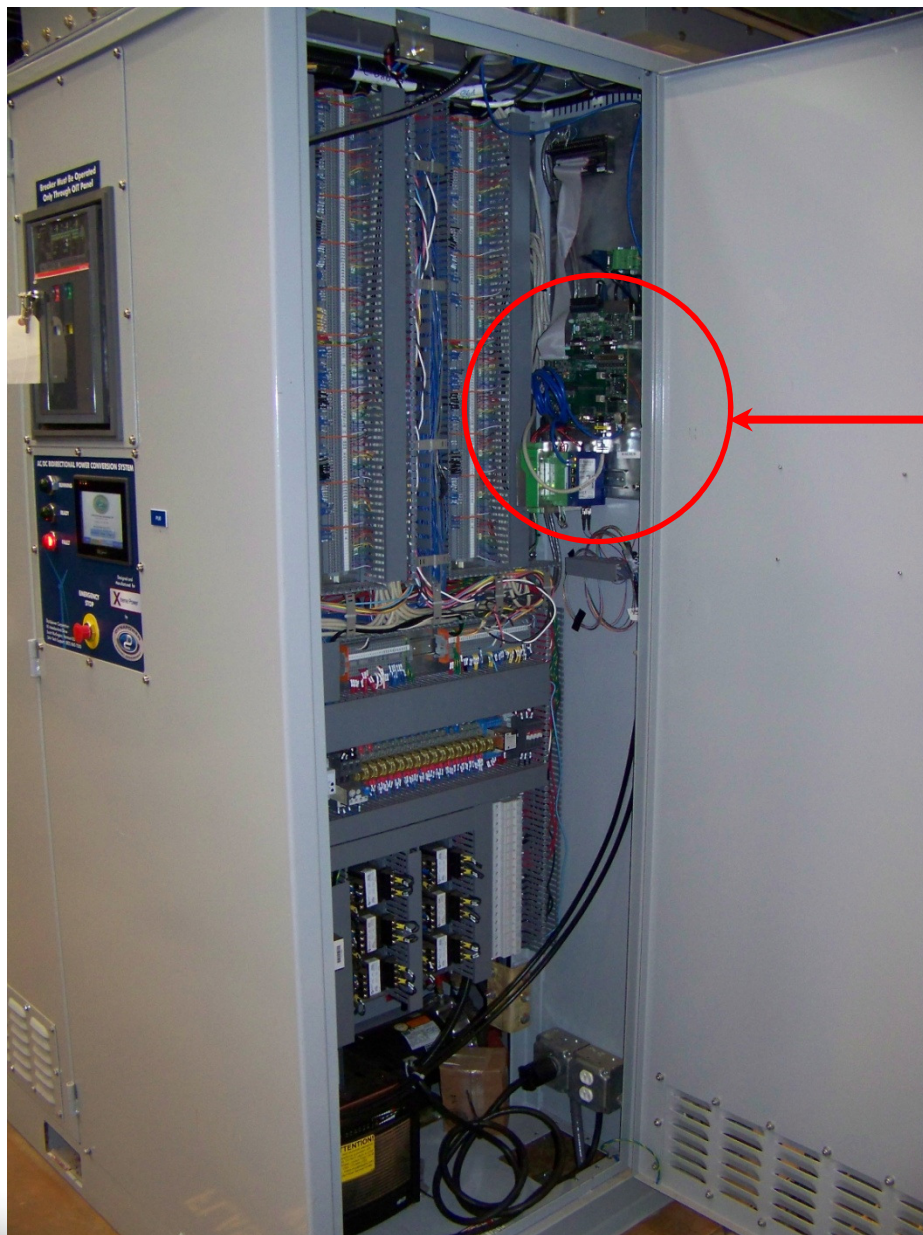
- 400 MHz PPC, 128 MB RAM
- 2 M Gate Xilinx FPGA
- 110 5V digital lines
- 32 24V Digital lines
- 16 +/- 10V Analog inputs
- 4 +/- 10V Analog outputs





# NI sbRIO Communication

- Two communication paths
  - XP Fiber-Optic link for real-time control.
  - TCP/IP for slow/bulk data and commands.
    - TCP/IP network is shared by all systems.
    - Communication latency is affected by:
      - Network traffic
      - Processing on PXI controller
      - Processing on sbRIO (inverter coms 950 ms, 99k 150 ms,..)



NI 9642 sbRIO

#### LabVIEW RT

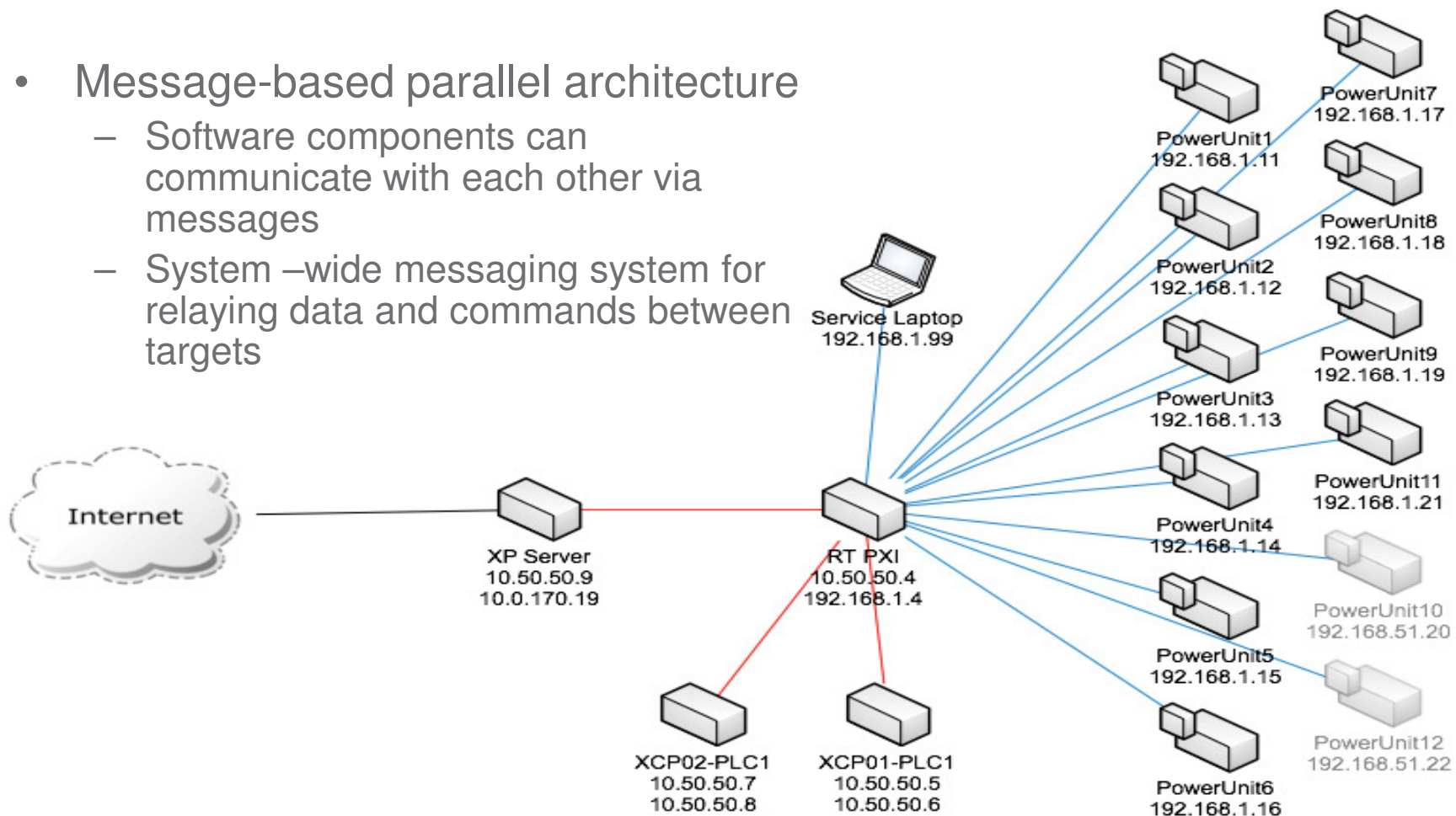
- Manages PowerCells
- UDP communication to RT PXI.

LabVIEW FPGA handles real-time control via fiber-optic interface.

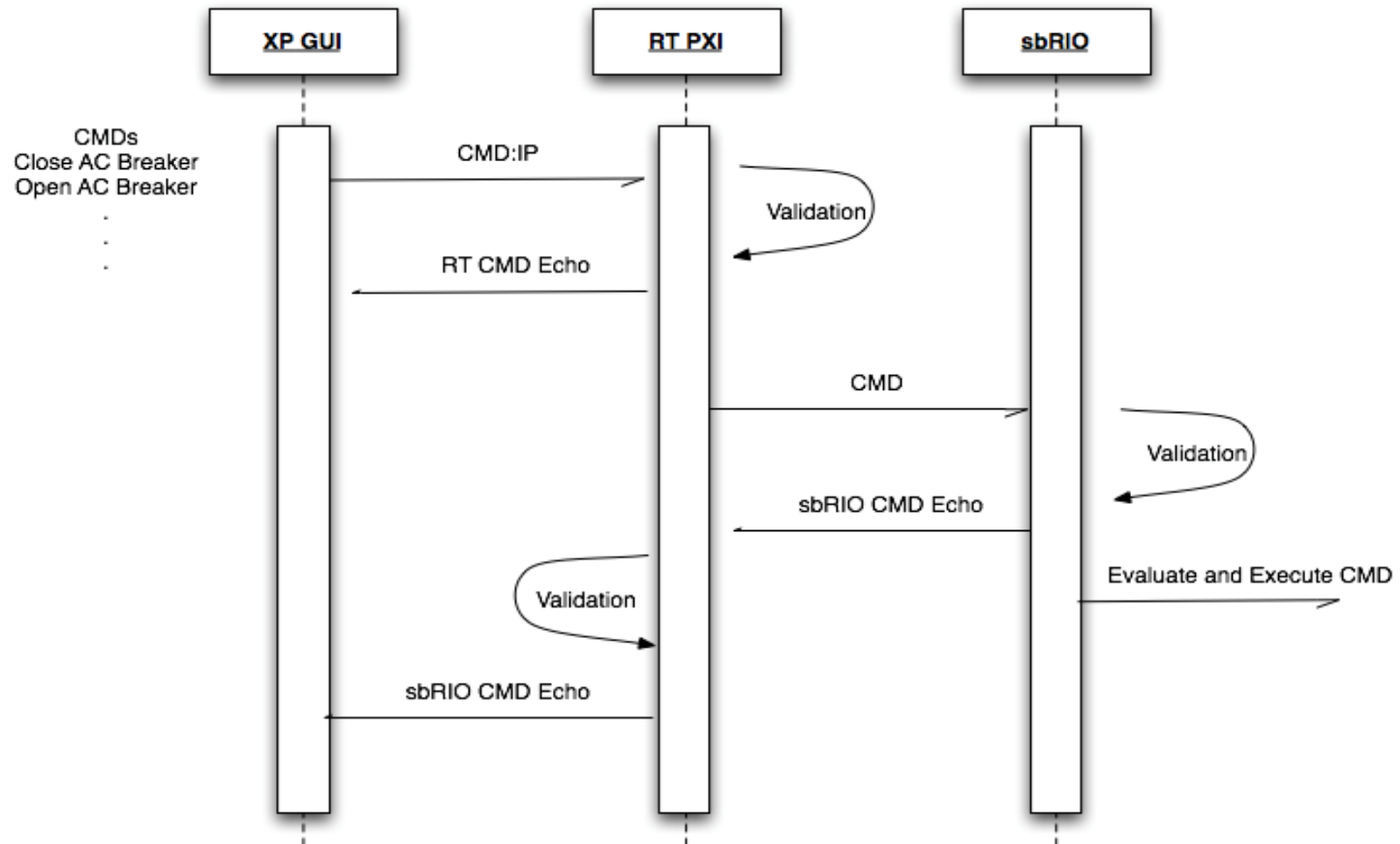
- Measures and transmits analog signals DC V and DC I to RT PXI FPGA
- Receives P and Q control signals from RT PXI FPGA

# Software Design Pattern - Communication

- Message-based parallel architecture
  - Software components can communicate with each other via messages
  - System –wide messaging system for relaying data and commands between targets



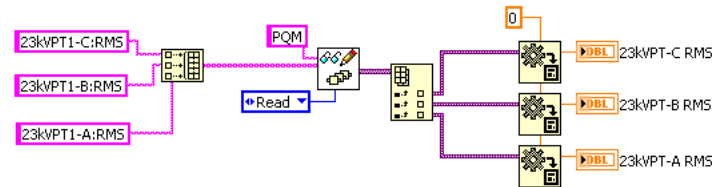
# CMD Sequence



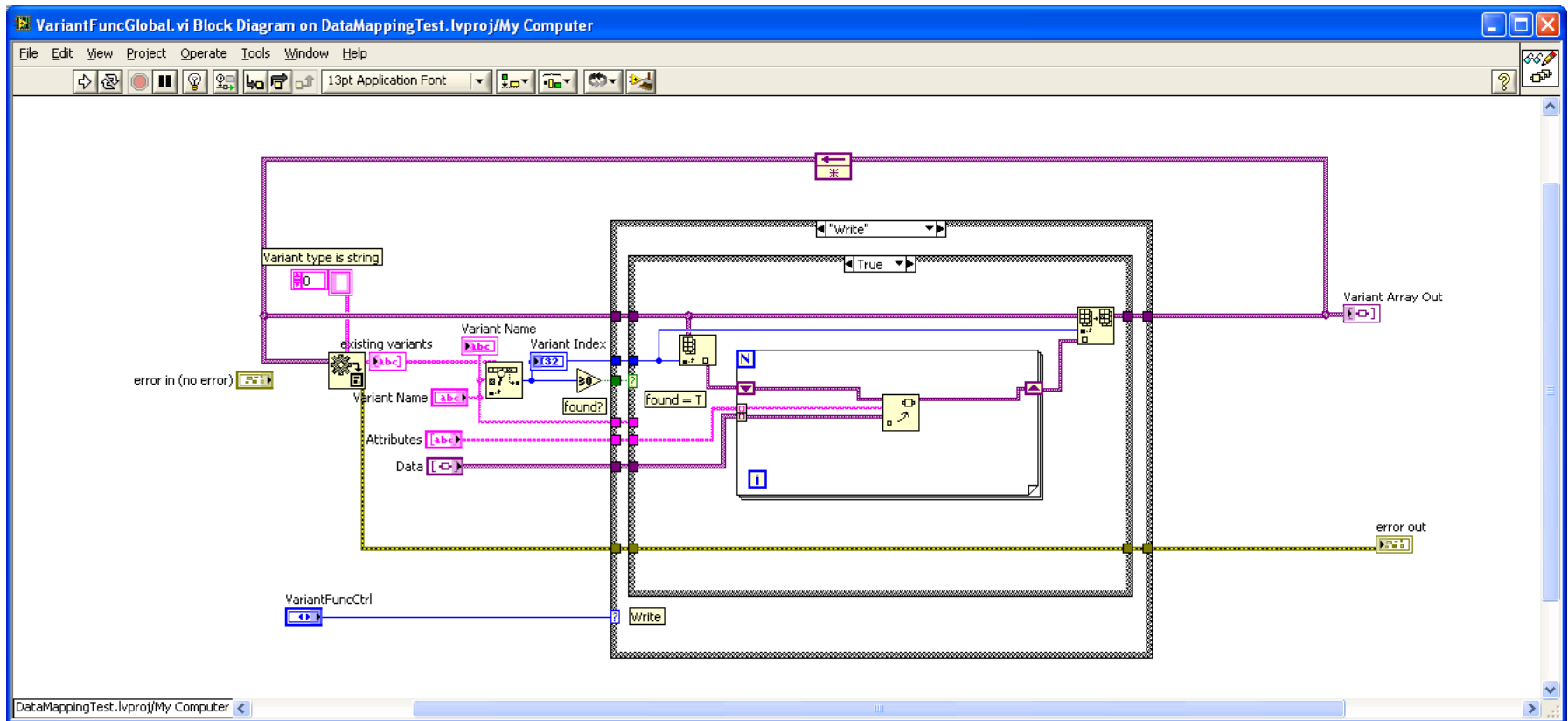
# Software Design Patterns

## - Data Sharing

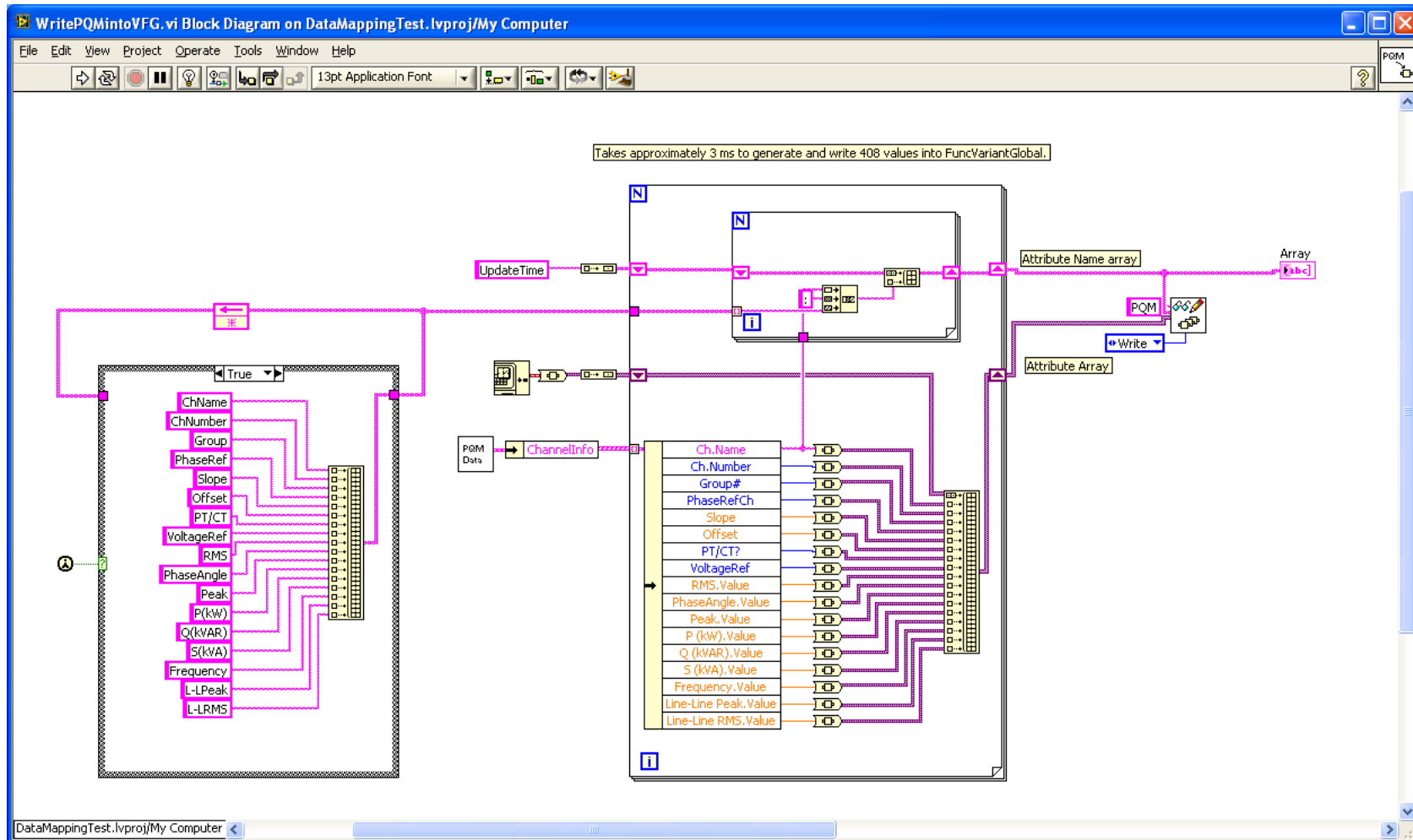
- Observer-like data sharing
  - Data producers publish data
  - Asynchronous consumers access data by name



# Variant Functional Global

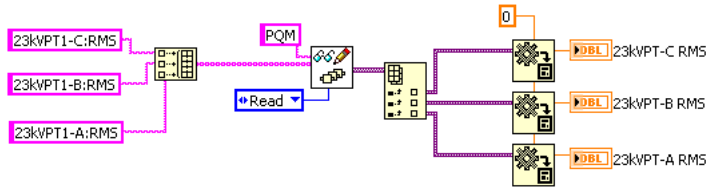


# Write Data Into VFG

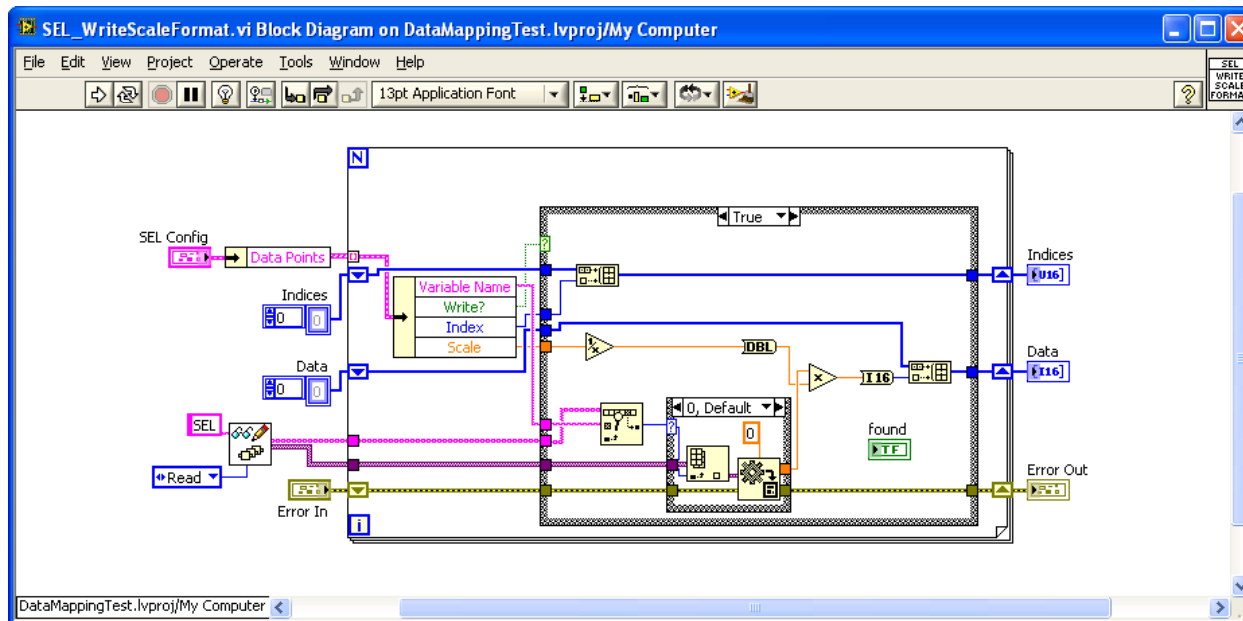




# Read Data From VFG



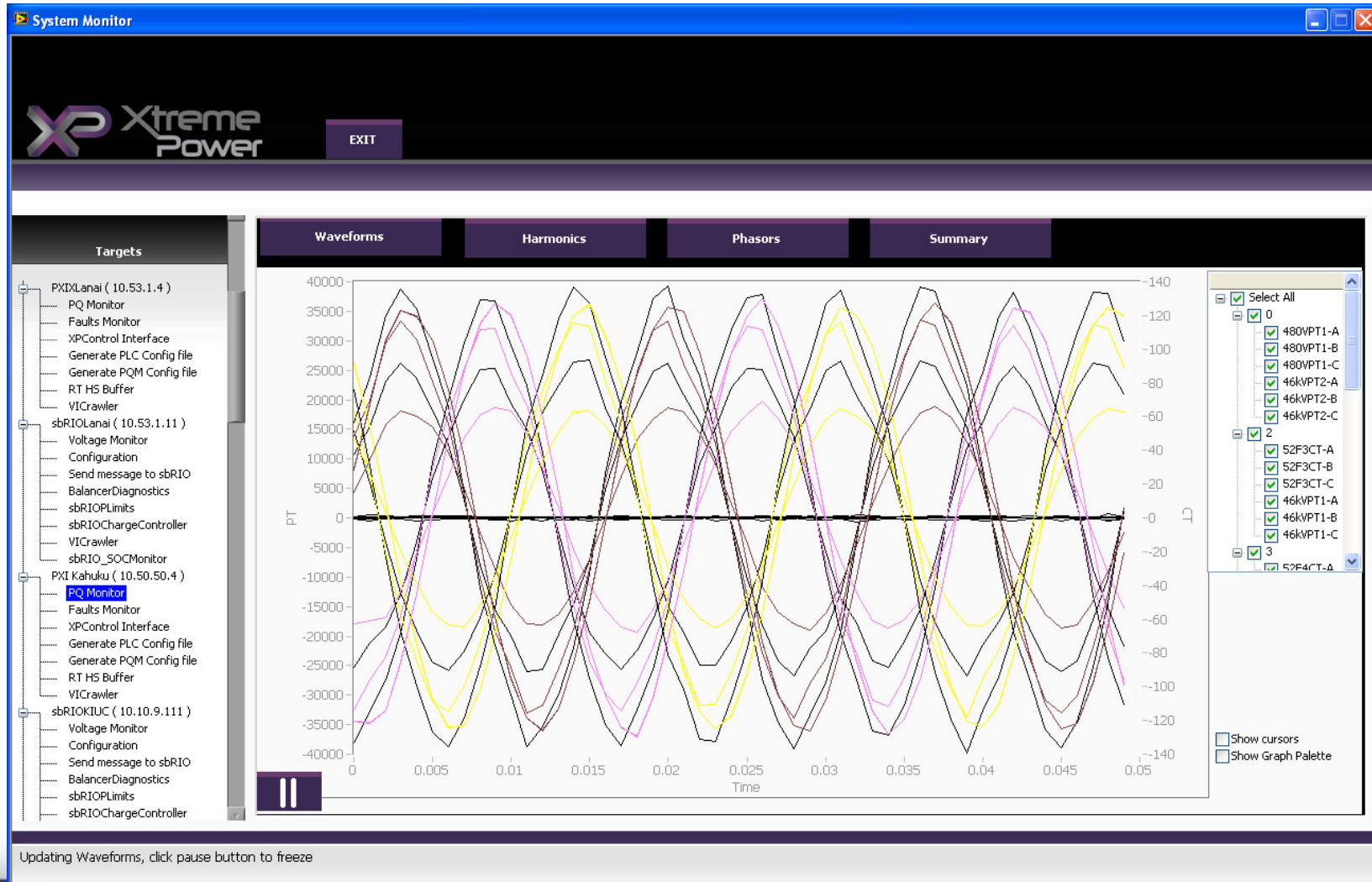
Data accessed by name



Data accessed by source



# VI Server for Operator Diagnostics



# VI Server for Debugging

EXIT

**Targets**

- Configuration
- Send message to sbRIO
- BalancerDiagnostics
- sbRIOPLimits
- sbRIOChargeController
- VICrawler
- sbRIO\_SOCMonitor
- sbRIOPU06 ( 10.50.51.16 )
  - Voltage Monitor
  - Configuration
  - Send message to sbRIO
  - BalancerDiagnostics
  - sbRIOPLimits
  - sbRIOChargeController
  - VICrawler**
  - sbRIO\_SOCMonitor
- sbRIOPU07 ( 10.50.51.17 )
  - Voltage Monitor
  - Configuration
  - Send message to sbRIO
  - BalancerDiagnostics
  - sbRIOPLimits
  - sbRIOChargeController
  - VICrawler
  - sbRIO\_SOCMonitor
- sbRIOPU08 ( 10.50.51.18 )
  - Voltage Monitor
  - Configuration
  - Send message to sbRIO
  - BalancerDiagnostics
  - sbRIOPLimits
  - sbRIOChargeController

**All VIs in Memory**

sbRIO Global.vi

Attribute name	Attribute type	Attribute value
Control Name	Data type	
BattV(sgl)	Array, Single Float	
Temp(sgl)	Array, Single Float	
DCV	Double Float	
DCI	Double Float	
Batt in Range?	Boolean	
Error Rate	Array, Single Float	
PXI TCP/IP Link OK?	Boolean	
FO Link OK?	Boolean	TRUE
Inverter IP	String	empty string
sbRIO Config	Cluster, Array, Cluster	<Cluster> <Name> cluster </Name> <NumElts>2 </NumElts> <I32> <Name>Size </Name> <Val>51 </Val> <I32> <String> <Name>e
System Running?	Boolean	FALSE
Batt Max	Double Float	12.331000
Batt Min	Double Float	12.047000
SOC %	Double Float	38.457229
Batt OCV SOC %	Double Float	39.392177
Batt Median	Double Float	12.194000
InvComm OK?	Boolean	TRUE
Temp Max	Double Float	752.000000
Cycle Counts	Array, Double Float	<Cluster> <Name> array </Name> <NumElts>3 </NumElts> <Array> <Name>Size(s) </Name> <Dimsize>1 </Dimsize> <U32> <Name>
KW Actual	Double Float	0.000000
kVAR Actual	Double Float	0.000000
WatchDogTO(60)	U16	60
Error?	Array, Boolean	<Cluster> <Name> array </Name> <NumElts>3 </NumElts> <Array> <Name>Size(s) </Name> <Dimsize>1 </Dimsize> <U32> <Name>
AHrs	Double Float	-15.908980
Batt Average	Double Float	12.196038
DKF SOC	Double Float	0.000000
SOC Parameters	Cluster, Double Float, I	<Cluster> <Name> cluster </Name> <NumElts>2 </NumElts> <I32> <Name>Size </Name> <Val>12 </Val> <I32> <String> <Name>e
RemoteEnable?	Boolean	FALSE

**SubVIs**

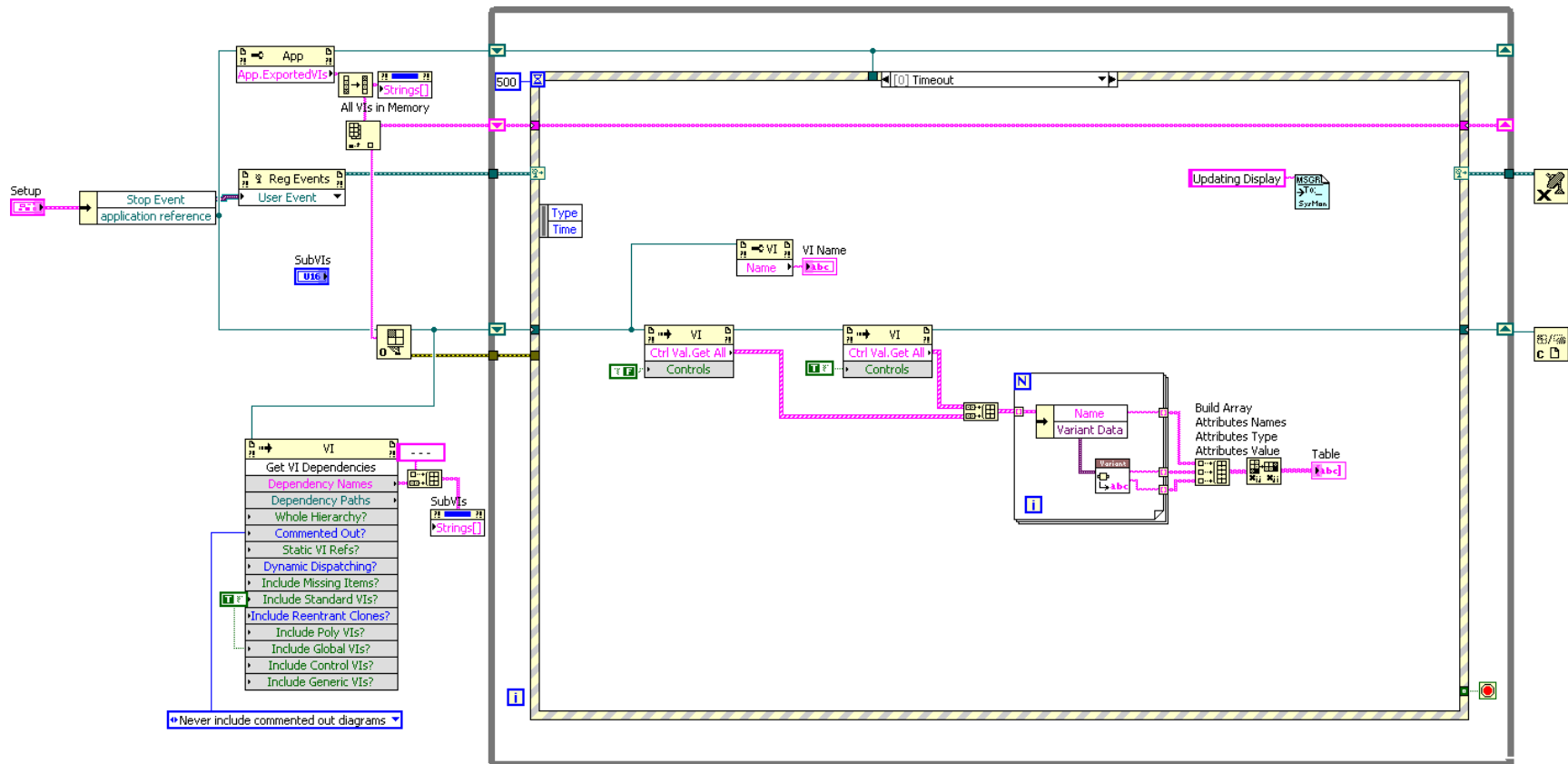
- 99KDataArrayTypeDef.cti
- 99KDataTypeDef.cti
- BatterOverUnderThresholds.cti
- Inverter Run Mode.cti
- OperatingParametersScaling.cti
- PackOverUnderThresholds.cti
- sbRIOConfigTypeDef.cti
- sbRIOSetupTypeDef.cti
- SOCConfigTypeDef.cti

**VI Name**

sbRIO Global.vi

Updating Display

# VI Server Reads Front Panel Controls and Indicators



# Lessons Learned

- TCP/IP is a lousy real-time control link.
- It is very easy to run out of TCP/IP sockets on LabVIEW RT. RT platforms (PharLap and VxWorks) only have 64 TCP/IP sockets available. The OS holds a socket open for 1 min after the application releases.
- Datasocket server can be killed with a void variant. RT can be killed by writing a variant with a void attribute into datasocket.
- You must own your communication bus for reliable RT communications.

# Typical DPR™ Economics

**DPR™ 15-100C**

## Equipment

- 1.5 MVA inverter/charger (480 VAC, 3 phase)
- 1.0 MWh PowerCells
- Control System Hardware
- 11' x 11' x 40 container
- Internal Ambient Controls as Needed

## Services/Labor

- System Integration
- Controls Programming
- Factory Acceptance Testing
- Field Installation and Commissioning

**TOTAL** **\$1,600,000**



# Real Projects, Real Solutions

Project	Application	DPR™	COD	Services
<b>South Pole Telescope</b>	Microgrid	0.5 MW / 0.1 MWh	Q4 2006	Peak-Shaving, Load-leveling
<b>Maui</b>	Wind	1.5 MW / 1.0 MWh	Q3 2009	Ramp Control
<b>Kahuku</b>	Wind	15 MW / 10 MWh	Q1 2011	Ramp Control, Voltage Regulation
<b>Xcel</b>	Solar	1.5 MW / 1.0 MWh	Q1 2011	Ramp Control, Ancillary Services, Firming/Shaping
<b>Lanai</b>	Solar	1.125 MW / 0.5 MWh	Q2 2011	Ramp Control, Ancillary Services
<b>Ford</b>	End-User	0.75 MW / 2.0 MWh	Q2 2011	Peak-Shaving, Load-leveling
<b>KIUC</b>	Solar	1.5 MW / 1.0 MWh	Q3 2011	Responsive Reserves, Ramp Control, Ancillary Services
<b>KWP II</b>	Wind	10 MW / 20 MWh	Q4 2011	Ramp Control, Curtailment Capture, Responsive Reserves
<b>Fosters*</b>	End-User	3.0 MW/ 2.0 MWh	Q4 2011	Uninterruptible Power Supply
<b>Tumbleweed*</b>	Wind	36 MW / 24 MWh	Q4 2012	Ramp Control, Ancillary Services
<b>Tres Amigas</b>	T&D	~ 100 MW / 200 MWh	Q2 2013	Ancillary Services

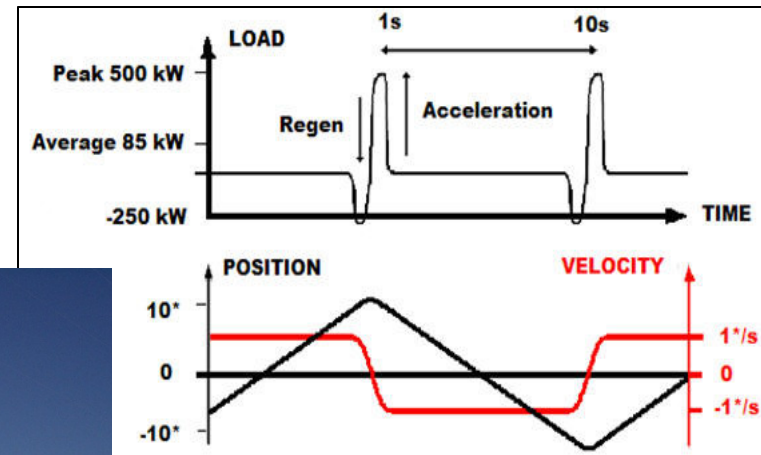
\* Project not yet announced



# South Pole Telescope

## 5 Years Experience

Location	South Pole, Antarctica
Application	Microgrid
DPR™	0.5 MW / 0.1 MWh
COD	Q4 2006
Services	Peak-shaving, Load-leveling



In collaboration with several centers of higher education, the University of Chicago chose the Xtreme Power DPR™ to power the 200-ton South Pole Telescope's scan cycles without infringing on the station's life support system. The Telescope requires up to 259,200 cycles/month.

# Kaheawa Wind Power

## First Commercial Installation with Renewables

Location	Maui, Hi
Application	Wind
DPR™	1.5 MW / 1.0 MWh
COD	Q3 2009
Services	Ramp Control



The first utility-scale Xtreme Power DPR™ operates on a 30 MW wind farm on a 80-200 MW grid. This DPR™ smoothes output to  $\pm 100$  kW/min and controls ramps to  $\pm 1$  MW/min.



# Kahuku Wind Power

## Largest North American Installation with Wind

Location	Oahu, HI
Application	Wind
DPR™	15 MW / 10 MWh
COD	Q1 2011
Services	Ramp Control, Voltage Regulation



This DPR™ will operate on a 30 MW wind farm on the island of Oahu to meet PPA ramp control and smoothing requirements.

# Kaheawa Wind Power II

## Increasing Revenues, Reducing Reserves

Location	Maui, HI
Application	Wind
DPR™	10 MW / 20 MWh
COD	Q4 2011
Services	Ramp Control, Curtailement Capture, Ancillary Services, Responsive Reserves



This DPR™ will operate on a 21 MW wind farm on the island of Maui, and it will provide the Maui Electric Company (MECO) with responsive reserves, as well as support services such as frequency and voltage regulation.

# Xcel and SolarTAC

## Mainland Installation for Testing with Solar

Location	Aurora, CO
Application	Solar
DPR™	1.0 MW / 1.0 MWh
COD	Q1 2011
Services	Ramp Control, Ancillary Services, Firming/Shaping



**SolarTAC**   
Technology Acceleration Center

This system will collect operational data on the integration of energy storage and solar energy systems at the Solar Technology Acceleration Center.

# Lanai Sustainability Research

## Doubling Renewable Output

Location	Lanai, HI
Application	Solar
DPR™	1.125 MW / 0.5 MWh
COD	Q2 2011
Services	Ramp Control, Ancillary Services



Lanai Sustainability Research's 1.2 MW solar farm is currently curtailed to 600 kW, until it can guarantee output that will not vary by more than  $\pm 360$  kW/min. DPR™ will smooth power and increase its output to full capacity, as well as provide ancillary services.



# Ford Michigan Assembly Plant

## Reducing Costs, Increasing Reliability

Location	Wayne, MI
Application	End-User
DPR™	0.75 MW / 2.0 MWh
COD	Q2 2011
Services	Peak Shaving, Load-leveling



Ford selected the Xtreme Power DPR™ to operate with one of the largest solar power generation systems in Michigan. The DPR™ will help the plant save an estimated \$160,000 in energy costs annually by shaving peak demands and leveling load.

# Kaua'i Island Utility Cooperative

## Taking Advantage of DPR™ Versatility

Location	Kaua'i, HI
Application	Solar
DPR™	1.5 MW / 1.0 MWh
COD	Q3 2011
Services	Responsive Reserves, Ramp Control, Ancillary Services



The KIUC DPR™ will mitigate the variability of a 3 MW solar PV project for the Kaua'i Island Utility Cooperative. This marks Xtreme Power's first direct sale to a utility, and first project to provide responsive reserves.

# The Power to Control.