Intelligent Power Conditioning for Renewable Generation

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- Russel Bonn, Jerry Ginn (DETL)

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Overview

- *Initial Focus: optimal control of remote hybrid power systems*
- *Scope has expanded to include Microgrids and general DER communications, monitoring and control*

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History

- *Identified the need for separation of power conversion & control…*
- *The advantages of droop mode paralleling (instantaneous load sharing)*
- *Developed a standard communications protocol for inverters and BOS (in use by Plug Power)*

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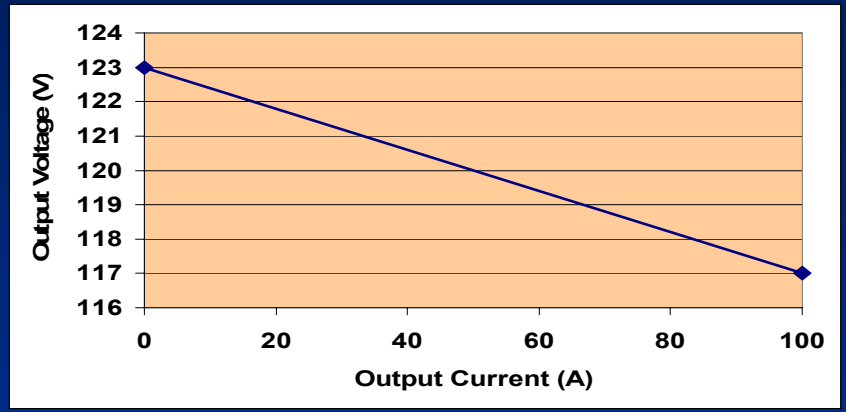
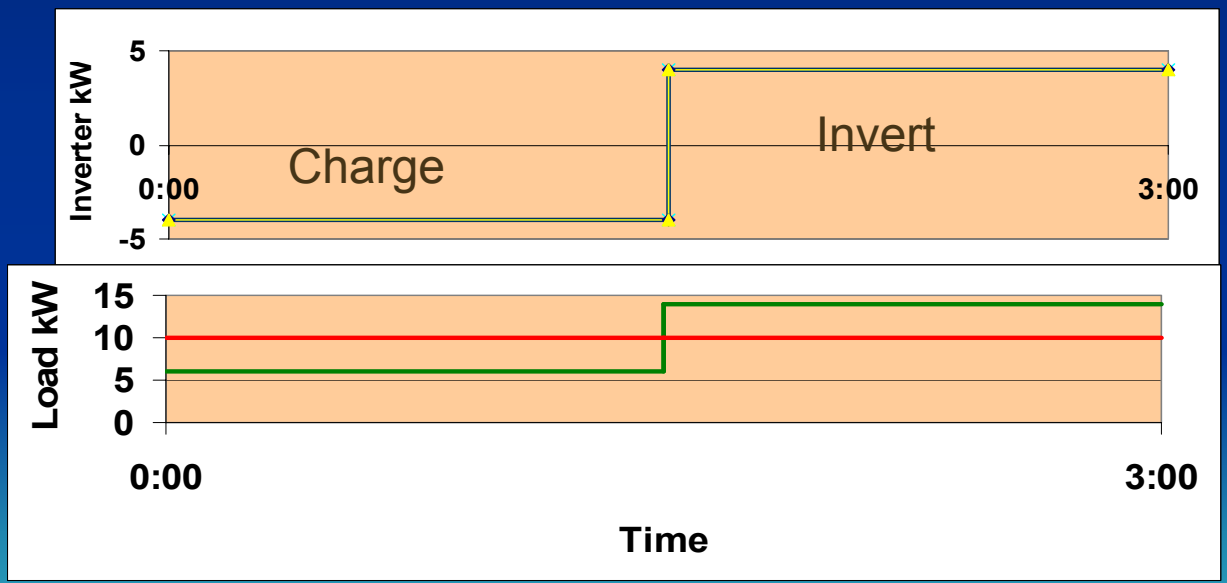
Droop Control Explained

Output voltage "droops" with current or frequency





Inverter changes from charging to inverting automatically on load step

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Support for IEEE 1547.3

Draft Guide for Monitoring, Information Exchange and Control of Distributed Resources Interconnected with Electric Power Systems

- *Looked to be a protocol battle, but the group is working well, focused on object models and functionality.*
- *Original intent was to create a standard inverter protocol*
- *The work now is to create standard DER object models which can be translated to any protocol*
- *Interim head of the security sub-committee*
- *Working to form a microgrid industry sub-group*

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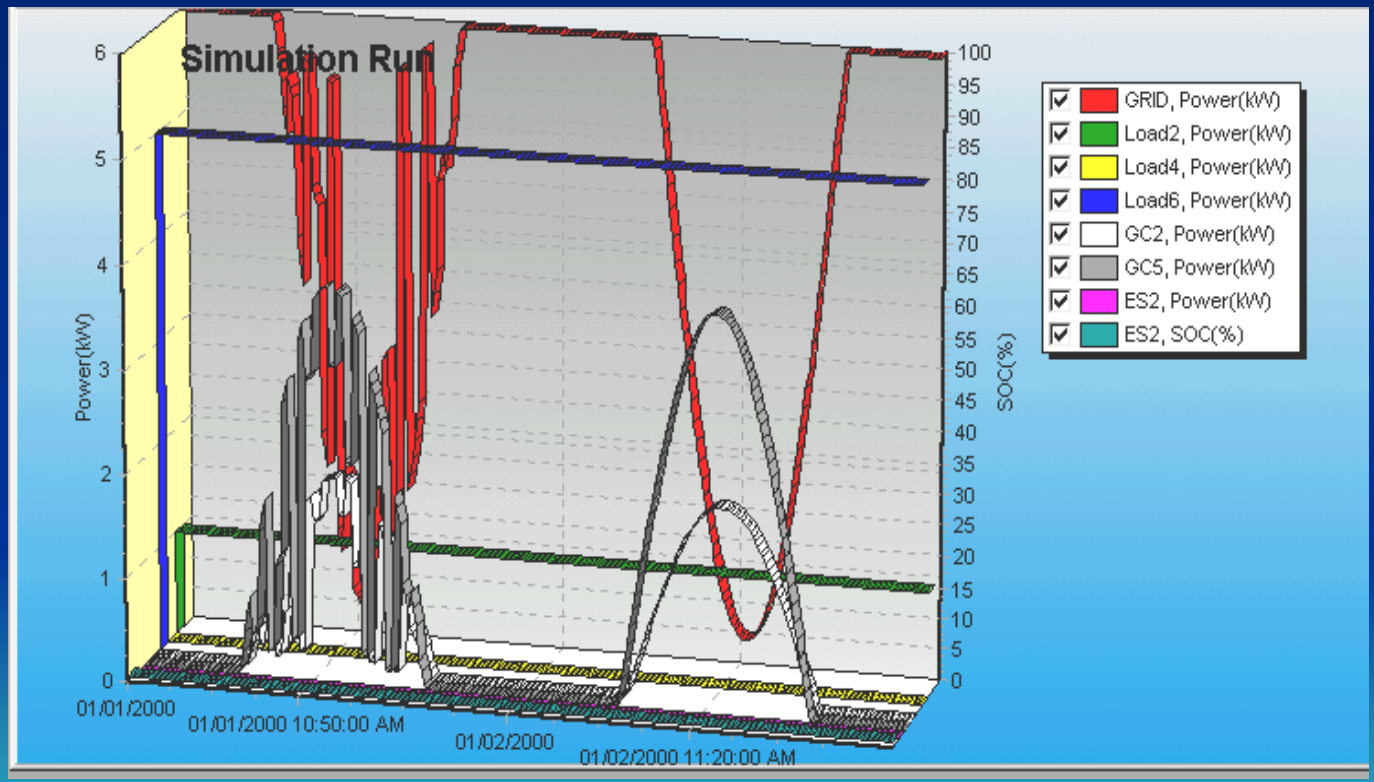
Multiple Device Control

- *Scheduling algorithms developed*
- *Simulator program written*



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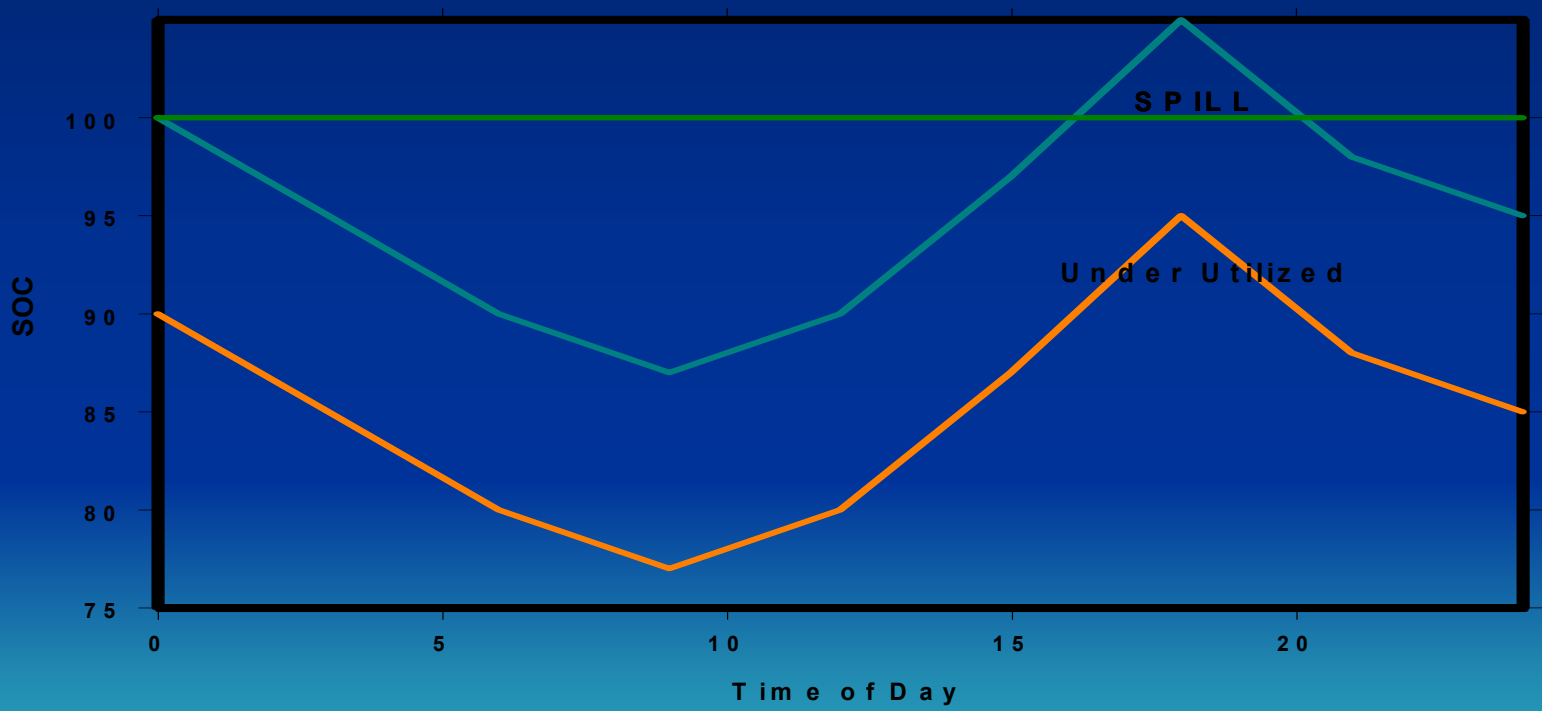
Simple PV control

- *Adjust Gen Start SOC setpoint so that peak SOC is 100%*



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Optimization research

			Savings Over		
Load Profile	**Peak Load (kW)**	**3 Day Cost ($)**	**Set Point**	**Load Following**	**Annual Savings over Set Point ($)**
Typical "3 Hump"	6	30.07	37.4%	36.7%	2,185.76
Typical "3 Hump"	10	65.66	12.4%	18.0%	1,128.60
Typical "3 Hump"	10	66.24	11.6%	17.3%	1,057.54
Intermittent	6	26.91	12.5%	16.2%	467.72
Intermittent	10	48.17	24.3%	-0.8%	1,881.30
Intermittent	10	48.91	23.2%	-2.4%	1,793.40
Evening	6	18.71	30.2%	15.2%	984.91
Evening	10	25.80	31.6%	16.3%	1,448.40
Evening	10	29.17	22.6%	5.3%	1,036.28
Daytime	6	63.91	19.8%	25.7%	1,919.69
Daytime	10	90.37	21.7%	19.6%	3,039.30
Daytime	10	93.98	18.5%	16.4%	2,595.50
Constant*	10	181.17	N/A	-1.0%	N/A
Constant	6	122.14	5.5%	10.3%	864.89

major improvements in hybrid control

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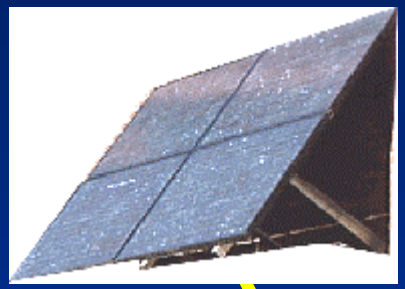
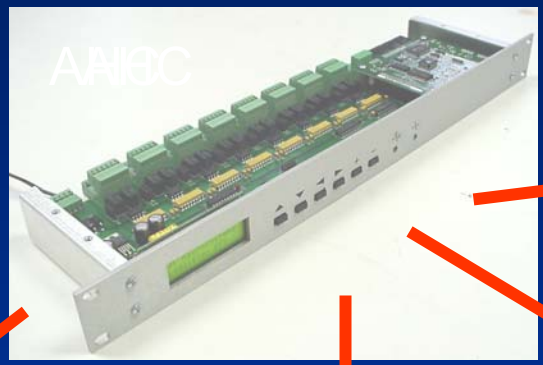
Advanced Hybrid Controller Designed & Installed at Sandia DETL



PV Array



Load

Inverter

Batteries

Generator

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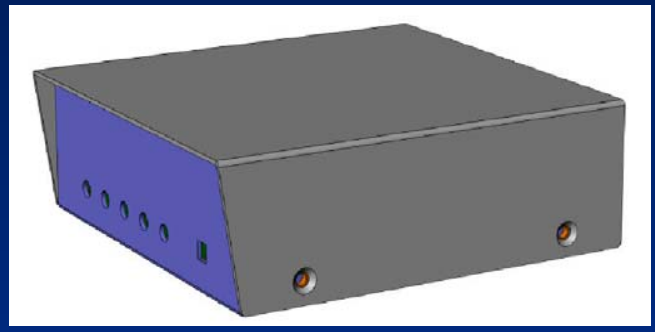
Introducing the DGNode



- *Low cost DER Monitoring and Control System*
- *Local Data Collection & Storage*
- *Communicates with Internet central server*
- *“Table Driven” configuration – no special programming*
- *Support for “Real Time” monitoring and control*

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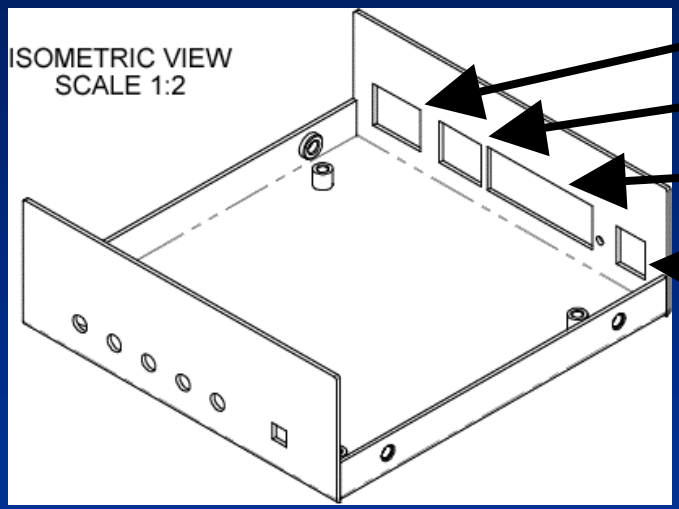
DGNode Concept



Ethernet (10 base T)

Inverter Protocol (RS485)

Serial/Modem

Power (Wall Transformer)

- *Low cost ($150)*
- *386 single board computer*
- *Uses available internet connections (ISP/modem, DSL, Cable).*
- *Web Services – Microsoft .net. SOAP, XML*
- *Small quantities of data(10kb/day) – 8 to 200 MB of data storage*

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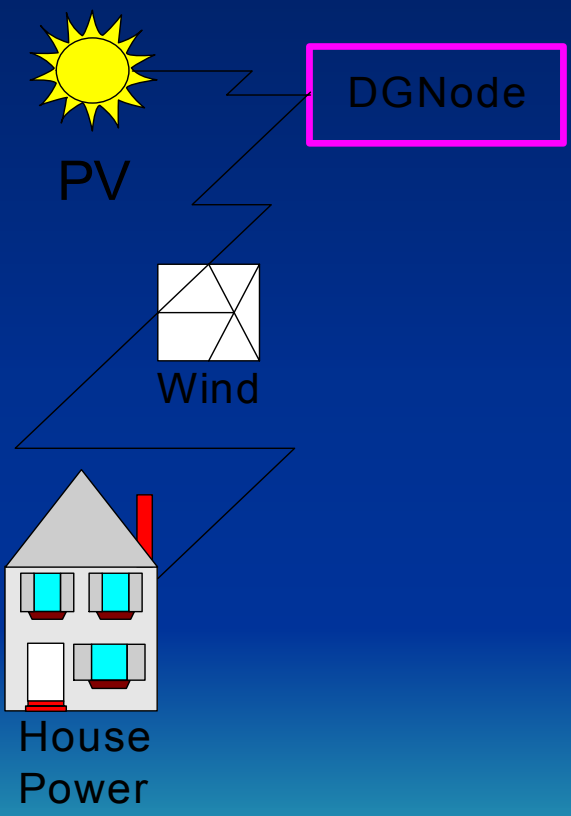
Application - Low Cost Residential DG Monitoring

- *Aimed first at Solar Power market*
- *$150 basic cost, $50 installation*
- *$25/year service cost*
- *$150 to add house power and grid quality monitoring*
- *DGNode dials into server every night via ISP*
- *Can implement "Tucson Electric" scheduled battery dispatch concept*



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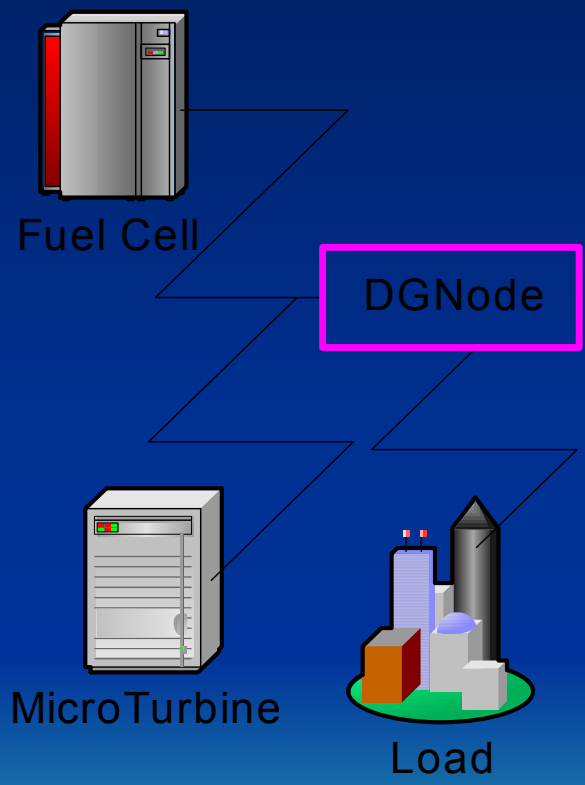
Application: Microgrid and DG System Control

- *Microgrid Dispatch and Monitoring*
- *Economic Dispatch algorithm*
- *"Real Time" via intranet connection to Nodes*
- *Node is universal interface for DG devices*
- *Can control local microgrid or dispersed DG*



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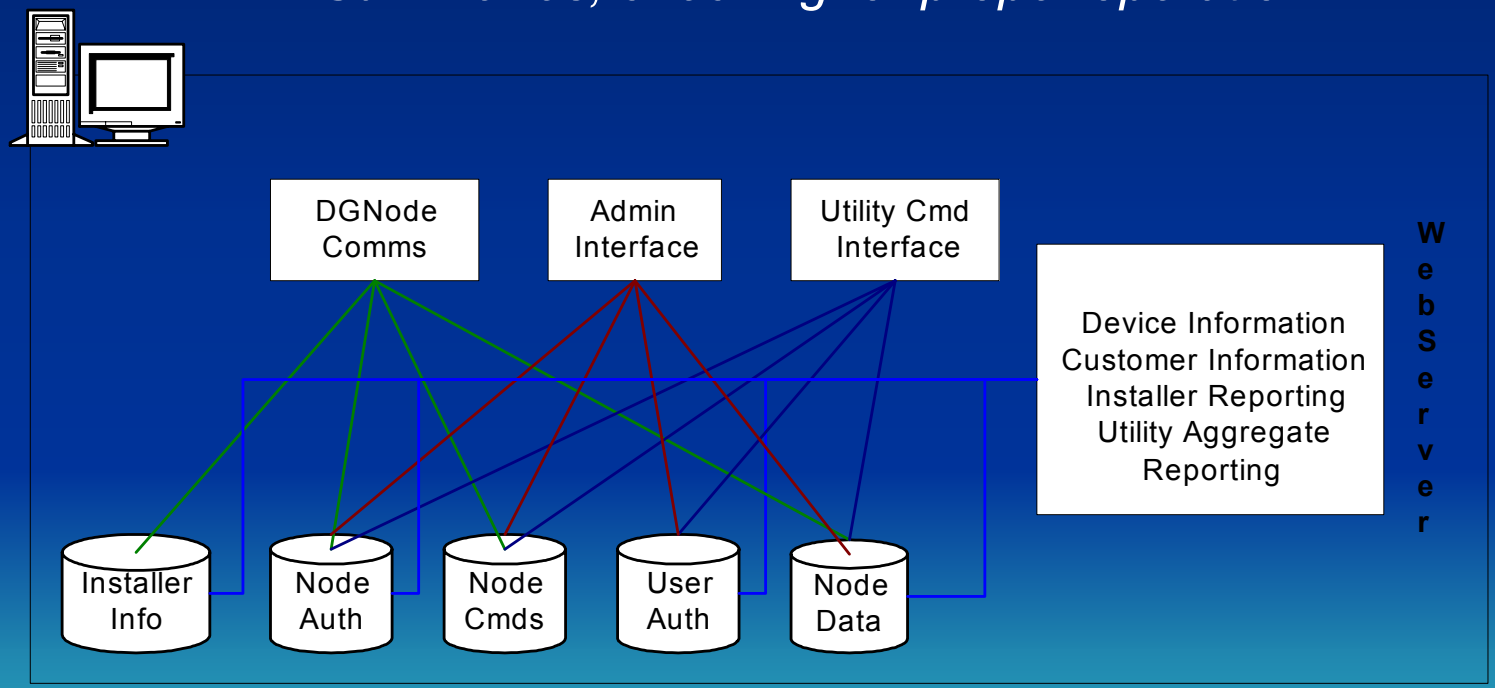
Server Capabilities

- *User types: user, installer, utility, auditor, administrator*
- *User event logging*
- *SQL database, .Net Application*
- *Summaries, checking for proper operation*



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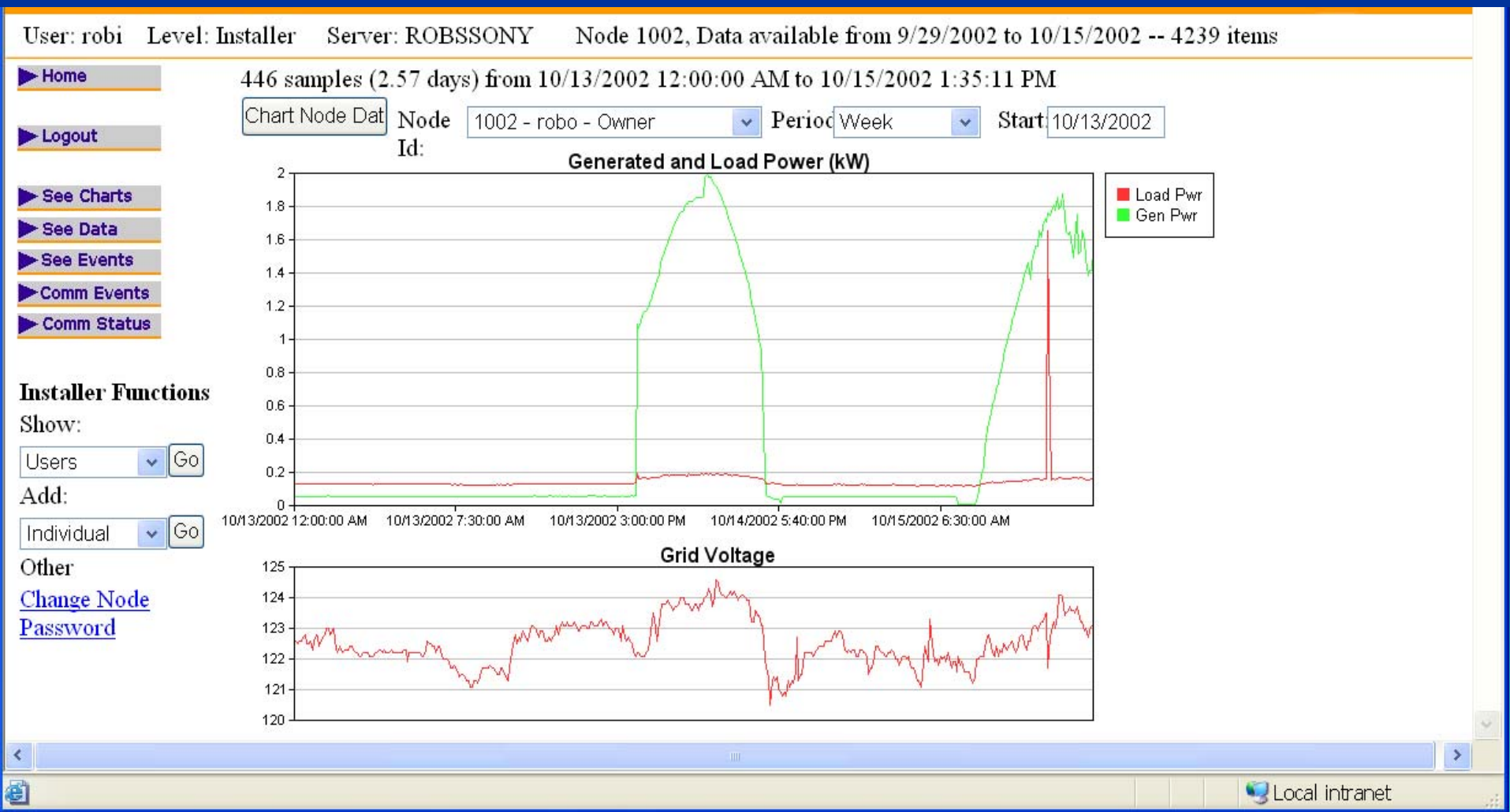
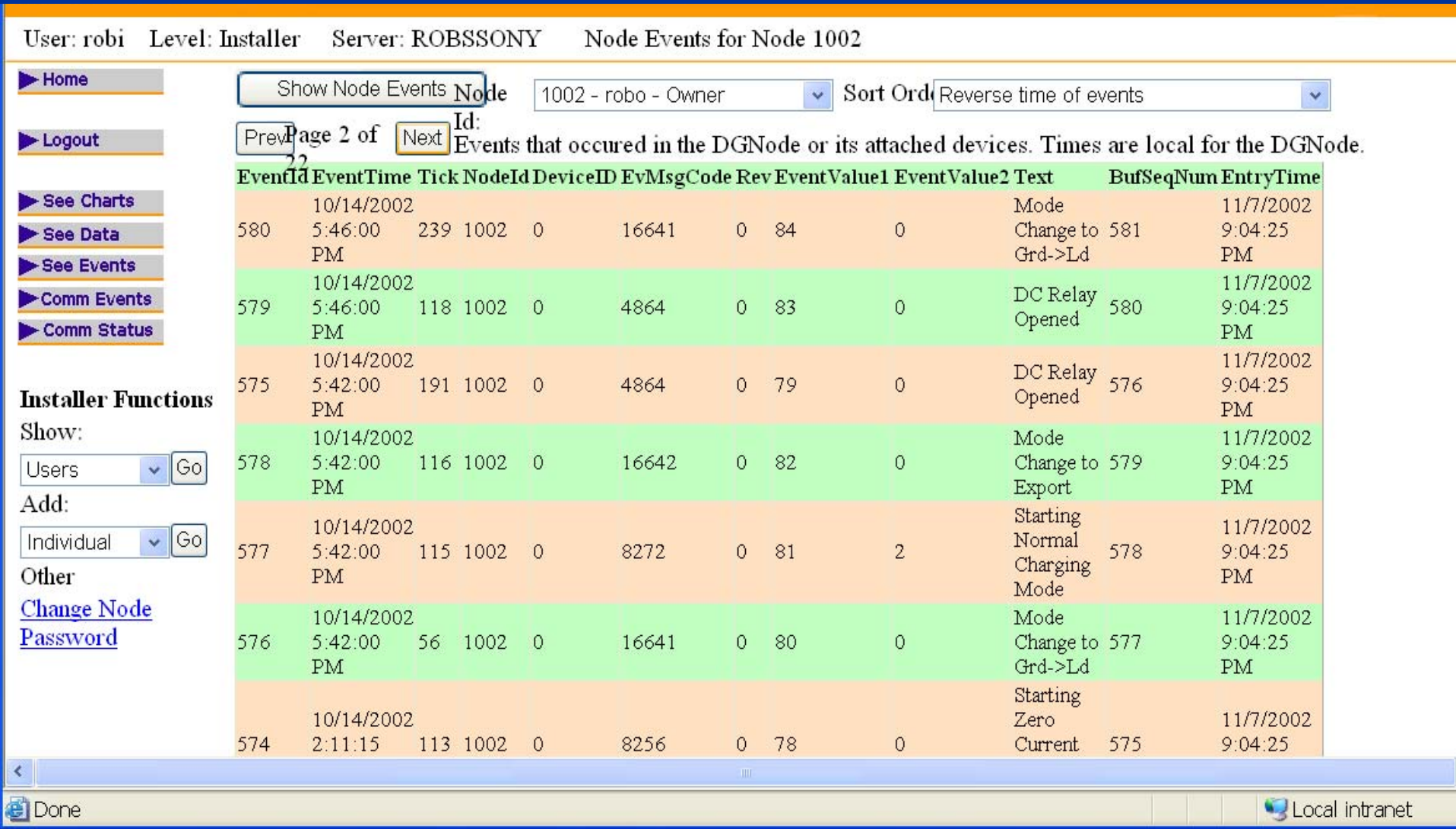
DGNode Demonstration



DGNode Demonstration



User: robi Level: Installer Server: ROBSSONY Node Events for Node 1002

Home

Logout

See Charts

See Data

See Events

Comm Events

Comm Status

Installer Functions

Show:

Users Go

Add:

Individual Go

Other

Change Node Password

Show Node Events Node Id: 1002 - robo - Owner Sort Ord Reverse time of events

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Events that occured in the DGNode or its attached devices. Times are local for the DGNode.

EventId	EventTime	Tick	NodeId	DeviceID	EvMsgCode	Rev	EventValue1	EventValue2	Text	BufSeqNum	EntryTime
580	10/14/2002 5:46:00 PM	239	1002	0	16641	0	84	0	Mode Change to Grd->Ld	581	11/7/2002 9:04:25 PM
579	10/14/2002 5:46:00 PM	118	1002	0	4864	0	83	0	DC Relay Opened	580	11/7/2002 9:04:25 PM
575	10/14/2002 5:42:00 PM	191	1002	0	4864	0	79	0	DC Relay Opened	576	11/7/2002 9:04:25 PM
578	10/14/2002 5:42:00 PM	116	1002	0	16642	0	82	0	Mode Change to Export	579	11/7/2002 9:04:25 PM
577	10/14/2002 5:42:00 PM	115	1002	0	8272	0	81	2	Starting Normal Charging Mode	578	11/7/2002 9:04:25 PM
576	10/14/2002 5:42:00 PM	56	1002	0	16641	0	80	0	Mode Change to Grd->Ld	577	11/7/2002 9:04:25 PM
574	10/14/2002 2:11:15	113	1002	0	8256	0	78	0	Starting Zero Current	575	11/7/2002 9:04:25

Done Local intranet

Convergence

- *The AHC and DGNode are based on the same hardware and software platforms*
- *By combining code, we combine functionality – the AHC becomes a DGNode with in-built control capability*
- *The central server collects AHC system data and event logs*
- *DGNode code is currently running on the AHC test unit at Sandia (ahc.sandia.gov)*

Market Research

- *All major PV distributors, dealers and a number of possible end-users were surveyed.*
- *Generally positive response.*
- *Little imaginative feedback – the concepts are too new*
- *Agree that most customers would be willing to pay $25/year for monitoring*

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Continuing Work

- *Completion of server and Node code development*
- *Communications Security – implementing SSL in Node*
- *Investigating CDPD (Cellular) & 2 way pager options*
- *Replacing RS-485 with Zigbee RF links*
- *Full integration with modem on board*
- *Real time monitor, Arbitrage, uGrid optimal control*
- *Field testing*

Microgrids & Intentional Islanding

Recommendation 16: Technology should be developed for an intelligent, adaptive power grid that combines a threat-warning system with a distributed-intelligent-agent system. This grid would be able to rapidly respond with graceful system failure and rapid power recovery. It would make use of adaptive islanding—a concept employing fast-acting sensors and controls to "island" parts of the grid as the rest comes down—and technologies such as storage units positioned at key points to minimize damage during shutdown. The system would need to be able to differentiate between a single component failure and the kind of concurrent or closely coupled serial failures at several key nodes that would indicate the onset of a concerted attack --- National Reseach Council report to congress.

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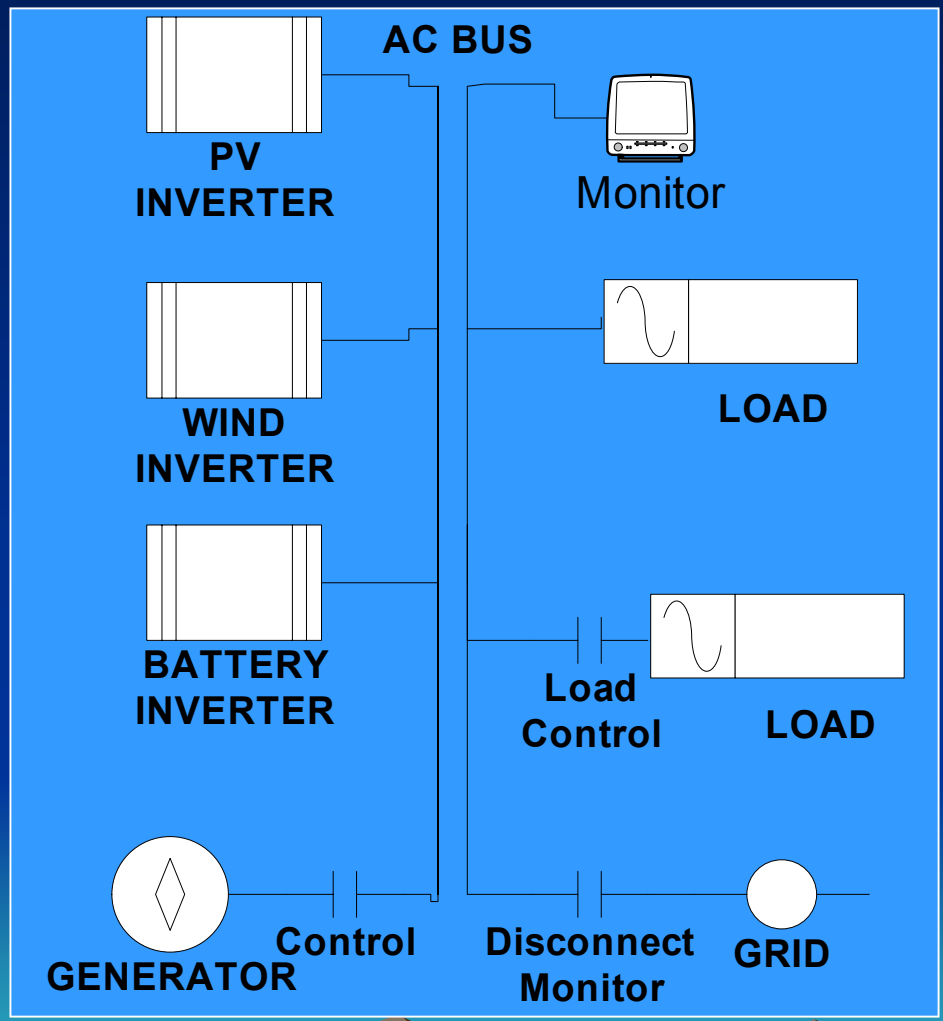
Questions (from AHC work)

- How can we integrate inverters and various types of rotating machines in a microgrid?
- How do we synchronize & control bus frequency?
- What mode will inverters run in (current control, voltage control, droop, or a mix?)?
- Different types of rotating machines

Answers?

- "Slow" communications combined with instantaneous droop control
- Programmable droop impedance (magnitude and phase) included in inverter control
- Inverter phase locked loop control with synthetic inertia/programmable dynamics
- Make the inverter look like a generator

Nanogrid Concept



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Microgrid Continuing Work

- *White Paper on microgrid control*
- *Plan a Nanogrid demonstration at Sandia's DETL*
- *Form microgrid industry working group under 1547.3*
- *Alt Configuration possibilities*