Modernizing Power Grids with Distributed Intelligence and Smart Grid-Ready Instrumentation

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Our Challenges

• Smart Grid is an umbrella term defining multiple efforts for modernizing power systems
  – *Utilities are learning as they go, so flexibility is paramount*

• Technology and Standards are constantly evolving
  – *Instruments are designed for functions and standards of an specific/fixed point in time (obsolescence risks)*

• Computerized systems require enhanced/flexible security approaches
  – *Special technology and costly components must be developed making existing instrumentation expensive and slow to adopt*

• Global Economy Decline
  – *Shrinking budget and resources and favors, high efficiency, multi-purpose/field-configurable instrumentation*
Grid: Measurement – Visualization – Automation

100's of Devices
Multiple Protocols
Multiple Buses
Fixed Functionality
Hundreds of Vendors
Poor Data Visualization Tools

Alarm Event Recorder
Recloser Control
Sectionalizer Control
Transformer Monitoring
Phasor Measurement Unit
Capacitor Control
Substation Automation
Demand Response
Metering
Power Quality Analyzer
Smart Grid Instrumentation Requirements

• **Distributed Intelligence**
  – Promotes optimum network response times and bandwidth utilization
  – Allows unprecedented amounts of data and grid control operations to be seamlessly managed through the system
  – Enhances reliability through decentralized coordination instead of through the imposition of hierarchical control.

• **Flexible communication protocols**
  – Facilitates instrumentation interoperability

• **Future-proof architecture**
  – Real-time platform that allows capture of fast moving data such as transients and line disturbances
  – High Fidelity ADCs with 24-bits and Filtering Capabilities for Quality Measurements
  – Common data file formats (Standards Based)
  – I/O Expandable and Remote Upgrades

• **Security**
  – NERC/CIP, SSL
Smart Grid-Ready Instrumentation

Computers
- Processing Power
- Open Source
- I/O Expandable
- Programmable
- Software-Defined

T&D Instrumentation
- Measurement Quality
- Embedded Processing Power
- Reliable and Robust
- Open source and Programmable
- I/O Expandable and Standards-Based
- Software-defined

GAP
- Measurement Quality
- Embedded Processing Power
- Reliable and Robust
- Open source and Programmable
- I/O Expandable and Standards-Based
- Software-defined
Closing the GAP: FPGA

Graphical Programming | Desktop Test Bench | Compilation | Synthesis | Place & Route | Deployment

Performance

Programmability

Reliability

LabVIEW FPGA

Reconfigurable Hardware
NI CompactRIO FPGA-based Platform

- Reconfigurable FPGA for high-speed and custom I/O timing, triggering, and control
- I/O modules with built-in signal conditioning for connection to sensors/actuators
- Real-time processor for reliable measurement, analysis, connectivity, and control

Environmental
- -40 to 70 °C temperature range
- 50g shock, 5g vibration

Low Power Consumption
- 9 to 35 VDC power, 7-10 W typical
NI LabVIEW FPGA (RIO) Hardware Targets

- **R Series Multifunction RIO**
  - General Purpose I/O for Measurement and Control

- **CompactRIO**
  - Industrial Control and Monitoring

- **Single-board RIO**
  - Embedded Systems

- **FlexRIO**
  - Manufacturing Test and Design Validation

- **Other**
  - RIO IF Transceiver
  - PCIe Framegrabbers
  - Compact Vision System

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Over 100 C Series I/O Modules

• Analog Input
  – Up to 1MS/s, simultaneous sampling
  – 4, 8, 16, and 32-ch options
  – Built-in signal condition for sensors
    – Strain gages, accelerometers, thermocouples, RTDs
  – Up to ± 300 VRMS, ±5ARMS
  – 12, 16 and 24-bit resolution
  – Available ch-to-ch isolation

• Analog Output
  – Up to 100 kS/s simultaneous updating
  – Up to 16-ch per module
  – 10 V, ±20 mA
  – Isolation

• Digital I/O
  – Up to 10 MHz timing
  – Counter/timer, PWM
  – 8 and 32-channel options
  – 5V/TTL, 12/24/48/60 V logic levels

• Specialty
  – 2-port CAN modules
  – Brushed DC servo motor drive

• Third Party Modules
  – LIN, Profibus, WLAN, MIL-1553, ARINC-429, GPS, and more
## LabVIEW Power Quality and PMU Pioneer Toolkits

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<th>Voltage and Current</th>
<th>Power and Energy</th>
<th>Power Quality</th>
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<td>Three Phase RMS (V and I)</td>
<td>Power per Phase</td>
<td>Voltage Sag (dip)</td>
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<tr>
<td>THD</td>
<td>Three Phase or Total</td>
<td>Voltage Swell</td>
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<tr>
<td>Harmonic (up to 64(^{th}))</td>
<td>Power Factor</td>
<td>Impulsive Transient (V + I)</td>
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<td>Interharmonics (0.5 to 63.5(^{th}))</td>
<td>Active Power Total</td>
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<td>Voltage Unbalance</td>
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<td>Apparent Power Total</td>
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<td>DC Portion</td>
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<td>Reactive Power Harmonic</td>
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<td>Energy Active Total</td>
<td>Harmonic per sec and per cycle</td>
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<td>Energy Apparent Total and +/-</td>
<td>Synchrophasor IEEE-C37.118</td>
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<td>Energy Reactive Total and L/C</td>
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ADVANCED SMART SWITCH
CenterPoint’s Vision and Project Goal

- **Vision**
  - To be recognized as America’s leading energy delivery company

- **Project Goal**
  - To modernize and install smart/intelligent reclosers and sectionalizer on distribution grid
    - Faster fault identification
    - Automatic fault isolation
    - Real-time grid health monitoring
Advanced Smart Distribution Switch

- Advanced analytics for distribution automation
- Development and introduction of advanced switching features
- Embedded electrical power measurements and monitoring
- Wireless communication for configuration and file transfer
- Remote updates, configuration and firmware upgrades

Distribution Switch
- Rated Through 38kV
- Vacuum Interruption Technology
- Integrated CTs & Voltage Sensors
- Optional future upgrades
  - ANSI / IEEE C37.60
  - 3-phase protection

Analytics (NI Smart Grid Analyzer)
- 833 Samples/Cycle, 24-bit Resolution
- Advanced Embedded Analytics
- Data Storage, 1000+ event captures
- Remote upgrade
- Multi Protocol Communications
Putrajaya - Malaysia

61850 DATA CONCENTRATOR FOR SUBSTATION AUTOMATION
Who is Tenaga Nasional?

• Early Predecessor, Central Electricity Board founded in 1949

• Manages & operates the National Grid, a comprehensive transmission network that is also interconnected to Thailand & Singapore

• Largest Utility in Malaysia
  – 12,000 MW Installed
  – 28,000 Employees
  – 7 Million Customers

• Businesses
  – Core Activities: Generation, Transmission & Distribution
  – Other diversified activities: Manufacturing of transformers, high-voltage switchgears & cables
61850 Concentrator

- Development of transmission substation automation system based on IEC 61850.

- High performance, expandable platform
  - Memory and disk space can be added as needed
  - FPGA and I/O can be added as needed

- Reliability (two independent boxes)
Strengths of NI FPGA platform

• Measurement quality
  – High-accuracy A/D
  – High sampling rates
  – High-resolution timestamp

• Computing power
  – Local, multi core/parallel analysis

• Flexibility
  – Modular I/O
  – Software-defined device

Better fault location and prevention
Install once, upgrade remotely
Questions

“When you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind.”

- Lord Kelvin, 1894

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Support Slides
Advanced Switch High Level Diagram

- Control Cable (48V DC)
- Siemens Control Board
- Sensor Data (Analog)
- HMI/User Controls
- Open, Closed, Trip, Status
- Distribution Switch
- Data Link to Operations Control
- Control Cubicle
- Service Port (Front Panel)
- WiMAX
- GE MDS 3460
- GPRS
- TCP, DNP3, SSL
- LV Dashboard
- SmartSynch Router
- Serial to Ethernet Box

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Advanced Switch System Diagram

Operations Server

Operations Workstation Operations Workstation

LabVIEW Application

Engineering Workstation Engineering Workstation

NI SGA

NI SGA

NI SGA

Status & Controls
DNP 3.0 and 61850 (Future)

Analytic and non-Operational Data SSL