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 a 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*

• Economic pressure
  – *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

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

IEEE PES Power & Energy Society
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

Vendor-Defined
- Measurement Quality
- Embedded
- Reliable and Robust
- 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

Source: Xilinx

CONFIGURABLE LOGIC BLOCK (CLB)
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
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 & PMU Toolkit Functionality

<table>
<thead>
<tr>
<th>Voltage and Current</th>
<th>Power and Energy</th>
<th>Power Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three Phase RMS (V and I)</td>
<td>Power per Phase</td>
<td>Voltage Sag (dip)</td>
</tr>
<tr>
<td>THD</td>
<td>Three Phase or Total</td>
<td>Voltage Swell</td>
</tr>
<tr>
<td>Harmonic (up to 64&lt;sup&gt;th&lt;/sup&gt;)</td>
<td>Power Factor</td>
<td>Impulsive Transient (V + I)</td>
</tr>
<tr>
<td>Interharmonics (0.5 to 63.5&lt;sup&gt;th&lt;/sup&gt;)</td>
<td>Active Power Total</td>
<td>Oscillatory Transient (V + I)</td>
</tr>
<tr>
<td>Voltage Unbalance</td>
<td>Active Power Harmonic</td>
<td>Overvoltage and undervoltage</td>
</tr>
<tr>
<td>Frequency Oscillation</td>
<td>Apparent Power Total</td>
<td>Overcurrent</td>
</tr>
<tr>
<td>Flicker</td>
<td>Apparent Power Harmonic</td>
<td>Phasor Imbalance</td>
</tr>
<tr>
<td>DC Portion</td>
<td>Reactive Power</td>
<td>Three Phase Voltage Harmonic</td>
</tr>
<tr>
<td></td>
<td>Reactive Power Harmonic</td>
<td>Four Current Harmonic</td>
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<tr>
<td></td>
<td>Energy Active Total</td>
<td>Harmonic per sec and per cycle</td>
</tr>
<tr>
<td></td>
<td>Energy Apparent Total</td>
<td>Synchrophasor IEEE-C37.118</td>
</tr>
<tr>
<td></td>
<td>Energy Reactive Total</td>
<td></td>
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</tbody>
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### Communications Protocols
- Released: UDP, TCP/IP, Modbus RTU/ASCII/TCP, Ethernet/IP, DNP3.0, IEC 60870-5
- Expected in 2012/2013: IEC 61850 MMS & GOOSE
ADVANCED SMART SWITCH

Houston, TX - USA
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
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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