Wide Area Measurement Systems - Monitoring and Control for the Grid of the Future

Department of Energy
Transmission Reliability Program

Third Annual Carnegie Mellon Conference on the Electricity Industry

March 13-14, 2007

Phil Overholt
Office of Electricity Delivery and Energy Reliability
Transmission Reliability Mission

Develop technologies and technically-based policy options to enhance the reliability and economic efficiency of the Nation’s electric power delivery system under competitive electricity markets
Transmission Reliability Projects Summary

- Real Time Grid Reliability Management
  - Reliability Adequacy Tools
    - NERC - Performance metrics research, standards development support, and compliance monitoring prototypes, including visualization
  - Advanced Measurement and Control
    - North American Synchro-Phasor Initiative

- Reliability and Markets
  - Market Design and Market Monitoring

- Load as a Resource
Power System Reliability Analysis Gaps

- Lack of wide-area visibility
- Lack of situational awareness
- Need for time-synchronized data recorders
  - Phasor measurement technology is the solution
Lack of Visibility and Situational Awareness Led to Aug. ’03 Blackout

August 14, 2003 Blackout

Notes:
Angles are based on data from blackout investigation. Angles are calculated from a Powerflow Simulation. Angle reference is Browns Ferry.
North American Synchro-Phasor Initiative (NASPI) Elements

- Leadership Team (led by Phil Overholt/DOE and Stan Johnson/NERC)
- Participating operating entities investing in equipment and communications
- Executive Steering Group
The Work Group’s mission is to create a robust, widely available and secure synchronized data measurement exchange network over the North American grid with associated analysis and monitoring tools for better planning and operation, and improved reliability.
PMU Deployment

Legend
Green, Red, & Gray: 50 networked PMUs
Cyan: 75 planned PMUs
Eastern Interconnect Phasor Project (EIPP)
TVA Super Phasor Data Concentrator and Comprehensive Database Architecture

Real-time Data Acquisition
- PDCstream input
- OPC based input
- IEEE 1344 input
- PC37.118 input (In Testing)

Inputs are developed as in-process DataWare archive assemblies...

Real-time Data Broadcast
- UDP Stream from Super PDC
- PDCstream output
- PC37.118 output (In Testing)

Note that all incoming PMU data is broadcast to Super PDC directly from data acquisition, before it is even archived, for concentration and real-time broadcast. Local disk space is used as an intermediate data cache should connectivity with any server in a sub-second array be lost.

DatAware 30-Day Sub-second Archive Array
- PMUDV(n) Multiple DL360
  - 2 CPU, 2.7 GHz
  - 260Gb Raid 5 with Hot Spare

  - Online sub-second DataWare archive
  - Future sub-second DataWare archive
  - Future sub-second DataWare archive

  One instance of PGARC and PCSERVER per server

Note that all archived sub-second PMU phasor data is backed up nightly. Sub-second data will be online for at least 30 days, older data will be permanently archived at an offsite location. Actual data window will often be larger depending on disk space availability and permanent data archive schedule.

PMU Demographics Web Site
- PMUWEB
  - Cluttered DL360
  - 2 CPU, 3.2 GHz
  - 40Gb SAN Disk

  RTDNS Server and PMU Point Definition
  - Web tool to retrieve large XML datasets from real-time data archive
  - Web interface to manage PMU’s, points and configurations

J. Ritchie Carroll - TVA
December 3rd, 2004
Last updated July 26th, 2005
Real Time Dynamic Monitoring System for Wide Area Phasor Monitoring
Warning Signs of the August 10, 1996 WSCC Breakup

008 Malin-Round Mountain #1 MW
caseID=Aug10E5loadPF casetime=04/16/98_14:41:48

PPSM at Dittmer Control Center
Vancouver, WA

0.264 Hz, 3.46% damping

Reference time = 15:35:30 PDT

0.276 Hz

0.252 Hz

15:42:03
Keeler-Allston line trips

15:48:51
Out-of-Step separation

15:47:36
Ross-Lexington line trips/
McNary generation drops off

(see detail)
AEP Kanawha River bus frequency for Aug14 Blackout
12:00-16:10 EDT

KNRV Kanawha River Bus KV1  FreqL
LcaseID=AEPpmu030814_krNBP1  casetime=09/22/03_14:36:45

Scalar Autospectrum: WFmode 3
view(10,70)
Visualization and Control -- Challenges and Needs for an Evolving Industry Structure

CURRENT AND PROPOSED LEVELS:

Wide-Area Level 3

- DOE Situation Awareness

Wide Area Level 2

- FERC Reliability Standards Performance

Wide-Area Level 1

- NERC Emerging Wide-Area Reliability Performance Monitoring and Compliance

Level 3

- ENERGY MANAGEMENT SYSTEMS (EMS) RTO, ISO, CONTROL AREA

Level 2

- SCADA - REGIONAL CONTROL CENTER

Level 1

- LOCAL CONTROL SUBSTATIONS
- LOCAL CONTROL GENERATION PLANTS

MONITORING AND CONTROL:

- Situation Awareness for Emergency Response
- Standards Performance, Monitoring, Notification and Reporting
- Real Time Wide-Area Monitoring and Compliance for Interconnections, Load-Generation, Inter-Area Schedules, and Transmission Adequacy
- System State Estimation, Security Analysis, and Security Constraint Dispatch
- Regional Load-Generation and Grid Switching Control
- Local Generation and Substation Control
## Summary of Research Goals and Milestones

<table>
<thead>
<tr>
<th>Research Areas</th>
<th>Near-Term (1-2 Years)</th>
<th>Mid-Term (2-5 Years)</th>
<th>Long-Term (5-10 Years)</th>
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<tbody>
<tr>
<td></td>
<td>• Wide-area visibility with common situational awareness screens</td>
<td>• Wide-area visibility with full coverage</td>
<td>• Real-time protection</td>
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<td>• Baseline normal operating conditions, limits and alarms for EI</td>
<td>• Approaching real-time state measurement for operators</td>
<td>• Distributed closed loop control</td>
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<td>• Demonstrate improved state estimation with phasor measurements</td>
<td>• Dynamic system security assessment tools</td>
<td>• Automatic smart-switchable networks</td>
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<td>• Model validation for better system understanding</td>
<td>• Common operator tools deployed</td>
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<td>• Identify human factors &amp; visualization needs for phasor based operations tools</td>
<td>• Congestion management</td>
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<td>• Define best practices for enhanced grid “forensics”</td>
<td>• Dynamic ratings</td>
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<td>• Design next generation data and communications infrastructure</td>
<td>• Improved LMP</td>
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<td>• Define research and demonstration approach for real-time control</td>
<td>• Work with industry to initiate major demonstration of real-time control for dynamic security</td>
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<td>• Identify research needs for federal investment</td>
<td>• Work with industry to demonstrate adaptive islanding protection concepts to improve protection from wide-area blackouts</td>
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<td>• Develop strategy for next-generation operational tool concepts</td>
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**Research Areas**
- Visualization
- Monitoring
- Planning
- Phasor Infrastructure Management
- Control
- Protection
- Switching

**Milestones**
- **2006 - 2007**
- **2007 - 2010**
- **2010 - 2015**
**Phasor Technology Vision & Roadmap -- Summary**

**Research Outcomes**
- System visibility & situational awareness across entire interconnection
- Wide area grid monitoring – common data & visualization platform
- Interconnection wide state estimation
- State measurement based grid operations & security management
- Uniform standards & protocols for data collection, communications & security
- Reliable & high quality phasor data to facilitate smart grid control & operations
- Dynamic system security assessment

**EPACT ‘05 Compliance**

**DOE Vision for Grid of The Future**

**Blackout Study Recommendations**

**Industry Changes & Challenges**
Advanced Energy Initiative

- Develop advanced batteries for plug-in hybrid-electric vehicles
- Complete clean coal technology research funding and move resulting innovations into the marketplace
- Develop a new Global Nuclear Energy Partnership to address spent nuclear fuel, eliminate proliferation risks, and expand the promise of clean, reliable, and affordable nuclear energy
- Reduce the cost of solar photovoltaic technologies, and expand access to wind energy through technology

www.eere.energy.gov/cleancities/toolbox/pdfs/energy_booklet.pdf