PJMJ Interconnection
Smart Grid Investment Grant Update

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PJM Project Participants

• PJM Leads:
  – Project Manager: Bill Walker (walkew@pjm.com)
  – SynchroPhasor Technical Lead: Mahendra Patel (patelm3@pjm.com)

• Vendor Partners:
  – Electric Power Group (PDC and visualization software)
  – Quanta Technology (engineering/project management)
  – Virginia Tech University (PMU/PDC device testing)
Project Summary

• 12 Transmission Owners installing measurement devices at 81 substations
  – TO’s selected their own vendors
• Transmission Elements Monitored
  – 64 SS > 345kv
  – 17 SS < 345kv
• Approx. 20% of regional footprint monitored
• Installing PMU’s, Relays, DFRs, DDRs
<table>
<thead>
<tr>
<th>Transmission Owner</th>
<th># of Substations with PMU Installations</th>
<th># of Central PDCs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allegheny Power</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>American Electric Power</td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>Baltimore Gas &amp; Electric</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Commonwealth Edison</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Duquesne Light</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>FirstEnergy Services</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>PECO Energy</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>PEPCO Holdings Inc.</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>PPL Electric Utilities</td>
<td>12</td>
<td>2</td>
</tr>
<tr>
<td>Public Service Electric &amp; Gas</td>
<td>12</td>
<td>2</td>
</tr>
<tr>
<td>Orange &amp; Rockland Electric</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>VA Electric &amp; Power (Dominion)</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>Duke Ohio</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>
Installing PMUs at 81 substations; Building support for 150+ substations
PMU Installations (Substations)

- Latest Forecast
- Completed Installations
- Communicating to PJM

# of Substations:
- 2010Q3: 0
- 2010Q4: 0
- 2011Q1: 0
- 2011Q2: 0
- 2011Q3: 0
- 2011Q4: 0
- 2012Q1: 0
- 2012Q2: 0
- 2012Q3: 57
- 2012Q4: 71
- 2013Q1: 57
- 2013Q2: 32

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PDCs and Communications

• PDCs
  – 11 (+5) TO Control Centers with Central PDC
  – Archive Database Status
    • Storage Size – 220 TB (approx 3 years retention)
    • Data archive considerations
      – 90 days real-time; 1 year near-real-time; 7 year archive
  – PDC Availability: 99.99%

• Communication System
  – 11 (+5) dedicated links to TOs (T1 lines)
  – 2 dedicated MPLS Clouds; 1 Verizon and 1 AT&T
  – System Availability: 99.99%
Telecommunications Network

Vendor 1
MPLS Network

Vendor 2
MPLS Network

TO Sites
PPL PDC
CE PDC
DLCO PDC
PS PDC
AEP PDC
RECO PDC
PHI PDC

PE PDC
AP PDC
FE PDC

SPDC
Catalyst 4948 Switches
Catalyst 4948 ASA 5520 Firewalls

DS3
CISCO 3845 Routers
Catalyst 4948 ASA 5520 Firewalls

DS3
CISCO 3845 Routers
Catalyst 4948 ASA 5520 Firewalls

BGE PDC
2 PMUs
DOM PDC
11 PMUs
• Q4 2012
  – Complete initial TO connections (final 5)
  – Data Quality and Availability
  – TO Operator Training
  – Production Hardware/Software installation
  – System Testing
Project Timeline

• Q1 2013
  – “Go Live” with Production hardware/software
  – Implement backup communications network
  – Deploy visualization & analysis software to TO’s

• Q2 & Q3 2013
  – Additional PJM and TO Operator Training
  – Full Transition to Operations Support
  – Initiate pilot projects to gain insight
  – Test EMS/SE Modifications
SynchroPhasor Applications

Data Analysis
- Use recorded data
- Verification of operations
- Analyze dynamic performance
- System model maintenance

Wide Area Monitoring
- Situational awareness display & alerts
- Visual status displays
- Interface into EMS
- Limit alarms
- State measurement

System Dynamics Monitoring
- Visual displays and Alarm Processing
- Dynamic operation limits (oscillations, mode shapes…)
- Parameter estimation
- Oscillation detection

System Control, Protection & Reliability
Control Actions For:
- Wide area problems
- Out-of-step detection
- Excessive power flow, high phase angles
- Both low and high speed operation

Controller
PMU
PDC
SVC
## Application Assessment - Future Deployment

### Synchrophasor Application Prioritization for Implementation Roadmap

<table>
<thead>
<tr>
<th>Implementation Requirements &amp; Risks</th>
<th>Special protection system design; System operating limits evaluation and design</th>
<th>Fault location</th>
<th>Transient stability monitor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium</td>
<td>Controlled system separation; System restoration; Real-time transfer limits; Real-time reactive power and voltage control</td>
<td>Voltage stability monitoring and alarming;</td>
<td>Oscillation detection</td>
</tr>
<tr>
<td>Low</td>
<td>Frequency monitoring</td>
<td>Grid stress</td>
<td>Improve accuracy of state estimation; System model calibration and validation; Post event analysis</td>
</tr>
<tr>
<td><strong>Business Benefits</strong></td>
<td></td>
<td>Low</td>
<td>Medium Term</td>
</tr>
<tr>
<td>DEFER</td>
<td></td>
<td>High</td>
<td>Short Term</td>
</tr>
</tbody>
</table>
Data Quality

- 71% of PMUs with “Good” (or better) rating
- 45% of PMUs delivering Timely data
  - With latency under .5 seconds
- 35% of PMUS are both “Good” and “Timely”

- Poor Quality – Root Cause
  - PMU Calibration - Loss of telecom connection
  - GPS Clock issues - Server overload
  - Data Name limitations - Aliasing at PDC
  - Loose cables - PDC configurations
Phasor Data Sharing

• RTO/ISO Data Sharing
  – MISO (send/receive)

• Application Outputs
  – 12 PJM TO’s (target Dec/Jan)

• Research Projects
  – Multiple planned
• High-level Project Challenges
  – TO Installation Schedule Changes
  – Data Quality and Availability
  – Coordination of all project stakeholders
    • TOs, Vendors, ISO/RTOs, DOE
  – Expanding scope to use available funds
  – Ensuring the architecture is scalable
  – Storage, Storage, Storage
  – R&D approach vs. “touch it once” approach
  – Data Exchange with other RTO/ISO’s
Looking Ahead

• Future Roadmap
  – Data Sharing with other RTO/ISO’s
  – Integrate Phasor Data into existing applications/tools
  – Determine data archival/retention requirements
  – “Big Data” Analysis
  – Data Mining Applications

• Research Needed
  – Transient Stability
  – Dynamic Model Derivation
  – Bad Data Detection (near real-time)
  – Data Storage Efficiencies
Thank You