Topics

• Project Objective
• Study / Analysis Steps
• Major Technical Accomplishments
• Deliverables and schedule for activities to be completed under FY15 funding
• Risk factors affecting timely completion of planned activities as well as movement through RD&D cycle
• Early thoughts on follow-on work that should be considered for funding in FY16
Project Objective

• Conduct wide area angle pair analysis using Phasor Measurement System data from four ISOs
  • December 15, 2013 to February 14, 2015
  • September 1, 2014 to October 31, 2015
• Identify Phase Angle Pairs – Based on Data and Inputs from ISOs
  • Selected 22 inter-ISO angle pairs
• Investigate correlation between LMP and high stress system conditions
• Evaluate changes in angle differences to identify significant system events (December 1, 2014 to December 7, 2014)
Study / Analysis Steps

• **Data Collection**
  • Define Time period for data extraction / collection from ISOs
  • Obtain data from ISOs for 12/15/2013 to 2/15/2014, 9/01/2014 to 10/31/2014 and 12/01/2014 to 12/07/2014

• **Data Checking - evaluate data quality and other attributes**
  – Data Availability and data quality
  – Time synchronization and offset correction
  – Time stamp alignment
  – Data formats

• **Data Aggregation and synchronizing checks for Wide Area Analysis**
  – Combine data from different ISOs
    • Data conversion to a common format and Time alignment
  – Data extraction for selected/alternate angle pairs

• **Perform Statistical Analysis**
  – Box – Whisker and Time Duration Analysis
  – Correlation with Power Flow and Bus Voltage
  – Establish Typical Ranges for Selected Angle Pairs
  – Significant event analysis
Major Technical Accomplishments

• Analysis completed for twenty two wide area angle pairs using 2013-2014 phasor system data
• Angle pair selection based on the input from ISOS/TAG
  – Selected twenty two Angle pairs
  – Data required from fifteen substations to analyze the above 22 angle pairs
• Problems in analyzing wide area angle pairs using PMU data
  – Poor data quality – data quality needs improvement
  – Data synchronization
  – Offset errors – required adjustments to some PMU data
• Draft Report for winter (December 15, 2013-February 15, 2014-and fall (September 1,2014 to October 31, 2014) completed and submitted
  – Analysis of twenty-two wide Internal angle pairs
  – Wide Area Angle pair analysis and its correlation with LMP
• Phasor System data can provide good results and information for Wide area angle pairs across ISOS. Using phasor system data, ISOS can monitor
  – System stress conditions
  – Pre-cursors and high stress locations and event identification
  – Data checking and analysis
Wide Area Angle Pairs Covering Four ISOs
22 Angle Pairs and 15 Buses
# Results of Comparison for Different Time Periods - High\(^1\) and Low\(^1\) Values

<table>
<thead>
<tr>
<th>Index</th>
<th>From bus</th>
<th>To bus</th>
<th><strong>SE Data March 2011</strong></th>
<th><strong>PMU Data (1)</strong> 12/15/2013-2/15/2014</th>
<th><strong>PMU Data (2)</strong> 9/1/2014-10/31/2014</th>
<th><strong>PMU Data (3)</strong> 12/1/2014-12/7/2014</th>
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\(^1\) High and Low values are determined after eliminating top and bottom 0.5% of data to account for outliers
\(^\wedge\) Alternative data sources used due to poor data availability for some primary signals
Methodology to Identify Significant Events

- Control Chart analysis technique used to identify significant events
  - Method is commonly used in manufacturing to find samples outside the tolerance band
  - Three step method – find max and min values in one minute time window; calculate range; compare with range control value
  - Used angle pair angle difference values for selected angle pairs
  - Typical tolerance band for normal distributions is +/- 3 sigma (99.76 percent). For extreme events used high sigma values
  - Use of 20 sigma identified 2 extreme events; use of 15 sigma identified 3 major events – same as actual number of events

- Methodology can be used to extract significant events from large amount of data
12/03 1:22 NERC EI: MISO Callaway 1 Trip 1287MW Loss

12/04 10:58 NERC EI: Massena-Marcy 765kV Trip

12/04 15:05 NERC Quebec: LG2C generation trip with 1019 MW loss. Protective devices tripped on two 735-kV transmission lines carrying power from Baie James to southern Québec
Detected Events Summary (nSigma=20)
Dec 1 to Dec 7, 2014: 14 events identified

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<th>UCL</th>
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<th>12/2</th>
<th>12/3</th>
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<td>Ramapo*</td>
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</table>

*Phase angle regulator on Ramapo

MISO Event

NYISO Event

ISONE: System impact was small and no equipment tripping messages

PJM: went off-cost for reactive transfers at 12/07/2014 15:34
Deliverables and Schedules

• Analysis of ISO-internal angle pairs using SE data - Completed
• Report summarizing analysis process and analysis results using Phasor system data - Completed
• Periodic TAG meetings to report and discuss results (Three in-person meetings during FY15)
• Analysis of wide area angle pairs for event detection and as pre-cursors of significant events using one week (December 1-7, 2014) data – in progress
  – Data received and analyzed
  – Report presented and discussed with ISOs/TAG members
• Complete Report of Analysis – June 30, 2015
Risk Factors Affecting Timely Completion

- Data quality and data availability
  - Data quality needs improvement for some selected locations
  - Data availability for selected angle pairs from ISOs

- Data Synchronization
  - PMU data is well synchronized unlike State Estimator system data
  - Some phase angle adjustments are required – offset errors

- Additional Data
  - Power flow data and some voltage measurements will help in identification and analysis of pre-cursors
Summary and Next Steps

Summary:
• Received and collected Dec 1-7, 2014 phasor data from four ISOs;
• Extracted Dec 1-7, 2014 phasor data, cleaned and combined data for four ISOs;
  ▪ Angle change range can be used to identify system event;
  ▪ Angle difference value is related to system stress level;
• Angle pairs close to the event location can detect the event. Angle pairs that are far away from the event location can’t detect the event.

Next Steps:
• Prepare technical report
• Conduct Research to Identify event precursors that could lead to early warning and a new approach to alarming and system monitoring to allow operators time to react
  • Currently, alarms are based on thresholds.
  • Investigate whether for dynamic metrics
    – Phase angles
    – Oscillations
    – Sensitivities
  • Trend, duration and rate of change can be used to identify vulnerability to events
Thank You.

Any questions?

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