DOE/OE Transmission Reliability Program

Eastern Interconnection
Phase Angle Base Lining Study

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Topics

- Project objective
- Major technical accomplishments that will be completed this year—stage in RD&D cycle
- Deliverables and schedule for activities to be completed under FY13 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 FY14

Project Objective

- Operators monitor power flows at specific interchange points (such as Keystone-Juniata). However, power flows may not be a good measure of wide area system stress
- Phasor networks provide the capability to monitor phase angle differences in real time and other power system metrics which are better indicators of wide area system stress
- Angle differences can also be correlated with power flows and State Estimator outputs and are a good measure for system stress
- Research objective is to develop approach for EI baselining using data from different ISOs and establish angle difference ranges for use in real-time operations
- Approach being used is to use data from state estimator solutions and stressed power flow cases to:
  - analyze phase angle difference
  - analyze other power system metrics
  - establish baseline for performance, and
  - utilize results to establish benchmarks and norms for use by operators

Major Technical Accomplishments

- Reviewed and conditioned data received from four ISOs
- Selected angle pairs for analysis based on power flows for major sources and sinks
  - New York ISO (NYISO – 18 pairs)
  - New England ISO (NE-ISO – 54 pairs)
  - PJM (In progress – 35 pairs)
  - Mid West ISO (MISO- 20 pairs)
- Conducted statistical analysis of State Estimator/EMS data to define high, medium, and low phase angle range for selected angle pairs
- Determined phase angle separation range for selected angle pairs for the NYISO, NE-ISO, MISO and PJM in Eastern Interconnections
- Identified discrepancies by comparing range and angle pair plots for common angle pairs in different ISOs (e.g., Niagara – Farragut in PJM and NYISO)
- Correlated power flows at key interchange points and angle differences between selected angle pairs
- Established ranges for the selected angle pairs in the NYISO, NE-ISO, MISO and PJM. These limits can be used by operators real time for situational awareness and for alarms and alerts.
- Analyzed outliers in MISO and PJM to understand root cause and severity level
- Reports sent out to various ISOs

Deliverables and Schedules

- **Phase Angle and power flow analysis for study period (2010/2011)**
  - Local segments - Completed for all four ISOs
  - Wide area segments – in start-up.
- **Sensitivity analysis of data under normal conditions from**
  - Historical State Estimator heavily loaded cases – in progress for MISO
- **Extend analysis to other reliability parameters such as:**
  - Power/Voltage sensitivities at critical busses (PJM / MISO)
  - Power/Angle sensitivities for critical transmission paths (PJM/MISO)
- **Analysis Reports submitted to different ISOs for review and feedback**
- **A review meeting held with all ISOs on April 19, 2013**
- **Additional analysis for reliability management – study of highly stressed future operating scenarios planned to:**
  - validate limits from above analysis using a Stressed Planning case
  - define sensitivity patterns that operators may see in the future under normal, stressed, and line outage conditions (MISO)

Risk Factors

- **Data Formats Not Consistent. All ISOs have provided data. The data from ISOs is in different formats:**
  - **MISO and PJM have provided SE data**
  - **NYISO and NE-ISO have provided limited voltage angle, and power flow data**
- **Data Time Periods Not Consistent - data coordination and merging have been difficult**
- **Continuing Project Adjustments Based on Learning and ISO Feedback Project e.g., zonal analysis, seasonal analysis for PJM**
- **Lack of validated SE data with phasor measurement system data**

Base Lining Study Process Overview

- Identify major locations for angle pair monitoring
  - Wide area angle pairs (with ISOs and across ISOs)
  - Segment angle pairs (for each wide area angle pair)
- Identify critical power paths, sources and sinks
- Analyze past historical data (Phasor/EMS/State Estimator data) and obtain baselining limits information for peak, off-peak and seasonal conditions on identified paths flows, angle pairs and voltage at key locations
- Analyze datasets received from different ISOs for different system operating conditions such as:
  - Peak load
  - Off-peak load
  - Seasonal (summer, winter, light spring, etc.)
  - Stressed cases
- Compare results and establish operating ranges

Why Use Recorded SE or EMS Data for Establishing Ranges ?

- SE or EMS data is easily available for last few years
- Typically, SE data is at 3-5 minutes interval
- Large area coverage, entire control area + neighboring systems
- Large time duration (8-16 months in this study)
- Contains power flow, voltage angle and voltage magnitude data
- Good for static system limit analysis
- SE cases can be used for advanced analysis, such as
  - Voltage sensitivities
  - Angle sensitivities
  - Contingency analysis
- Detailed analysis is conducted on selected heavy loaded conditions

How Are the Range Limits Decided?

- Typically max and min for the data for *normal system* conditions
  - Exclude outliers in the box-whisker charts or needle peaks in the Time duration plots
  - Use "Filters" to exclude transient effects when selecting range
- Comparison/validation with power flows on the paths
- Range can be established based on
  - Yearly basis (In this present analysis)
  - Seasonal basis (Analysis done for PJM)
  - Peak / Off-peak basis (Analysis done for PJM)
- Operating ranges are needed to guide operators in real-time e.g., use of RTDMS or similar programs
  - Alert - 90 percent (Yellow)
  - Alarm - 100 percent (Red)

Example of Analysis Results for Angle Pairs in NYISO Area

NYISO West-East (Generation – Load) High Wide Area Angle Pair

Angle Pairs Type	NYISO Angle Pairs	Sep 2010 to Dec 2010		Jan 2011 to Apr 2011		Suggested Limits	
		Min (deg)	Max (deg)	Min (deg)	Max (deg)	Min (deg)	Max (deg)
Wide Area	Niagara - Farragut	4	102	21	97	4	102
	Marcy - Farragut	7	63	16	60	7	63
	Gilboa - Farragut	4	45	5	36	4	45
	Niagara - Sprainbrook	4	90	20	96	4	96
Common Area	Marcy - Sprain Brook	6	54	16	58	6	58
ISO-NE	Marcy - Sprain Brook	7	53	17	54	7	54
	Oakdale - Dun Woodie	7	48	14	49	7	49
ISO-NE	Oakdale - Dun Woodie	8	47	15	48	8	48
	Gilboa - Pleasant Valley	0	23	2	22	0	23
ISO-NE	Gilboa - Pleasant Valley	0	59	2	22	0	59
	Fraser - Millwood	4	34	8	36	4	36
ISO-NE	Fraser - Millwood	5	34	8	33	5	34
Segment Area Zone 1	Niagara - Clay	-11	33	-7	34	-11	34
Segment Area Zone 2	Clay - Marcy	3	13	1	12	1	13
	Marcy - Leeds	0	31	8	30	0	31
	Leeds - Millwood	3	25	4	26	3	26
Segment Area Zone 3	Marcy - Pleasant Valley	3	43	12	44	3	44
	Gilboa - Leeds	-3	9	-1	9	-3	9
	Leeds - Pleasant Valley	2	15	2	15	2	15
Segment Area Zone 4	Millwood - Sprain Brook	1	5	0	5	0	5
	Pleasant Valley - Sprain Brook	2	16	2	15	2	16
	Sprain Brook - Farragut	0	14	0	2	0	14

Example of Analysis Results for MISO System

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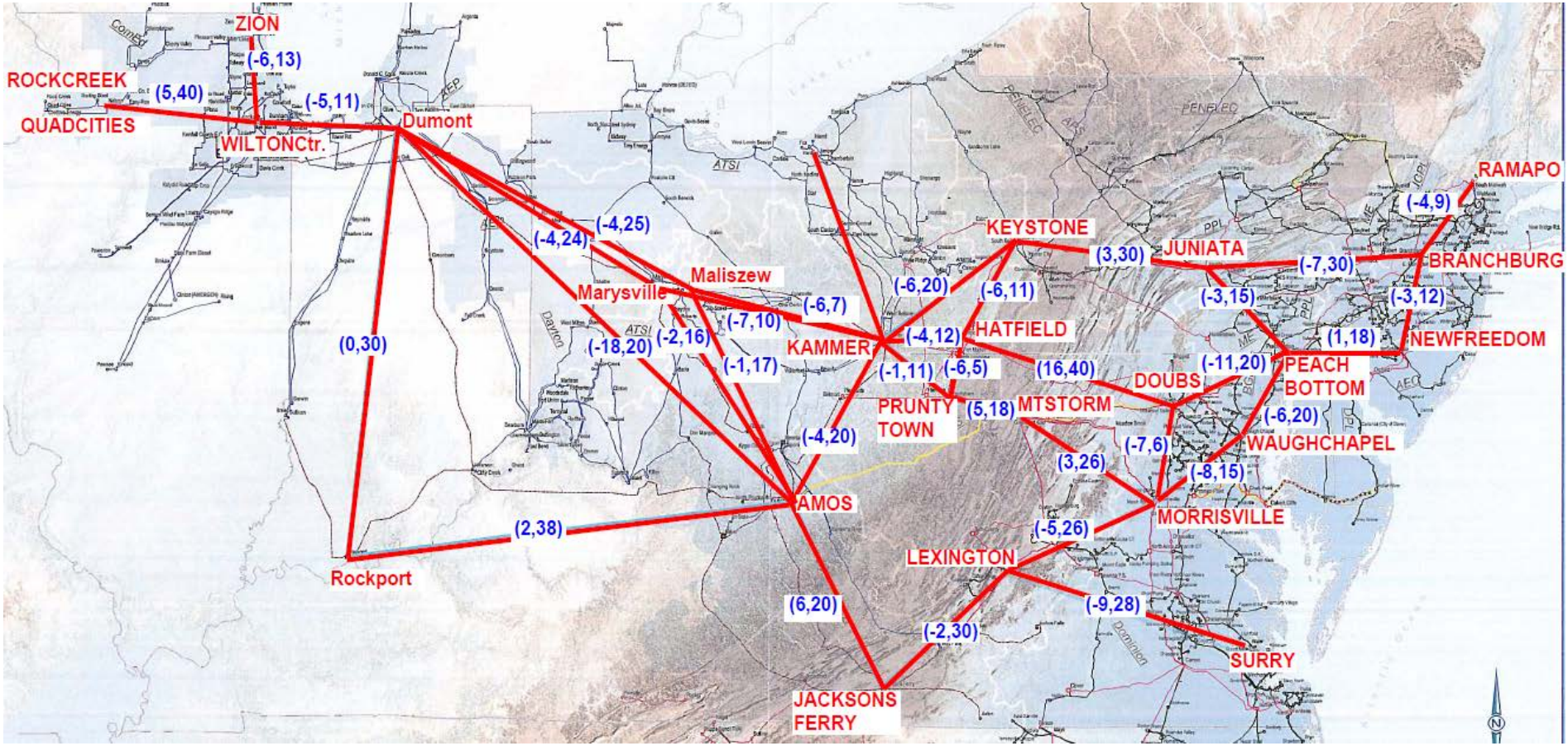
Example of Analysis Results for PJM for 35 Selected Angle Pairs



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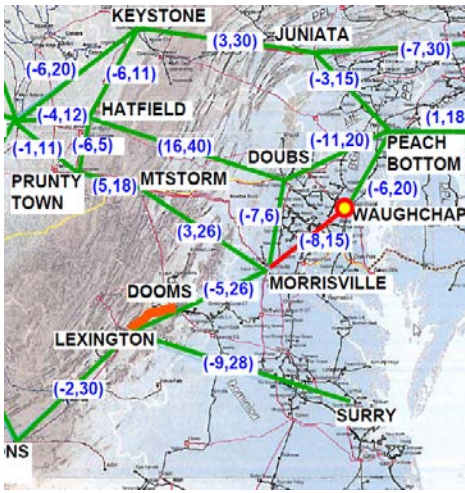
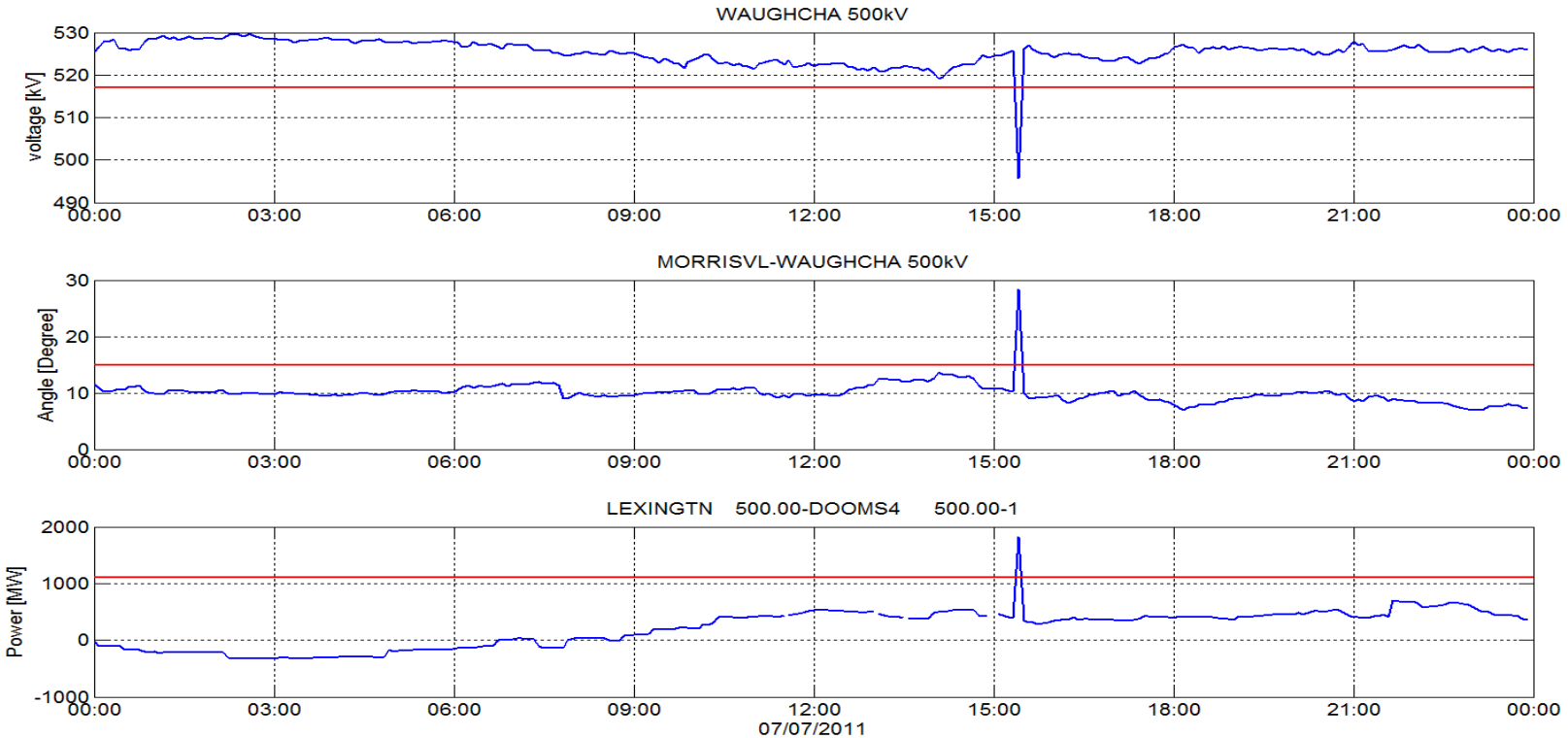
Example of Outlier Analysis - July 7, 2011 Event

- Outlier analysis - root cause assessment and severity level
- Results compared with PNNL analysis
- This outlier shows violations of
  - Power flow
  - Angle difference
  - Voltage level
- The situation may be classified as Level 3 and requires alerting operator





Stitching Data for Wide Area Monitoring of EI System

- Wide area monitoring is essential to ensure reliability of the entire Eastern Interconnection system
- Since EI data is not available, EPG is working to stitch the data from different ISOs to
  - establish the angle pairs that can be monitored across ISOs
  - establish the range of operation for the selected angle pairs
- EPG will conduct analysis using the SE data
- For analysis of inter ISO angle pairs, SE data for the same period is needed from all the ISO's
  - suggest using 2012/2013 data
  - data in the same format preferable
- Use of PMU data for inter ISO angle pairs is preferable – future step

Next Steps in Future Research

- Complete base lining and detailed analysis of 2012 data and stressed conditions /cases for the four EI ISOs
- Combine data from four ISOs and define wide-area angle pairs and their ranges between locations selected between ISOs
- Revise and recommend angle pair ranges for EI for use in real-time monitoring
- Analyze and compare actual performance against recommended range including analysis of outliers – number and type of violations
- Update ranges based on field experience, validation and changing system characteristics
  - resource mix and topography
- Conduct Voltage and Angle Sensitivities at critical locations
- Original Target completion date was September 2013
- New proposed target date 4Q FY2014 because of increased data processing and expanded scope of effort required
- Knowledge Transfer and development of a "Report & Hand Book for SE/Phasor system Data Analysis"

Thank You.

Any questions ?

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