Eastern Interconnection Phase Angle Base Lining Study

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Project Objective

- Operators monitor power flows at specific interchange points (like Keystone-Juniata). However, power flows may not be a good measure of wide area system stress
- Phasor networks provide the capability to monitor in real-time phase angle differences 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
- Research objective is to develop approach for EI baselining using data from different ISOs and establish limits for use in real-time operations
- Approach utilized is to use data from state estimation and stressed power flow cases to:
  - analyze phase angle difference and
  - other power system metrics to establish baseline for performance, and
  - utilize baseline data to establish benchmarks and operating norms for use by operators

Major Technical Accomplishments

- Conducted statistical analysis of State Estimator/EMS data to define high, medium, and low phase angle thresholds for selected angle pairs in:
  - New York ISO (NY ISO – 18 pairs)
  - New England ISO (NE ISO – 54 pairs)
  - PJM (In progress – 104 pairs)
  - Mid West ISO (MISO- in progress)
- Determined phase angle separation limits for selected angle pairs for the NY ISO, NE ISO and PJM in Eastern Interconnections
- Processed data from ISOs to make it suitable for baselining analysis
- Compared threshold limits and angle pair plots for common angle pairs in different ISOs (e.g. Niagara – Farragut in PJM and NY ISO)
- Correlated power flows at key interchange points and angle differences between selected angle pairs
- Established threshold limits for the selected angle pairs in the NY ISO, NE ISO and PJM. These limits can be used by operators for situational awareness and for alarms and alerts. These limits can be utilized in real time applications such as RTDMS

Deliverables and Schedules

- Phase Angle and power flow analysis for study period (2010/2011)
  - Local segments
  - Wide area segments
- Sensitivity analysis of data under normal conditions from
  - Historical State Estimator heavily loaded cases.
  - A heavily loaded and stressed power case of future year
- Analysis of highly stressed future operating scenarios 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
- Extend analysis to other reliability parameters such as:
  - Power/Voltage sensitivities at critical busses
  - Power/Angle sensitivities for critical transmission paths

Risk Factors

- All ISOs have provided data. The data from ISOs is in different formats and for different time period:
  - MISO and PJM have provided SE data
  - NY ISO and NE ISO have provided limited voltage angle, and power flow data
- Data received is not consistent and data coordination and merging has been difficult
- Project started late as data release was delayed
- Work scope is similar to PJM analysis reported earlier. Project scope will be refined further with individual ISOs, as the work progresses and the analysis reports are reviewed
- Validation of SE data with phasor measurement system data is very important

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 threshold limits

EI Baselining Phase Progress as of May 21, 2012

EI Baselining As of 5/21/2012										
Phase	High-Level Methodology	Baselining Procedure	NYISO	Completed Date	NEISO	Completed Date	PJM	Completed Date	MISO	Completed Date
	Data Description	Date Type	State Estimator		State Estimator		State Estimator		State Estimator	
		File Type	Excel Worksheet		Excel Worksheet		PSSE Cases		PSSE Cases	
		Data Time Duration	Sep 2010 - Apr 2011		May 2010 - Apr 2011		Jan 2010 - Nov 2011		May 2010 - May 2011	
I	Data Extraction	Data Extraction from datasets obatined from ISOs	[1]		[1]		√	15-Apr	√	15-May
	Obtain Informatinon	Obtain information about number of buses and bus mnemonics.	√	3-Feb	√	1-Mar	√	22-Feb	√	22-Feb
		Check availability of metrics in the datasets for Angles, voltages, and power flows.	√	7-Feb	√	7-Mar	√	28-Feb	√	28-Feb
	Identify buses/lines to be monitored	Identification of generation and load in footprint of region	√	10-Feb	√	21-Mar	√	10-Mar	√	10-Mar
		Identification of wide area and segment angle pairs	√	13-Feb	√	6-Apr	√	10-Mar	√	10-Mar
		Identification of common angle pairs with other datasets (if provided) for the same time period	√	15-Feb	√	13-Apr	√	17-Apr	√	17-Mar
		Select bus voltages and power flows for comparison with other datasets.	[2]		[2]		√	17-Apr	√	17-Mar
	Perform statistical analysis and plot distribution charts	Perform Statistical analysis on the identified angle pairs, bus voltages and lines to be monitored	√	22-Feb	√	27-Apr	√	10-May	√	
		Plot time duration curves and box-whisker charts	√	29-Feb	√	4-May	√	10-May	√	
	Identify stressed conditions	Identify heavy loaded conditions on the system like high angle differences	√		√		√		√	
		Identify heavy stressed conditions on the system like voltage stressed periods and high flows on corridors	√		√		√		√	
		Identify seasonal patterns and daily on- and off-peak conditions	[2]			[3]	√		√	
	Comparison and validation of dataset with other datasets/PNNL results	Validation of common angle pairs, bus voltages and flows with other datasets	√		√		√		√	
		Validation of statistical results/analysis with PNNL study results	√		√		√		√	
		Identify outliers and mismatch of data trend	√		√		√		√	
	Baseline selected site pairs	Establish suggested limits for all identifed angle pairs under normal conditions	√		√		√		√	
		Establish suggested limits for heavy stressed conditions, on- and off- peak conditions and seasonal patterns	[2]				√		√	

Notes	
	[1] - Obtained state estimator dataset in Excel sheet spreadsheet
	[2] - Limited dataset (four months each in 2010 and 2011 containing VA only)
	[3] - Perform if needed as requirement
	√ - Work to be completed as part of this project
	Date - Is the date when work is completed

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Why use recorded SE or EMS data for establishing limits ?

- 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 months -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
- Validation of SE data with phasor measurement system data is very important

How are the threshold limits decided ?

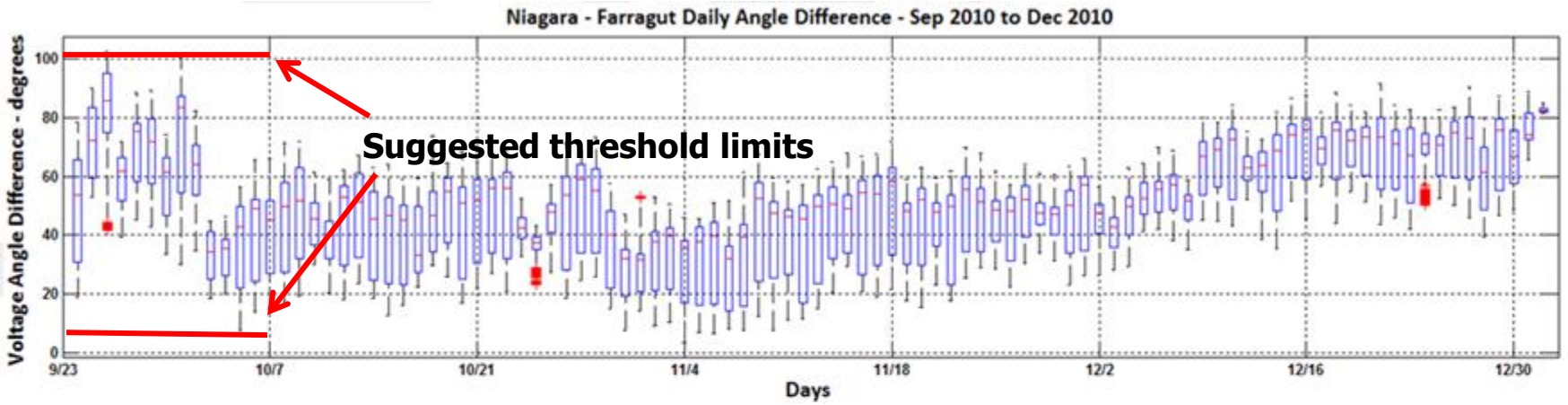
- Typically max and min for the data for ***normal system*** conditions
- Exclude outliers in the box-whisker charts or needle peaks in the Time duration plots
- Comparison/validation with power flows on the paths
- Limits can be established based on
  - Yearly basis (In this present analysis)
  - Seasonal basis
  - Peak / Off-peak basis
- Limits in RTDMS or similar programs can be set as
  - Alert - 90 percent (Yellow)
  - Alarm - 100 percent (Red)

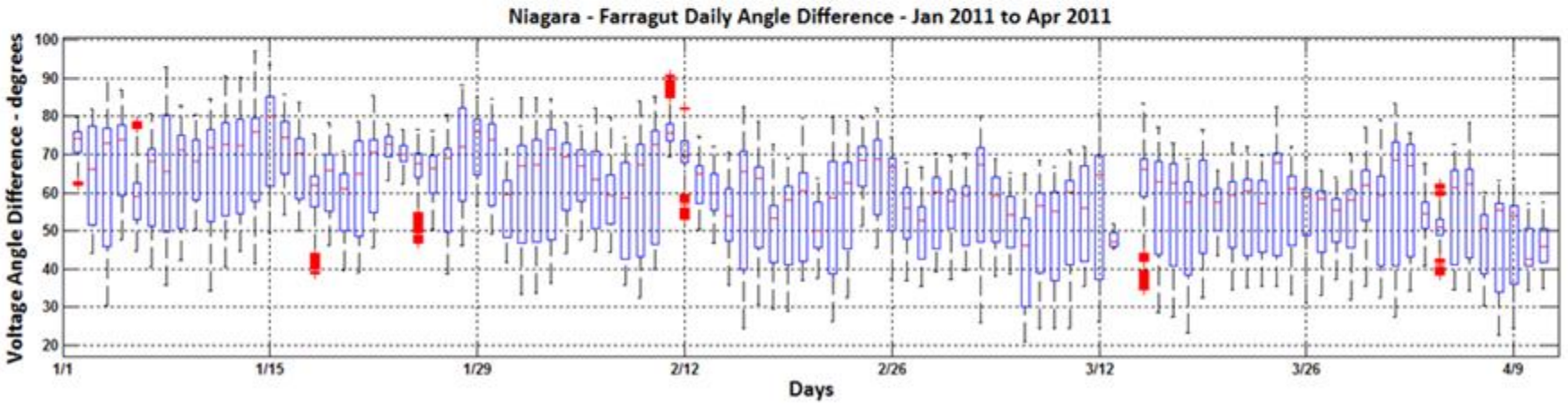
Angle Pairs with Suggested Thresholds Limits in NYISO Area

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

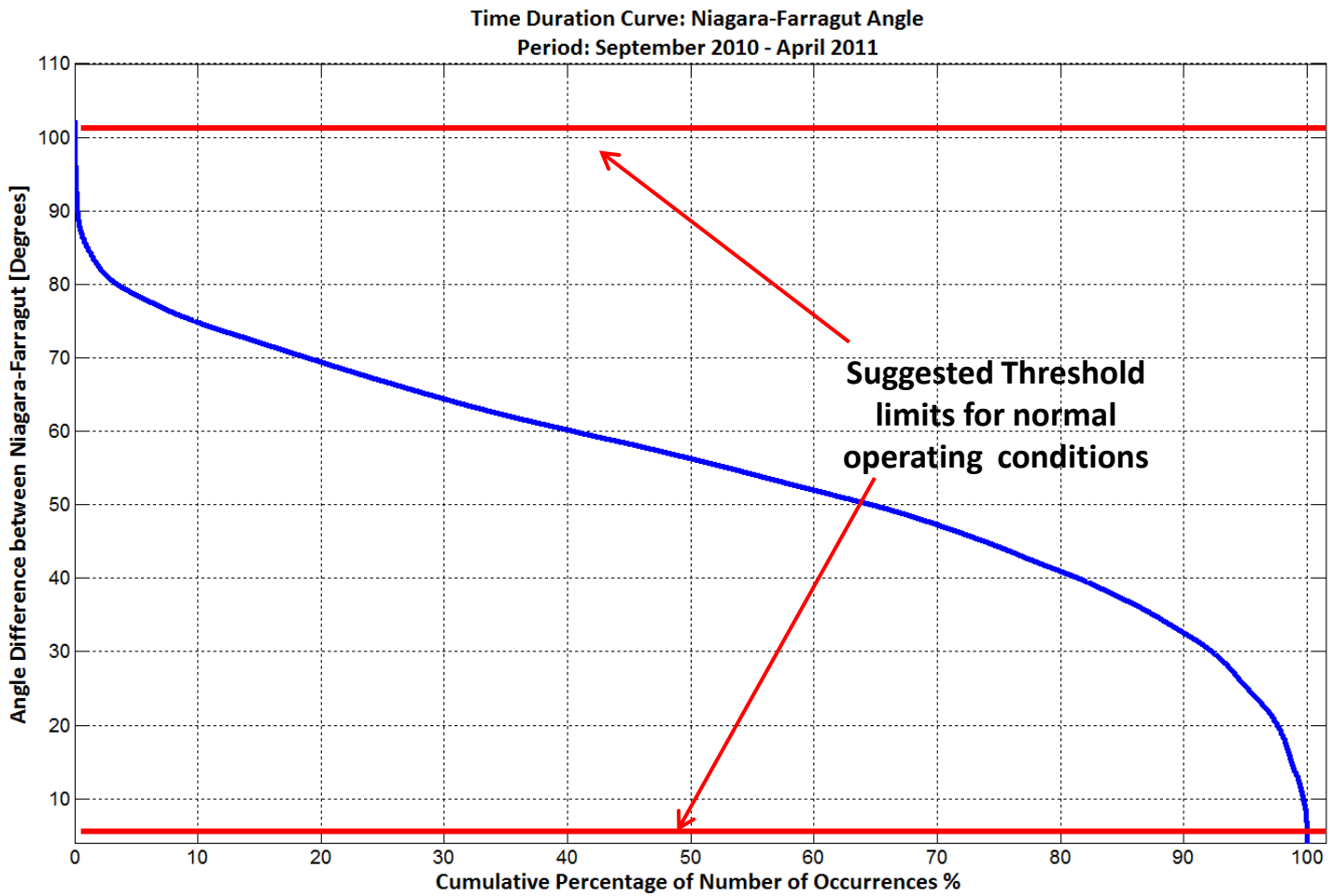
Angle Pairs Type	NYISO Angle Pairs	Sep 2010 to Dec 2010		Jan 2011 to Apr 2011		Suggested Limits	
		Min (deg)	Max (deg)	Min (deg)	Max (deg)	Min (deg)	Max (deg)
Wide Area	Niagara - Farragut	4	102	21	97	4	102
	Marcy - Farragut	7	63	16	60	7	63
	Gilboa - Farragut	4	45	5	36	4	45
	Niagara - Sprainbrook	4	90	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

Niagara – Farragut (NY ISO) Wide Area Angle Pair Box-Whisker Plot





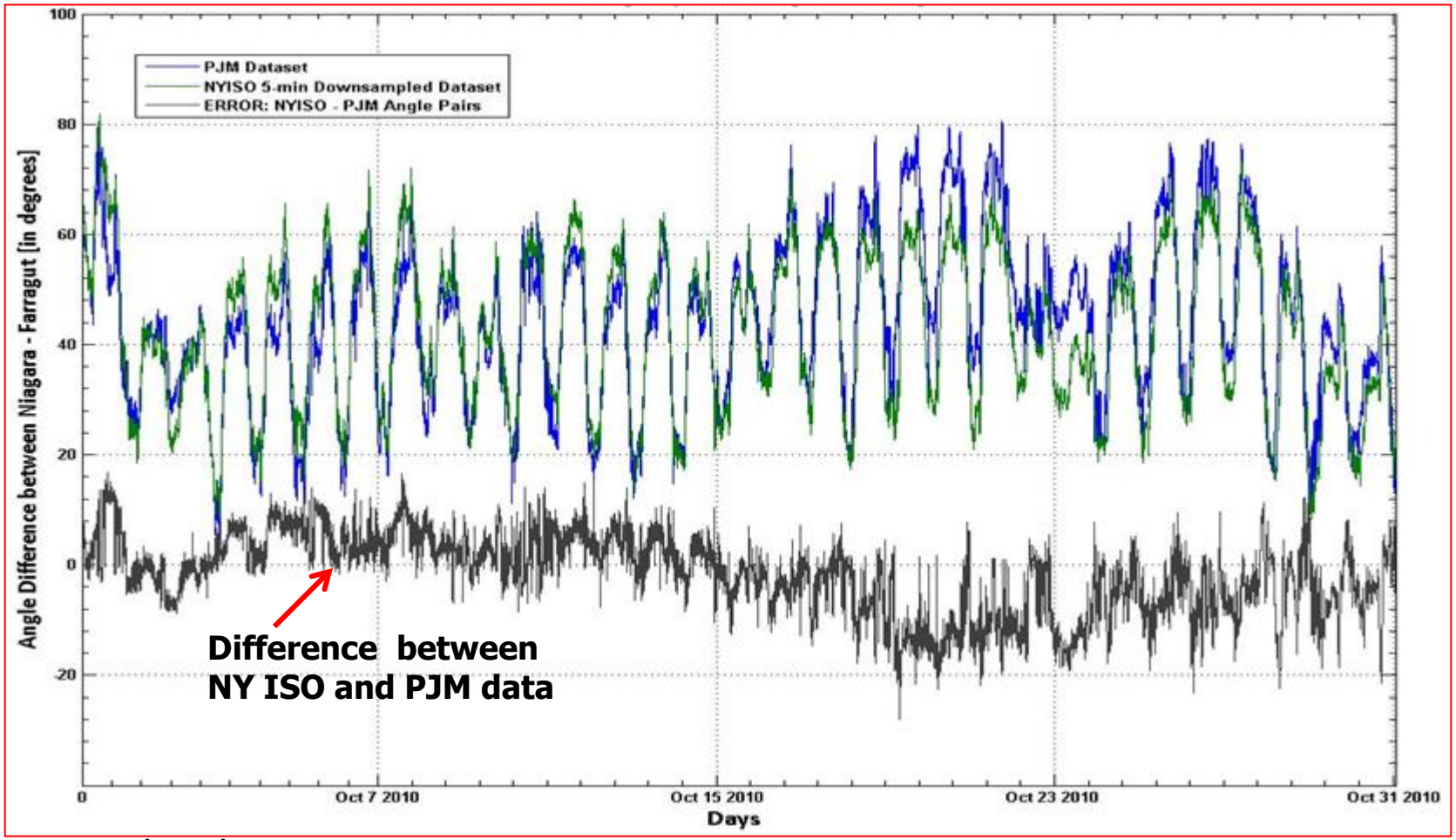
Niagara – Farragut (NY ISO)Wide Area Angle Pair Time Duration Plot



Angle Pairs with Suggested Thresholds Limits in PJM Area

PJM Angle Pairs		Base (kV)	Sep 2010 to July 2011		Suggested Limits		2009 Limits	Desired Limits
			Min (deg)	Max (deg)	Min (deg)	Max (deg)	Max (deg)	Max (deg)
JACKSONS	CLOVERD2	500	-2	36	2	23	10	23
BAKER	BELMONT	765	-6	39	-6	13	12	13
BAKER	MARYSVI2	765	-7	40	-8	14	15	15
BELMONT	WYLIERID	500	-5	23	-4	18	18	18
22 ZION	DUMONT2	345	-21	42	-7	28	25	28
112 WILT	DUMONT2	765	-7	47	-1	15	25	25
JEFFERSO	DUMONT2	765	-12	21	-8	16	25	25
4 QUAD C	3 POWERT	345	-23	33	-11	34	30	34
CLOVERD2	CARSON4	500	-5	30	-2	28	30	30
YUKON	CARSON4	500	-9	43	-2	42	30	42
3 POWERT	DUMONT2	345	-11	58	5	45	35	45
BLACKOAK	JUNIATA	500	-16	34	-12	30	35	35
4 QUAD C	22 ZION	345	-5	41	10	41	40	41
4 QUAD C	112 WILT	345	-14	83	5	44	40	44
BELMONT	DOOMS4	500	1	48	8	46	40	46
KEYSTONE	JUNIATA	500	-1	39	2	35	40	40
MTSTORM4	DOUBS	500	-3	28	3	30	40	40
DUMONT2	ERIEW	345	-14	67	4	56	45	56
MTSTORM4	CONASTON	500	-18	53	-9	41	45	45
KEYSTON2	ERIEW	345	-35	56	-31	31	45	45
WYLIERID	CONASTON	500	-6	63	4	57	60	60
RAUN 6	FARRAGUT	345	-3	215	63	207	190	207

Comparison of PJM and NYISO Data
Niagara-Farragut (NYISO Footprint) – October, 2010



ERROR = (A – B)

A – NYISO 5min Down sampled Dataset

B – PJM Dataset

Base Lining Study
Summary / Conclusions

- Analysis completed for New York (VM and VA) and New England ISOs (VA and MW) for common time period between September 2010 to April 2011
- NASPI Interim draft report was submitted to NASPI project manager on March 15, 2012. Next report will be submitted June 15, 2012
- Baselining Limits for Angle pairs are suggested
  - New York ISO
  - New England ISO
- Data Comparison and validation performed and analyzed for
  - PJM and NYISO
  - NE ISO and NY ISO
- Base lining analysis is in progress for PJM and MISO systems
- Further analysis will be conducted on summer data for New England ISO for the time period between May 2010 to August 2010
- Major Path flows and angle pairs are being co-related for PJM, New England ISO
- Voltage and Angle sensitivity analysis will be conducted for New England ISO, PJM and MISO systems

Next Steps in Future Research

- Complete base lining and detailed analysis of 2012 data and stressed conditions /cases for the four EI ISOs
- Revise and recommend angle pair threshold limits for EI for use in real-time monitoring
- Analyze and compare actual performance against recommended limits – number and type of threshold violations
- Update thresholds based on field experience and validation
- Update thresholds based on changing system characteristics
  - resource mix and topography
- Conduct Voltage and Angle Sensitivities at critical locations
- Original Target completion date –was September 2012
- New target date - 3Q FY2013 because of increased data processing effort required

Thank You.

Any questions ?

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