ERCOT Synchrophasor Data Baselining Study

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NASPI

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Data Baselining Study - Outline

- Introduction
- Background
- Study Objective
- Methodology and Approach Used
- Observations
- Analysis Results
- Benefit & Success Story
- Summary

Discovery Across Texas

Regional Demonstration Grant DOE-OE-0000194

- Center for the Commercialization of Electric Technologies
  - Dr. Milton Holloway - President
- Project TO/asset owner partners
  - American Electric Power Texas – 18 locations*, 1 PDC
  - Oncor Electric Delivery - 15 locations*, 3 PDCs
  - Sharyland Utilities - 3 locations*, 1 PDC
  - Electric Reliability Council Of Texas (ERCOT) - 1 PDC, RTDMS visualization platform, ePDC data archiving, PGDA event analysis
  - Texas Tech University – Wind Science and Engineering Center – wind and battery storage performance, 4+ PMUs, 1 ePDC, RTDMS, Security Fabric Demo
- Electric Power Group – synchrophasor tools & services
- Southwest Research Institute – project management services

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	Total Planned Locations	Committed for Cost Share
AEP	18	4
Oncor	15	12
Sharyland	3	3
Texas Tech	5	-

INTRODUCTION

- **Three** conditions must be met for a production quality real-time phasor monitoring system at any Utility/ISO. The data must be:

    1. Flowing reliably from PMU's to Operator's console
    2. **Valid**
    3. Monitoring the critical locations (right places).

- The Data Baselining Study addresses the **second condition**

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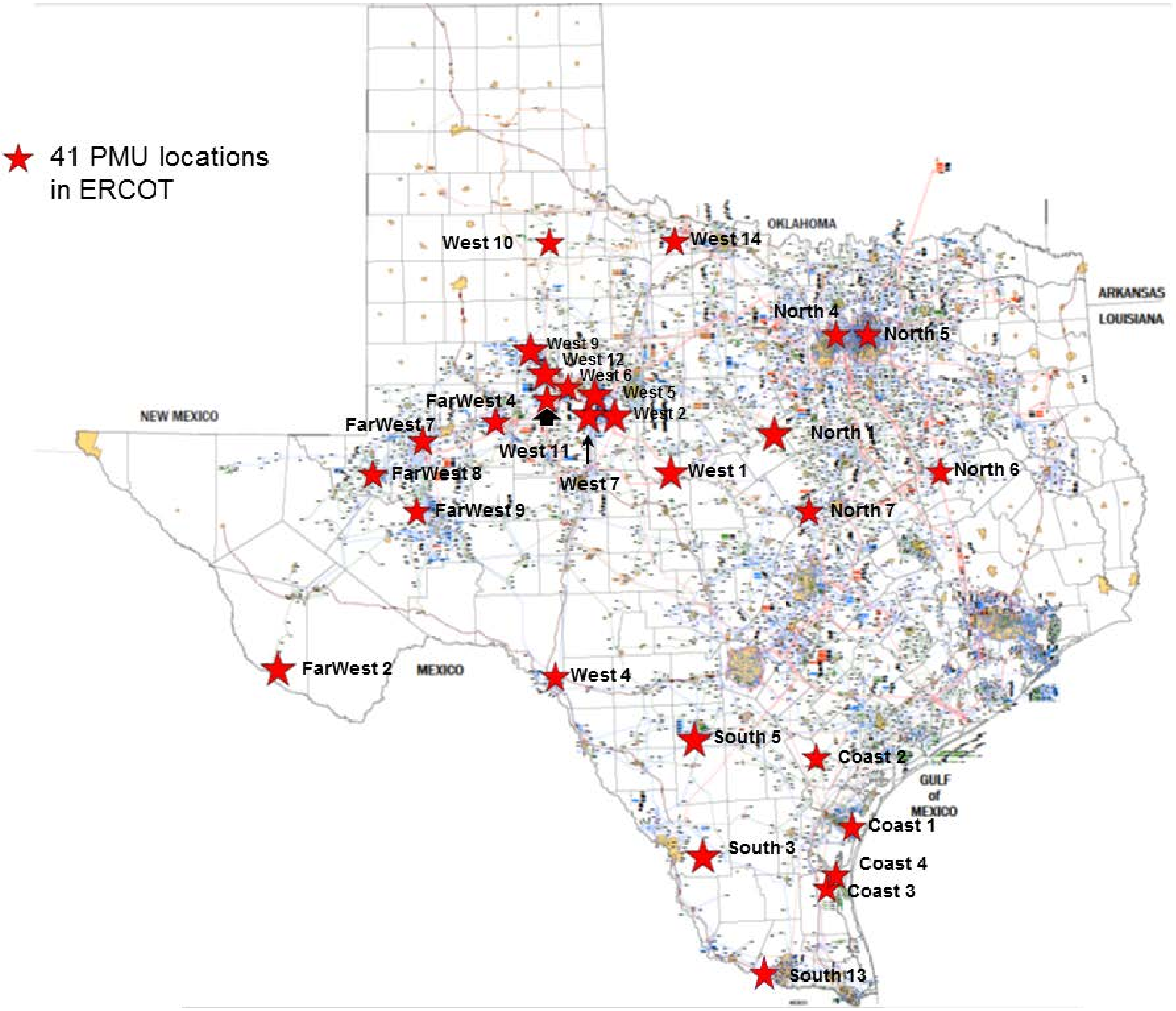
BACKGROUND – ERCOT PMU LOCATIONS



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Data Baselining Study - Need

- **Operators Need:**
  - **Data Accuracy** – For any phasor network, measurement data must be same as data used in current operations (such as State Estimator data)
  - **Alarm Limits** that can be used to translate PMU data into actionable items based on normal and abnormal operating conditions
- To use Phasor Data in operations, the Data needs to be
  - **Reliable** – Data Quality study was performed to address this
  - **Accurate** – Data compared with State Estimator data
  - **Actionable** – Data baselining analysis performed to identify alarm limits
- Study was initiated to perform baselining analysis on voltage magnitude/angle and angle difference pairs for key PMUs for the year 2012. The phasor data was validated by comparing with State Estimator data.
- The study was updated for year 2013 to account for newly installed transmission lines.

Study Objective

- Perform a comparison of voltage angle differences obtained using phasor measurements versus similar results using state estimator data (**phasor vs. state estimator comparison**)
- Perform a **baseline analysis** for voltage magnitudes and angle differences for selected pairs of substations.
- **Identify** normal system operating conditions and **alarm limits** based on the baseline analysis.
- **Implement alarm limits** in phasor data monitoring and analysis applications to identify and analyze abnormal system conditions.
- Revise and **update the alarm limits** to compare year **2013 vs 2012**

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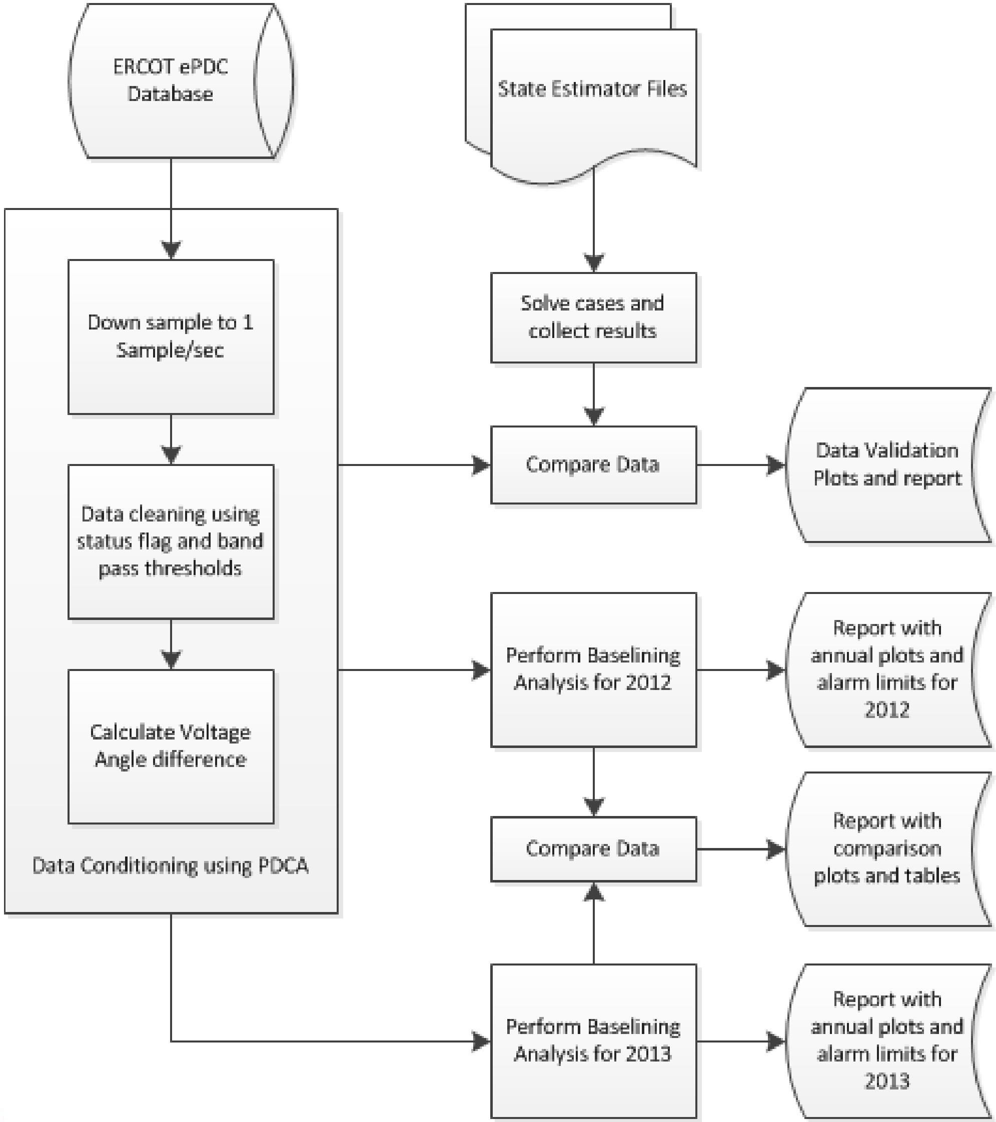
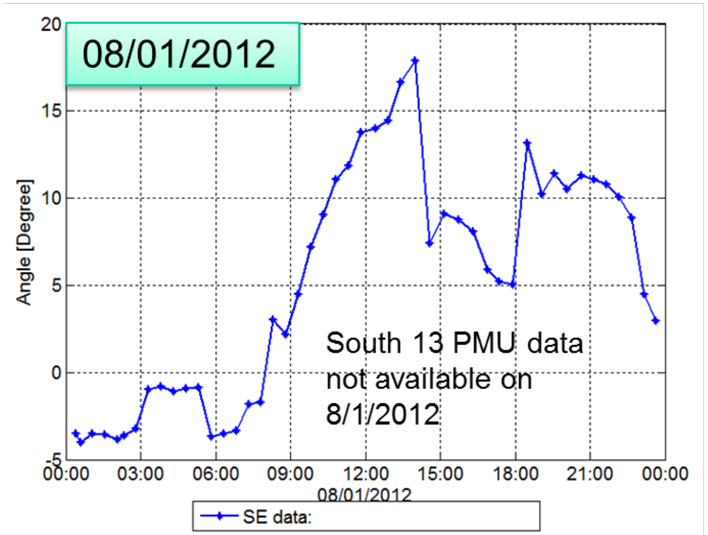
METHODOLOGY AND APPROACH

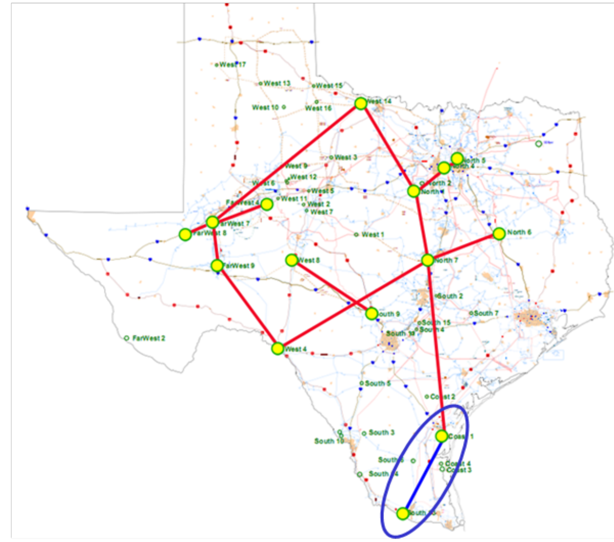
- Collect PMU and SE Data
- Perform data conditioning using Phasor Data Conditioning Application (PDCA)
- Compare PMU and SE data for selected days in 2012
  - August 1 (peak load)
  - November 23 (low load)
  - December 25 (high wind output)
- Perform baselining analysis for VM, VA and Angle Diff pairs
- Establish alarm limits
- Update alarm limits for year 2013

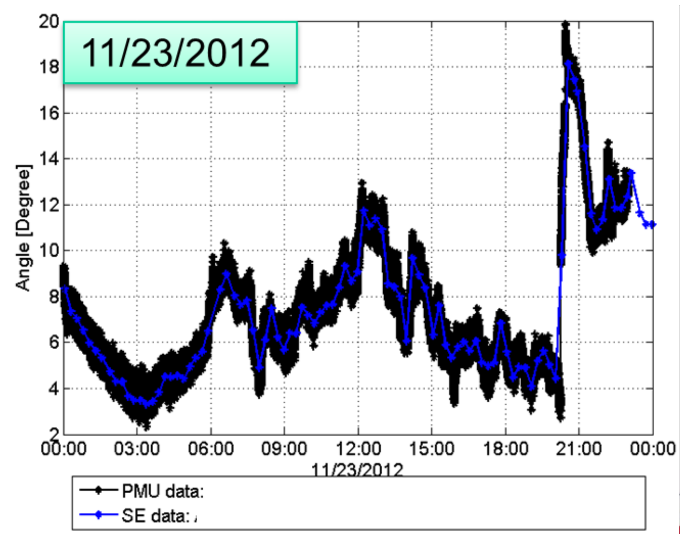


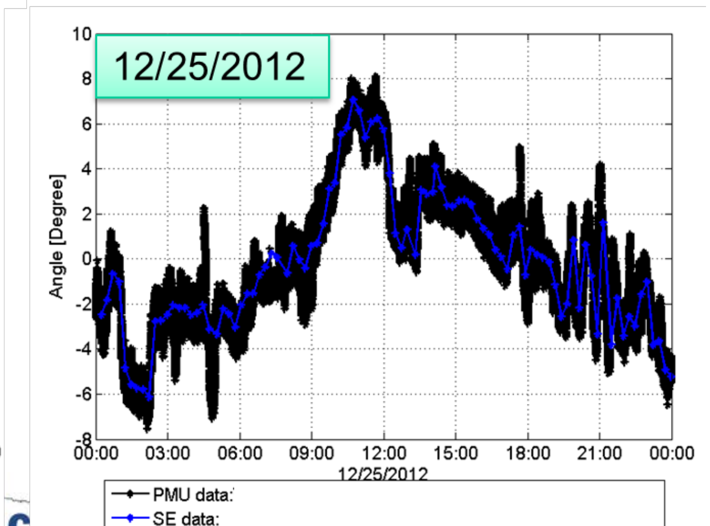
PMU Data vs SE Data Comparison -1

Coast 1-South 13









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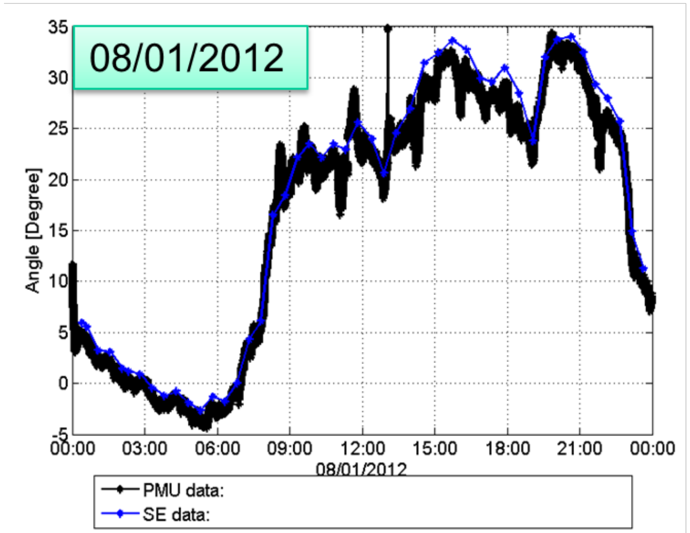
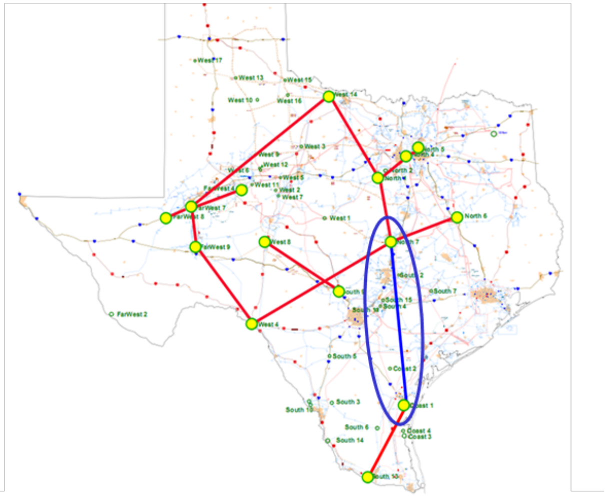
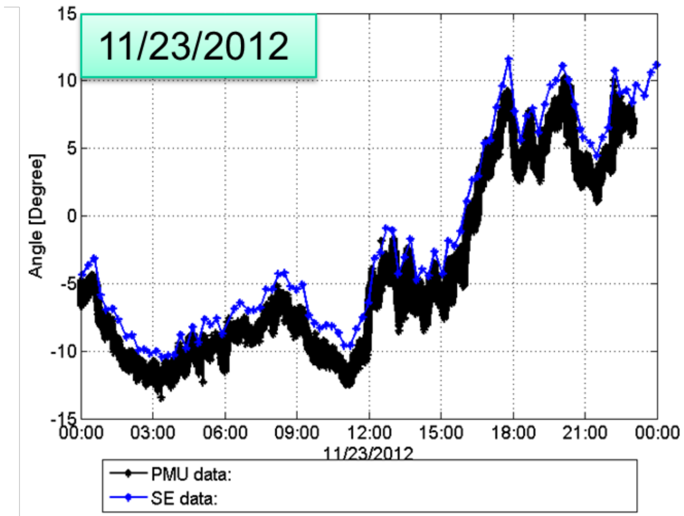
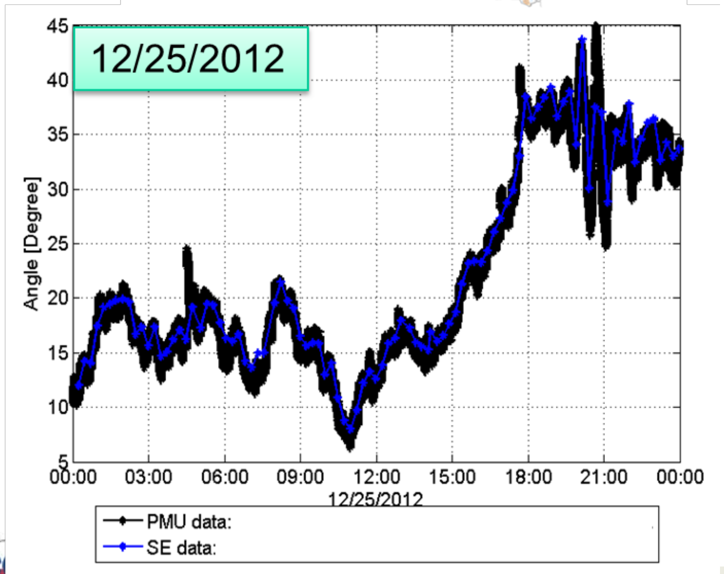
PMU Data vs SE Data Comparison - 2

Coast 1-North 7









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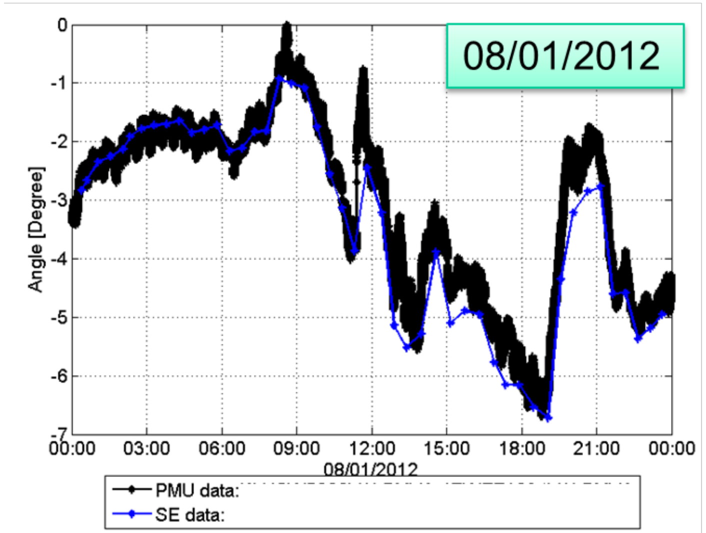
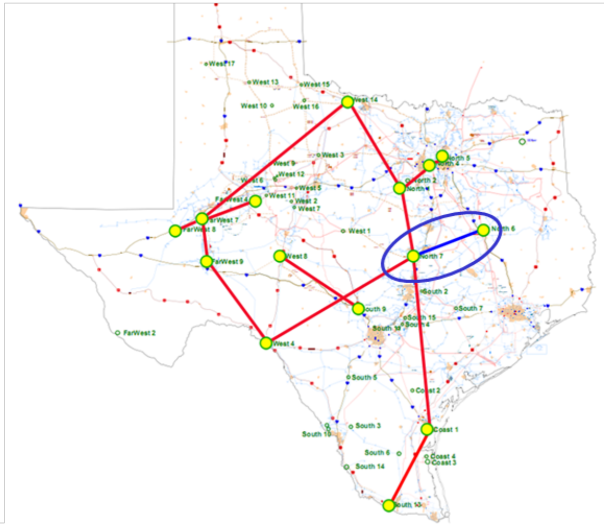
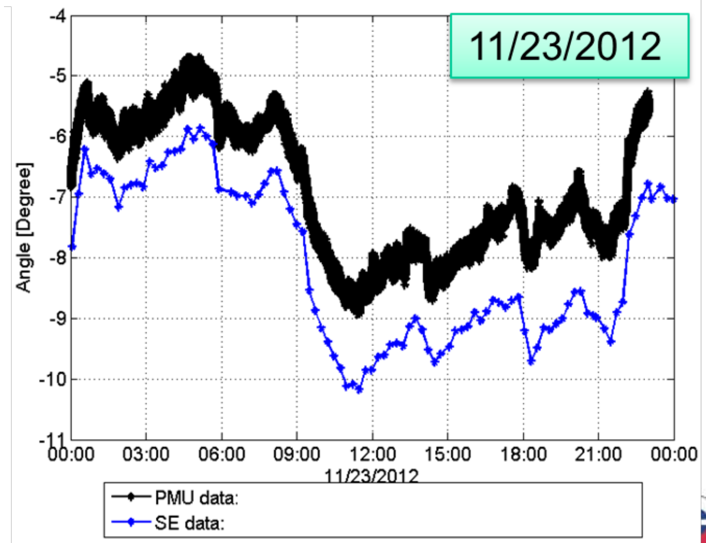
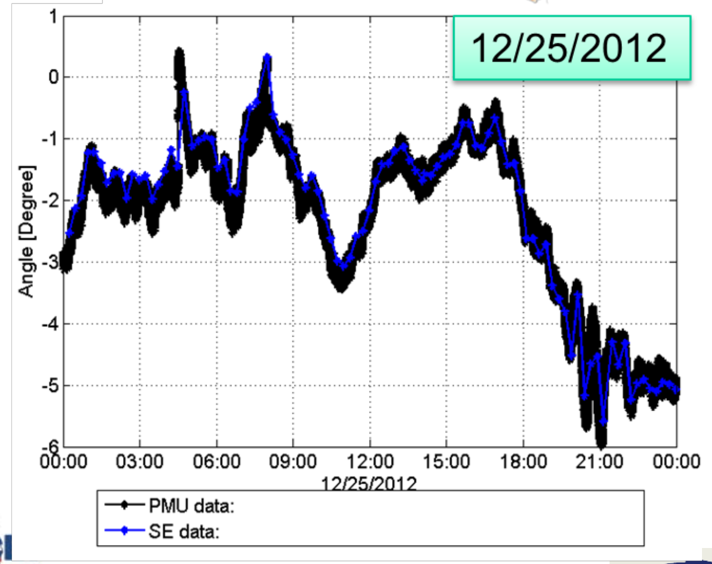
PMU Data vs SE Data Comparison - 3

North 7-North 6



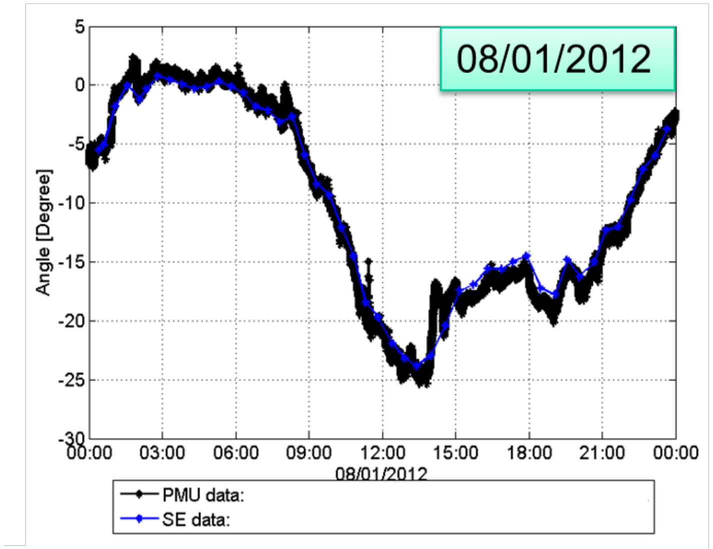


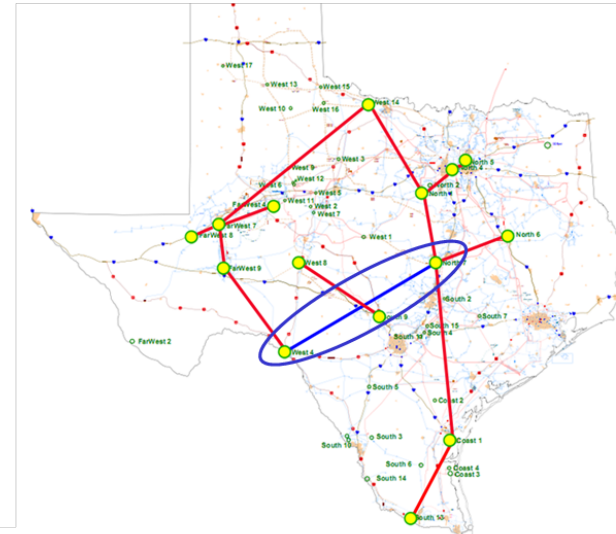


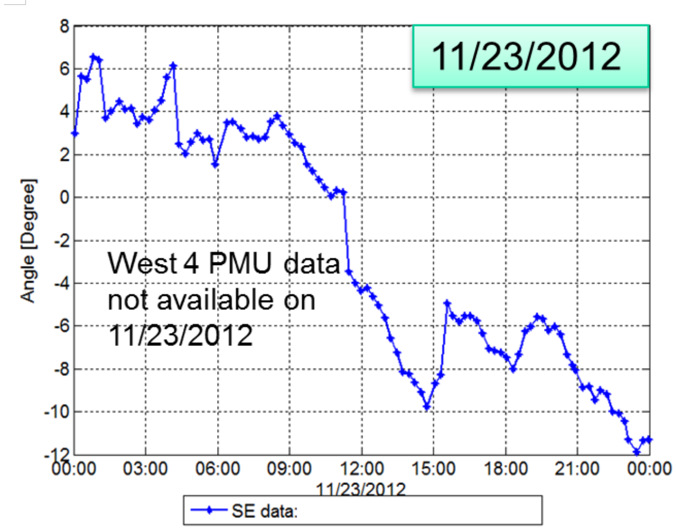


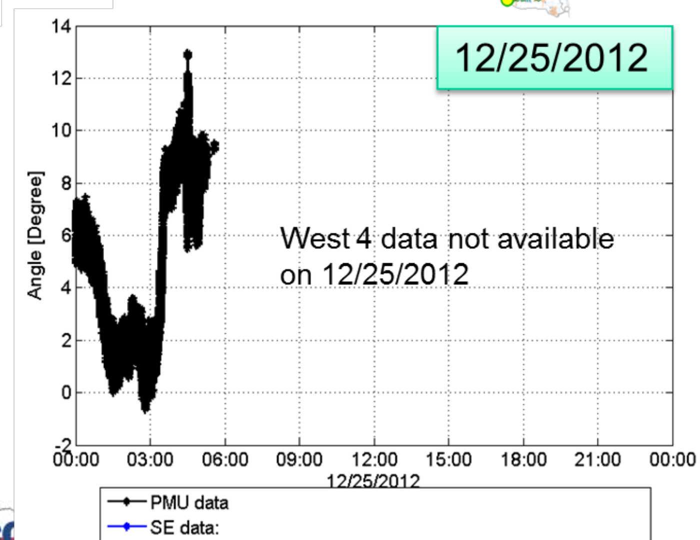
PMU Data vs SE Data Comparison - 4

West 4-North 7









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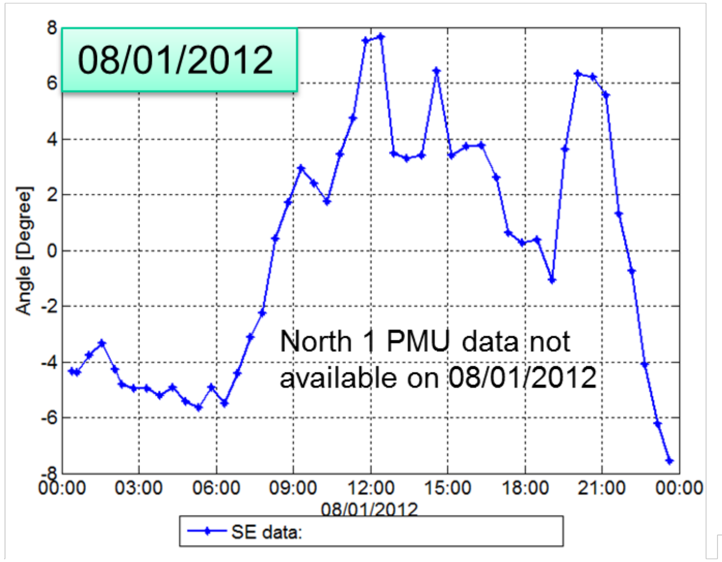
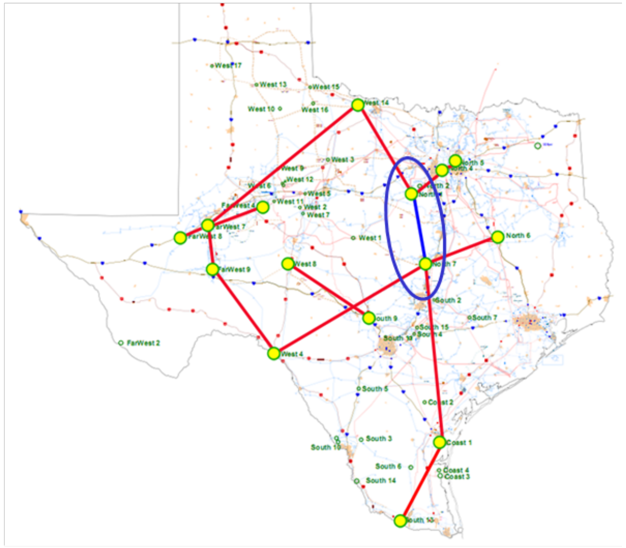
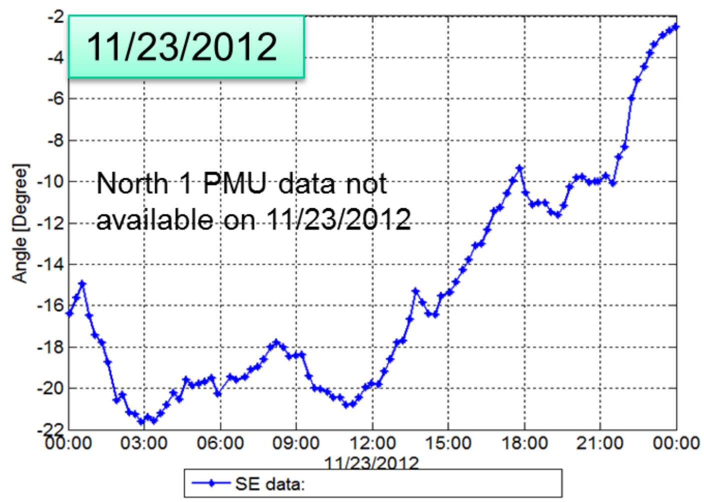
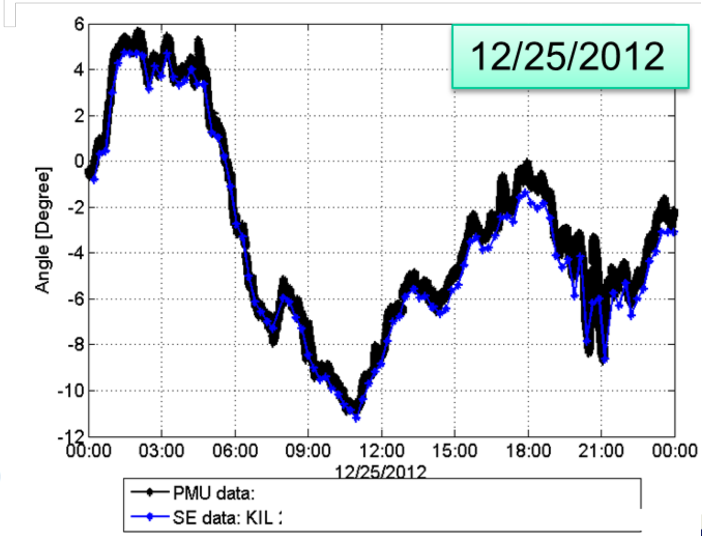
PMU DATA VS SE DATA COMPARISON - 5

North 7-North 1









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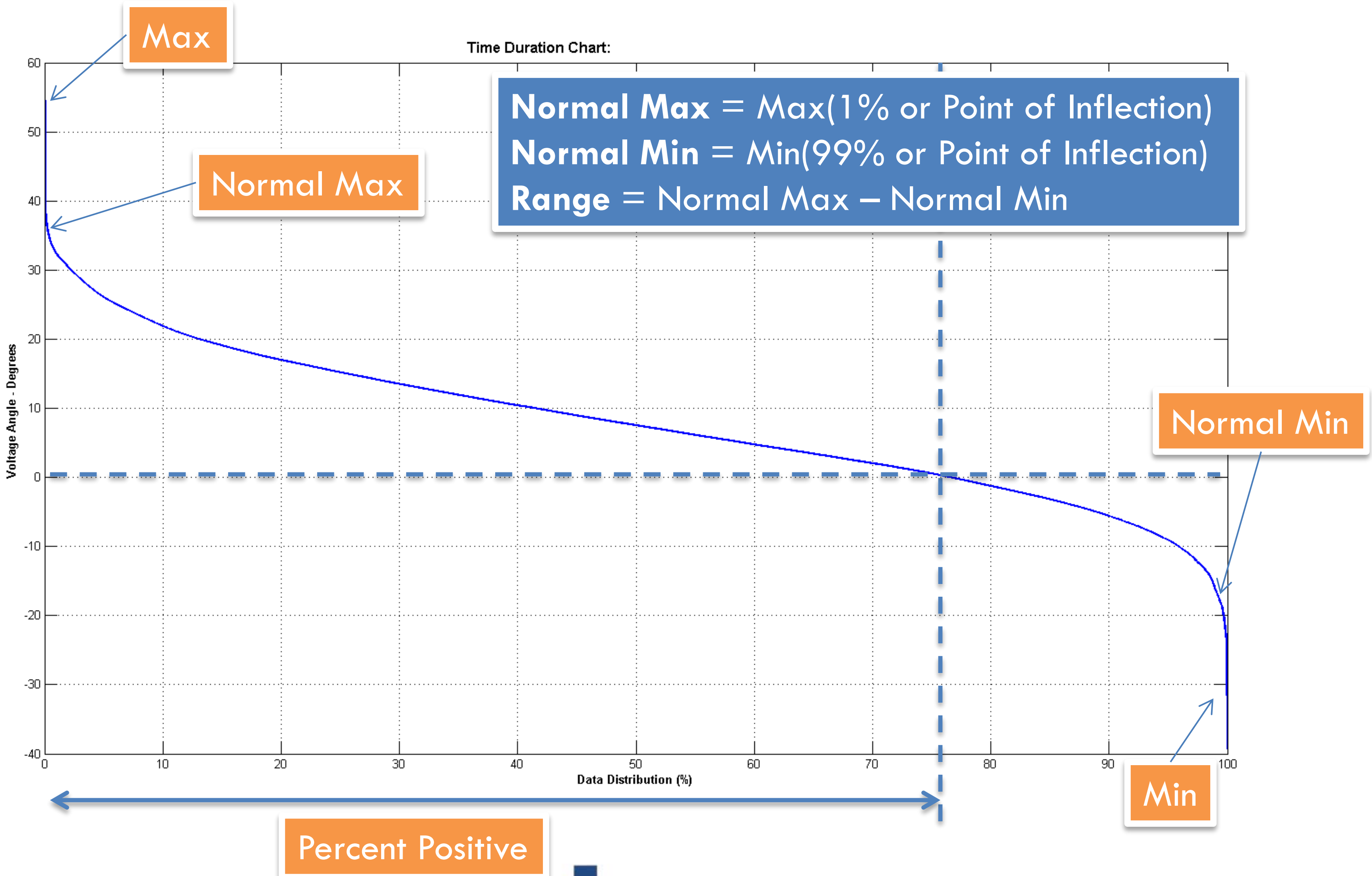
Baselining Analysis - Terminology

Normal Max = Max(1% or Point of Inflection)
Normal Min = Min(99% or Point of Inflection)
Range = Normal Max – Normal Min



Baselining Results – Voltage Magnitude

PMU	Base kV	Min	Normal Min	Normal Max	Max	Mean p.u.	Range	Percent Available
West 10	69	68.0	69.8	72.2	74.7	1.032	2.4	84.43
West 14	345	346.6	352.4	360.6	366.4	1.037	8.2	33.82
West 11	345	344.3	350.0	355.4	359.2	1.023	5.4	77.72
West 6	345	343.8	348.7	356.4	360.4	1.024	7.7	96.11
North 7	138	138.1	140.6	143.8	145.1	1.031	3.2	96.03
North 2	138	137.4	139.2	143.3	144.6	1.026	4.1	94.04
North 4	138	138.7	140.4	143.3	144.1	1.029	2.9	96.61
North 5	138	137.9	139.4	142.5	145.7	1.022	3.1	96.42
North 1	345	341.3	345.0	353.2	354.3	1.014	8.2	10.37
North 6	138	137.8	140.3	143.0	144.3	1.027	2.7	95.70
West 4	138	133.3	137.4	145.5	147.5	1.027	8.1	41.27
Coast 1	138	138.4	140.9	143.7	144.6	1.031	2.8	61.92
South 13	138	135.8	139.7	143.8	146.6	1.028	4.1	40.64
Coast 3	345	342.4	347.4	360.2	362.9	1.026	12.8	47.96
Coast 4	345	342.0	346.9	360.8	367.4	1.027	13.9	40.21
FarWest 8	138	137.4	139.7	143.8	145.5	1.004	4.1	73.53
FarWest 9	138	133.8	138.0	143.2	146.5	1.024	5.2	51.65
FarWest 4	345	347.2	352.2	356.8	360.6	1.027	4.6	95.52
FarWest 7	345	341.7	345.4	353.3	354.6	1.016	7.9	10.37
Coast 2	69	66.6	68.8	71.9	72.9	1.017	3.1	39.61
South 6	138	138.1	140.6	144.2	149.1	1.033	3.6	24.04

Coast 3 and Coast 4 with high range in voltage

Baselining Results – Voltage Angle

PMU	Base kV	Min	Normal Min	Normal Max	Max	Percent Positive	Range	Percent Available
West 10	69	-50.62	-36.54	57.70	86.46	64.09	94.24	80.76
West 14	345	-30.47	-18.22	32.83	51.50	71.45	51.05	31.78
West 11	345	-38.23	-27.33	47.77	58.28	61.95	75.1	76.97
West 6	345	-35.80	-25.43	46.82	57.41	66.36	72.25	95.24
North 2	138	-19.38	-13.13	19.64	26.35	70.45	32.77	93.11
North 4	138	-22.68	-16.30	14.27	21.60	47.73	30.57	95.72
North 5	138	-24.71	-18.38	12.66	19.82	37.84	31.04	95.55
North 1	345	-14.24	-10.18	21.04	27.29	88.37	31.22	10.08
North 6	138	-13.81	-0.14	15.42	46.79	98.58	15.56	94.80
West 4	138	-45.26	-29.93	14.76	34.93	25.60	44.69	39.21
Coast 1	138	-39.23	-16.02	32.30	54.52	76.87	48.32	60.29
South 13	138	-40.88	-20.26	32.75	49.78	65.31	53.01	39.03
Coast 3	345	-29.61	-15.14	29.34	55.00	74.96	44.48	43.91
Coast 4	345	-39.98	-18.81	32.59	49.99	79.82	51.4	13.38
FarWest 8	138	-53.36	-40.25	40.05	52.46	48.35	80.3	72.29
FarWest 9	138	-67.76	-42.10	53.85	86.98	57.32	95.95	49.62
FarWest 4	345	-40.52	-29.99	50.03	60.74	65.16	80.02	94.71
FarWest 7	345	-30.34	-25.01	45.47	54.40	67.91	70.48	10.08
Coast 2	69	-22.42	-14.98	14.74	22.92	39.75	29.72	18.37
South 6	138	-35.85	-13.28	25.52	36.26	70.64	38.8	22.60

All angles referenced to North 7 PMU

BASELINING RESULTS – ANGLE DIFFERENCE

Angle Difference Pairs	Base kV	Min	Normal Min	Normal Max	Max	Percent Positive	Range	Percent Available
Coast 1-South 13	138	-14.96	-12.12	17.79	24.97	65.96	29.91	24.07
North 1-North 4	345/138	6.05	6.84	13.20	13.73	100.00	6.36	9.13
North 4-North 5	138	-4.93	-2.20	4.84	6.99	82.27	7.04	95.09
FarWest 7 – FarWest 4	345	-6.83	-5.71	1.56	3.67	6.86	7.27	9.12
FarWest 7-West 14	345	-16.79	-13.35	20.45	23.20	47.43	33.8	2.92
FarWest 7-FarWest 8	345/138	4.19	5.22	11.99	12.68	100.00	6.77	7.28
FarWest 7-FarWest 9	345/138	-19.89	-11.02	14.87	19.66	64.83	25.89	9.09
West 14-North 1	345	-8.53	-5.97	13.05	16.03	74.93	19.02	2.92
FarWest 9-West 4	138	-39.88	-26.51	49.98	60.00	64.05	76.49	33.39

BASELINING UPDATE – 2013 VS 2012

			VOLTAGE ANGLE - MEDIAN		
#	**Substation A**	**Substation B**	**2012**	**2013**	**Difference**
1	West 10	North 7	21.70	12.30	-9.40
2	West 14	North 7	10.24	8.51	-1.73
3	West 11	North 7	15.67	10.20	-5.47
4	West 6	North 7	16.44	9.00	-7.44
5	North 4	North 7	2.50	-2.40	-4.90
6	North 5	North 7	0.91	-4.57	-5.48
7	North 6	North 7	7.38	4.65	-2.73
8	Coast 1	North 7	7.33	2.85	-4.48
9	Coast 3	North 7	4.57	1.28	-3.29
10	FarWest 4	North 7	17.03	9.51	-7.52
11	FarWest 8	North 7	4.60	2.15	-2.45
12	FarWest 9	North 7	10.92	10.01	-0.91

Note: The median angle difference has dropped for year 2013 indicating drop in system stress due to new transmission lines

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BENEFIT AND SUCCESS STORY

- Phasor data tracked closely with State Estimator data during comparison tests which validates phasor data for use in operations
- Baselining analysis provided information regarding normal and abnormal operating conditions, which enabled alarm limits to be established and made operational in phasor data monitoring and alarming application
- Update in baselining analysis resulted in revised alarm limits and also provided insight into change in system operating conditions due to significant addition of new transmission lines

SUGGESTIONS

Utility/ISO with a phasor network should

- Perform periodic baselining analysis (monthly, seasonal, annual) to establish alarm limits for phasor data monitoring and alarming applications
- Update alarm limits due to significant system changes such as new generation plants, load centers, and transmission lines
- Perform periodic comparison analysis of phasor data with State Estimator or SCADA data for data validation

Summary

- **Three** conditions must be met for a production quality real-time phasor monitoring system at any Utility/ISO. The data must be:

1. Flowing reliably from PMU's to Operator's console

This was achieved through the Data Quality Study

2. Valid

This was achieved through the Baselining studies

3. Monitoring the critical locations (right places) – Requires review of PMU Location vs Needed Observation Points for Visibility

Thank You.

Any questions ?