ELECTRIC POWER GROUP
WEBINAR SERIES

Welcome! The presentation will begin shortly.

Operationalizing Phasor Technology

Electric Power Group

Using Synchrophasor Technology for Real-Time Operations and Reliability Management

Webinar

August 20, 2013

Presented by
Jim Dyer

Electric Power Group

Webinar Outline

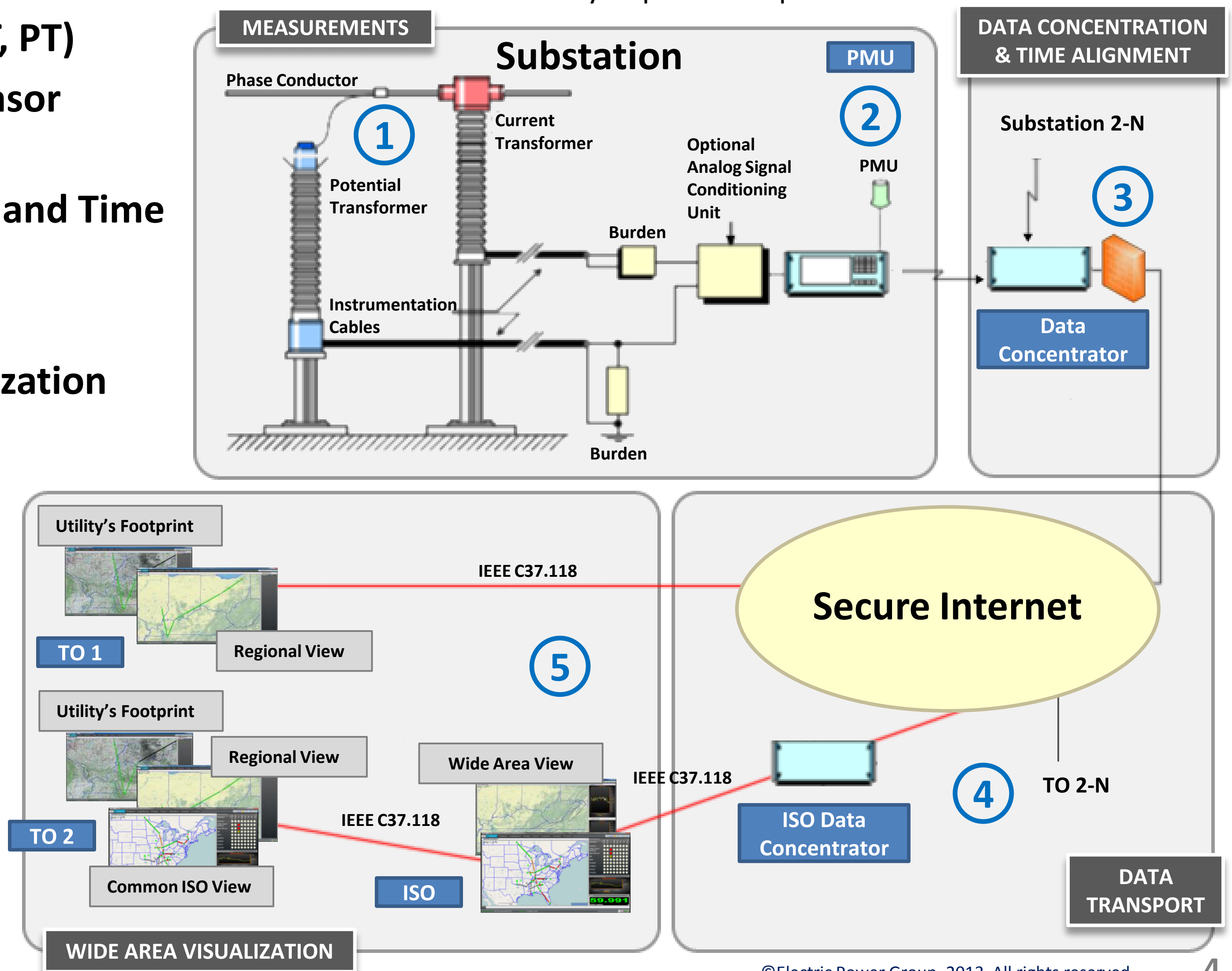
- July 16 Webinar - System Events- Deciphering the Heartbeat of the Power Grid
- **Today's Topic - Using Synchrophasor Technology For Real-Time Operations and Reliability Management**
  - Synchrophasor Technology Infrastructure
  - Synchrophasor Technology in Control Rooms – Monitor, Diagnose and Act
  - Learning from Major Blackout Events
  - Synchrophasor Technology in Operations – Today's Focus
    - Wide Area Visualization
    - Angle Difference
    - Voltage Sensitivities
    - Oscillations
- **Upcoming Webinars Schedule**
- **Q&A**

Synchrophasor Technology Infrastructure

Time Synchronized High Resolution Measurements and Wide Area Visualization

1. Measurement (CT, PT)
2. Conversion to phasor quantities - PMU
3. Data Aggregation and Time Alignment
4. Data Transport
5. Wide Area Visualization

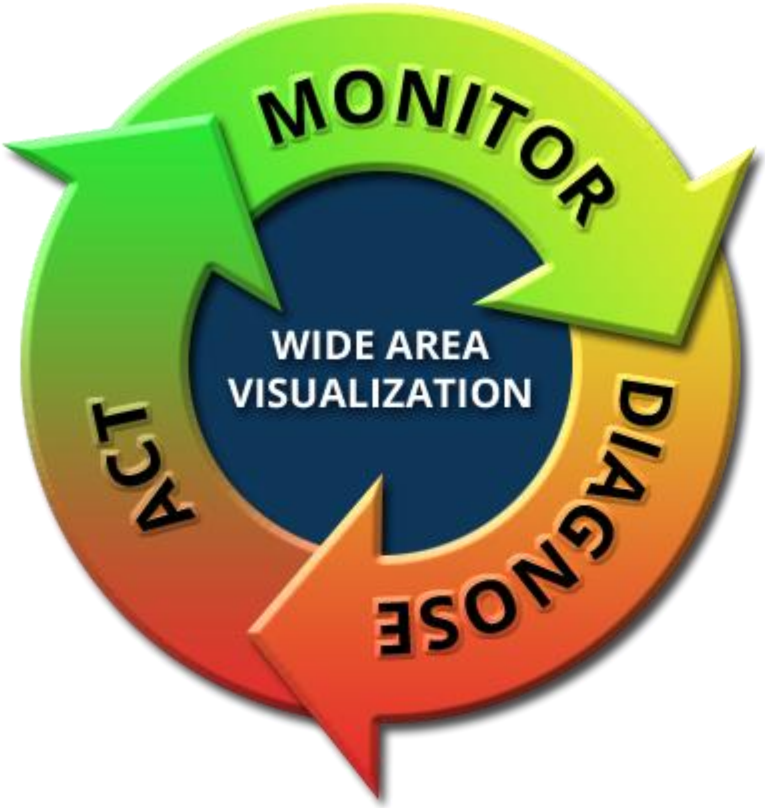
Courtesy: Adapted from EIPP presentation



Synchrophasor Technology in Control Rooms

Monitor, Diagnose and Act

Operator's Mission: Keep the lights on!

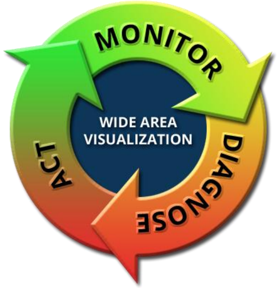


Synchrophasor Technology in Control Rooms

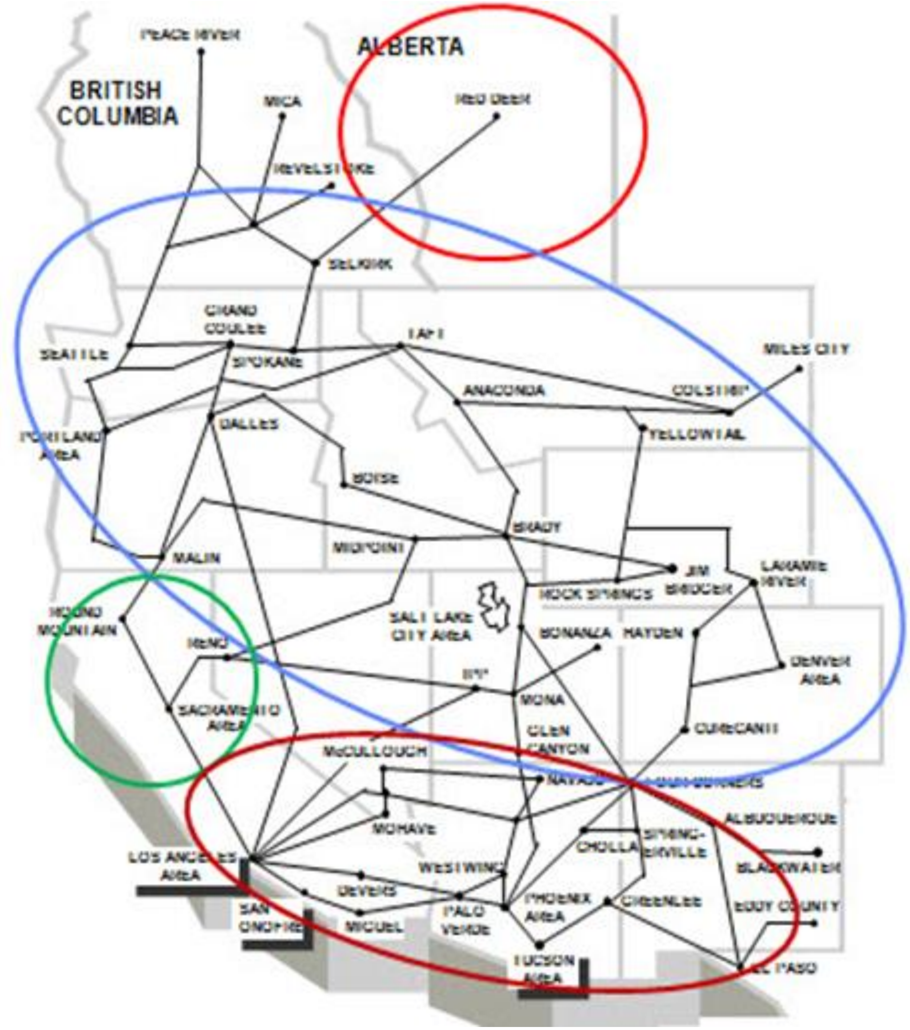
Monitor, Diagnose and Act

Synchrophasor technology enables operators to get early warning and take timely actions through monitoring:

- Wide Area Situational Awareness
- Grid Stress – phase angle differences, low damping, frequency oscillations
- Voltage Instability – low voltage zones and areas approaching nose of the Power-Voltage curves
- Reliability Margin –"How far are we from the edge?"–sensitivity metrics



August 10, 1996:
WECC Blackout

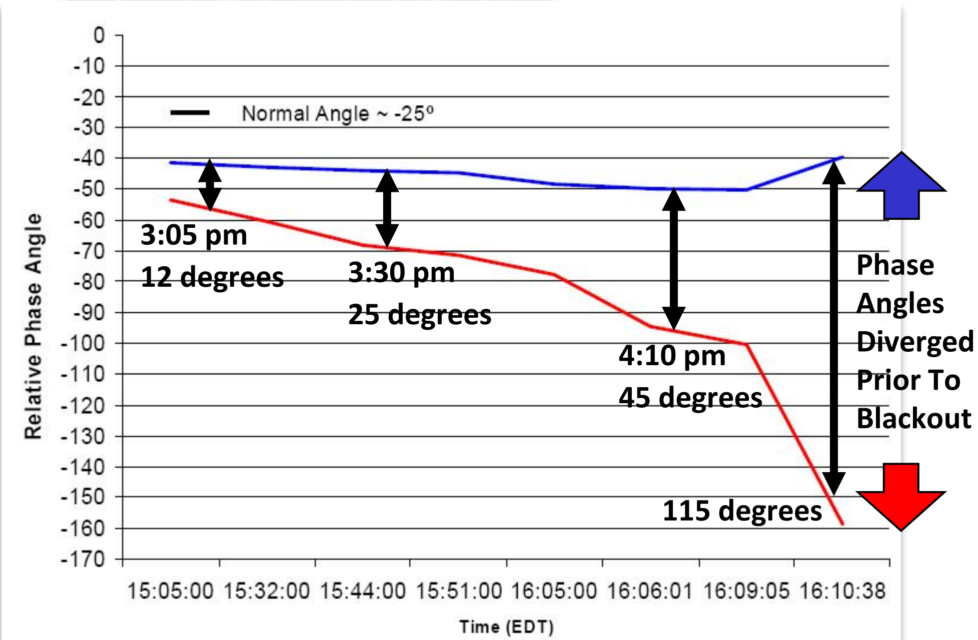


- **Hot Summer Day**
- **Problem started in Idaho, propagated to Oregon, and led to system collapse into four islands within two hours.**

TOTAL WECC IMPACTS	
Load Lost	30,489 MW
Generation Lost	27,269 MW
Customers Affected	7.49 Million
Outage Time	Up to 9 Hours

Synchrophasor technology provides wide-area visibility to monitor diverging phase angles to enable operators to take timely action.

August 14, 2003:
Eastern Interconnection Blackout



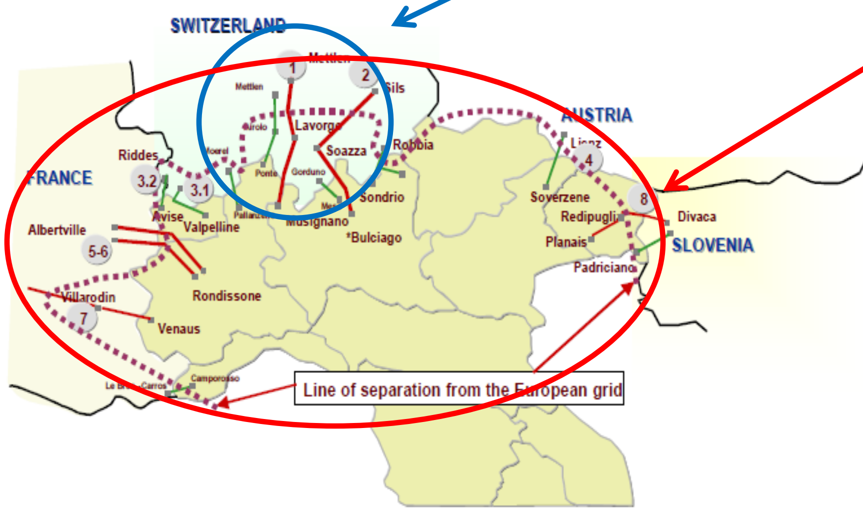
Problem started in Ohio, and over several hours, propagated into Canada and New York

OUTAGE IMPACTS	
Load Lost	61,800 MW
Generation Lost	55,000 MW (508 Units)
Customers Affected	50 Million
Outage Time	Few hours up to 2 weeks

Synchrophasor technology provides wide-area visibility to monitor diverging phase angles to enable operators to take timely action.

Note:
Angles are based on data from blackout investigation. Angle reference is Browns Ferry.

September 28, 2003:
Italy Blackout



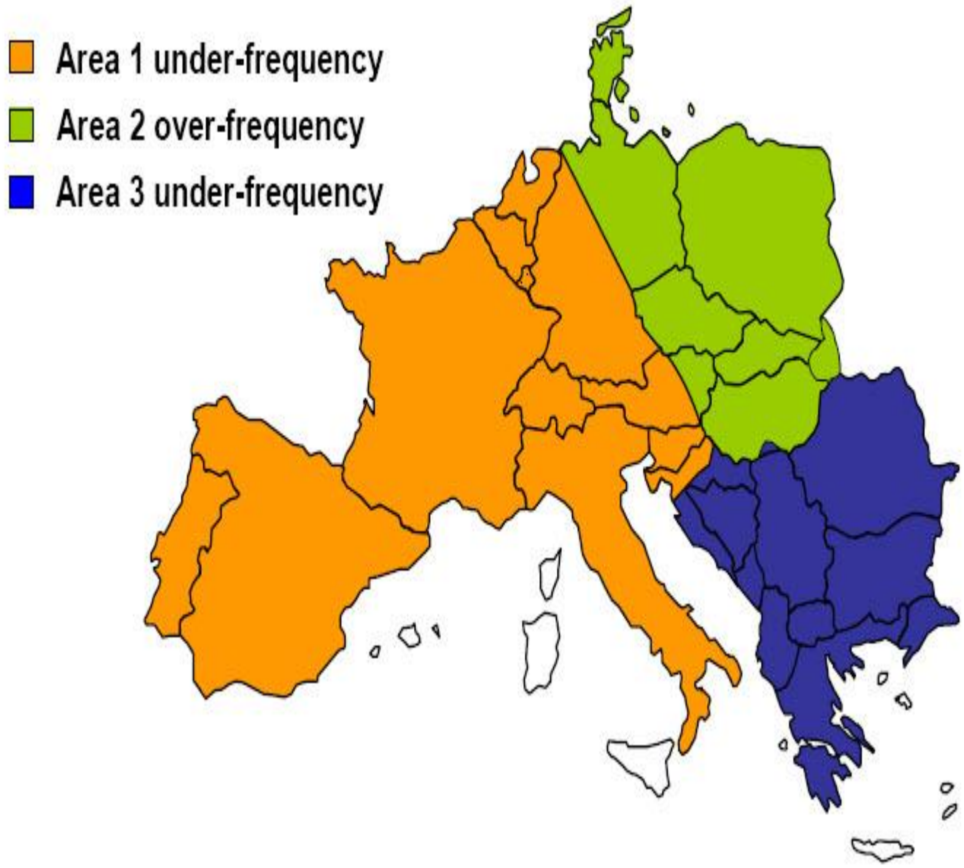
Transmission line between Italy and Switzerland tripped, storm related

Trip started a cascade event resulting in loss of all transmission lines into Italy

56 million people impacted for up to 12 hours

Synchrophasor technology provides wide-area visibility to monitor diverging phase angles to enable operators to take timely action.

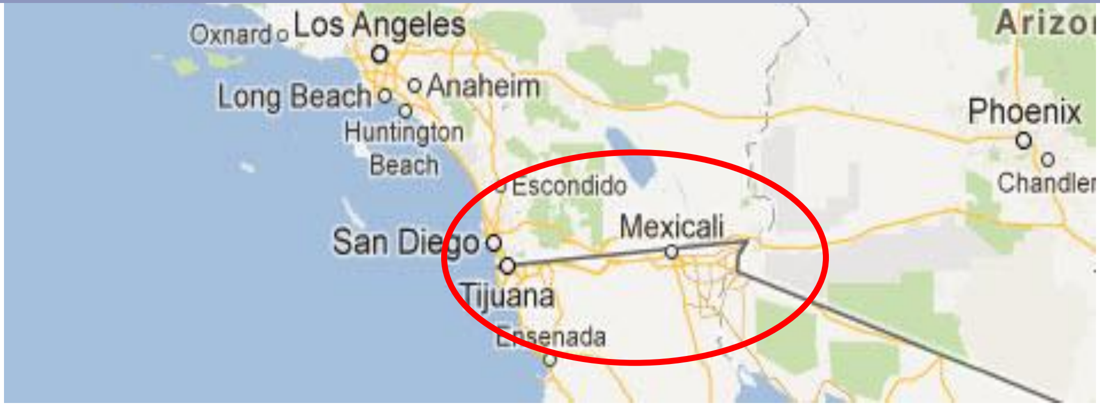
November 4, 2006:
EU Blackout

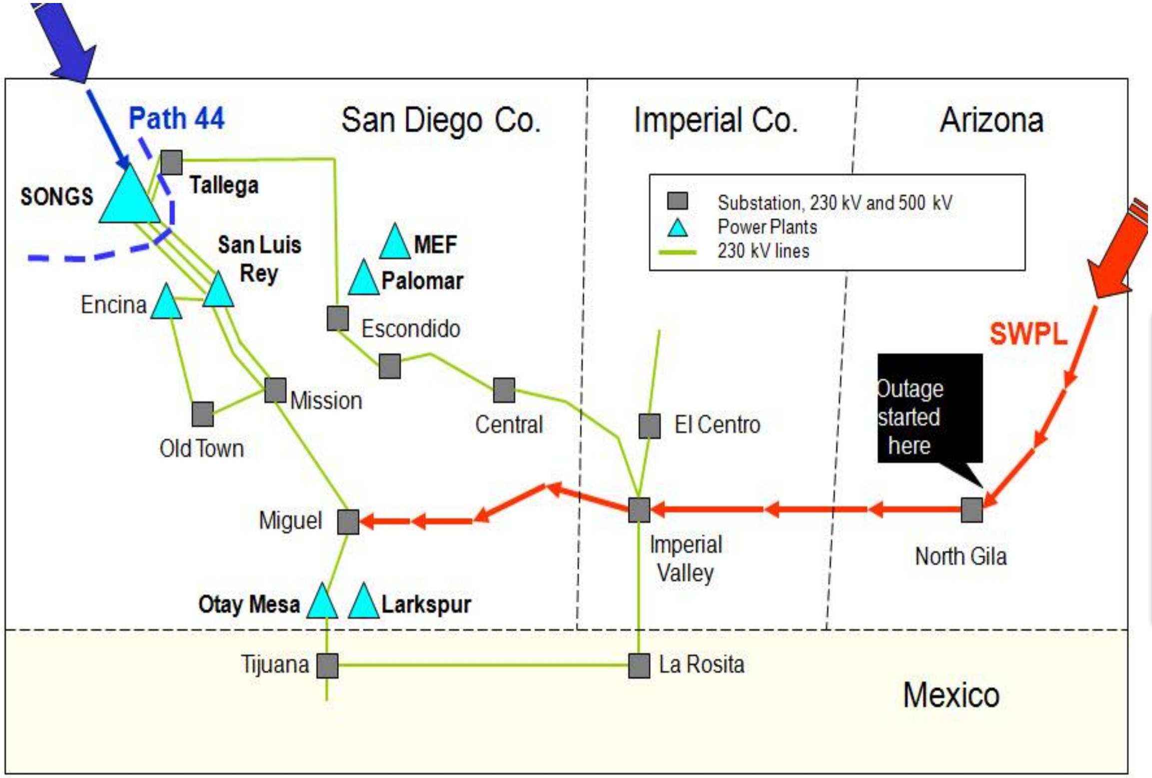


- **400 kV transmission scheduled outage led to a cascading event**
- **System could not withstand an N-1 event**
- **Outage impacted 15 million European households**

Synchrophasor technology provides wide-area visibility to monitor diverging phase angles to enable operators to take timely action.

Sept. 8, 2011:
Arizona - Southern California Blackout



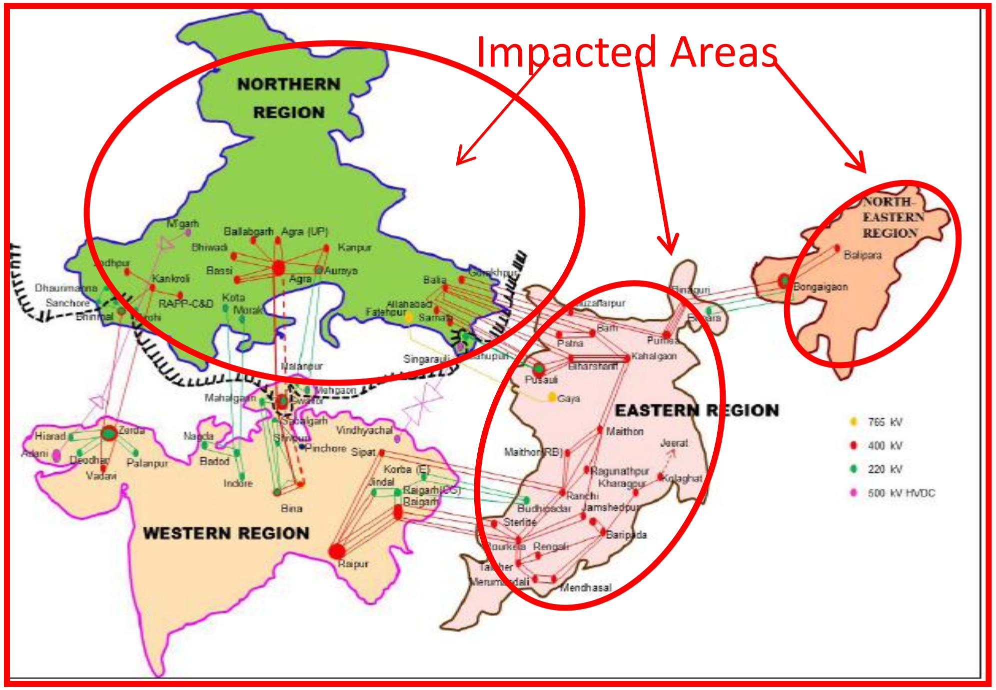


"This failure stemmed primarily from weaknesses in two broad areas—operations planning and real-time situational awareness." Source: FERC

OUTAGE IMPACTS	
Load Interrupted	7,835 MW
Generation Lost	6,892 MW
Customers Affected	2.7 Million
Outage Time	6 to 12 hours

Synchrophasor technology provides wide-area visibility to monitor diverging phase angles to enable operators to take timely action.

July 31, 2012:
India Blackout



Sl. No	Region	Generation	Demand	Import
1	NR	29884MW	33945MW	4061MW
2	ER	13524MW	13179MW	(-) 345MW
3	WR	32612MW	28053MW	(-)4559MW
4	NER	1014MW	1226MW	212MW
Total	NEW Grid	76934MW	76403MW	

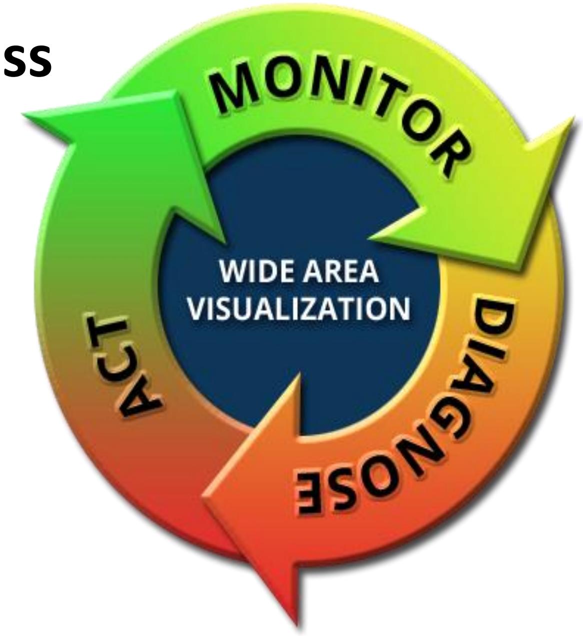
Forty six (46) 400 kV and 765 kV line outages prior to blackout in the NR, ER and WR

OUTAGE IMPACTS	
Load Interrupted	48,000 MW
Generation Lost	32,000 MW
Customers Affected	600 Million
Outage Time	2 to 8 hours

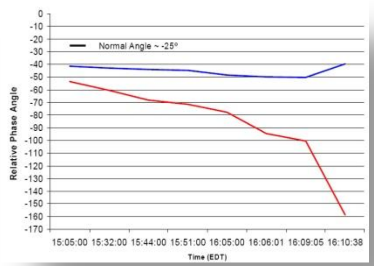
Synchrophasor technology provides wide-area visibility to monitor diverging phase angles to enable operators to take timely action.

Synchrophasor Technology in Operations
Today's Focus

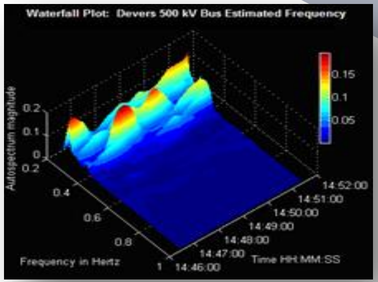
- **Wide Area View – Situational Awareness**
- **Phase Angle Difference**
- **Voltage Sensitivities**
- **Damping and Oscillation**
- **Synchrophasor Technology Enables Operators to:**
    - Monitor Grid Dynamics
    - Integrate Renewables
    - Improve Asset Utilization
    - Prevent Blackouts
    - Enable Faster Recovery



Monitoring – Wide Area View and Grid Metrics

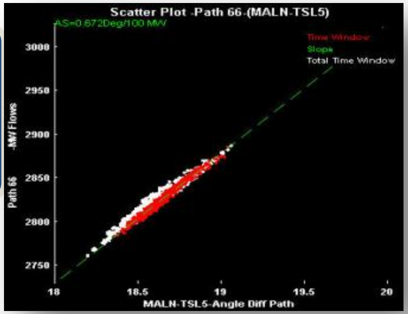


Grid Stress
Phase Angle Separation



Dangerous Oscillations
Modal Damping & Energy

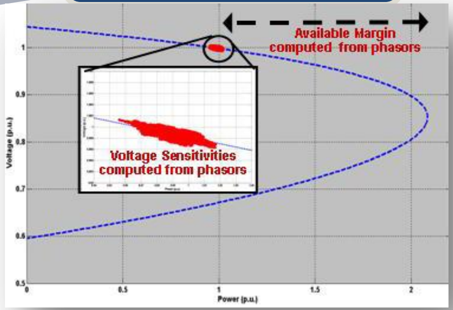
Angular Stability
Angle Sensitivities

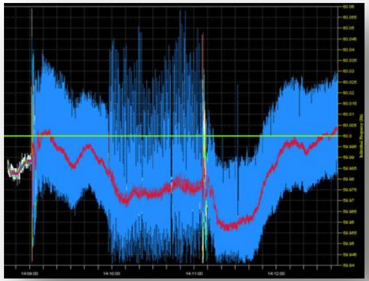


Wide Area View

PHASOR RTDMS®

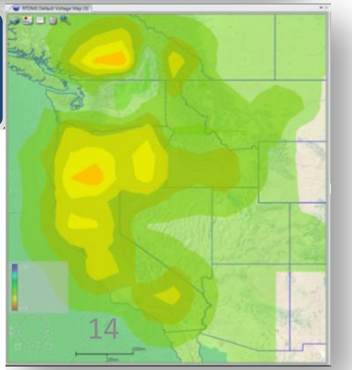
Margin
“How far are we from the edge?”



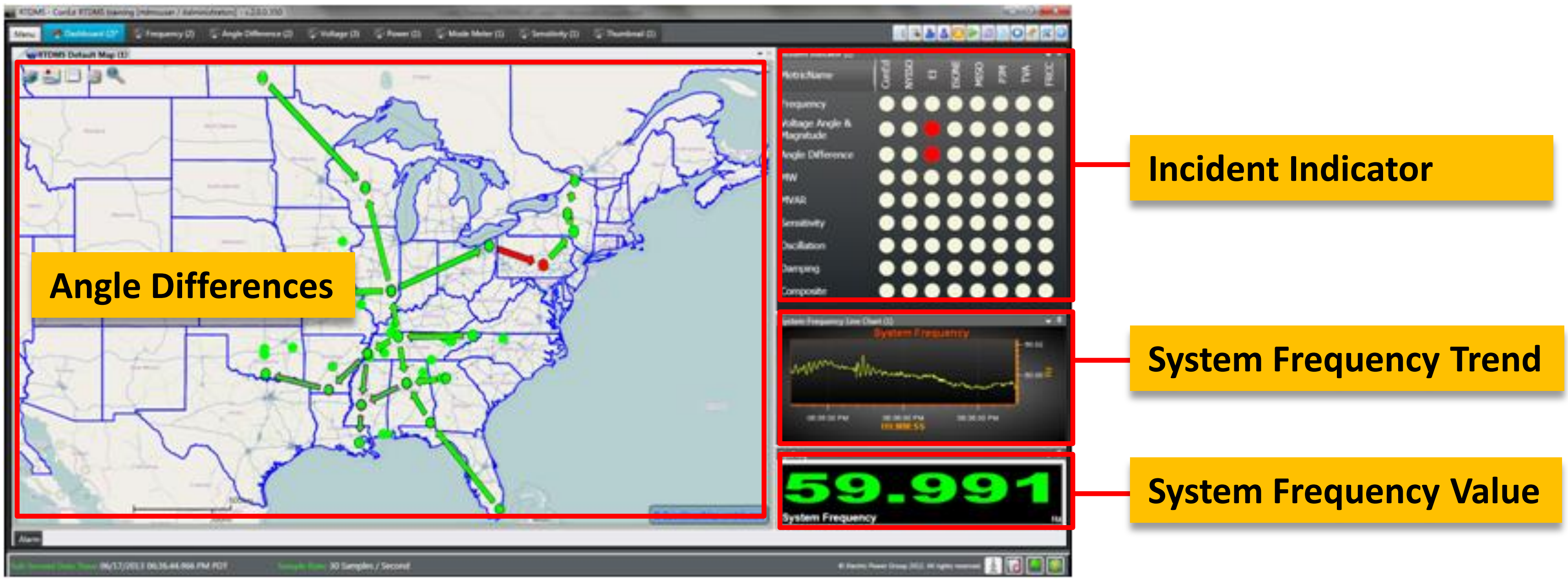


Frequency Instability
Frequency variations across grid

Voltage Stability
Low Voltage Zone



Real-Time Monitoring Display - Dashboard
Wide Area View



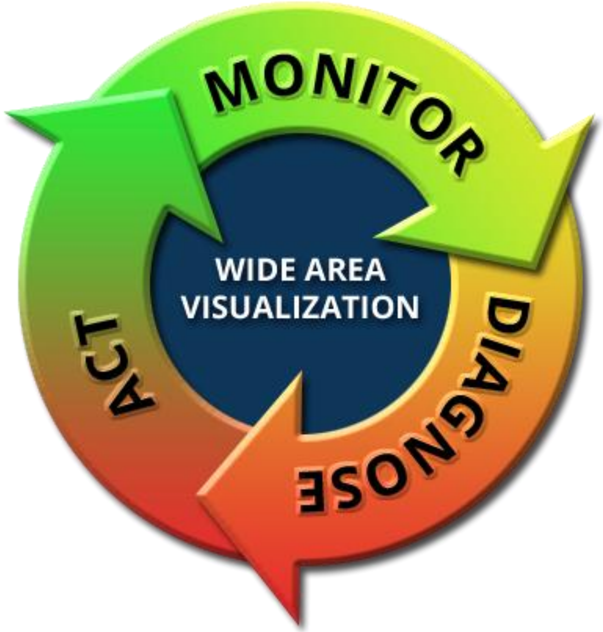
Screenshot of RTDMS® – Real Time Dynamics Monitoring System

Synchrophasor technology provides wide-area visibility to enable operators to Monitor, Diagnose, and Act

[®]Electric Power Group. Built upon GRID-3P platform, US Patent 7,233,843, US Patent 8,060259, and US Patent 8,401,710. All rights reserved.

Synchrophasor Technology in Operations
Use Cases

- **Three Use Cases**
  - **Line Trip - EI**
  - **WECC Simulations of Stressed Conditions**
  - **Oscillations**
- **Cases Illustrate Use of Synchrophasors**
  - **Phase Angle Difference**
  - **Voltage Stability – Using Sensitivities**
  - **Damping and Oscillation**



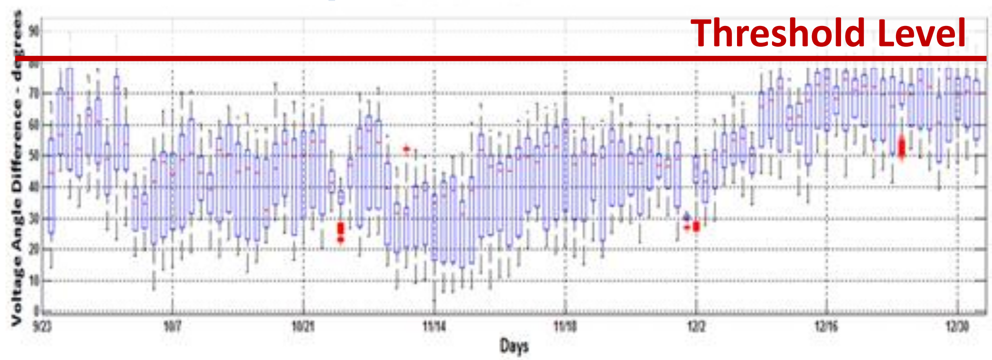
Phase Angle Difference
Seasonal Pattern

Threshold levels are established via Baseline Analysis of seasonal pattern.

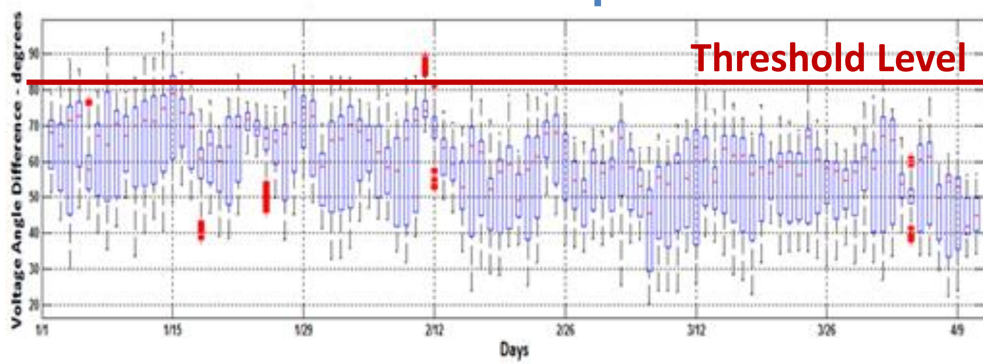
Niagara, NY **NYC**

Niagara – NYC Angle Difference

Sep 2010 to Dec 2010

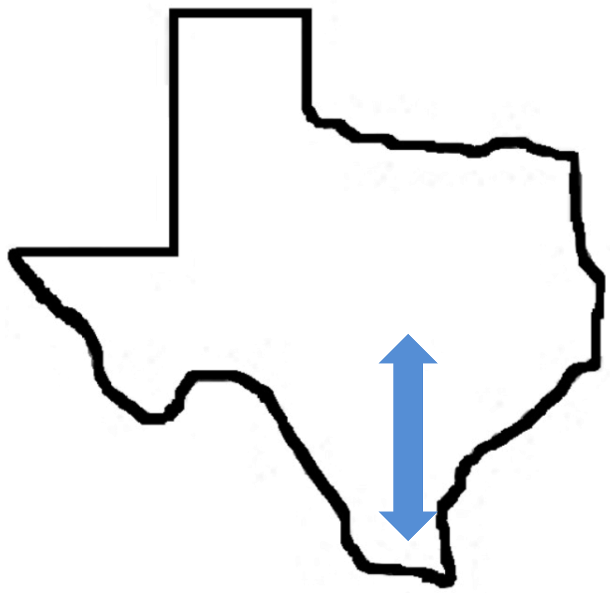


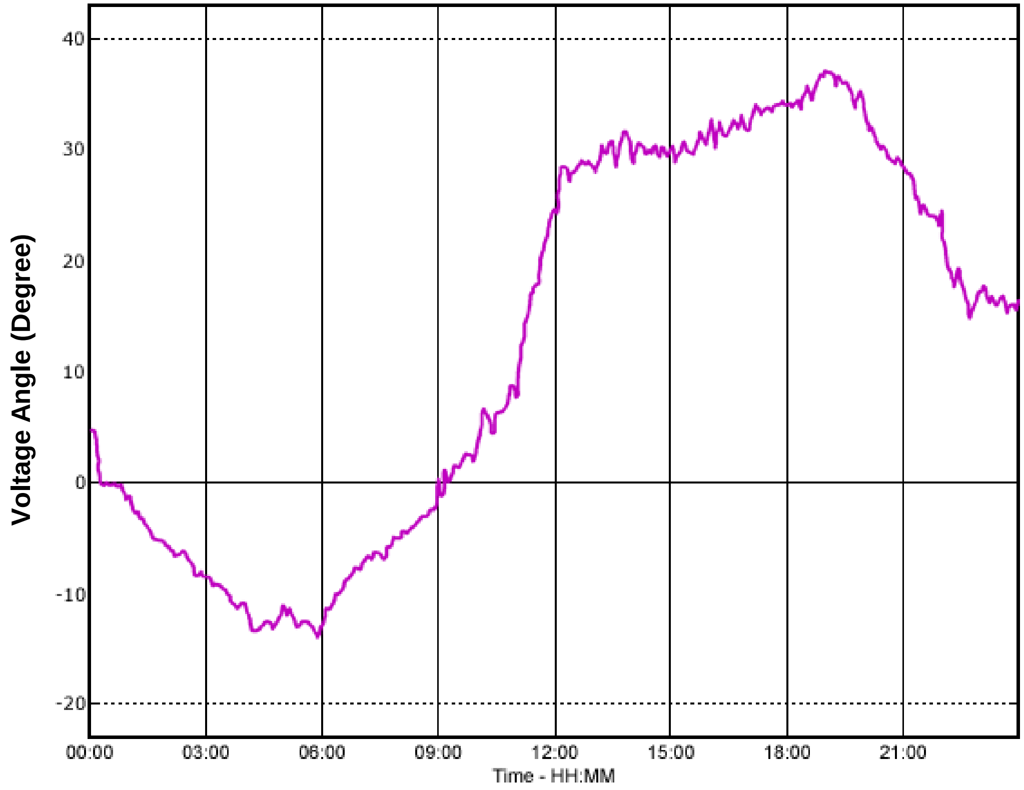
Jan 2011 to Apr 2011



Phase Angle Difference
Daily Pattern

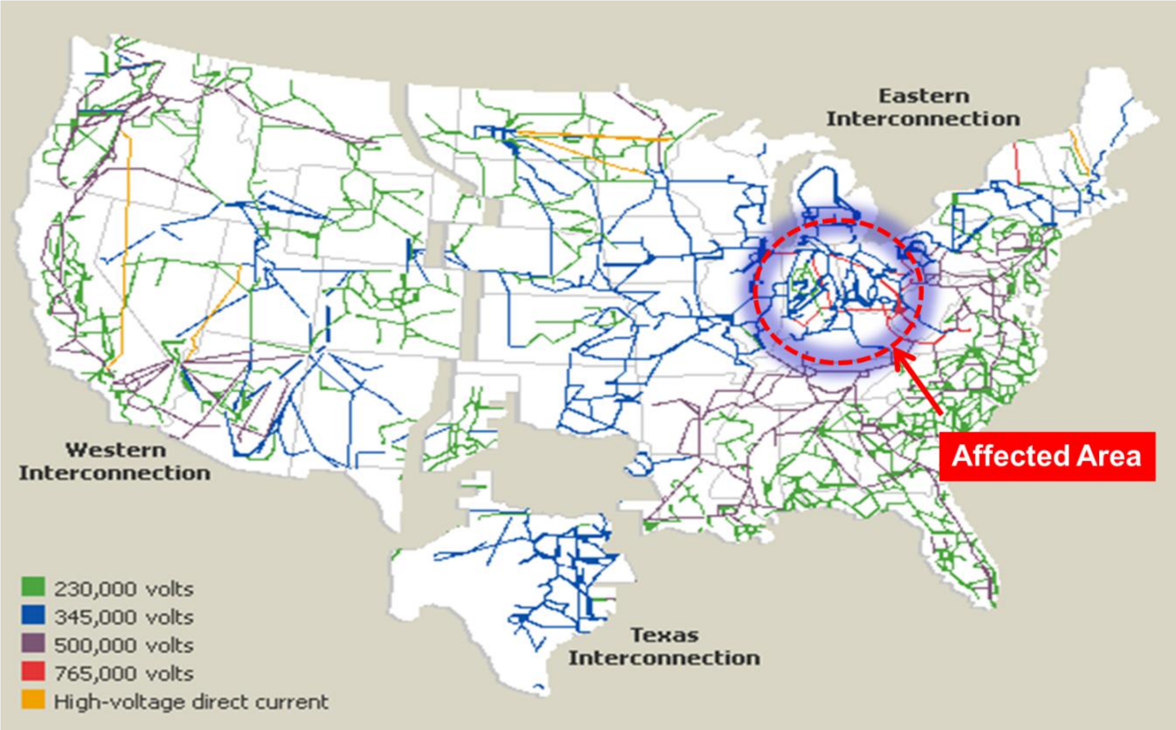
South to Central Texas Voltage Angle Difference





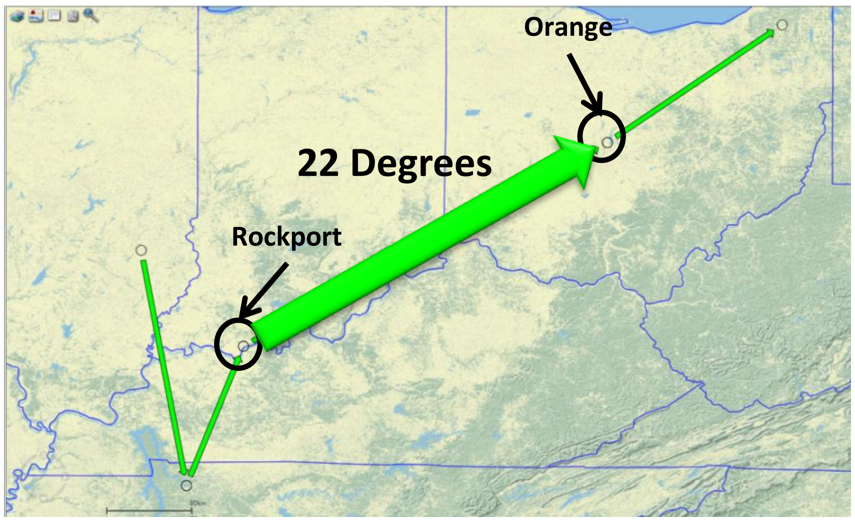
Synchrophasors in Operations
Line Trip in Eastern Interconnection

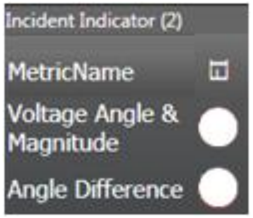
Rockport – Jefferson 765 kV Line Trip in Eastern Interconnection



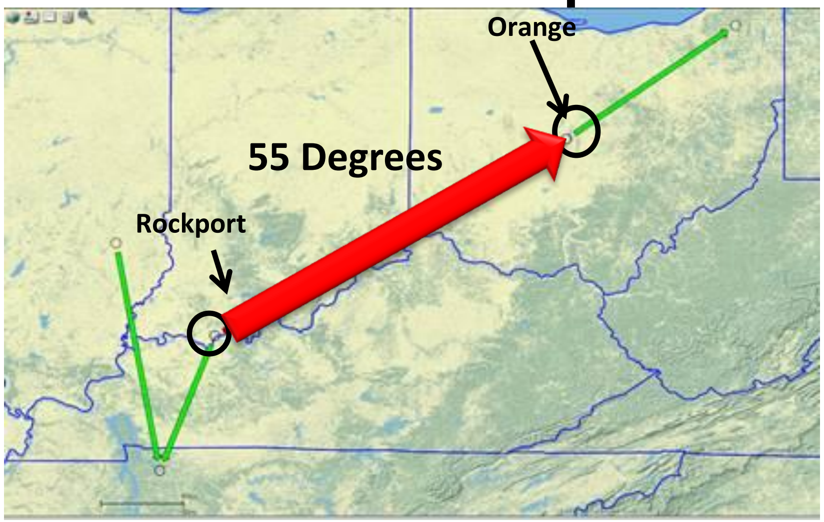
Angle Difference Between Rockport and Orange
Normal and After Line Trip

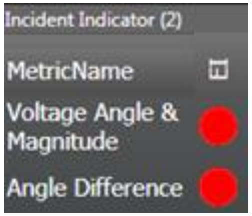
Normal





After Line Trip

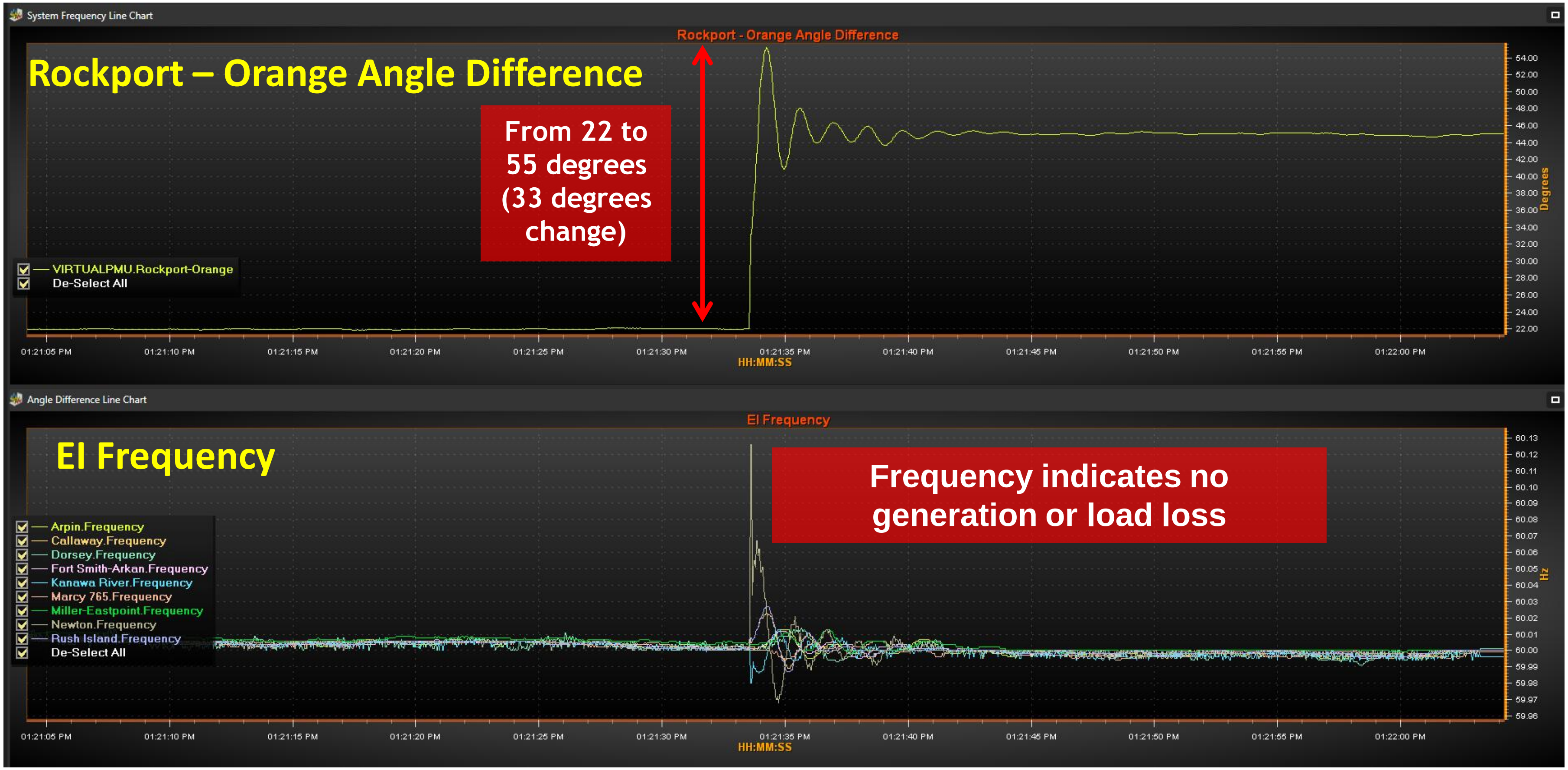




Source: Screenshots of RTDMS – Real Time Dynamics Monitoring System

Rockport to Orange Angle Difference and Frequency

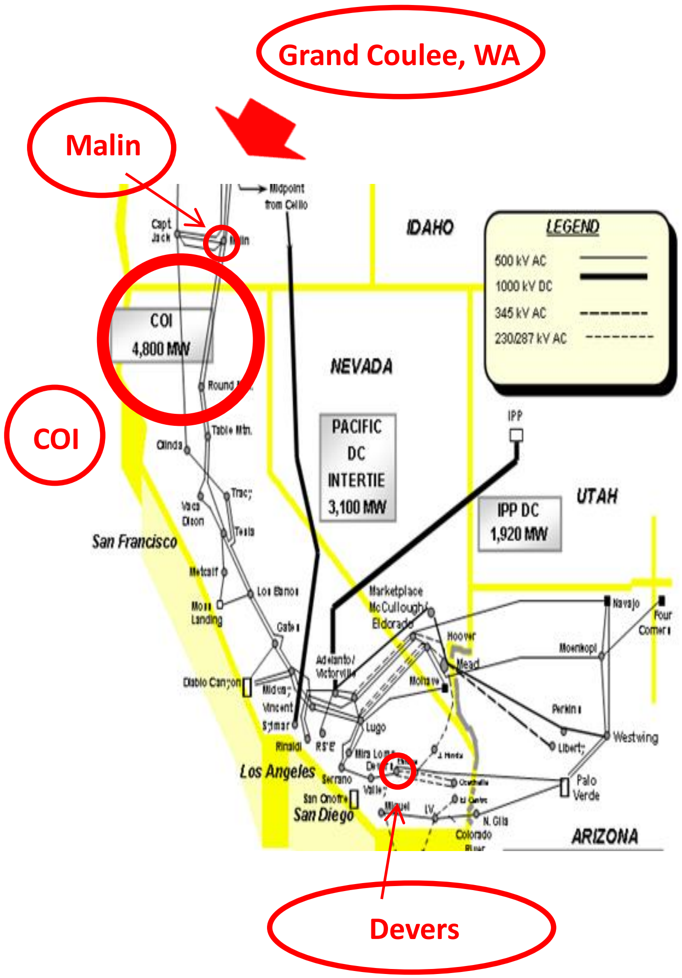
Line Trip, No Gen or Load Loss

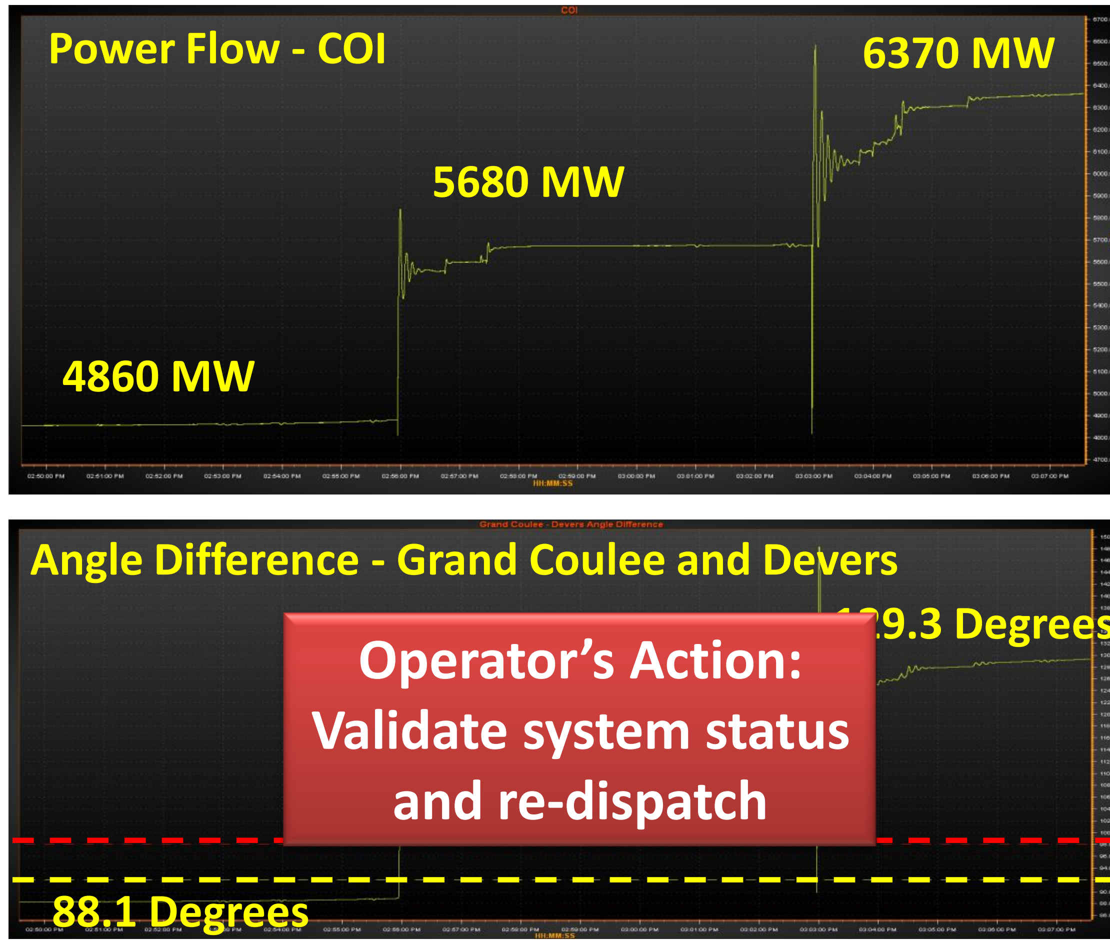


Screenshot of RTDMS – Real Time Dynamics Monitoring System

Monitoring WECC System

WECC Simulation Case: California - Oregon Intertie Stress Test





Screenshots of RTDMS – Real Time Dynamics Monitoring System

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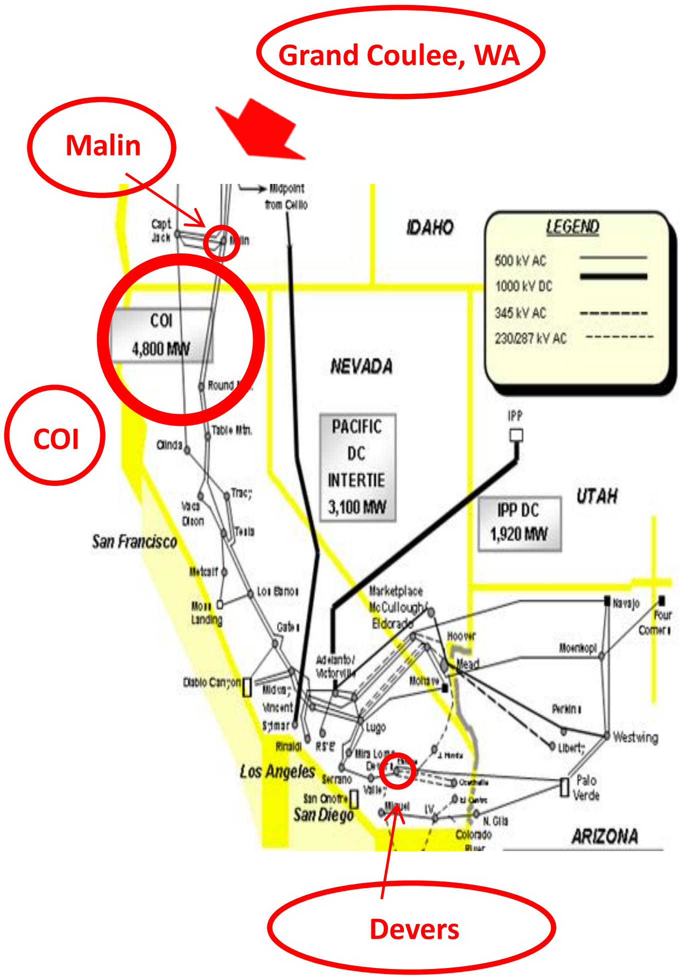
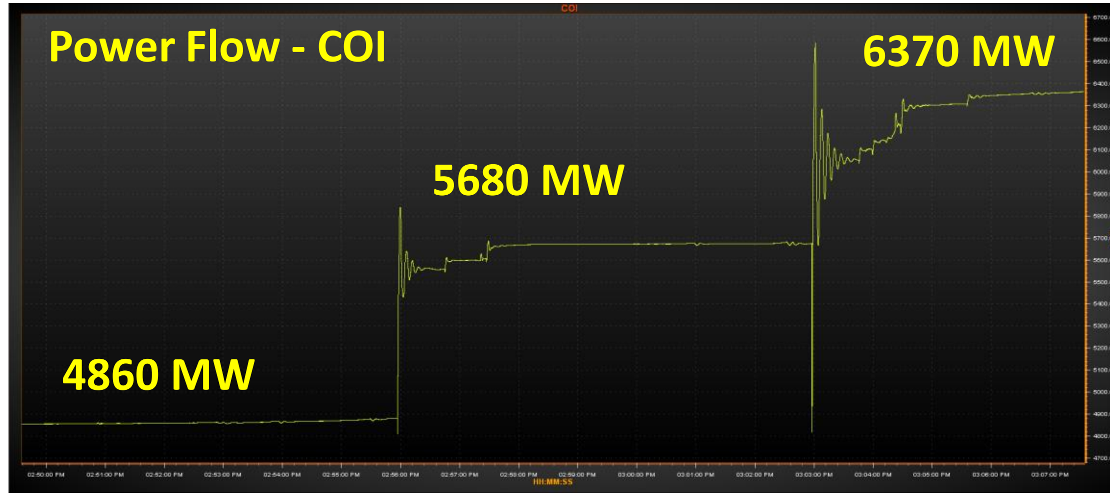
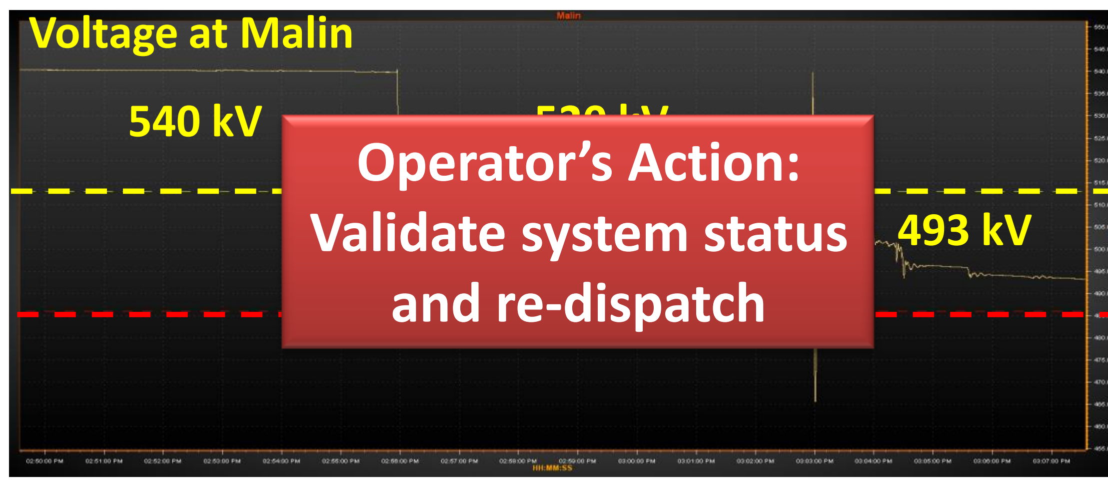


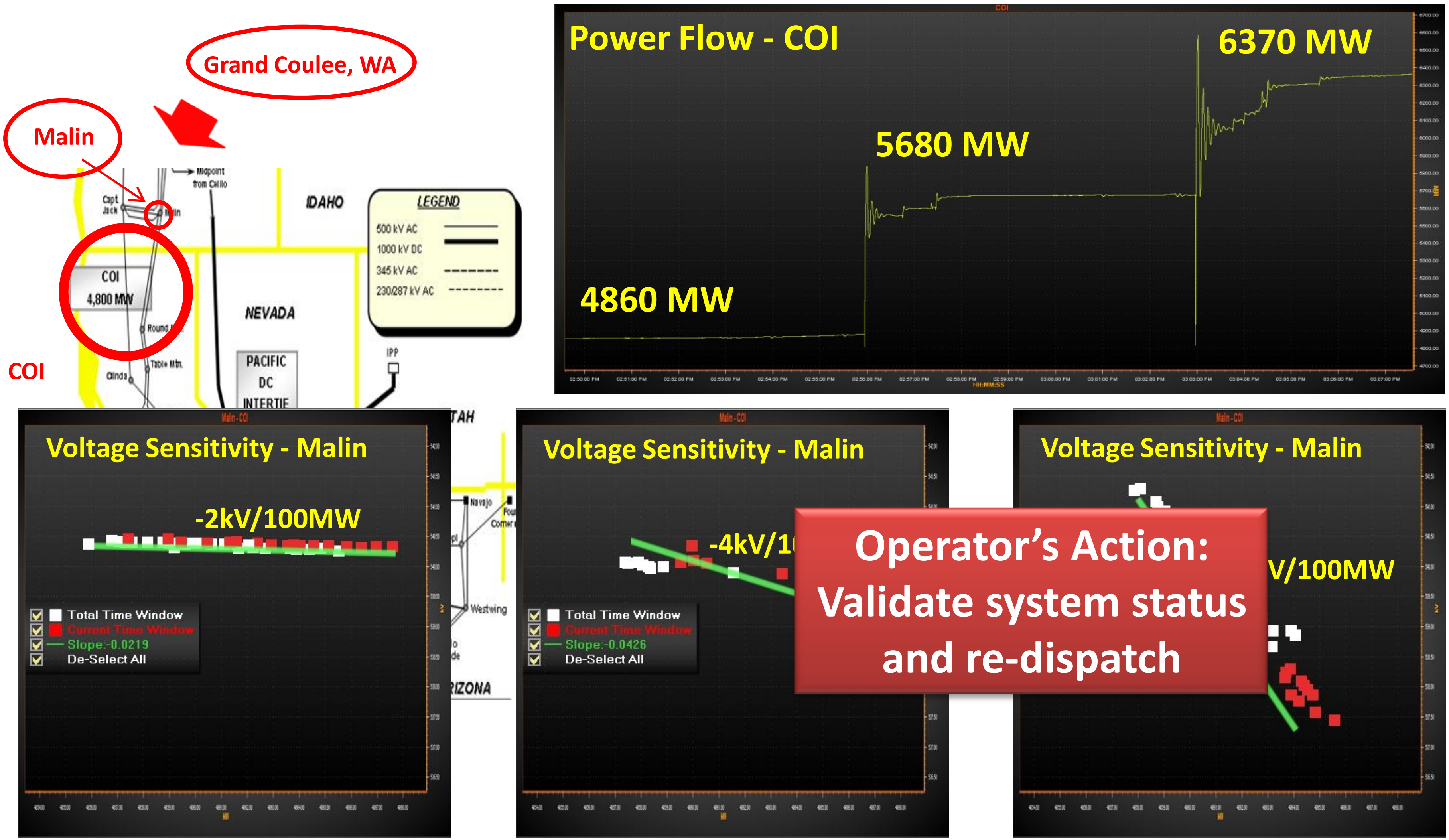




Screenshots of RTDMS – Real Time Dynamics Monitoring System

Monitoring WECC System

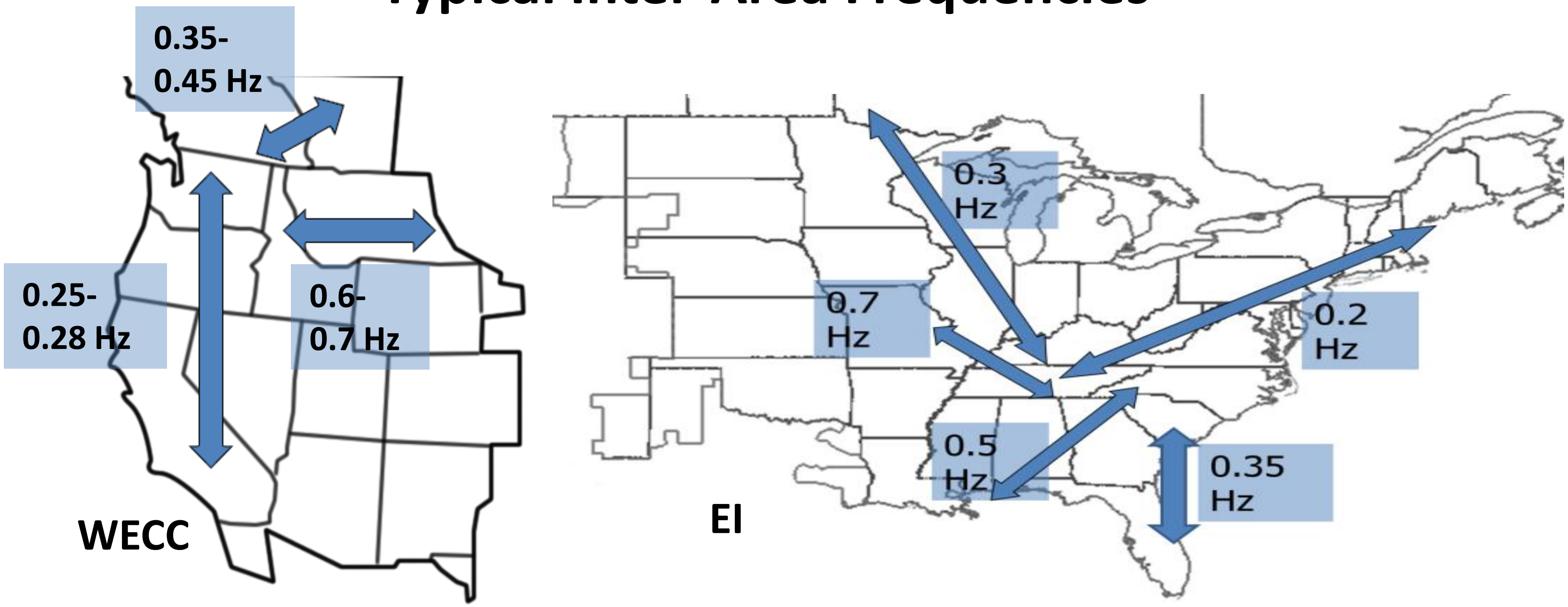
WECC Simulation Case: California - Oregon Intertie Stress Test



Screenshots of RTDMS – Real Time Dynamics Monitoring System

Oscillation Frequencies
What do they mean for operations?

Typical Inter-Area Frequencies

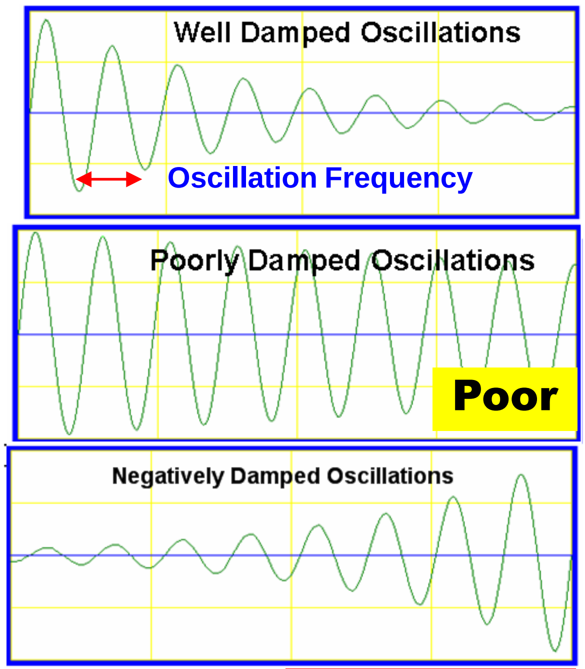


Frequency	Footprint	Action
0.01 Hz to 0.8 Hz	Wide Area	Check Damping
0.8 Hz to 3.0 Hz	Local Area (BA)	Check Generator Controls
3.0 Hz to 10Hz	Wide or Local Area	Check DC/FACTS Devices

Characterizing Oscillations
Frequency and Damping

Oscillatory Frequency & Damping Interpretation

Desirable Condition



Dangerous

Decay Rate (i.e., Damping)

Well Damped: 10% or Higher Damping

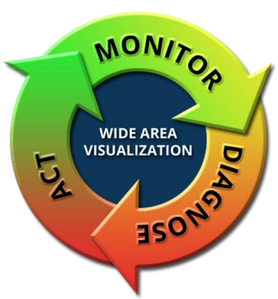
Poorly Damped: Less Than 3% Damping

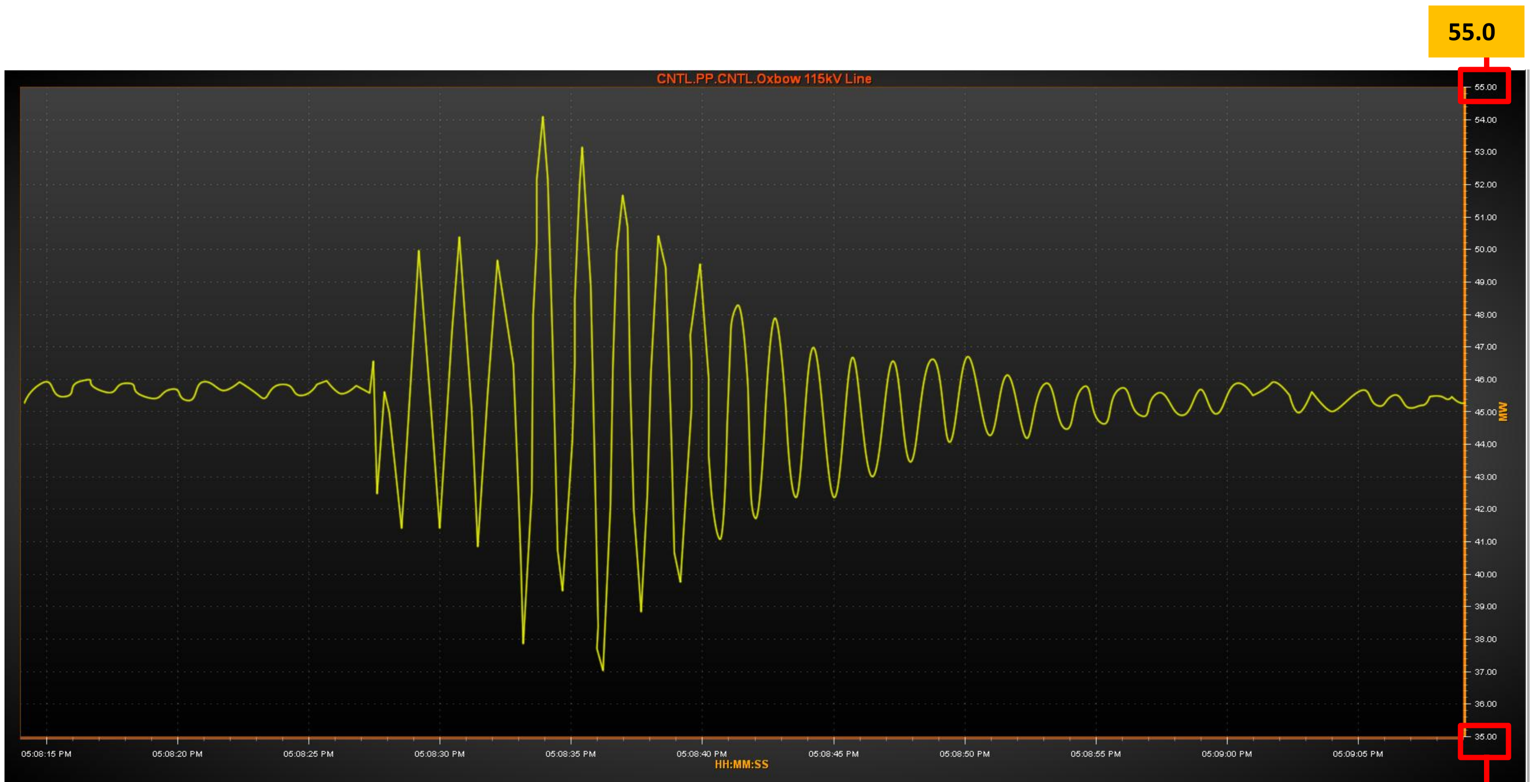
Growing Oscillations- Negative Damping

Screenshot of RTDMS – Real Time Dynamics Monitoring System

Oscillations Event Example:
CAISO Radially Connected Geothermal Generator Oscillation

Frequency	Diagnosis	Action
0.8 Hz	Poorly tuned generator governor controller	Advise generator owner to tune governor controller



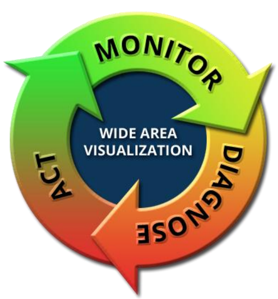


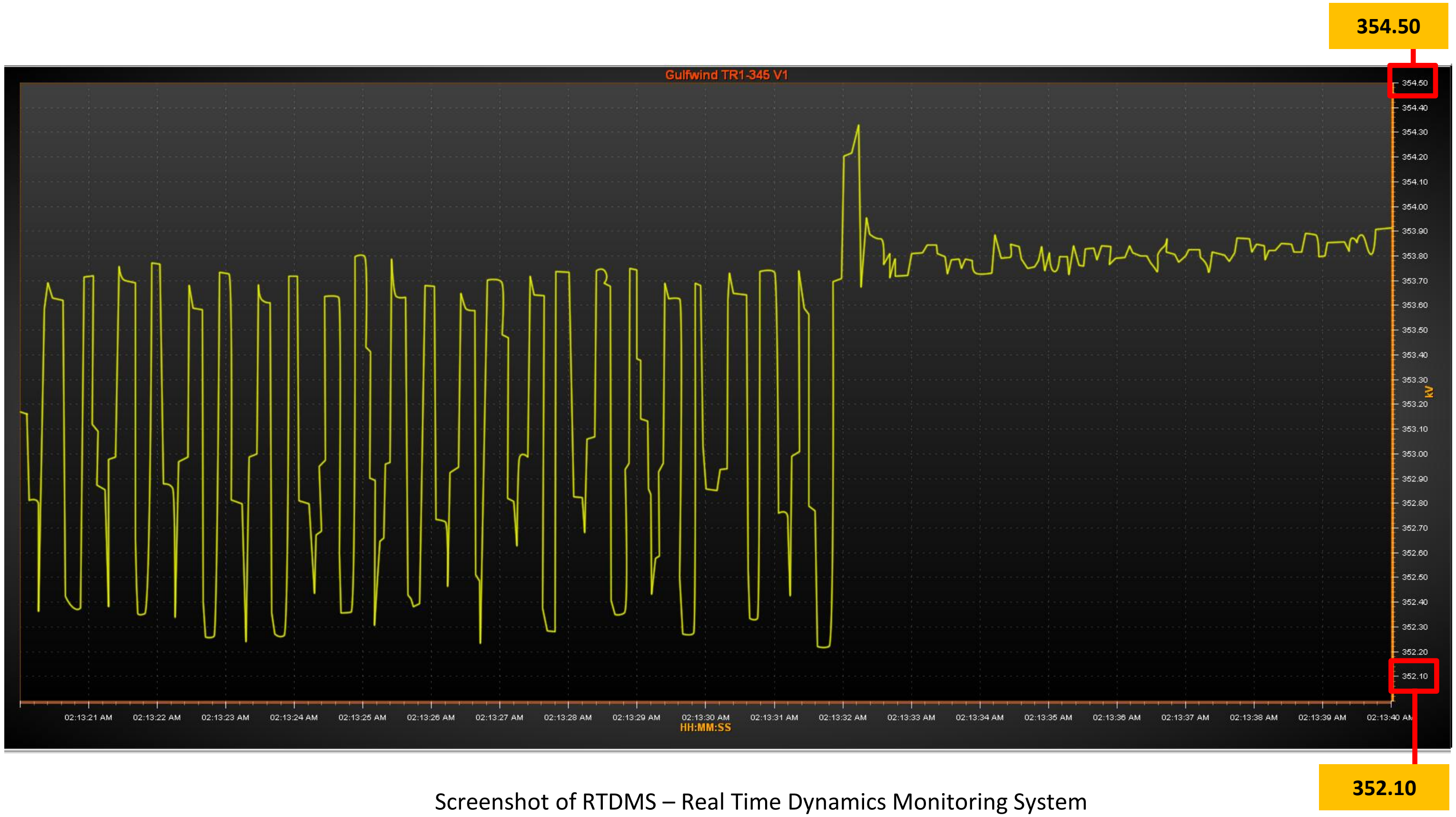
Screenshot of RTDMS – Real Time Dynamics Monitoring System

Oscillations Event Example:

ERCOT Wind Generator Oscillation

Frequency	Diagnosis	Action
2.0 Hz	Improper voltage controller setting	Identify generation causing oscillations, advise to adjust regulator settings

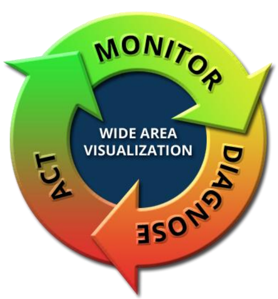


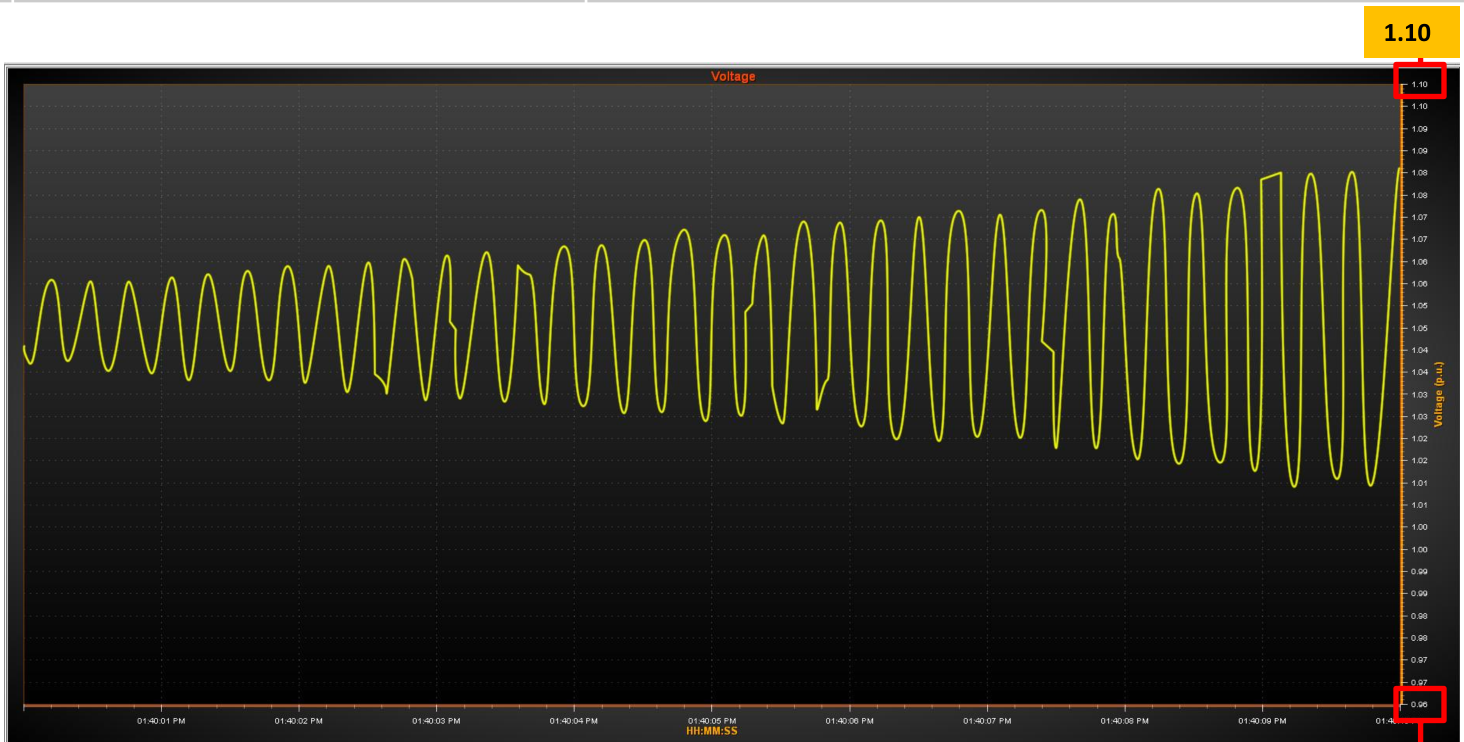


Screenshot of RTDMS – Real Time Dynamics Monitoring System

Oscillations Event Example:
ERCOT Wind Generator Trip

Frequency	Diagnosis	Action
3.7 Hz	Improper voltage controller setting caused undamped oscillations and generation tripping following parallel line maintenance outage	Identify generation causing oscillations, advise to adjust regulator settings

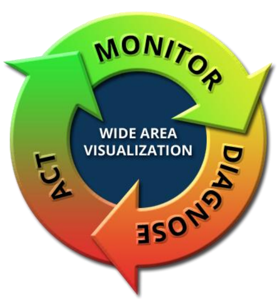


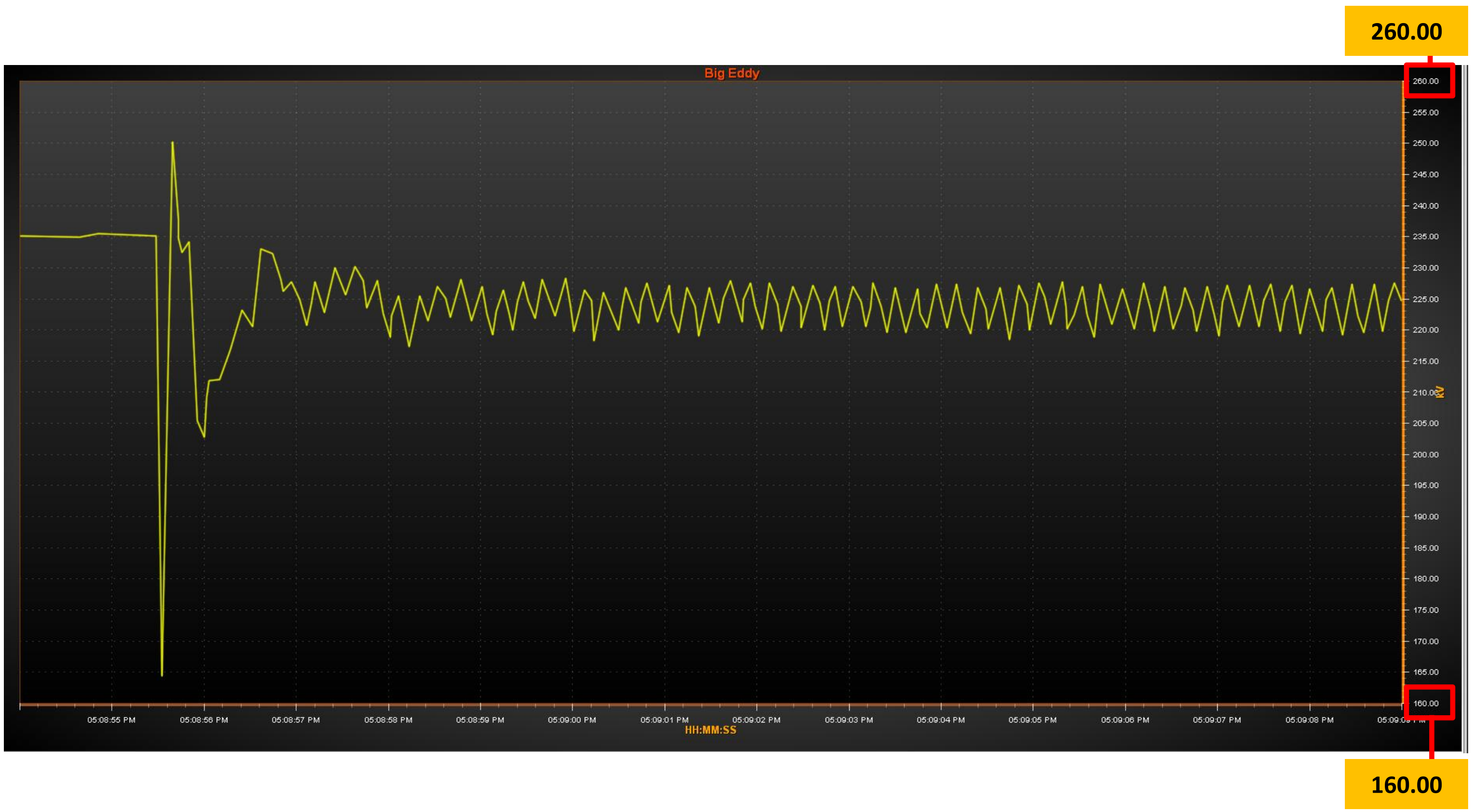


Screenshot of RTDMS – Real Time Dynamics Monitoring System

Oscillations Event Example:
PDCI Oscillations 2008

Frequency	Diagnosis	Action
4.6 Hz	Inadequate voltage support for DC Line power order setting	Reduce DC Line power order setting





Screenshot of RTDMS – Real Time Dynamics Monitoring System

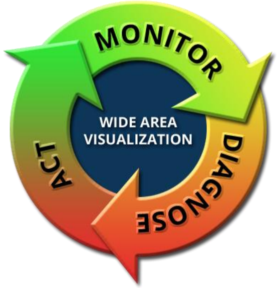
Oscillations Event Examples

Recap

Event	Frequency	Diagnosis	Action
CAISO Radially Connected Geothermal Generator Oscillation	0.8 Hz	Poorly tuned generator governor controller	Advise generator owner to tune governor controller
ERCOT Wind Generator Oscillation	2.0 Hz	Improper voltage controller setting	Identify generation causing oscillations, advise to adjust regulator settings
ERCOT Wind Generator Trip	3.7 Hz	Improper voltage controller setting caused undamped oscillations and generation tripping following parallel line maintenance outage	Identify generation causing oscillations, advise to adjust regulator settings
PDCI Oscillations 2008	4.6 Hz	Inadequate voltage support for DC Line power order setting	Reduce DC Line power order setting

What Operators Need to Monitor

- **Wide Area View - Situational Awareness**
  - Integrate Renewables, Improve Asset Utilization, Prevent Blackouts and Enable Faster Recovery
- **Grid Dynamics**
  - Phase Angle Difference
  - Damping and Oscillation
  - Voltage Sensitivities



EPG WEBINAR SERIES

Webinars are planned monthly, on the third Tuesday of each month from 11 a.m. to 12 Noon Pacific. The initial webinar topic list includes:

- System Events - Deciphering the Heartbeat of the Power Grid (Jul 16)
- Using Synchrophasor Technology For Real-Time Operation and Reliability Management (Aug 20)
- **Phase Angle Differences – What They Mean and How to Use Them For Operations (Sep 17)**
- Data Diagnostics (Oct 15)
- Using Synchrophasor Technology to identify Control System Problems (Nov 19)
- Establishing Alarm Limits For Use in Operations (Dec 17)
- Model Validation (Jan 21, 2014)

Your feedback and suggestions are important!
PLEASE do let us know…

Q&A

Thank You!

For questions, please contact **Frank Carrera**:
carrera@ElectricPowerGroup.com

Or if you prefer, call and tell us directly:
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