

Electric Power Group Presents Operationalizing Phasor Technology

Welcome!

The presentation will begin at:
2:00 p.m. EDT / 11:00 a.m. PDT
November 19, 2013

Webinar Teleconference Number: 1-650-479-3208
Access code: 662 746 127

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Operationalizing Phasor Technology

Phasor Simulations: How Can They Be Used in Operations?

Webinar

Nov 19, 2013

**Presented by
Bharat Bhargava**



Electric Power Group

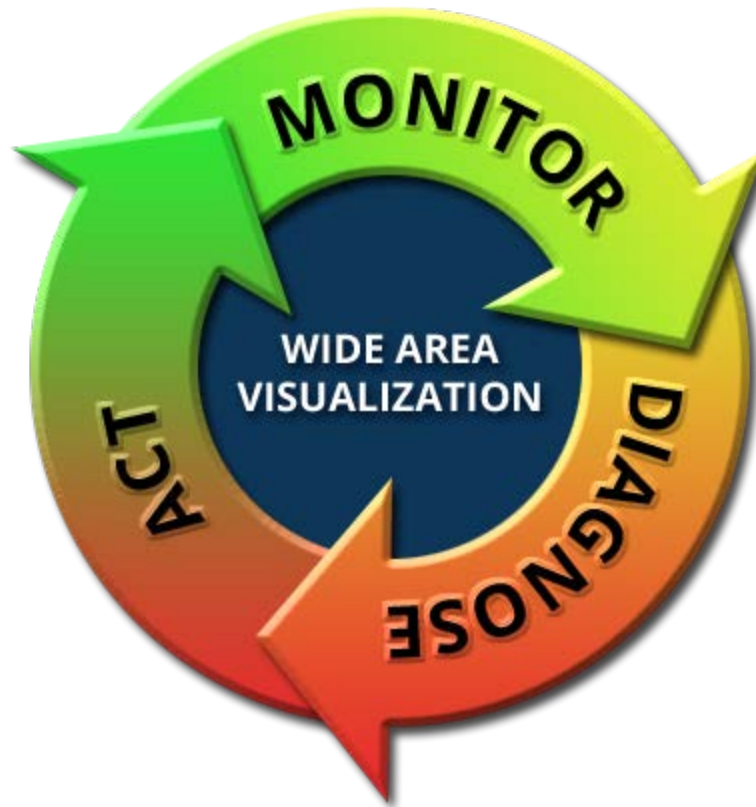
Webinar Outline

- **Today's Topic: Phasor Simulations - How Can They be Used in Operations**
 - **What are Phasor Simulations ?**
 - **Why are Phasor Simulations needed?**
 - **EPG Phasor Simulation Method – Overview**
 - **Phasor Simulations – Case Studies and Use Case Examples**
 - Trip of Palo Verde Units
 - Pacific DC Intertie (PDCI) oscillations – Jan 2008
 - Pacific Southwest Blackout – Sep 2011
 - **Phasor Simulations – How Can They Used in Operations**
- **Upcoming Webinars Schedule**
- **Q&A**

Synchrophasor Technology in Control Rooms

Monitor, Diagnose and Act

Operator's Mission: **Keep the lights on!**



What Are Phasor Simulations?

■ Phasor Simulations

- Generate Dynamic Simulations of events, cases and operating scenarios
- Cover a Wide Area – Real Time View of Simulated Events as they Unfold
- Provide Operators with Visibility of Dynamic Metrics such as Phase Angles, Oscillations and Sensitivities
- Enables Operators to Monitor, Diagnose and Act with streaming simulated results on a real time phasor application platform (like RTDMS)
- Allow testing of alternate operator actions and observe impact on grid operations

■ Phasor Simulations are performed to:

- Simulate Extreme Events – Static and Dynamic
- Visualize Extreme Events – Wide Area View
- Analyze Grid Performance During Extreme Events – Frequency Response, Oscillations, Damping, Phase Angles, Sensitivities

Why Are Phasor Simulations Needed?

- **Phasors provide additional and different insights compared to SCADA. For example:**
 - Higher resolution allows visibility of event signatures; System dynamics and dynamic metrics like phase angles, oscillation, damping, voltage sensitivity; Wide area situational awareness for prognosis is available
- **Operators need to be trained on phasor technology, dynamic metrics, visualization as well as interpretation of EMS information along with phasor dynamics**
- **Currently, companies rely on use of recorded events – this approach has several shortcomings**
 - Significant events don't happen very frequently
 - Data streams from recorded data are often of bad quality making use of events for training unsatisfactory
 - Event data is proprietary, inhibiting knowledge sharing and wide area view
- **Recorded events do not cover some of the critical contingencies that may result in cascading blackouts i.e., N-n situations as was the case for 1996 Western Interconnection, 2003 Eastern Interconnection, and 2011 Pacific Southwest blackouts**

EPG Phasor Simulation Method - Overview

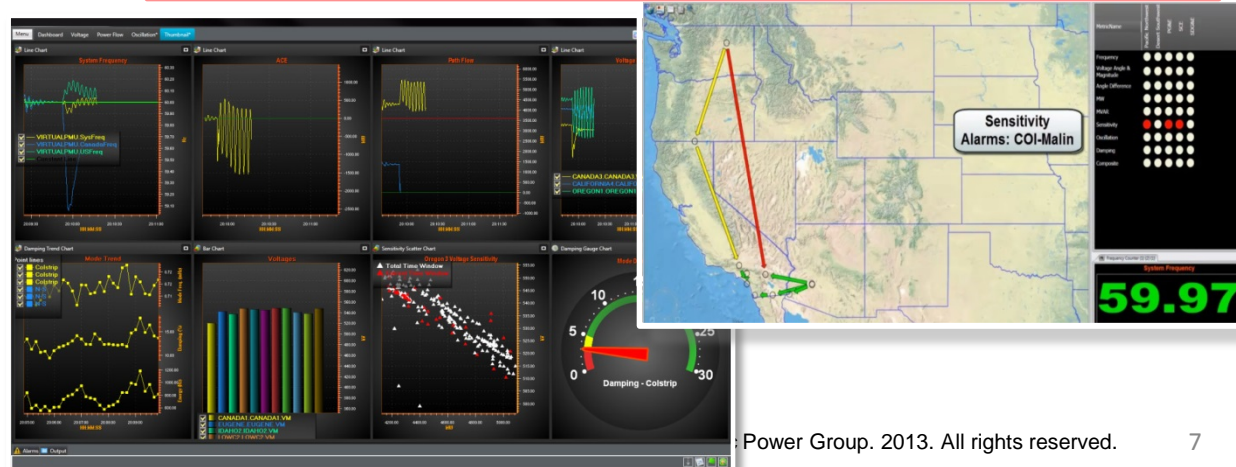
Output files from cases using PSLF, PSSE or Power World

Phasor Simulation Converter

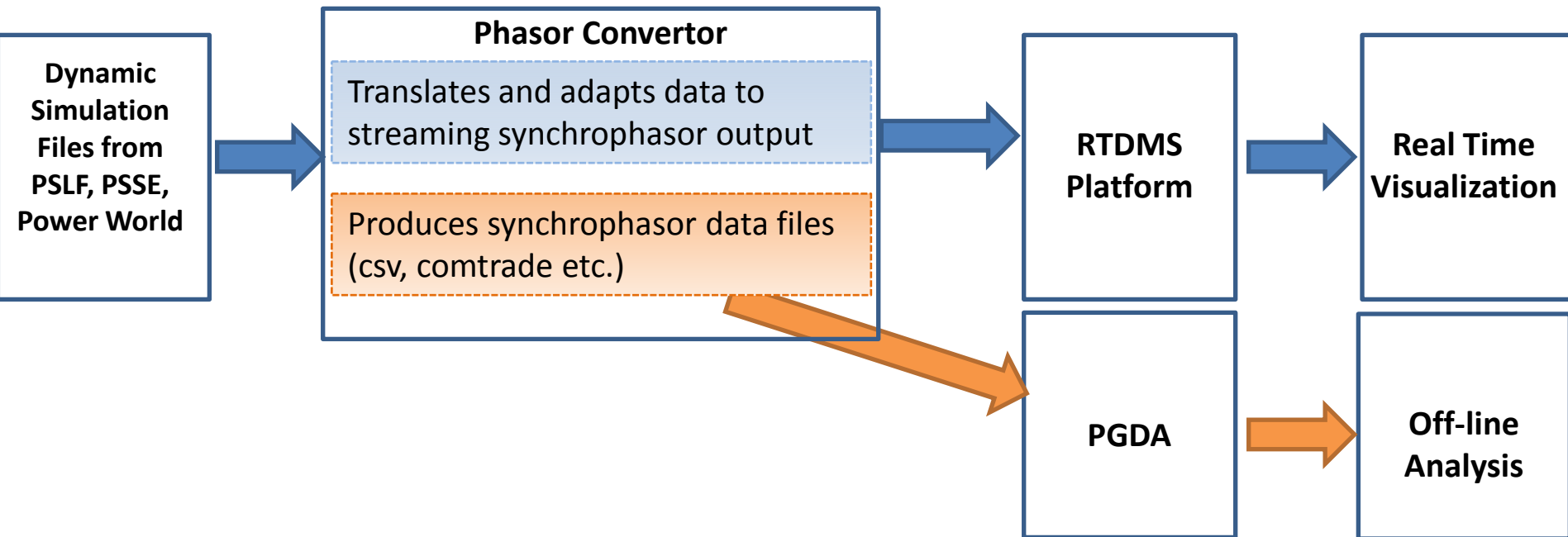
RTDMS Platform

Real Time Operator Interactions with Phasor Simulations

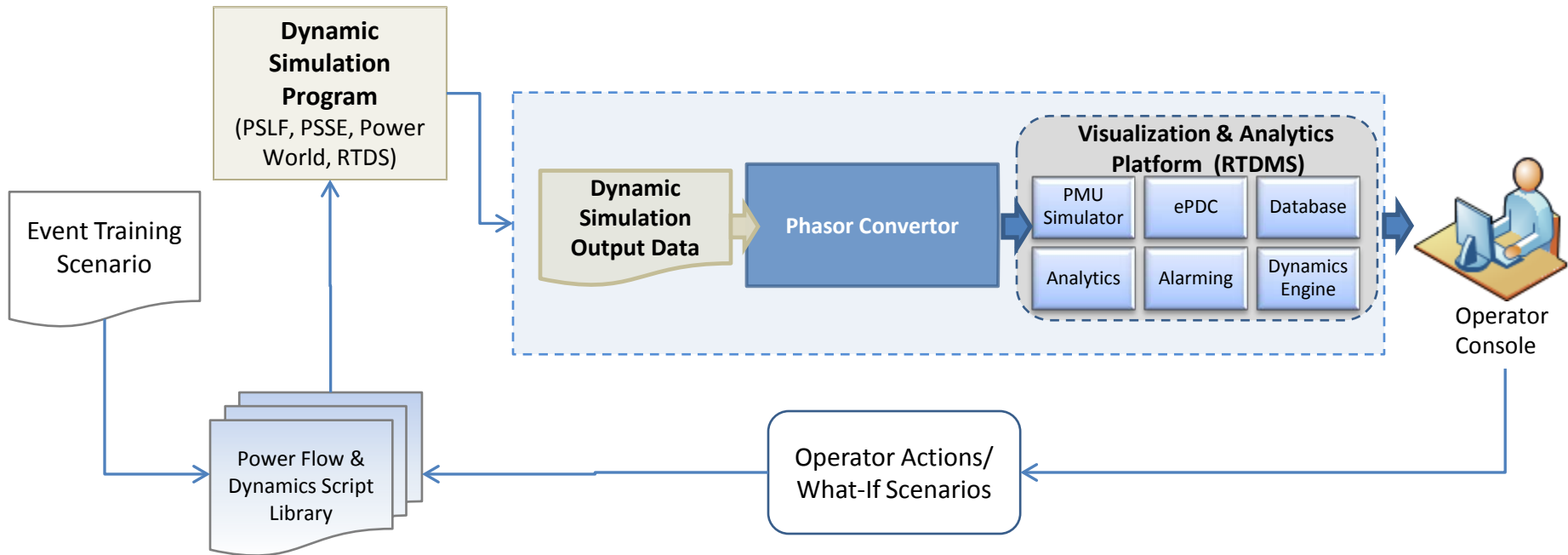
- Real Time Wide Area Situational Awareness
- Phase Angle Differences
- Voltage and Angle Sensitivities
- Frequency Stability Monitoring
- Monitoring Oscillations, Damping
- Oscillation Detection
- Islanding Detection
- Intelligent Alarms



EPG Phasor Simulator Overview



EPG Phasor Simulator for Operator Training (PSOT[®])



Comparison

SCADA Simulations

- Provides *Steady State* Simulation of the Electrical Network from the Perspective of the Operator
- *Do not provide wide-area* situational awareness
- *Dynamics are not available*, observable, simulated. Steady state results are available
- Resolution *every 2-4 sec.*
- *Static* – series of snapshots

SCADA Simulations

- Provides Dynamic Simulation of the Electrical Network from the Perspective of the Operator
- Wide Area Situational Awareness is provided
- Dynamics like phase angles, sensitivities, oscillation, damping, are only available through phasors
- High Resolution- 30 samples/sec. visibility of transients, signatures
- Streaming – like a full motion video. Can see trends, changes, movement in real time

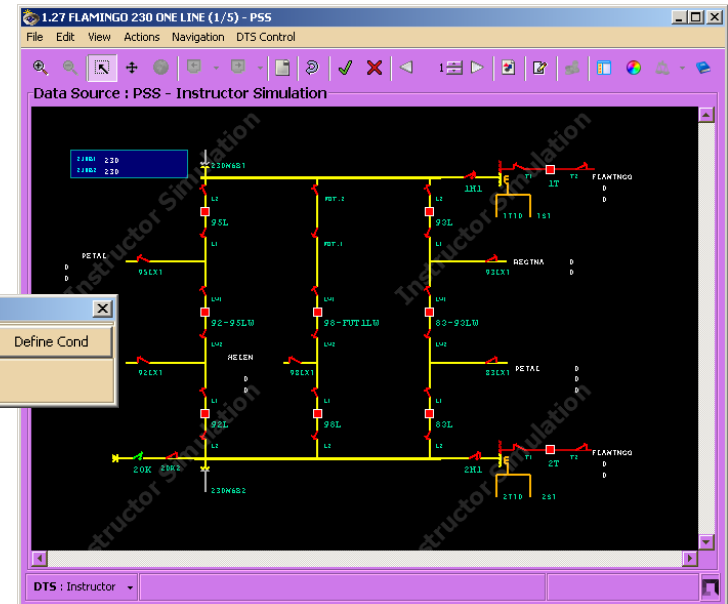
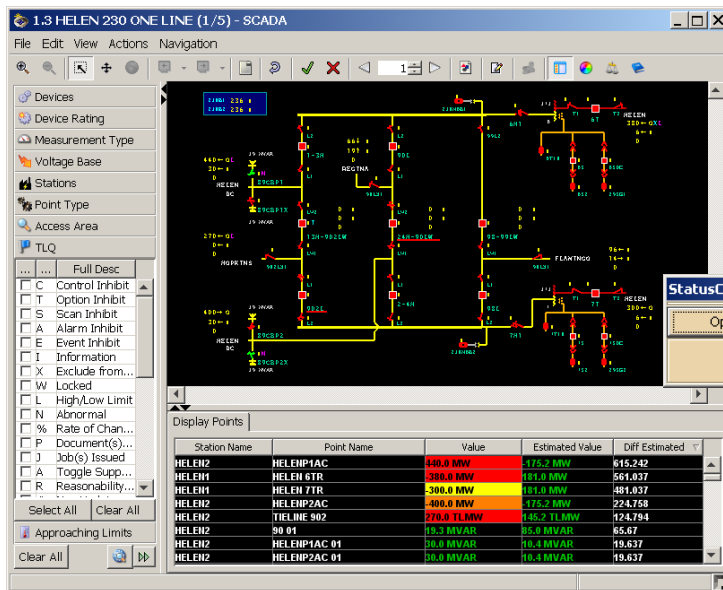
Simulation Vs. SCADA OTS Vs. Phasor Simulations

Dynamic Simulation Output (PSLF, PSSE, Power World, etc.)

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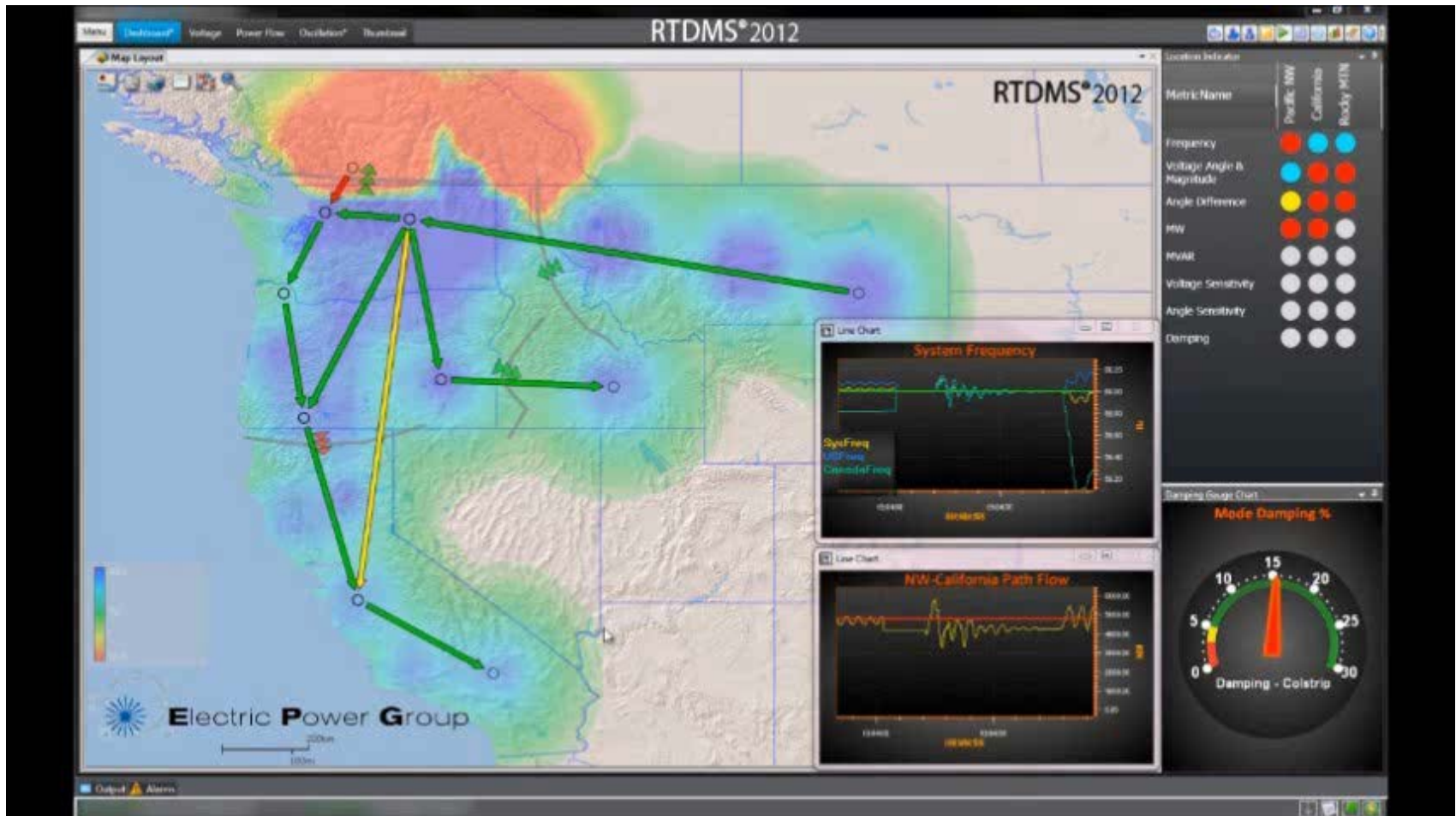
Simulation Vs. SCADA OTS Vs. Phasor Simulations

SCADA Steady State Simulation (OTS)



Simulation Vs. SCADA OTS Vs. Phasor Simulations

Phasor Simulations



Case Studies

- 1. Palo Verde Unit Trip – Dynamic Stress Scenarios**
- 2. Pacific DC Intertie (PDCI) Oscillations – Jan 2008**
- 3. Pacific Southwest Blackout Event – Sep 2011**

Case Study 1 – Palo Verde Unit Trip

Dynamic Stress Scenarios

Description of the Case:

- Load on the California Oregon Intertie (COI) is 5480 MW
- Dynamic Stress situations are simulated by tripping Palo Verde Units in succession
 - Unit 1 is tripped
 - Unit 2 is tripped (Units 1 & 2 tripped)

Starting (Base) State:

COI Loading	Grand Coulee - Devers Angle Difference (Static)	Stress Condition
5480 MW	106°	Stressed

Palo Verde Unit Trip

**PALO VERDE UNIT TRIP CASE
(TRAINING CASE)**



Palo Verde Unit Trip

Summary

COI Loading	Base Case	1 Unit (1370 MW) Trip	2 Unit (1370 MW) Trip
5480 MW	106° (Safe)	126° (Vulnerable) High Stress	Voltage Collapse and Separation

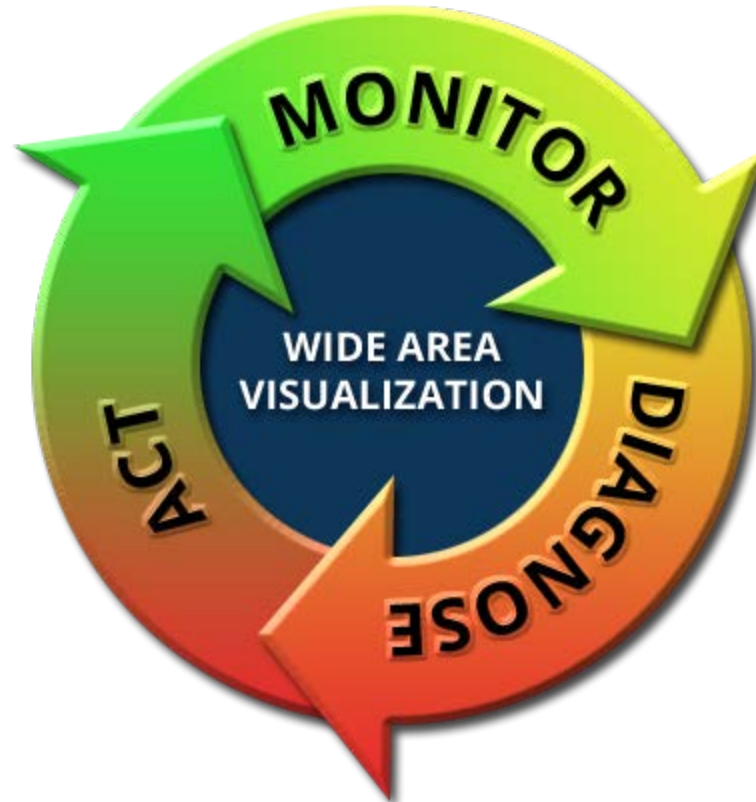
Operators able to see in real time /streaming:

- Alarms get triggered
- Angle Differences increase – system vulnerable
- Signature of generator trip
- Power flow oscillating
- Voltage drop
- Unit 2 trip: Angles increase sharply (signature of separation)
- Voltage collapse

Palo Verde Unit Trip - Dynamic Stress Scenarios

ALARMS – Voltage, Angle Difference, Power Flow & Sensitivity

- Reduce COI Power Flow to reduce angle difference between Devers and Grand Coulee - options
 - Drop load in South
 - Increase generation in South
- Add voltage support at Malin substation



- Large generation loss in Southern area
- Large Angle Swings
- Large voltage drop at Malin substation
- Vulnerability to Cascade and Separation when GC-Devers angle difference exceeds 120°

What can operators learn in training?

- **Understand angle difference is a good indicator of grid stress**
- **Estimate available margin**
- **Assess alternative corrective actions**

Case Study 2 – Pacific DC Intertie (PDCI) Oscillations

Simulation of a real event

- Event occurred on January 26, 2008
- High frequency oscillations occurred at the two ends of the PDCI line at Celilo and Sylmar
- Damping dropped below 2 %
- Simulation shows high frequency oscillations occurring on power, voltage and frequency at Celilo and Sylmar
- Damping is below 2 % in simulations – **matching the event**

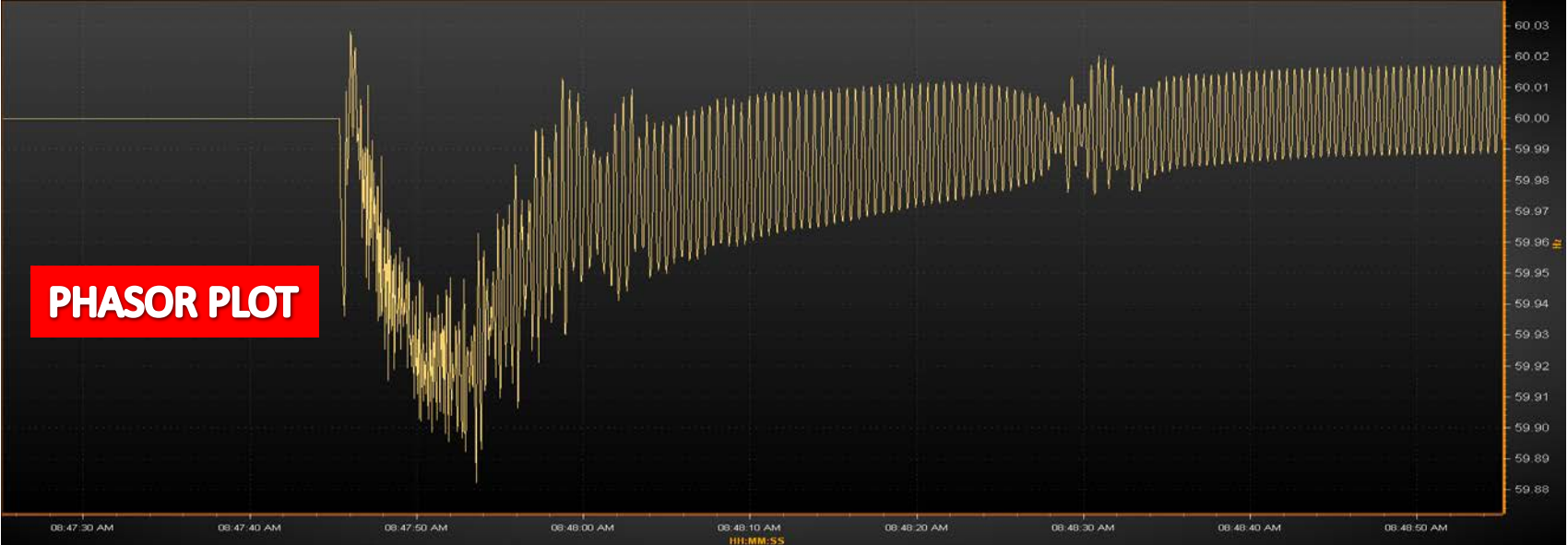
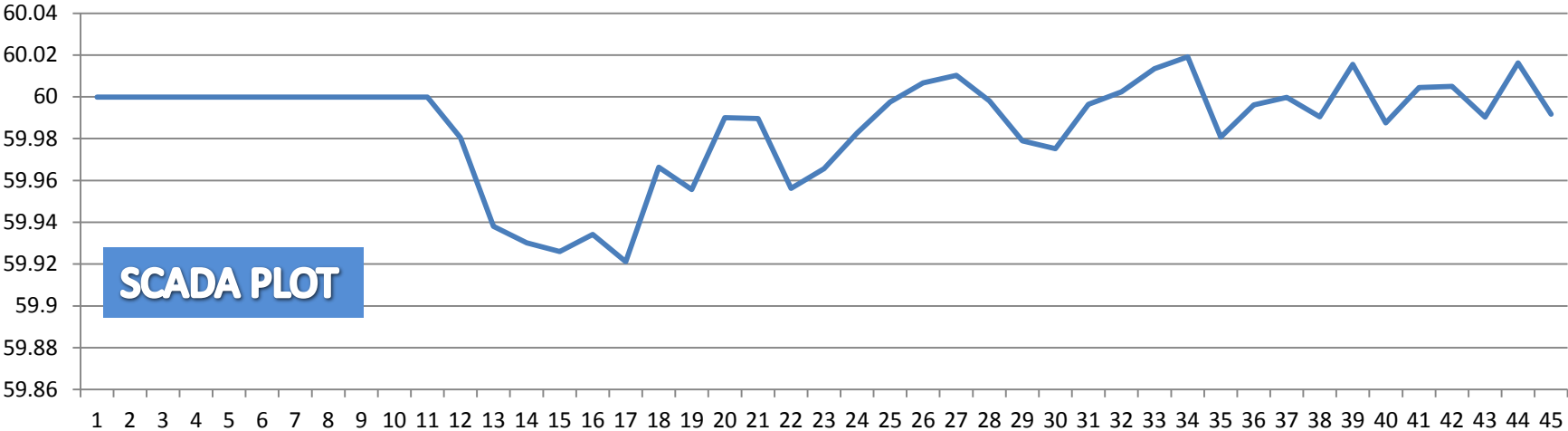
Pacific DC Intertie (PDCI) Oscillations

PACIFIC DC INTERTIE OSCILLATION CASE



SCADA vs Phasors

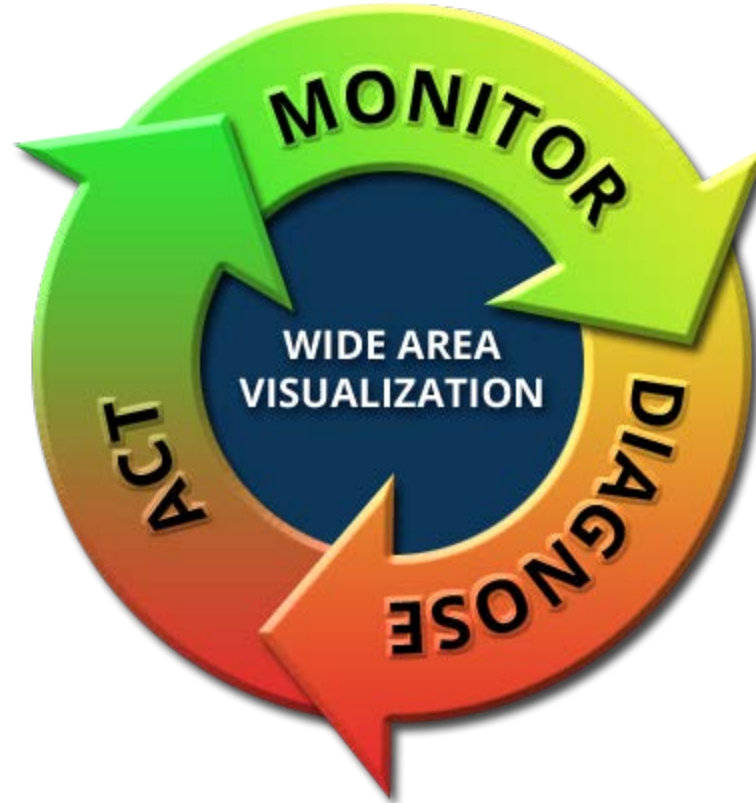
Sylmar frequency



PDCI Oscillations

ALARMS - Low damping, Power oscillations on PDCI

Block PDCI - oscillations stop



Root Cause of Oscillations
– Celilo (Northern Terminal
of PDCI)

What can operators learn in training?

- **Recognize event signatures**
- **Pinpoint source/sink of oscillations**
- **Evaluate alternate corrective actions**

Case Study 3 – Pacific Southwest Blackout

Simulation of a real event

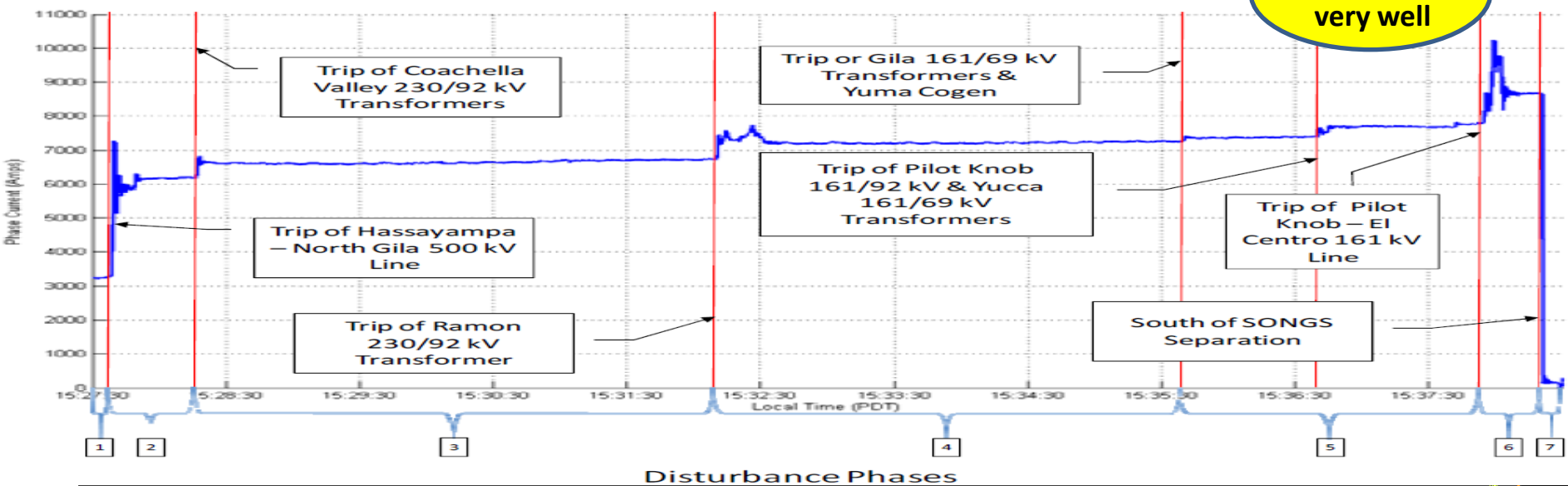
- **Event occurred on Sep 8, 2011 and took about 12-minutes**
- **Simulation Created Based on Sequence of Events in NERC/FERC report**
 - Outage of Hassayampa-North Gila line
 - Outage of IID transformers
 - Load drop in IID and CFE
 - Loss of CFE and IID generation
 - Separation of SDGE at San Onofre Nuclear Gen. Station (SONGS)
- **Simulation results match the event**
- **Simulation developed to validate event and train operators**

Pacific Southwest Blackout

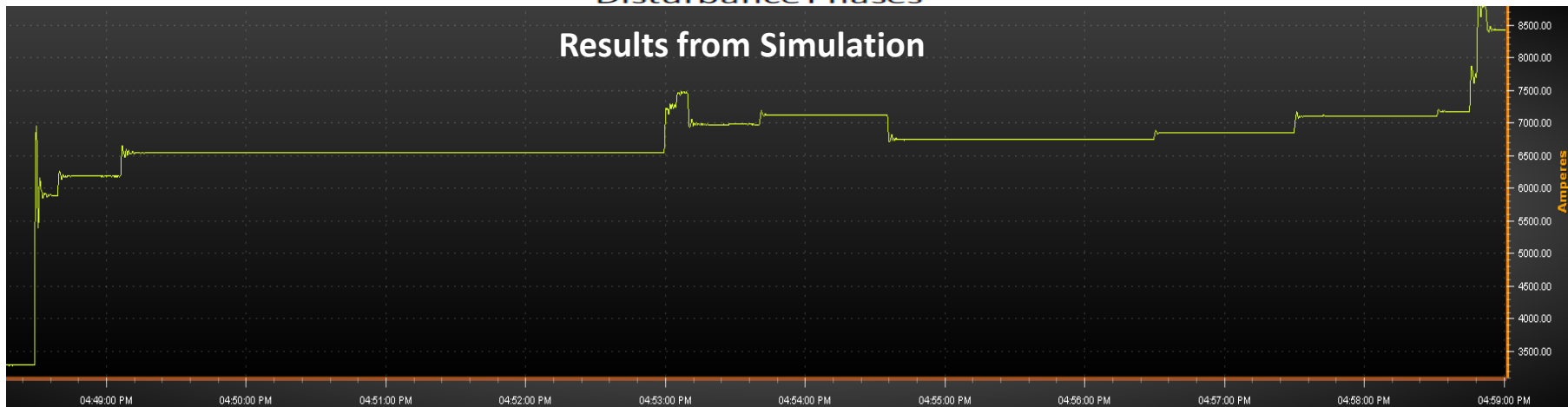
Comparison of South of SONGS currents

Results from NERC/FERC report

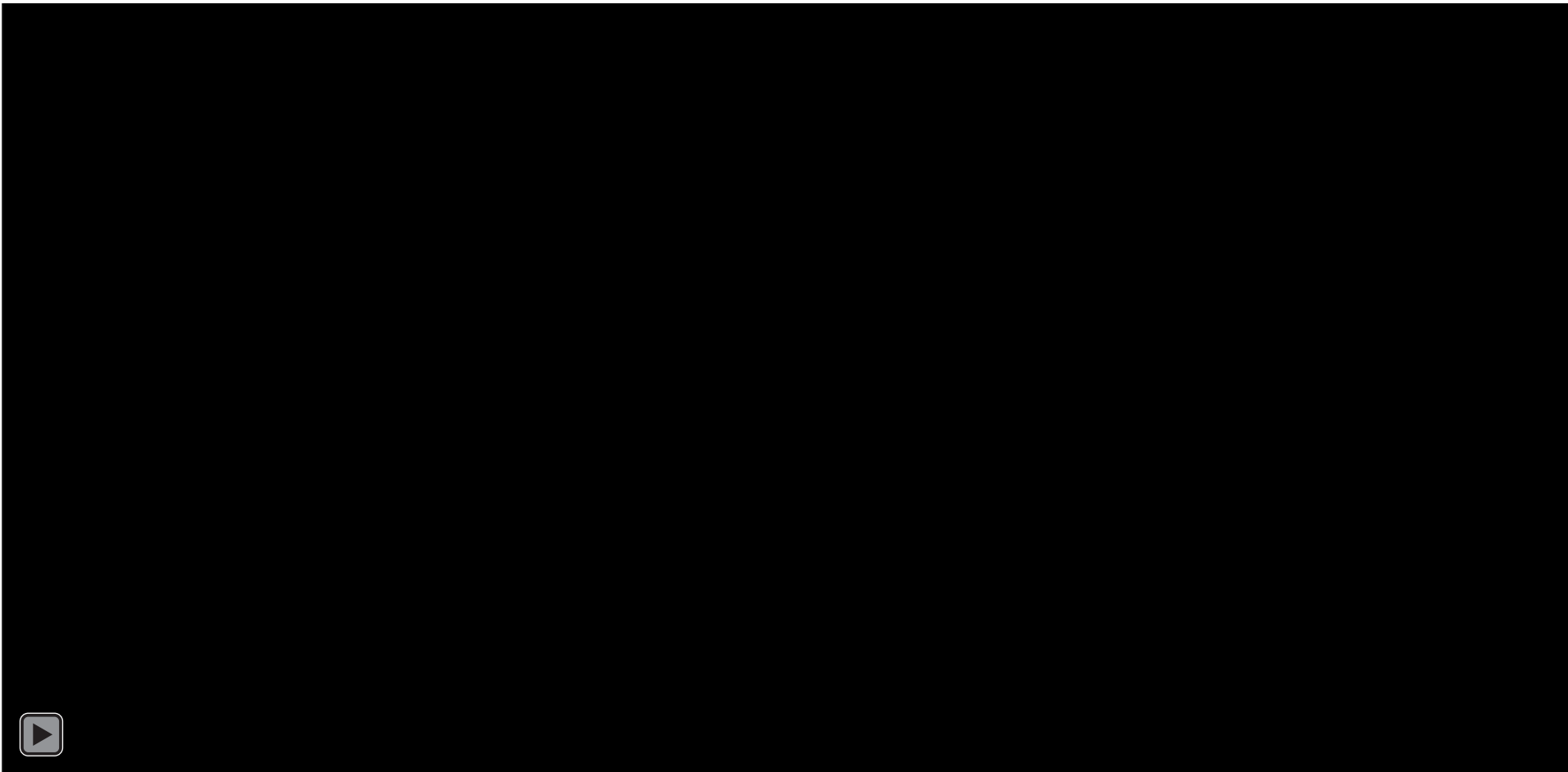
Results match very well



Results from Simulation

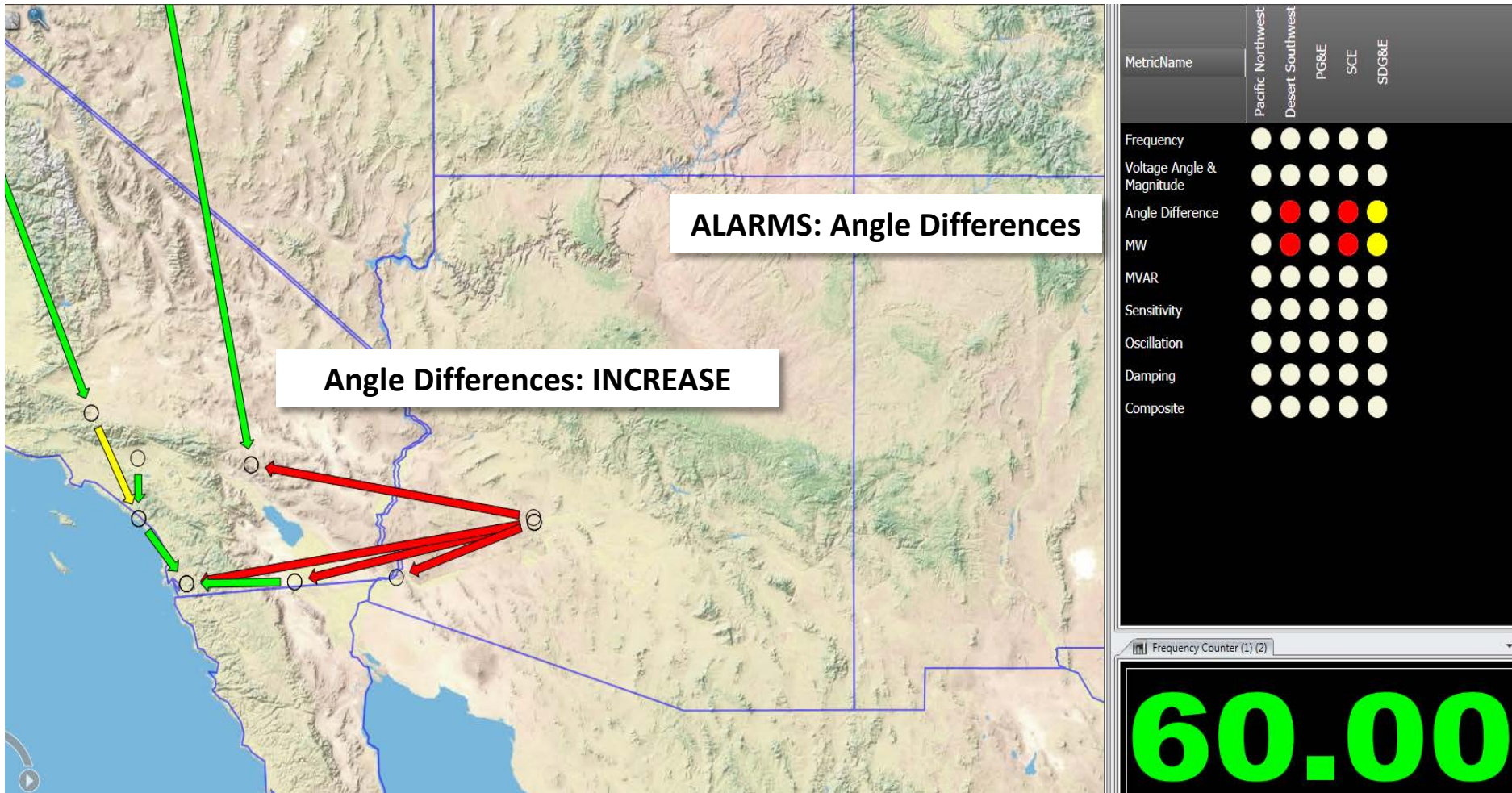


Pacific Southwest Blackout



Pacific Southwest Blackout

(Simulation replay: Just after start of event)



Angle Differences in Southwest increase and get alarmed.
Simulations enable operators to test corrective actions.

Pacific Southwest Blackout Alarm Panel

MetricName	Pacific Northwest	Desert Southwest	PG&E	SCE	SDG&E
Frequency	●	●	●	●	●
Voltage Angle & Magnitude	●	●	●	●	●
Angle Difference	●	●	●	●	●
MW	●	●	●	●	●
MVAR	●	●	●	●	●
Sensitivity	●	●	●	●	●
Oscillation	●	●	●	●	●
Damping	●	●	●	●	●
Composite	●	●	●	●	●

Alarms just after start of event

MetricName	Pacific Northwest	Desert Southwest	PG&E	SCE	SDG&E
Frequency	●	●	●	●	●
Voltage Angle & Magnitude	●	●	●	●	●
Angle Difference	●	●	●	●	●
MW	●	●	●	●	●
MVAR	●	●	●	●	●
Sensitivity	●	●	●	●	●
Oscillation	●	●	●	●	●
Damping	●	●	●	●	●
Composite	●	●	●	●	●

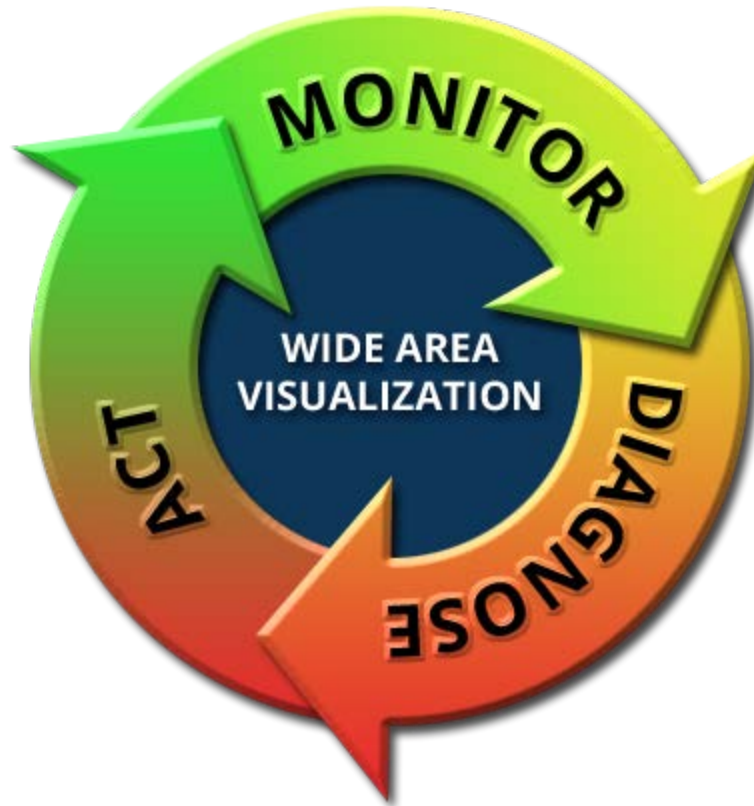
Alarms just before system separation

The number and severity of alarms triggered increases as the event worsens. Operators can evaluate corrective actions to prevent worsening of event and cascading.

Pacific Southwest Blackout

ALARMS – Multiple Angle differences, Devers bus voltage & sensitivity,
Power flow on South of SONGS

- Reduce power flow on South of SONGS
 - Drop load in SDGE
 - Increase generation in SDGE
- Add voltage support at Devers substation



- Heavy power transfers from SCE to SDGE
- System in insecure state

What can operators learn in training?

- **How the events unfolded?**
- **What thresholds were violated?**
- **Evaluate alternative actions at each phase?**

Conclusion

Phasor Simulations: How Can They be Used in Operations?

Phasor Simulations: How Can They be Used in Operations?

- Visualize and analyze extreme events
- Familiarize operators with alarms and metrics and how to use them to diagnose and act in real time
- Understand event signatures:
 - Line trip
 - Generation drop
 - Oscillations
- Assess grid performance after event scenarios – frequency response, sensitivities, phase angle differences
- Learn from past significant events – actual events and alternate outcomes with operator actions
- Identify key stress points and flow gates for monitoring
- Test and validate alarms / alert levels
- Validate models – system performance, generator models, load models
- Understand grid behavior under a variety of operating scenarios and be better equipped to monitor, diagnose and take timely corrective actions to prevent cascades and major blackouts
- Develop and test operating procedures/ guidelines

Using Simulations in Operations

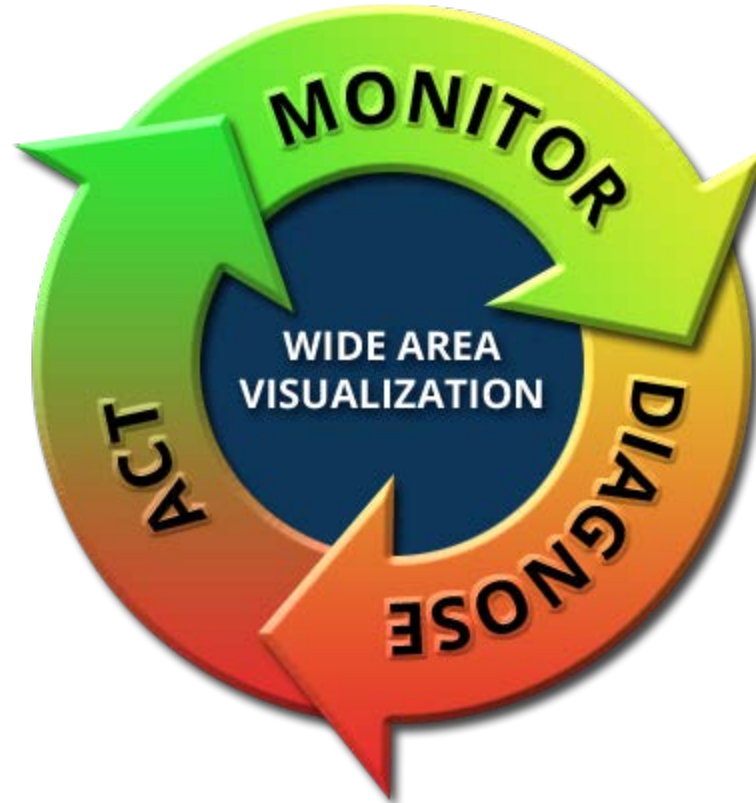
Key Takeaways

Extreme Event Simulations + What If Exercises For Operator Training

Grid Stress = Monitor Dynamic Metrics

Test Effectiveness of Alternative Operator Actions for Stability:

- Redispatch Generation
- Shed Load
- Provide Voltage Support



Grid Stress Diagnostics:

- Line Trip
- Load Trip
- Generation Trip
- Cascade
- Wide Area, Regional or Local

EPG Webinar Series

Webinars are planned monthly, on the third Tuesday of each month from 11 a.m. to 12 Noon Pacific. The 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)
- Establishing Alarm Limits For Use in Operations (Oct 8)
- **Phasor Simulations – How Can They Be Used in Operations? (Nov 19)**
- **NOTE: No Webinar in December, 2013**
- **Using Synchrophasor Technology to identify Control System Problems (Jan 21, 2014)**
- **Model Validation (Feb 17, 2014)**

Feedback

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



Q&A

Thank You!



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