Electric Power Group Presents
Maximizing Use of Synchrophasor Technology for Everyday Tasks

Welcome!

The meeting will begin at 2:00 p.m. ET / 11:00 a.m. PT August 16, 2017

Today's Topic: Oscillation Event Mining for Use in Event Analysis, Model Validation and Operations

Registration URL: https://electricpowergroup2.webex.com/
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Maximizing Use of Synchrophasor Technology for Everyday Tasks

Oscillation Event Mining For Use in Operations, Event Analysis and Model Validation

Webinar

August 16, 2017

Presented by
Prashant Palayam, EPG
Sidharth Rajagopalan, ERCOT

Outline

- **Industry Challenge –** Selecting Significant Historical Events from Archived Data for Analysis
- **Suggested Methodology –** Mining Historical Events to build Event Library for Analysis
- **Event Mining Reports Using Automated Event Miner (AEM)**
  - Oscillations, Low Voltage, Phase Angle Difference, and Frequency Events
- **Use Case Example –** Oscillation Event Mining
  - Mining Parameters
  - Mining Approach
  - Mining Report
- **Example of AEM Oscillation Mining Report – ERCOT Experience**
  - Mining Results and Oscillation Events - Location, Severity, Duration and Root Cause
- **FAQ's, Tools and Summary**
- **Discussion – Your Practice, Use Cases, Suggestions**

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Industry Challenge – Key Issues and Questions from Users

- **Operations –** *Need to establish proper alarm limits*
  - Event not detected – how to configure limits to detect significant system events?
  - Too many alarms are generated – how to tune parameters to avoid unnecessary alarms (avoiding operator overload)?
- **Operations Engineer –** *Need to perform event analysis*
  - Analysis of historical events will help identify grid issues and potential threshold limits for the various grid metrics (e.g. voltage, frequency, oscillations and phase angle).
- **Planning –** *Need to perform model validation*
  - How to obtain grid dynamics for both local or wide area events for the purpose of model validation?
- **How to gather and retain significant historical events in a library for use in operations, event analysis and model validation?**

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Mining for Oscillations

Use Cases, Reports & Mining Methodology

Use Case Examples Using Synchrophasors & Simulated Phasors

Oscillation Events by Location, Severity, Mode & Duration

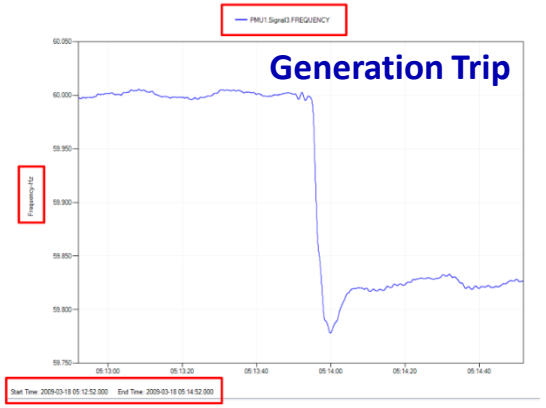
6	50	2	5	4 Days, 5 Hrs, 40 Min		15 (~0.1Hz)	Count of Events = 10
Signal Type	Location	Event Year	Event Month	Event Start Date, HH:MM, TZ	Event End Date, HH:MM, TZ	Average Oscillatory Frequency (Hz)	Maximum Peak-to-Peak Magnitude
MW	Signal Name 1	2009	12	18, 16:32, UTC-7:00	18, 17:32, UTC-7:00	3.33	15 MW
MW	Signal Name 1	2010	1	05, 02:32, UTC-7:00	05, 02:50, UTC-7:00	3.33	10 MW
MW	Signal Name 2	2009	6	05, 02:32, UTC-7:00	05, 02:50, UTC-7:00	0.74	6 MW
VM	Signal Name 5	2009	8	05, 02:32, UTC-7:00	05, 02:50, UTC-7:00	1.58	3 kV

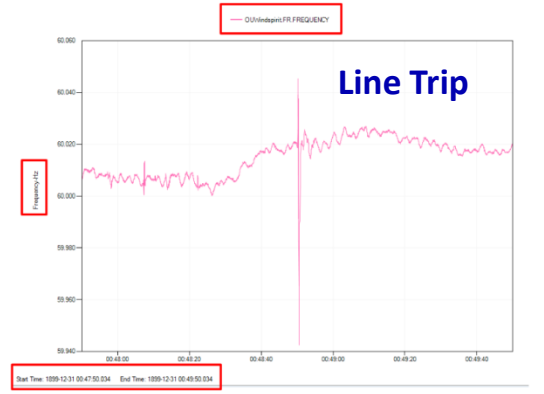
Poor and Negatively Damped Contingencies

File Name	Signal Name	Signal Type	Oscillatory Frequency (Hz)	Damping Ratio (%)
345kV C1	POWR2[unit20.6900]W1	MW	1.46	2
345kV C1	POWR1[unit1 18.000]N1	MW	1.04	0
345kV C2	POWR1[unit1 18.000]N1	MW	0.73	11
345kV C3	POWR1[unit1 18.000]N1	MW	0.08	11
345kV C1	VOLT [unit1 18.000]N1	VM	3.06	3
345kV C1	FREQ [unit1 18.000]N1	FREQ	2.00	-2

Frequency Events by Location, Severity, Timing & Count

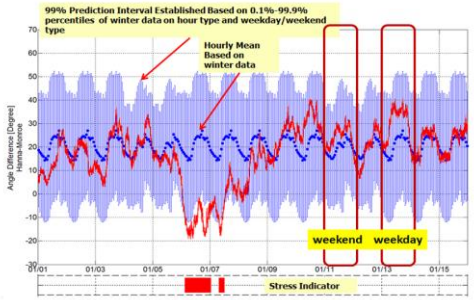
Event #	Location	Event Year	Event Month	Event Date, HH:MM, UTC-7:00	**Frequency declined to (Hz)
Event 1	Signal Name 1	2009	3	18, 16:32	59.78
Event 2	Signal Name 5	2009	5	1, 5:10	59.85
+ Event 3	Signal Name 6	2009	8	5, 8:14	59.6
+ Event 4	Signal Name 10	2009	10	25, 22:10	59.75





Automatic
Event
Miner

Wide Area Angle Events by Location, Timing, Count, Severity



Voltage Events & Clusters by Zones, Severity, Duration, Count

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Oscillation Event Mining Methodology - 3 Steps

Parameter Selection - Engine for Event Detection - Generate Reports

Mining Parameters

- Duration – Hours to Years
- Footprint
- Filters – Energy, Modal Frequency & Duration

Mining Approach

- Engine – Oscillation Detection Module (ODM)
- Output – When, Where, What, How & Why
- Oscillations are categorized by root cause using 4 bands

Oscillation Report

- Count of Events
- Location of Events
- Event Timing
- Dominant Modes
- High Energy Events

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Oscillation Event Mining Parameters – Step 1

Parameter Selection - Engine for Event Detection - Generate Reports

- **Duration**
  - Historical data – Hours to Years
- **Footprint & PMU Locations**
  - PMU locations – All or Critical stations close to generation, load and line/flowgate power flows of interest
- **Signal types –** Frequency (Hz), Voltage (kV), Current (Amps), Real (MW) & Reactive Power (MVar), angle difference (deg) between V-V & V-I
- **Filters**
  - Energy (Peak-to-Peak Magnitude) – Used to filter out low energy oscillations
  - Modal Frequency – Used to filter out low frequency oscillations
  - Duration – Used to filter out short duration oscillations

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Oscillation Event Mining Approach - Step 2

Parameter Selection - **Engine for Event Detection** - Generate Reports

- **Engine**
  - Oscillation Detection Module (ODM) from Dr. Dan Trudnowski, Montana Tech, MT
- **Bad Data**
  - Prior to detection – Using PMU Quality Flags, Outlier Filter, Stale Filter
  - After detection – Using Narrow Modal Frequency by Band, High Energy Filter by Metric
- **Root Cause & Root Cause**
  - Speed Governor (0.01 – 0.15Hz) = Band 1
  - Inter Area or Local Oscillations (0.16 – 1Hz) = Band 2
  - Local Controller (1.1 – 5Hz) = Band 3
  - HVDC/FACTS Controller (5.1 – 14Hz) = Band 4

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Oscillation Event Mining Report - Step 3

Parameter Selection - Engine for Event Detection - Generate Reports

Count of Events, Mode and Location by Root Cause

Band	Root Cause	Mode Range (Hz)	Count of PMU Locations	Count of Events	Count of Modes
1	Speed Governor	0.01 to 0.15	-	-	-
2	Inter-area or Local Oscillations	0.16 to 1.0	13	25	7
3	Local Plant Control Systems	1.1 to 5.0	3	2	2
4	Controllers	5.1 to 15	3	15	4

Count of Events & Dominant Mode – PMU 2

PMU Locations	Counts of Events by PMU Location	Count of Events by Mode	Mode (Hz)	Peak-to-Peak Magnitude of Oscillation by Metric
PMU2	9	3	0.6	77.3 Amps
PMU2	9	3	0.7	88.7 Amps
PMU2	9	1	0.3	10.6 Amps
PMU2	9	1	0.6	1.1 kV
PMU2	9	1	1	12.0 Amps

Signal Name	Signal Type	Event Start Time	Event End Time	Mode (Hz)	Peak-to-Peak Magnitude
PMU2.I1.IM	IM	3/18/2017 21:45	3/18/2017 21:49	0.3	10.62
PMU2.I1.IM	IM	3/22/2017 0:35	3/22/2017 0:43	0.65	38.04
PMU2.I1.IM	IM	3/22/2017 9:08	3/22/2017 9:13	0.7	88.73
PMU2.I1.IM	IM	3/22/2017 9:30	3/22/2017 9:37	0.7	73.96
PMU2.I1.IM	IM	3/23/2017 3:08	3/23/2017 3:12	1	11.96
PMU2.I1.IM	IM	3/25/2017 18:08	3/25/2017 18:13	0.6	77.25
PMU2.V1.VM	VM	3/25/2017 18:08	3/25/2017 18:13	0.6	1.06
PMU2.I1.IM	IM	3/25/2017 18:14	3/25/2017 18:18	0.7	67.36
PMU2.I1.IM	IM	3/25/2017 18:20	3/25/2017 18:26	0.65	76.00
PMU2.I1.IM	IM	3/27/2017 14:29	3/27/2017 14:36	0.4	39.52
PMU2.I1.IM	IM	3/27/2017 14:37	3/27/2017 14:43	0.7	61.79
PMU2.I1.IM	IM	3/27/2017 14:44	3/27/2017 14:49	0.6	73.72
PMU2.I1.IM	IM	3/28/2017 23:07	3/28/2017 23:12	0.7	57.96

Oscillation Events at PMU 2 Location

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Automated Event Miner (AEM) Overview

- AEM is designed to mine through archived data (Days to Years) to identify events based on user defined mining parameters
- AEM can be used for oscillations, low voltage, high phase angle difference and frequency signatures.
- Data Sources – Databases (MySQL, MSSQL, PI, OH), Flat Files (*.csv, COMTRADE)
- Data Types – Simulated and PMU
- AEM provides GUIs to setup mining parameters, select mining engines, visualize mining results and generate mining report
- Mined events are reported by location, severity, duration and count to provide engineers an event library to select significant events for analysis

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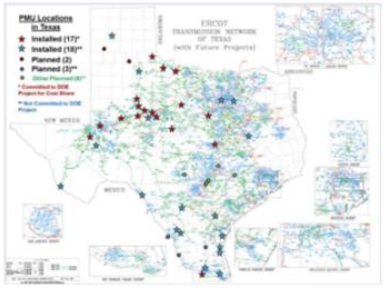
Example of AEM Oscillation Mining Report

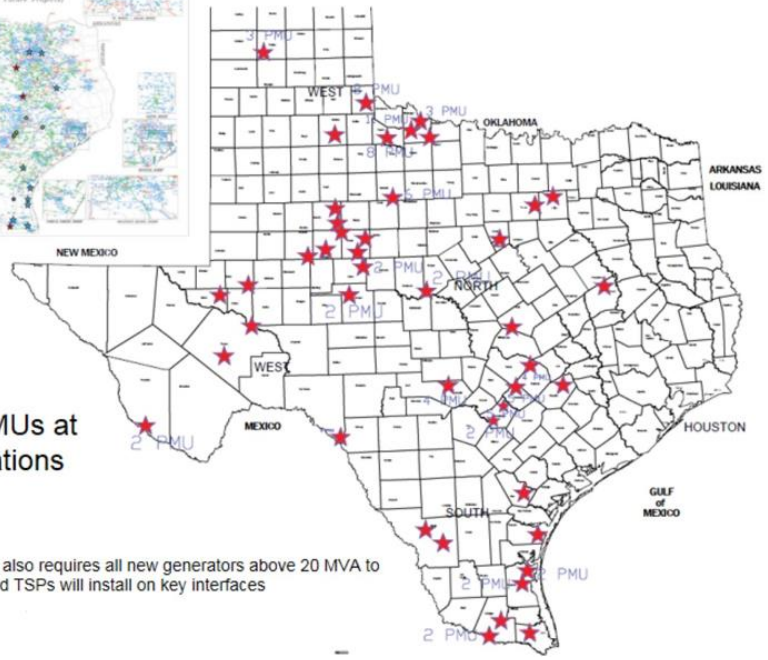
ERCOT Experience , Mining Results and Oscillation Events

ERCOT Experience with Oscillations and Event Mining

- **2010 – 2014 = Center for the Commercialization of Electric Technologies (CCET) Discovery Across Texas (DAT) project under Department of Energy (DOE) Award**
  - > **Event Analysis**
    - Inter-area oscillations (e.g. 0.6Hz N-S mode etc)
  - > **Operations**
    - Wind Farm oscillations (e.g. 3.33Hz Band 3 mode)
    - Hydro Unit oscillations (e.g. 1.8Hz Band 3 mode)
    - Conventional Unit oscillations (e.g. 0.13Hz Band 1 mode)
  - > **Oscillation Data Mining Activity**
    - Wind Production related (e.g. 0.9Hz Band 2 mode)
    - Wind Turbine Design related (e.g. 5-6Hz Band 3 mode)
    - Control Systems Settings related (e.g. 2Hz Band 3 mode)
    - Local Oscillations topology related (e.g. 0.6Hz Band 2 mode)

76 PMUs at
35 locations
2014





100 PMUs at
44 locations
2017

Jan 2017 Operating guides also requires all new generators above 20 MVA to install PMUs and as directed TSPs will install on key interfaces

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Oscillation Event Mining Report – ERCOT Example

Using 2 weeks of Historical PMU data

- **Need –** Oscillation Event Mining Tool
- **Automated Event Miner (AEM) –** Add-on application to Phasor Grid Dynamics Analyzer (PGDA) for mining power system events
- **Mining Parameters –** Energy Filters

Signal Type	69kV	138kV	345kV
Real Power (MW)	1	1	1
Reactive Power (MVar)	1	1	1
Frequency (Hz)	0.010	0.010	0.010
Voltage Magnitude (kV)	1	1	1
Current Magnitude (Amps)	10	10	10
Angle Pairs (deg)	1	1	1

- **Mining Summary –** Report by Band

Band	Root Cause	Mode Range (Hz)	Count of PMU Locations	Count of Events	Count of Modes
1	Speed Governor	0.01 to 0.15	-	-	-
2	Inter-area or Local Oscillations	0.16 to 1.0	13	25	7
3	Local Plant Control Systems	1.1 to 5.0	3	2	2
4	Controllers	5.1 to 15	3	15	4

- **Mining Report –** AEM Oscillations

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ERCOT Next Steps Using Oscillation Event Mining Report

- **Operations**
  - Upgrade to Real Time Dynamics Monitoring System (RTDMS) 2017 to have new Mode Meter and Oscillation Detection Algorithms
  - Use Mining Event Library to test, validate and establish alarm parameters in Phasor Simulator for Operator Training (PSOT) for use in Operations
  - Configure Mode Meter for known modes in known locations
  - Fine Tune Oscillation Detection for timely alarming
  - Use Mining Event Library in Phasor Simulator for Operator Training (PSOT) for use in Operator Training at ERCOT and also remote training including TDSP and GO operators.
- **Operations Engineer**
  - Upgrade PGDA with AEM application and continue effort on event mining and event analysis
- **Planning**
  - Model Validation Using PGDA for NERC MOD-033 Requirements

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FAQs, Tools, Summary

RTDMS, PGDA+AEM, PSOT

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FAQs

- **How long it took to mine 2 weeks of ERCOT data?**
  - 2 weeks of ERCOT data = 459GB. It took 1.2 Days using 3.33GHz processor, 48GB RAM, Windows 7 Tower Computer. The speed can be improved by choosing servers with high number of cores, larger memory and hard drive.
- **How to gather events in library from historical data and simulated data?**
  - Suggested Approach is to mine for events from historical data and perform dynamic simulations to generate simulated data
- **What data sources are targeted for AEM?**
  - Flat Files – Batch *.csv files and COMTRADE
  - Databases – OpenHistorian, ePDC (Phasor Archiver), RTDMS (MSSQL), PI Historian
- **How can we learn more about oscillation analysis?**
  - EPG, Montana Tech, University of Wyoming are hosting an oscillation analysis workshop at WECC office in Salt Lake City, UT on August 24th and 25th to share knowledge of power system oscillations, tools and configuration for operations, engineers and planners. **Contact:** chen@electricpowergroup.com for registration and logistics.

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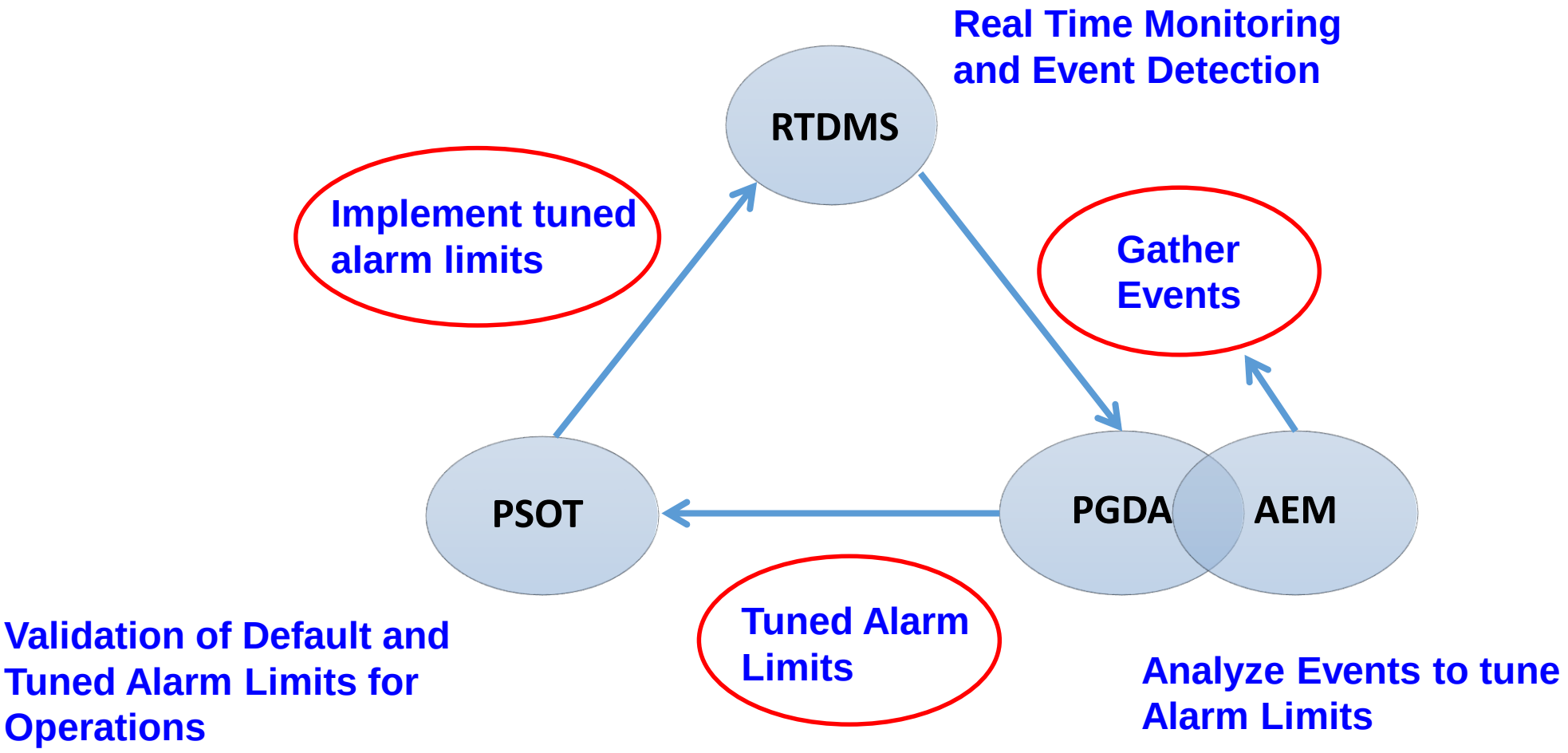
Tools Available for Gathering Event Library, Configuring and Validating Alarm Limits for Operations



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Webinar Summary – Key Takeaways

- **Industry Challenge –** Selecting Significant Historical Events from Archived Data for Analysis
- **Suggested Methodology –** Mining Historical Events to build Event Library for Analysis
- **Automated Event Miner (AEM) –** Mine Through Archived Data (Hours to Years)
  - Reports – Oscillations, Low Voltage, Phase angle difference and Frequency Events
  - Oscillation Event Mining Methodology – 3 Steps
- **Use Cases for Event Mining**
  - Operations – Establishing proper alarm limits and Operator training
  - Engineering – Perform event analysis to provide intelligent insights to Operations
  - Planning – System Level Steady State and Dynamic Model Validation

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Q&A, Discussion

Your Practice, Use Cases, Suggestions

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Q&A, Discussion

- **Q&A**
- **Event Mining**
  - Your Practices
  - Use Cases
  - Pain Points
  - Suggestions
- **Next Webinar Focus**
  - Priority
  - Other topics
- **Oscillation analysis workshop**
  - WECC office in Salt Lake City, UT on August 24th and 25th

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EPG Webinar Series

- Extracting large amounts of synchrophasor data efficiently for offline analysis. (August 2016)
- Quickly creating an event report that could be distributed to operators, engineers and managers. (Sept. 2016)
- System Model Validation for MOD-33 Requirement (Oct. 12)
- Configuring alarms and validate parameters to provide meaningful results for operators. (Dec 14)
- Synchrophasor Intelligence in EMS for Use in Operations (Jan 2017)
- Use Cases of Linear State Estimator Technology for Grid Resiliency (Feb 2017)
- Delivering Reliable and Validated PMU Data for Use by Operators (April 2017)
- Generator Model Validation using PMU data for MOD-26, MOD-27 Requirements (June 2017)
- Oscillation Event Mining for Use in Event Analysis, Model Validation and Operations (August 2017)
- Monitoring, Detection and Analysis of Oscillations in Real-Time (October 18 2017)
- Using composite alarms as early warning for operator action
- Addressing data issues, such as PMU timing, phase correction, etc.
- ePDC/DataNXT/RTDMS pub/sub Synchrophasor Distribution Service
- Remote/Mobile access with local host for real-time monitoring and event diagnostics during emergencies
- Other topics?

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Thank you for participating!

If you have any questions regarding any part of the webinar, please contact us at Contact@electricpowergroup.com

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