Establishing Alarm Limits

And Using Them in Real-Time Operations

October 8, 2013

Presented by:

Jim Dyer

Electric Power Group

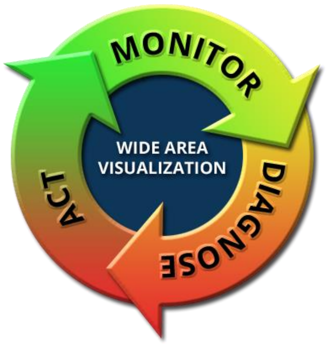
Webinar Outline

- **Today's Focus: Establishing Alarm Limits and Using them in Real-Time Operations**
  - Use of Synchrophasor Technology in Operations
  - The Need for Synchrophasor Alarm Limits
  - Establishing Alarm Limits: Methods for Setting Synchrophasor Alarm Limits
    - Rules of Thumb Based on Operating Experience
  - Establishing Alarm Limits for Angle Differences
    - Method 1: Getting Started
    - Method 2: Advanced Analysis
  - Alarms Implementation in RTDMS
  - Use of Alarms in Real-Time Operations
- **Upcoming Webinar Schedule**
- **Q&A**

Use of Synchrophasor Technology in Operations

Use of Synchrophasor Technology in Operations

- **Synchrophasor technology delivers:**
  - **Wide Area View –** Real-time visualization and situational awareness of interconnection or sub-region
  - **High Resolution –** Improved observability and event diagnostics
  - **Grid Dynamics –** Measurement-based phase angles, oscillations, damping and sensitivities
  - **Reliability Margin –** "How far are we from the edge?" - Voltage and Angle sensitivities

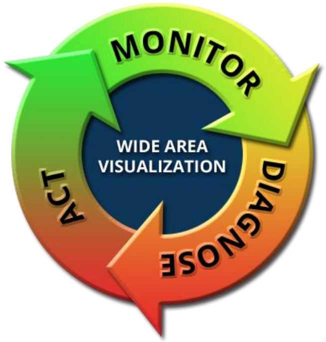


Operator's Mission: Keep the lights on!

The Need for Synchrophasor Alarm Limits

The Need for Synchrophasor Alarm Limits

- **Early Warning of Grid Stress (Increasing Phase Angle differences)**
- **Pinpoint Incident Location (First PMU to Move - frequency, voltage etc.)**
- **Assess Incident Severity (Number of Metrics that Alarm)**
- **Assess Vulnerability to Cascade (Multiple Alarms in Large or Multiple Footprints)**
- **Guide Operator Actions**



Establishing Alarm Limits: Methods for Setting Synchrophasor Alarm Limits

Establishing Alarm Limits:

Methods for Setting Synchrophasor Alarm Limits

Synchrophasor Alarm Metric:	Method for Setting Alarm Limit:
Frequency	Initially use current *SCADA* limits; in future, some metrics may become *Dynamic* limits
Voltage	
MW Flow	
MVAR Flow	
Damping/ Oscillation	Rule of Thumb/ Operating Experience (e.g. Damping – Alert at 5% , Alarm at 3%)
Sensitivity – Voltage and Angle	Rule of Thumb/ Operating Experience (e.g., Alert at 4 kV/100MW, Alarm at 5kV/100MW for 500 kV line)
Composite	Example: Combination of voltage sensitivity and phase angle difference metrics
*Angle Difference**	*Power Flow Study/ Baselining*

**Today's Focus*

Establishing Alarm Limits for Angle Differences

Establishing Alarm Limits for Angle Differences

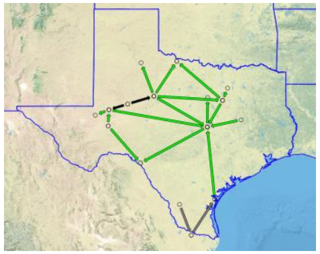
- **Method 1: Getting Started**
  - Using Existing Operating Studies
- **Method 2: Advanced Analysis**
  - Baselining and Cluster Analysis
    - Statistical Analysis
    - Operating and Planning Studies

Method 1: Getting started
Using Existing Operating Studies

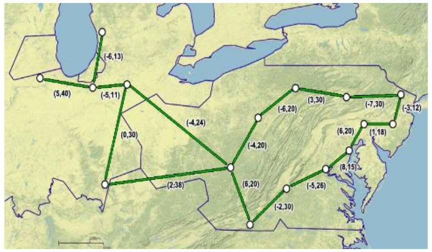
Using Existing Operating Studies:

- Identify Key Angle Pairs (10 to 20, depending on Interconnection size) – Suggested Pairs between Large Generators (Source) and Load Centers (Sink) and across Major Flow Gates

WECC



ERCOT



ISO-PJM

- Extracting Angle Pair Information from Seasonal Stress Case Operating Studies

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Method 1: Getting Started

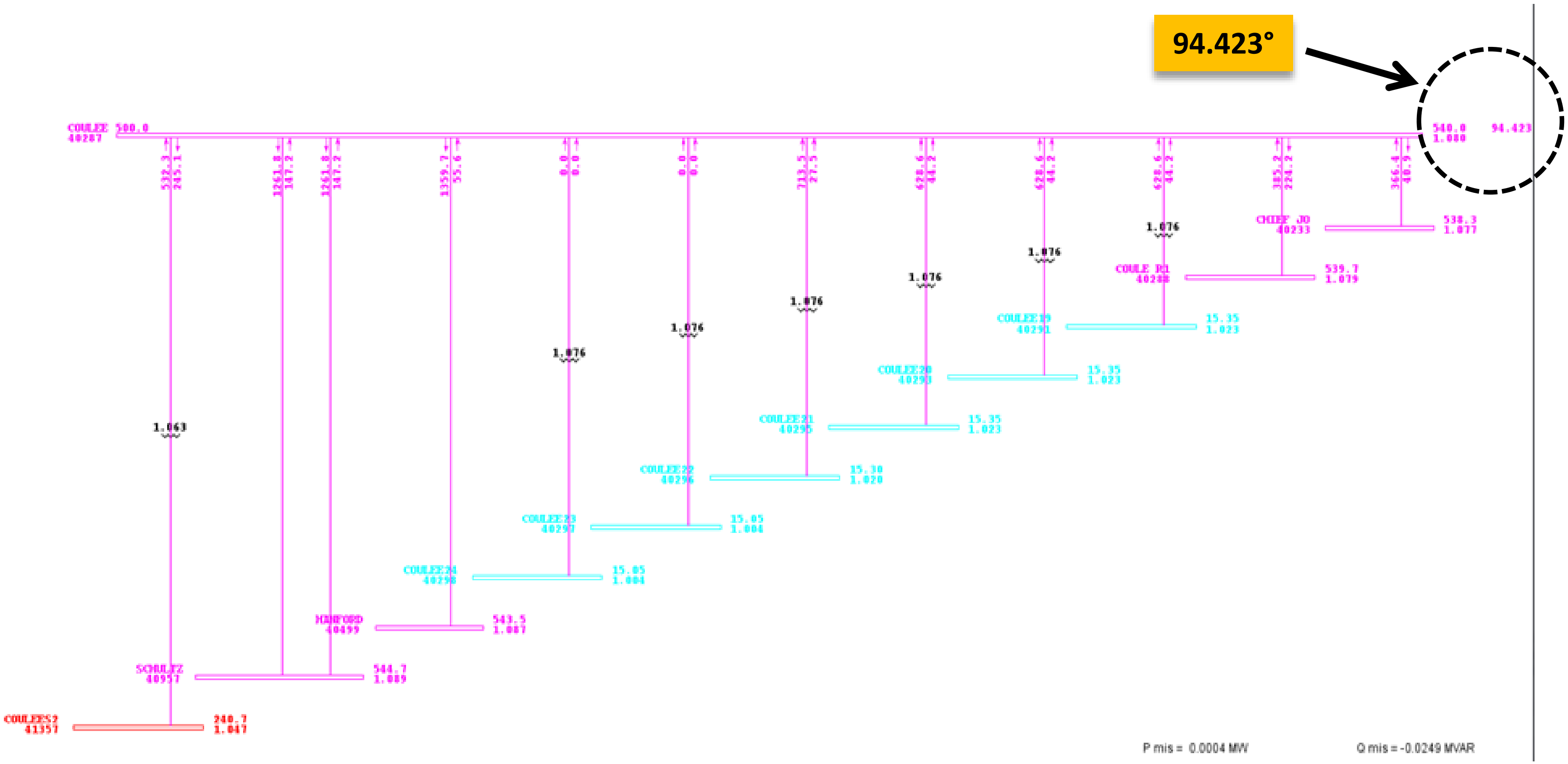
Using Existing Operating Studies – Grand Coulee to Devers Example

- **Step 1: Identified Angle Pair – Grand Coulee to Devers**
  - Grand Coulee Power Plant is in Washington State, and Devers Substation is in the Palm Springs area of So. Calif. (1,300 miles)
- **Step 2: Obtain Operational Studies – North-South Stressed Case under Peak Load Conditions (Tested for N-1 and other contingency scenarios)**
- **Step 3: Extract Angle Pair Information**
  - Angle from Grand Coulee to Reference Bus (Plant in L.A. Area)
  - Angle from Devers to Reference Bus
  - Angle Difference Based on the above Two

Method 1: Getting Started

Using Existing Operating Studies – Grand Coulee to Devers Example

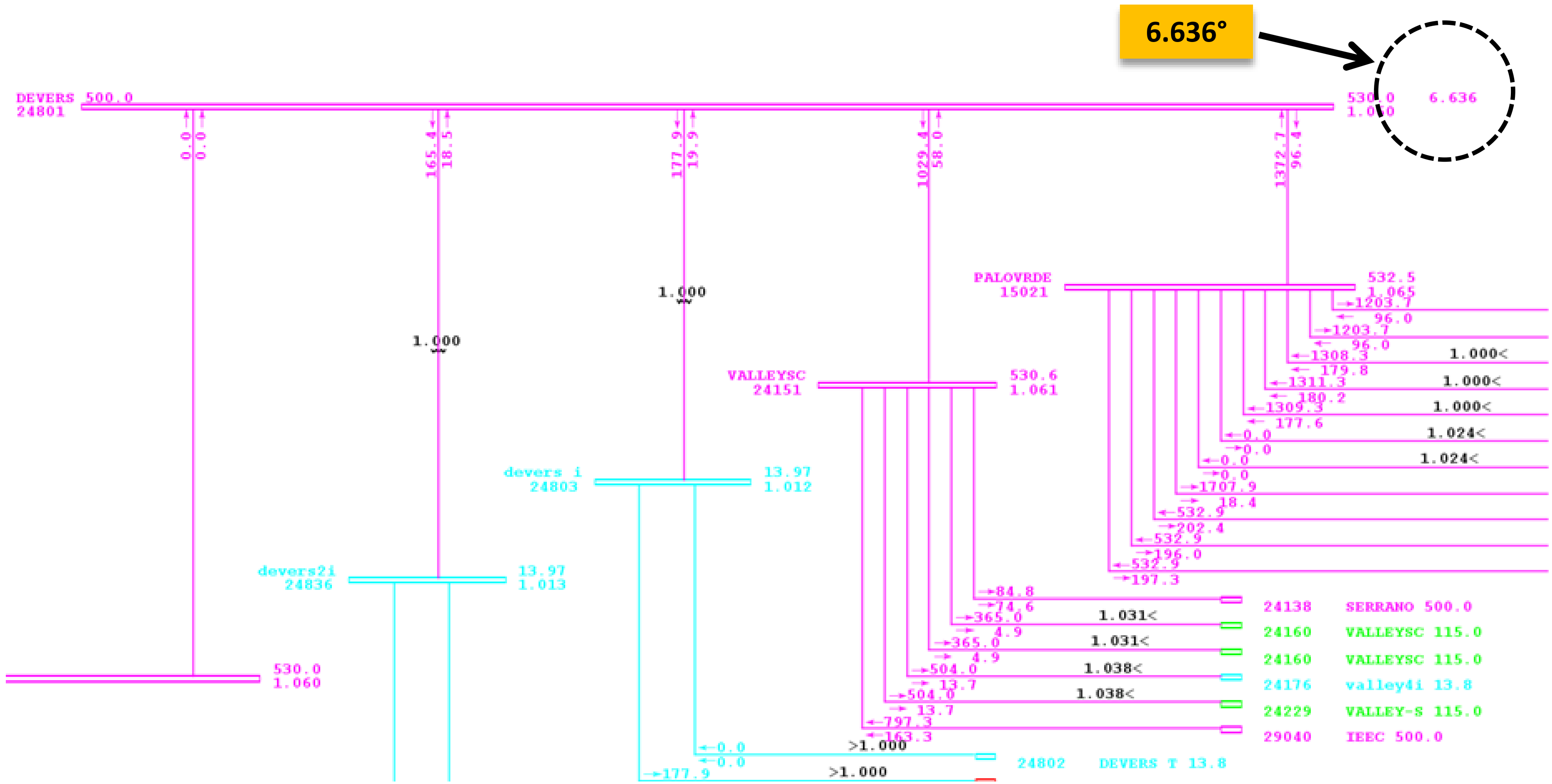
PSLF Output Showing Grand Coulee Bus Phase Angle



Method 1: Getting Started

Using Existing Operating Studies – Grand Coulee to Devers Example

PSLF Output Showing Devers Bus Phase Angle



Method 1: Getting Started

Using Existing Operating Studies – Grand Coulee to Devers Example

- **Step 4: Recommending Alarm Limits**
  - Angle Difference (Grand Coulee-Devers) in a stressed case: 94.423° - 6.636° = 87.787° (See Calculation Steps Below)
    - Calculation Steps:
      1. Grand Coulee = A
      2. Devers = B
      3. Reference Bus (Alamitos) = C
      4. Grand Coulee Phase Angle = A – C
      5. Devers Phase Angle = B – C
      6. Angle Difference between GC and Devers = (A – C) – (B – C) = A – B
  - Suggested Alert and Alarm Limits
    - Alert: 85°
    - Alarm: 90°
- **Step 5: Repeat Process for Each Additional Angle Pairs**

Establishing Alarm Limits for Angle Differences
Method 2: Advanced Analysis

- Method 1: Getting Started
  - Using Existing Operating Studies
- **Method 2: Advanced Analysis**
  - Baselining and Cluster Analysis
    - Statistical Analysis
    - Operating and Planning Studies

Method 2: Advanced Analysis

Baselining and Cluster Analysis

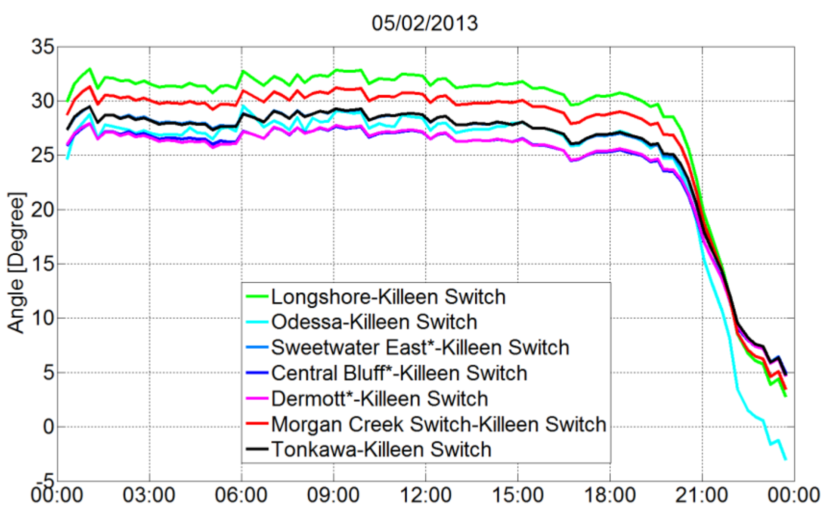
Process Step		Notes
Identifying Angle Pairs	→	Load Centers (Sink), Flow Gates and Large Generators (Source)
Cluster Analysis – Select Representative PMU	→	Manage Data Overload
Data Extraction – To Analyze Past Performance - Typically 12 Months Data	→	State Estimator or Phasor Measurement
Statistical Analysis	→	Example: Niagara – Farragut (NY ISO)
Establishing Alarm Limits (Seasonal, On/Off Peak)	→	NYISO
Validate and Refine Using Operating and Planning Studies		

Method 2: Advanced Analysis

Cluster Analysis

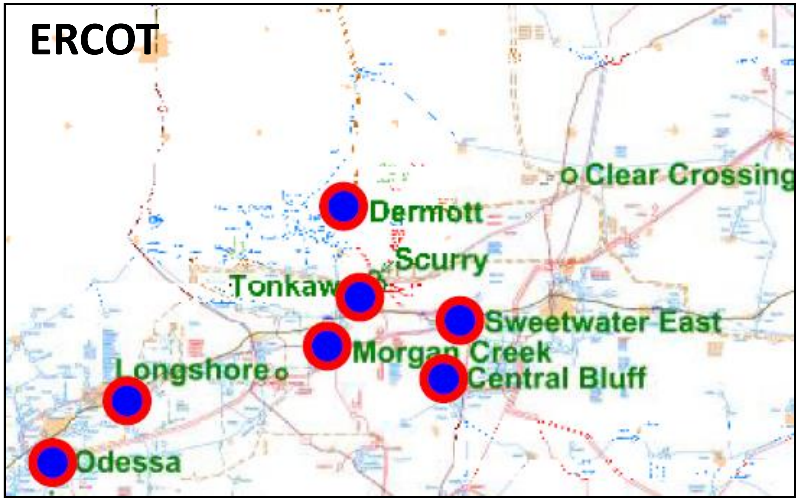
Group 1 Cluster: Voltage Angle Cohesiveness

Average Representative (e.g., Morgan Creek)



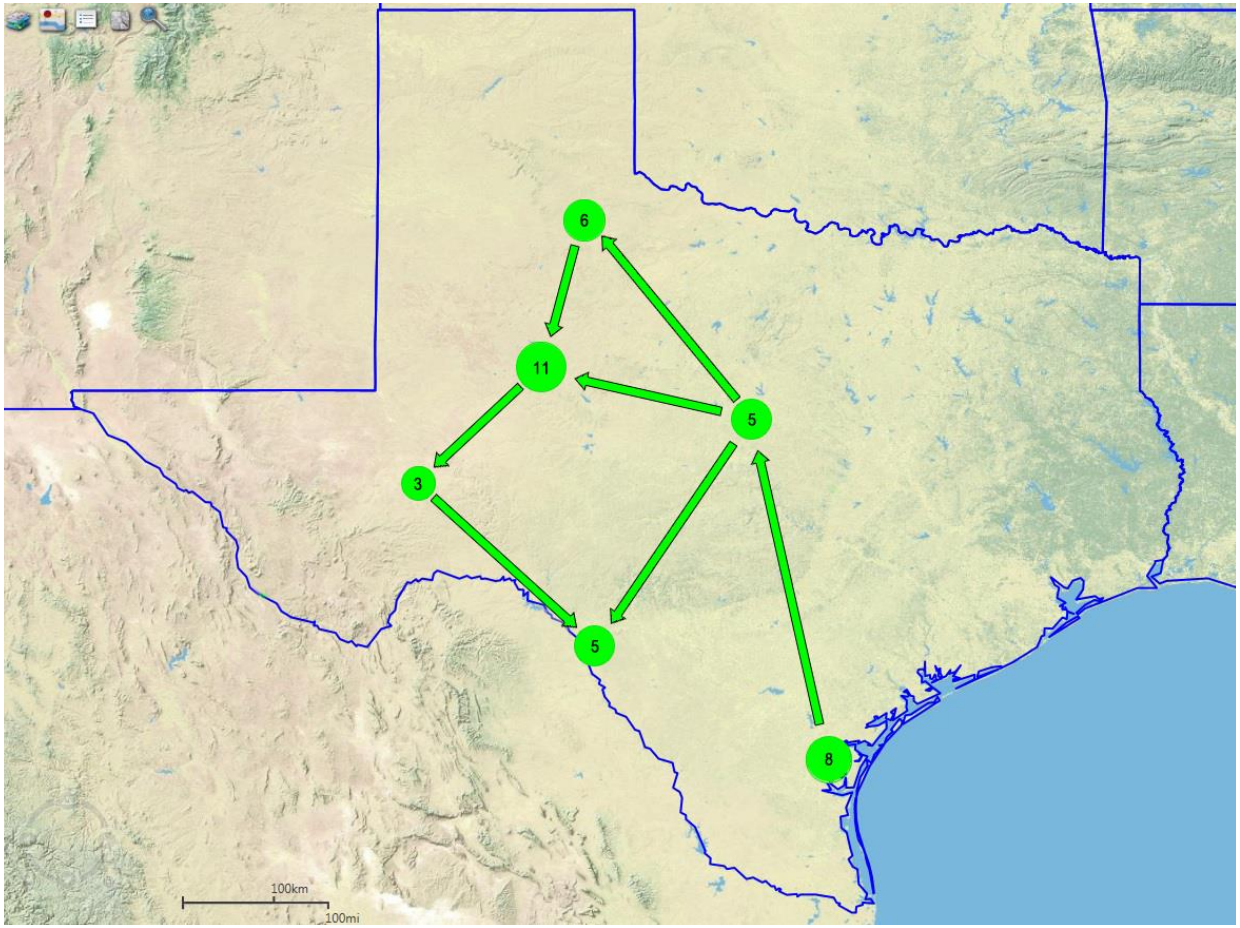
Clustering Methodology:

- Physical Proximity
- Electrical Proximity
- Cohesiveness Over Time
- Criteria: +/- 3 to 7 Degrees Based on Footprint



Method 2: Advanced Analysis
Cluster Analysis (Continued)

Clustering Example: ERCOT – 38 PMUs Clustered Into 6 Groups



Method 2: Advanced Analysis

Statistical Analysis

Identifying Angle Pairs → Load Centers (Sink), Flow Gates and Large Generators (Source)

Cluster Analysis – Select Representative PMU → Manage Data Overload

Data Extraction – To Analyze Past Performance - Typically 12 Months Data → **State Estimator or Phasor Measurement**

Statistical Analysis → **Example: Niagara – Farragut (NY ISO)**

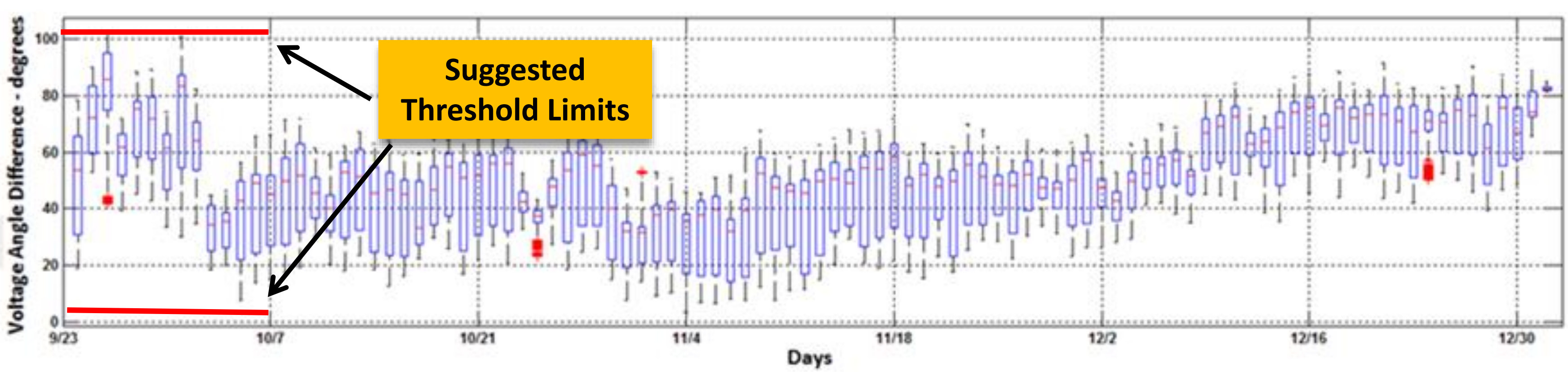
Establishing Alarm Limits (Seasonal, On/Off Peak) → NYISO

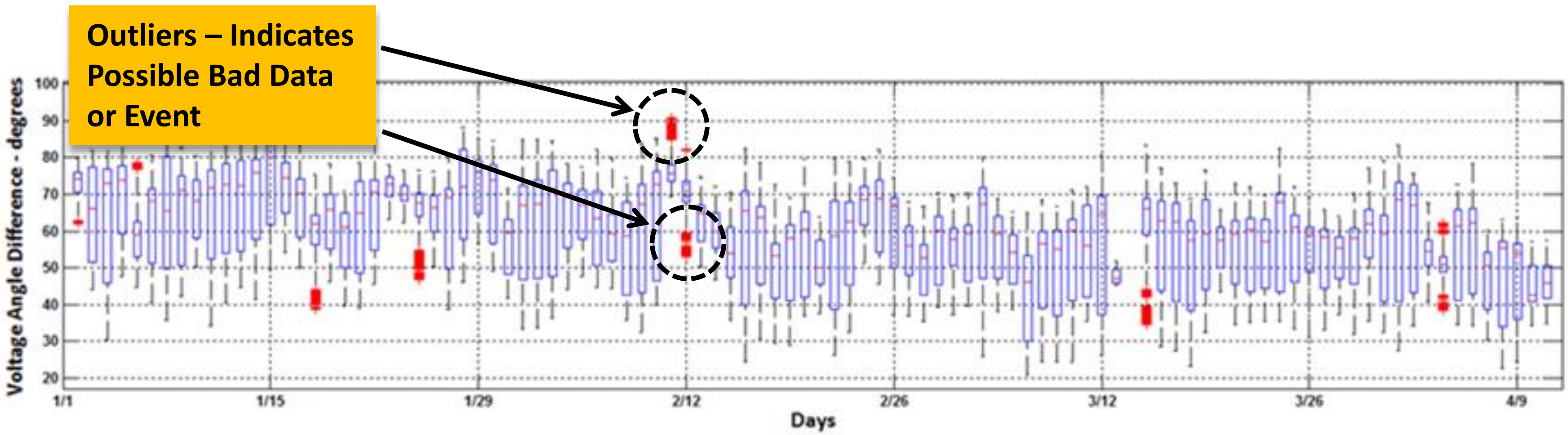
Validate and Refine Using Operating and Planning Studies

Method 2: Advanced Analysis
Statistical Analysis - Example

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

Daily Angle Difference: Sep 2010 to April 2011



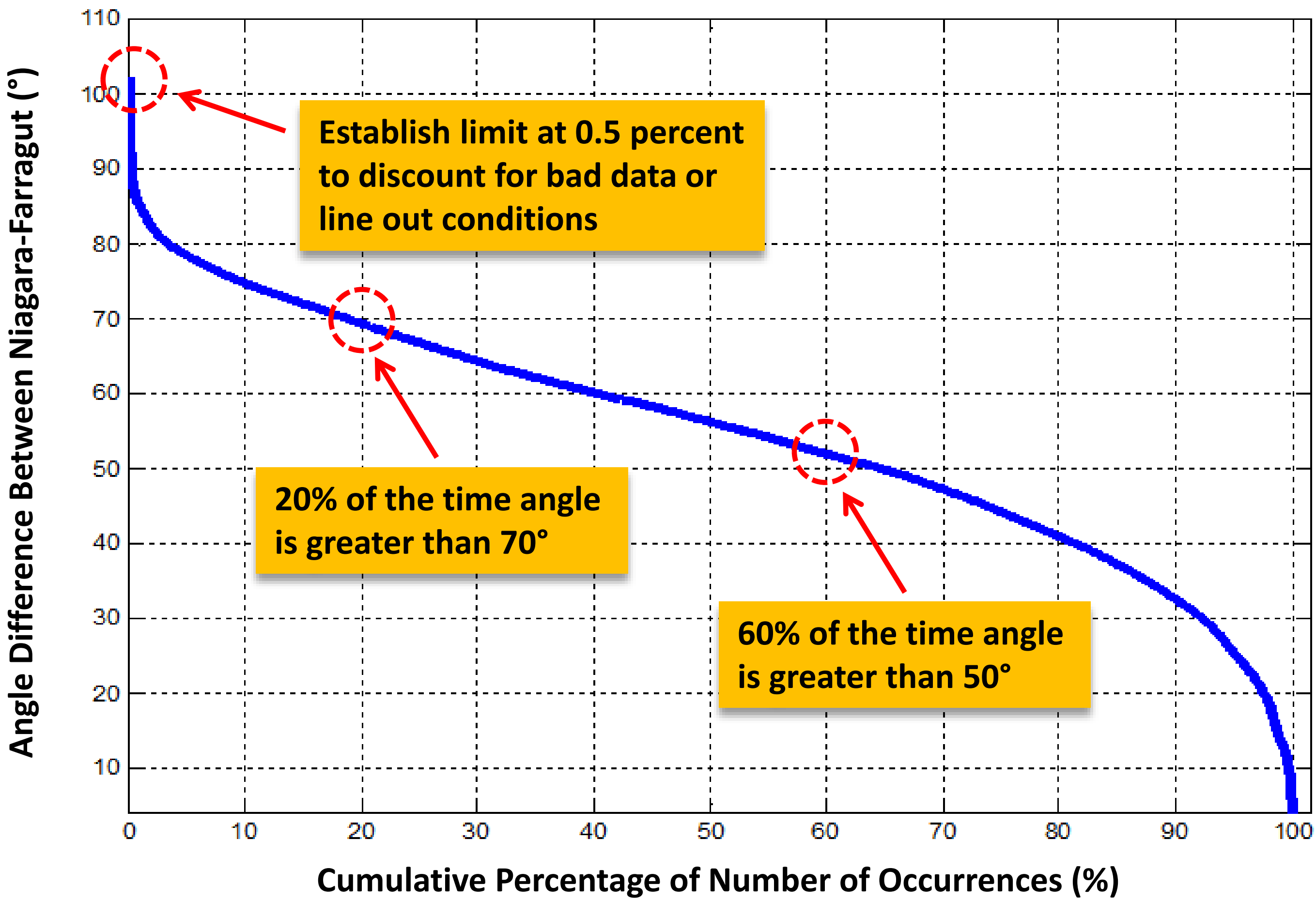


Method 2: Advanced Analysis

Statistical Analysis - Example

Duration Curve for Niagara – Farragut (NY ISO) Wide Area Angle Pair

Time Duration Curve: September 2010 – April 2011



Method 2: Advanced Analysis

Establishing Alarm Limits

Identifying Angle Pairs → Load Centers (Sink), Flow Gates and Large Generators (Source)

Cluster Analysis – Select Representative PMU → Manage Data Overload

Data Extraction – To Analyze Past Performance - Typically 12 Months Data → State Estimator or Phasor Measurement

Statistical Analysis → Example: Niagara – Farragut (NY ISO)

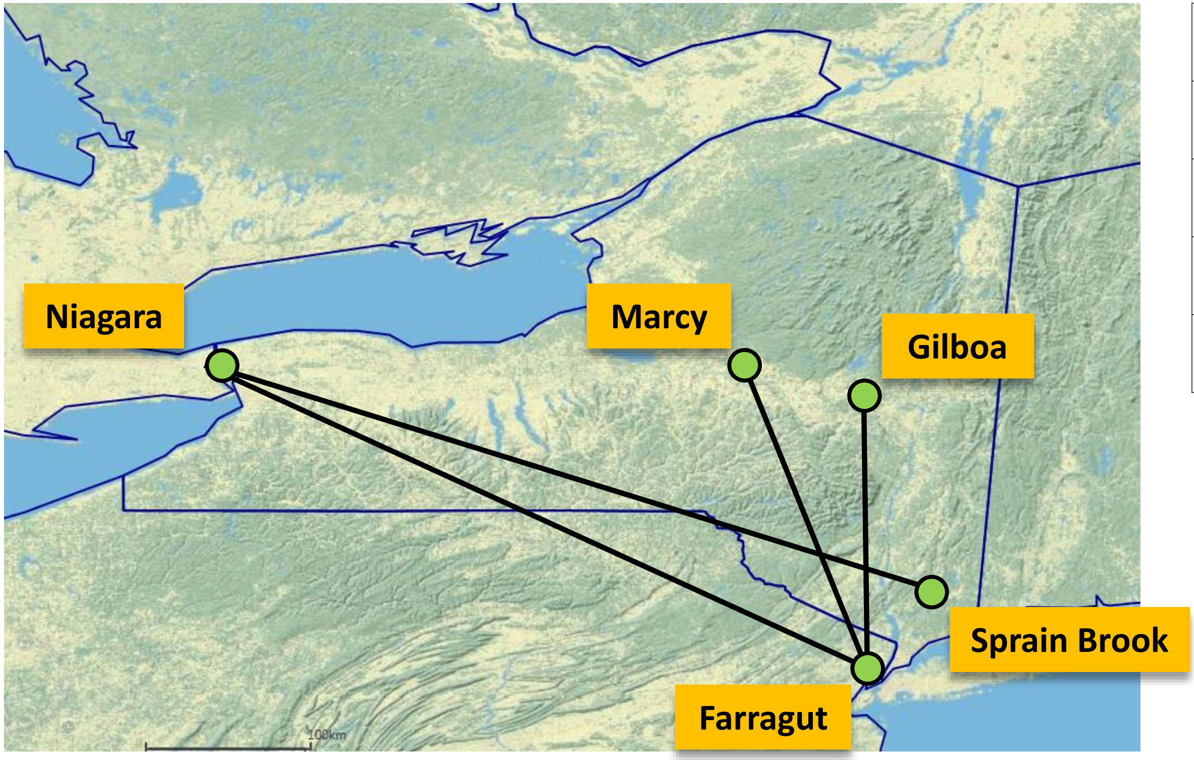
Establishing Alarm Limits (Seasonal, On/Off Peak) → NYISO

Validate and Refine Using Operating and Planning Studies

Method 2: Advanced Analysis

Establishing Alarm Limits

Alarm Limits - NYISO Wide Area Angle Pairs



From	To	Low	High
Niagara	Farragut	4	102
Marcy	Farragut	7	63
Gilboa	Farragut	4	45
Niagara	Sprain Brook	4	96

Method 2: Advanced Analysis
Operating and Planning Studies

Identifying Angle Pairs	→	Load Centers (Sink), Flow Gates and Large Generators (Source)
Cluster Analysis – Select Representative PMU	→	Manage Data Overload
Data Extraction – To Analyze Past Performance - Typically 12 Months Data	→	State Estimator or Phasor Measurement
Statistical Analysis	→	Example: Niagara – Farragut (NY ISO)
Establishing Alarm Limits (Seasonal, On/Off Peak)	→	NYISO

Validate and Refine Using Operating and Planning Studies

Method 2: Advanced Analysis
Operating and Planning Studies

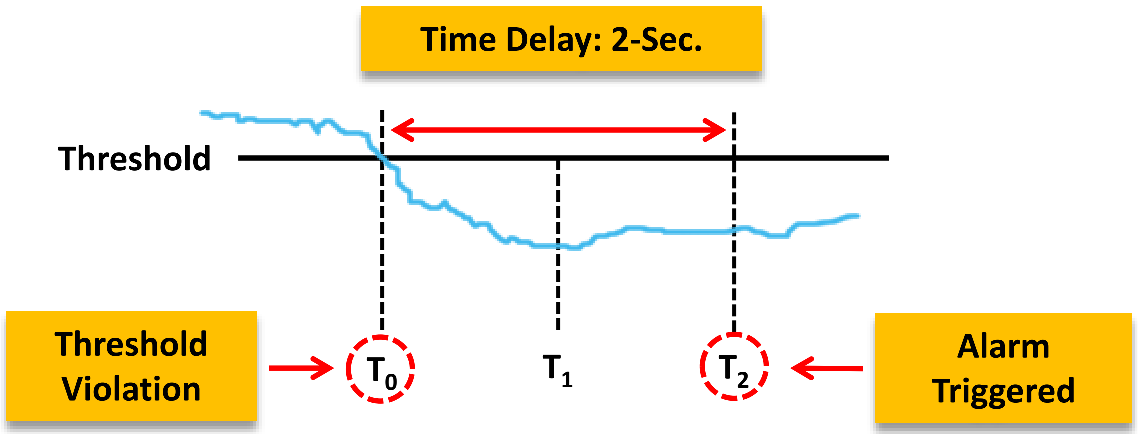
Validate and Refine Using Operating and Planning Studies

Angle Pair	Baselining Results	Operating (Stressed) Case	Planning Case (2015)	Adjusted Alarm Limits
Niagara - Farragut	102	104	106	105
Marcy - Farragut	63	67	68	67
Niagara – Sprain Brook	96	100	100	100

Alarm Implementation in RTDMS

Alarm Implementation in RTDMS

- **Alarms Trigger:**
  - Threshold (59.95 Hz)
  - Time Delay (2 Seconds):



  - Rate of Change (40 MHz/S)
  - Composite: User-defined and/or Combination (WECC Example: Voltage Sensitivity at Malin AND Grand Coulee to Devers Phase Angle Difference)
- **Alarm Level: 2 levels, 4 levels and 8 levels**

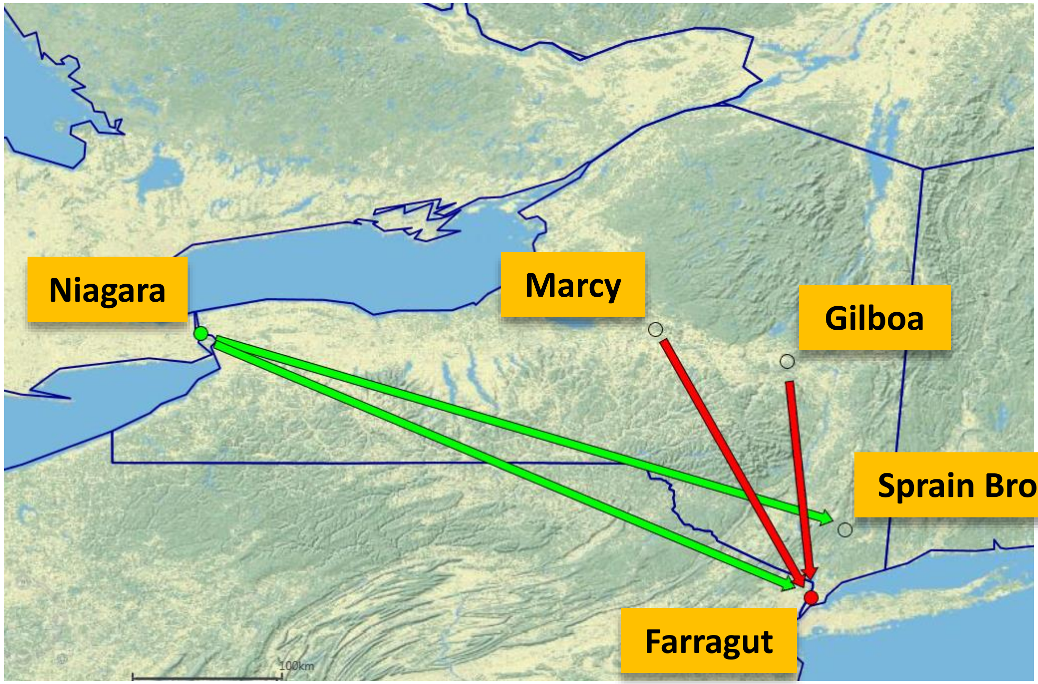
Alarm Implementation in RTDMS

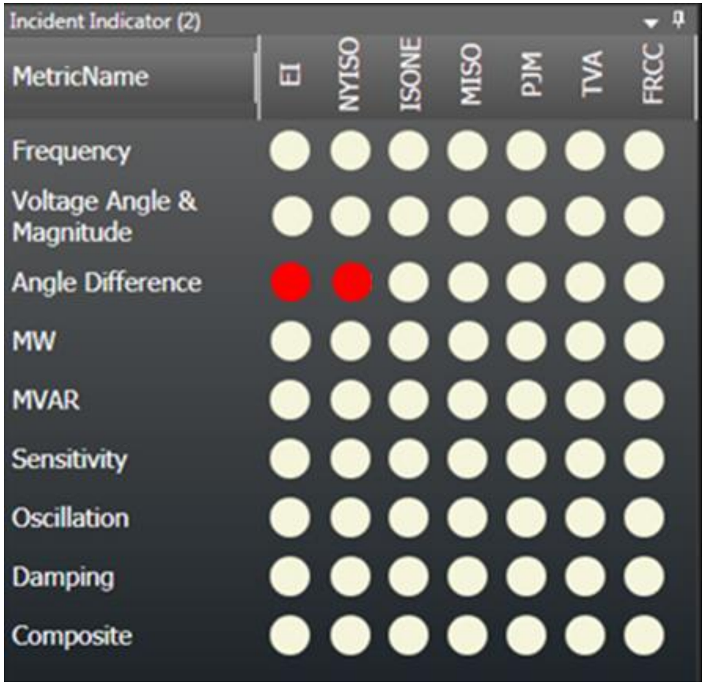
4-Level Threshold Alarm Example: Frequency

Threshold	Frequency	Alarm Color
Low 2	59.90 Hz	
Low 1	59.95 Hz	
Normal	60.00 Hz	
High 1	60.05 Hz	
High 2	60.10 Hz	

Alarm Example in RTDMS

Rock Tavern-Ramapo 345kV Lines Trip (Feeding NYC)



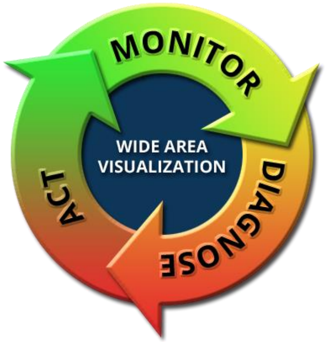


Outage List	Angle Monitored	Alarm Limit	Base Case	Line Trip
ROCK TAVERN – RAMAPO 345kV	Niagara – Farragut	102	89	91
	Niagara – Sprain Brook	96	79	81
	Marcy-Farragut	63	62	67
	Gilboa-Farragut	45	41	46

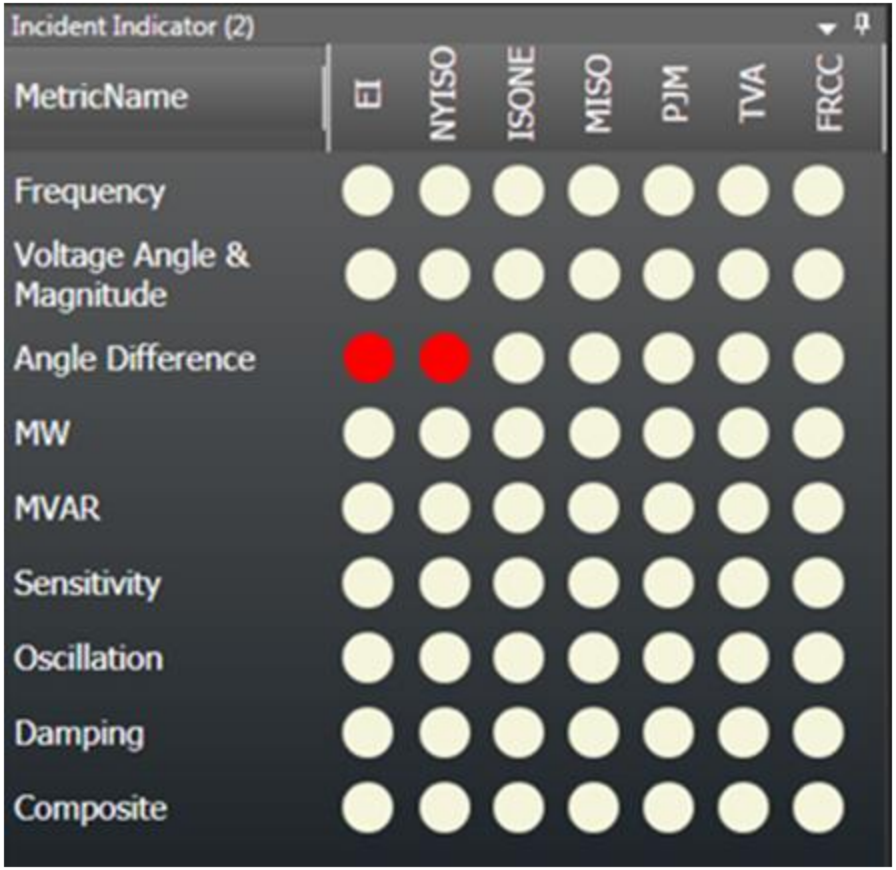
Use of Alarms in Real-Time Operations

Use of Alarms in Real-Time Operations

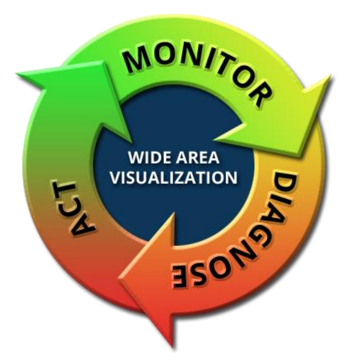
- Early Warning of Grid Stress (Increasing Phase Angle differences)
- Pinpoint Incident Location (First Mover PMU - frequency, voltage etc.)
- Assess Incident Severity (Number of Metrics that Alarm)
- Assess Vulnerability to Cascade (Multiple Alarms in Large or Multiple Footprints)



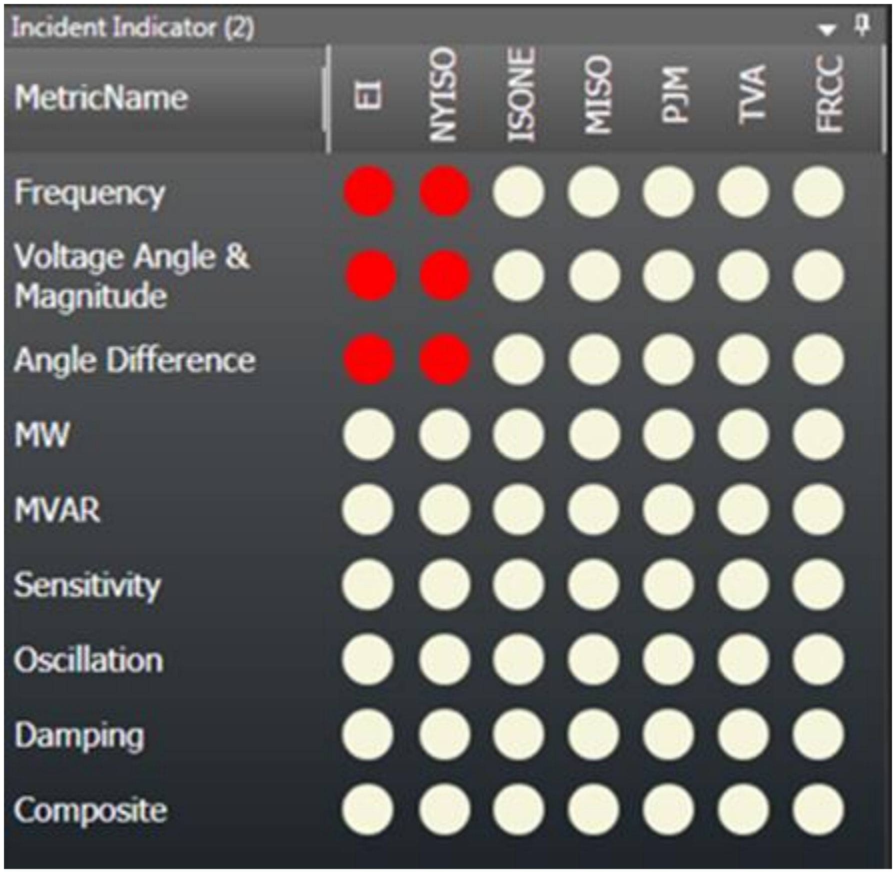
Use of Alarms in Real-Time Operations



- **Early Warning of Grid Stress (Increasing Phase Angle differences)**
- **Pinpoint Incident Location (First Mover PMU - frequency, voltage etc.)**
- Assess Incident Severity (3 Metrics alarm)
- Assess Vulnerability to Cascade (Multiple Alarms in Large or Multiple Footprints)



Use of Alarms in Real-Time Operations



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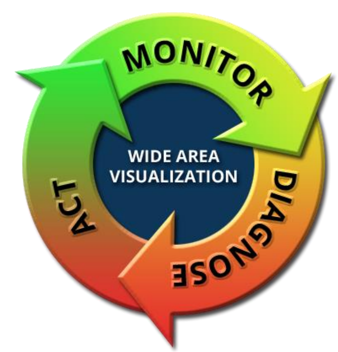
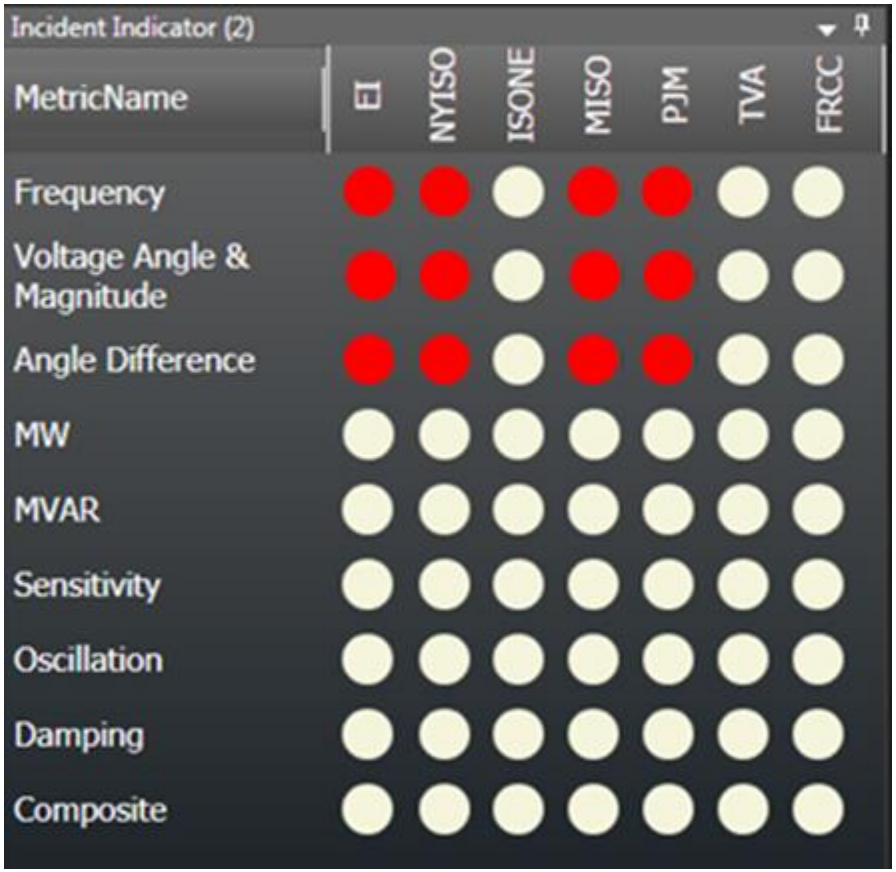


Use of Alarms in Real-Time Operations



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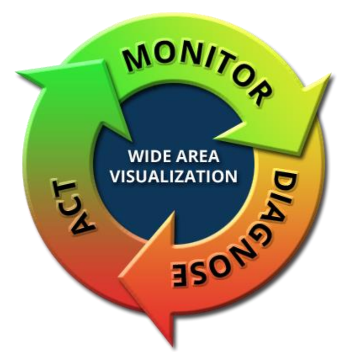
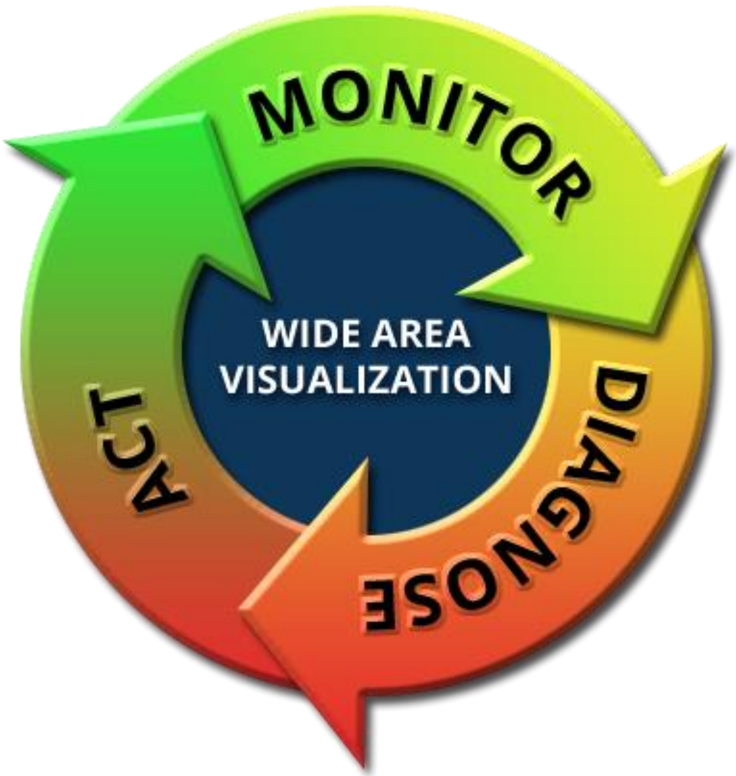


Use of Alarms in Real-Time Operations

Use of Alarms in Control Rooms: Monitor, Diagnose and Act

Wide Area Situational Awareness

Early Warning to Allow Operator Actions



Diagnose the Health of the Grid

Key Takeaways

- Synchrophasor metric alarms complement SCADA/EMS
- Angle pair alarm limits can be set initially using PSLF/PSSE studies
- Alarm limits can be refined using historical State Estimator or Phasor Measurement data and operating experience
- Stressed conditions and contingencies can be used to establish alarm limit margins
- Alarm management is important to provide operators the right information– not too much and not too little
- Synchrophasor metrics and alarms covering a wide area are available in real-time visualization applications such as RTDMS

FAQs

- **How do I set alarm limits?**
  - Method 1 - Getting Started: Utilize existing operational studies
  - Method 2 – Advanced: Analysis, simulations and studies
- **When do I have to change alarm limits?**
  - When significant system changes occur, like addition of a line or load and power flow/generation change
- **What actions are required?**
  - Operating procedures need to be in place to identify the desired operator action – redispatch generation, shed load, provide voltage support

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)
- **Establishing Alarm Limits For Use in Operations (Oct 8)**
- **Phasor Simulations – How Can They Be Used in Operations? (Nov 19)**
- **Using Synchrophasor Technology to identify Control System Problems (Dec 17)**
- **Model Validation (Jan 21, 2014)**
- **Data Diagnostics (Feb 17, 2014)**

Feedback

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:
(626)685-2015

Electric Power Group

201 S. Lake Ave., Suite 400
Pasadena, CA 91101
(626)685-2015
www.ElectricPowerGroup.com