# Showing the Location of a Frequency Disturbance using PMU data

Nick Leitschuh – Synchrophasor Proj Manager for BPA Control Centers

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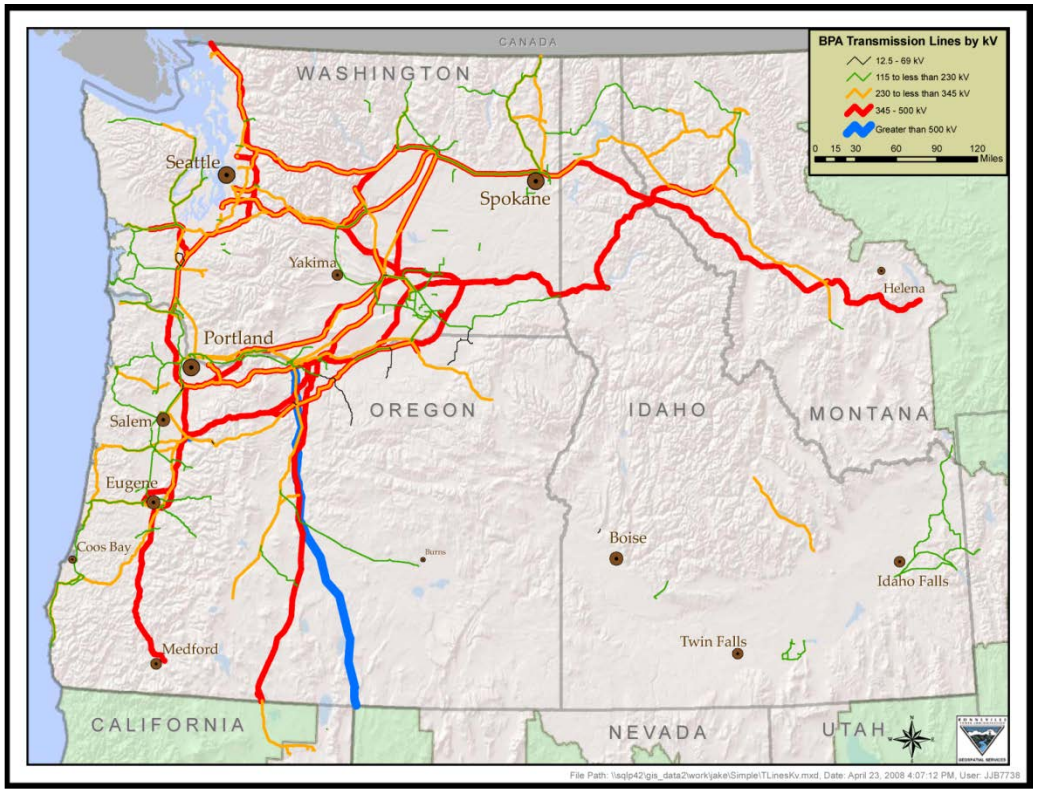
# BPA Overview




- Bonneville Power Administration (BPA) is a federal Power Marketing Agency in Pacific Northwest
- BPA markets power from 31 Federal dams and the Columbia Generating Station Nuclear Plant
- BPA operates more than 15,000 miles of transmission, including 4,735 miles of 500-kV lines

- BPA operates several large paths in the Western Interconnection – **California Oregon AC Intertie** (4,800 MW), **Pacific HVDC Intertie** (3,100 MW), **Northern Intertie** (3,100 MW), and **Montana Intertie** (2,200 MW)

# Presenting:

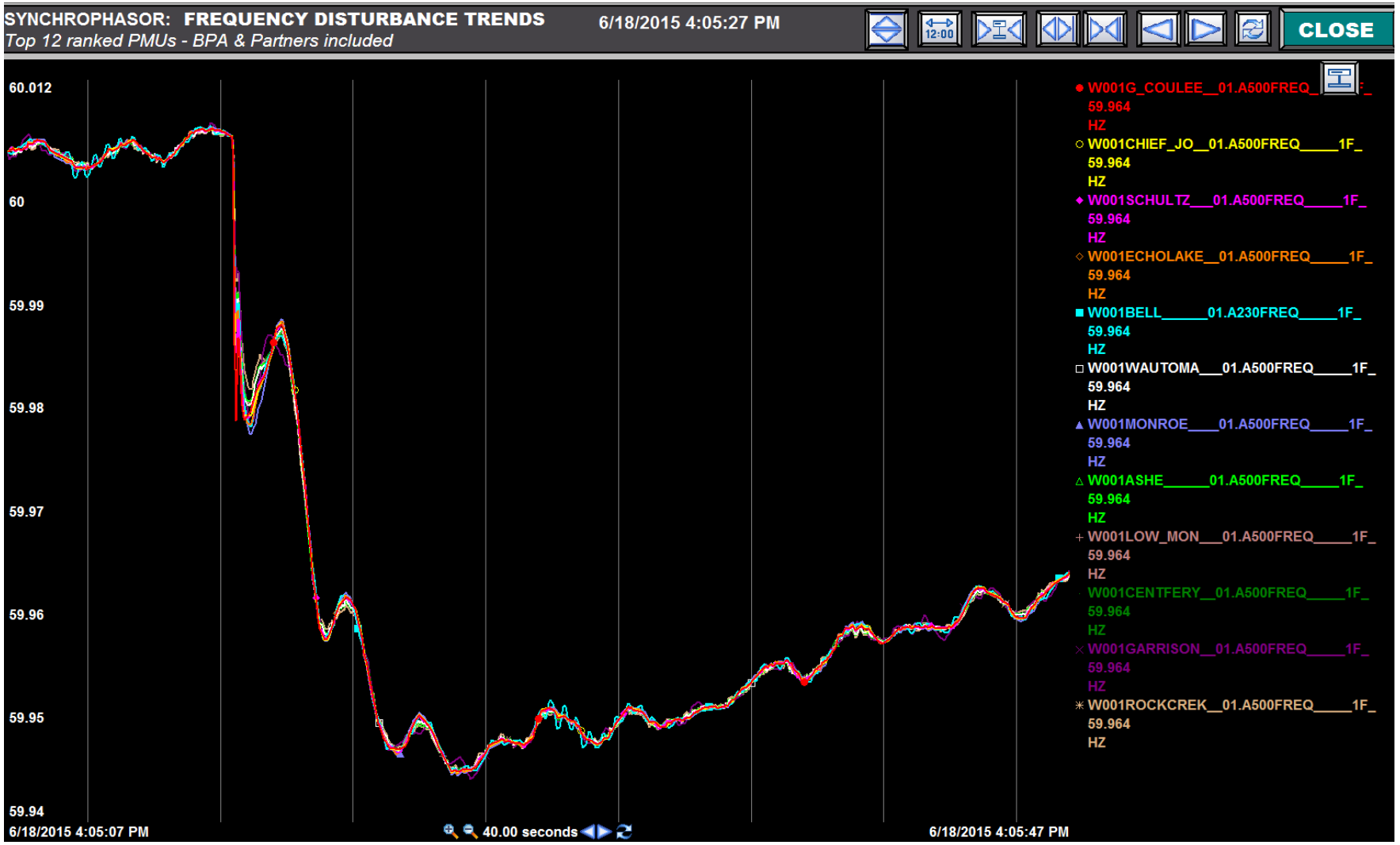
- My favorite Synchrophasor app. We also have other apps, like Oscillation detection, Islanding…
- Dispatcher displays showing location (Inside or Outside the BA)
- How the app finds the location
- How well does it work

# Background

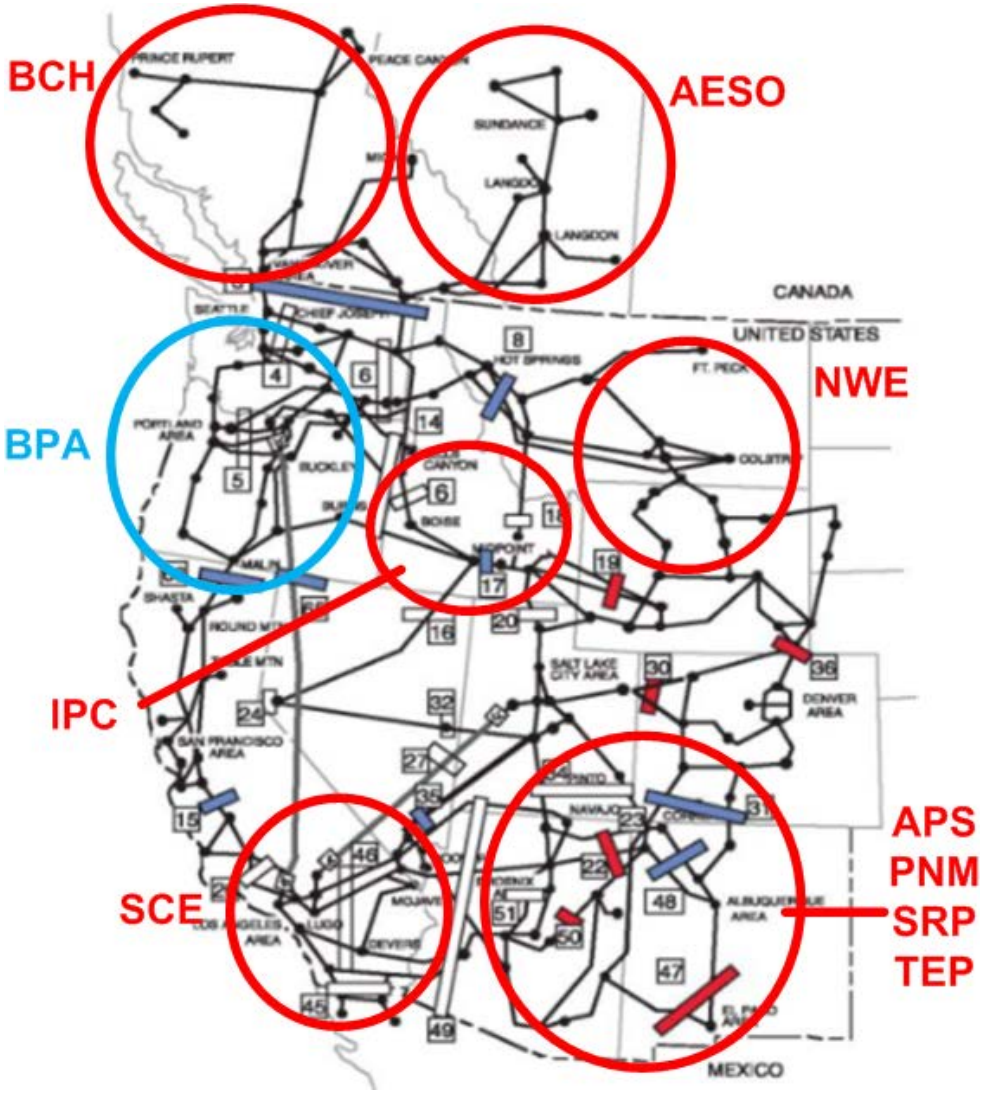
- BPA developed C# app.  Have been fine tuning it for over a year

- Uses PMU freq data from 30 BPA PMU at 60sps and 17 Partner PMUs  (9 Partners total) at 30sps.

# We just had a Frequency Disturbance on the Grid

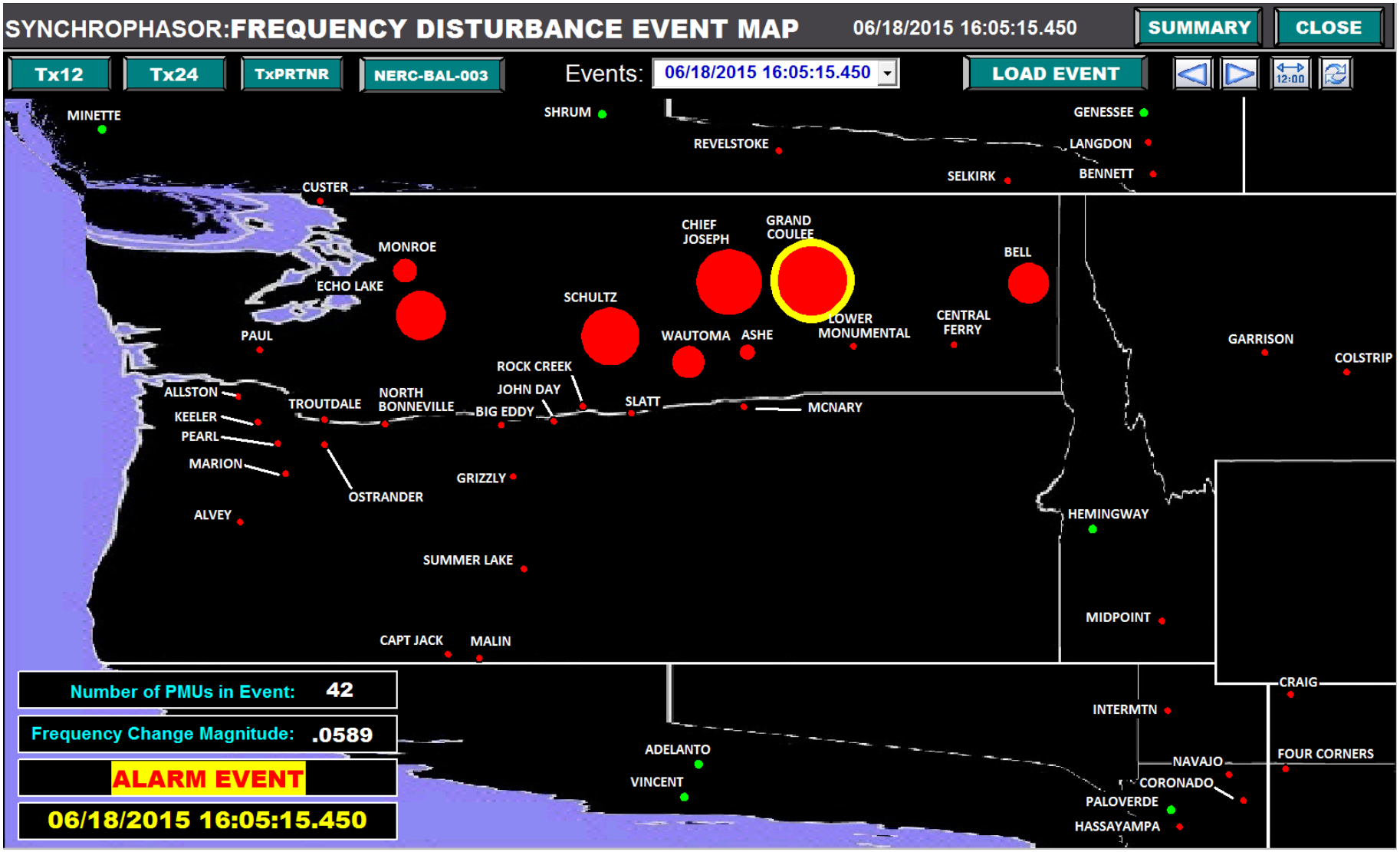


# Location is somewhere inside Western Interconnect

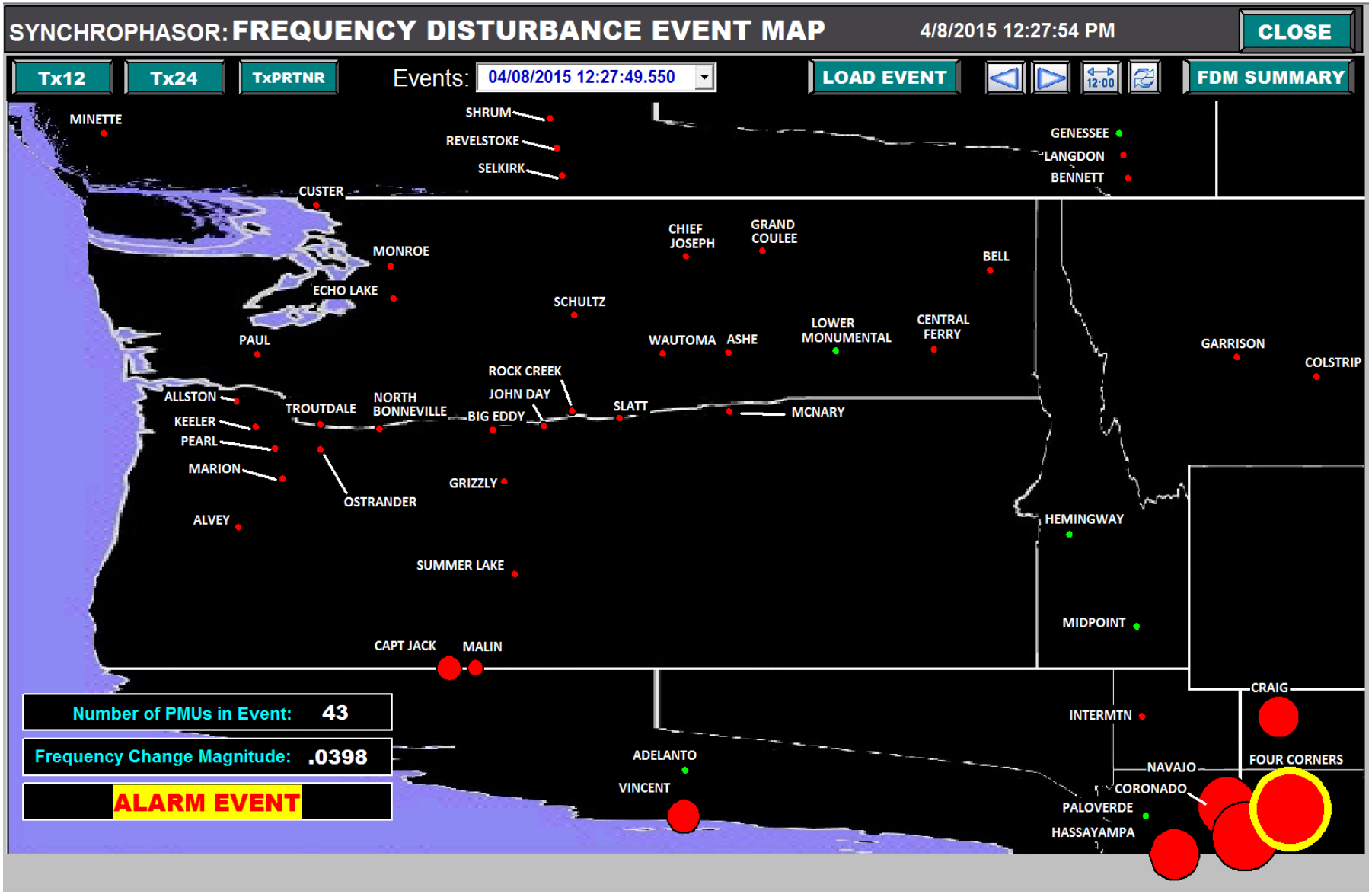



# Location shown on video wall within15 seconds.

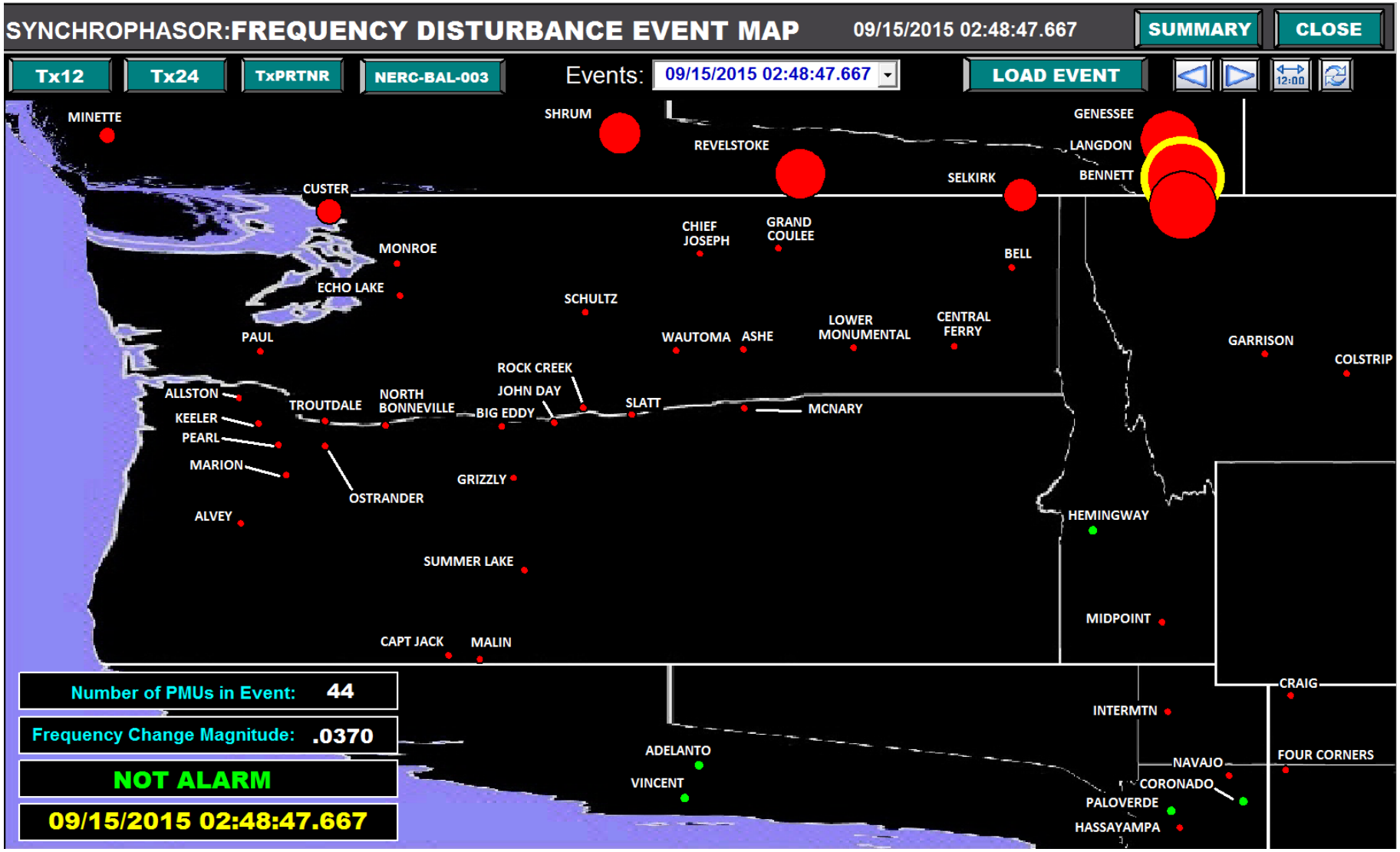
The larger the bubble the closer it is to the fault



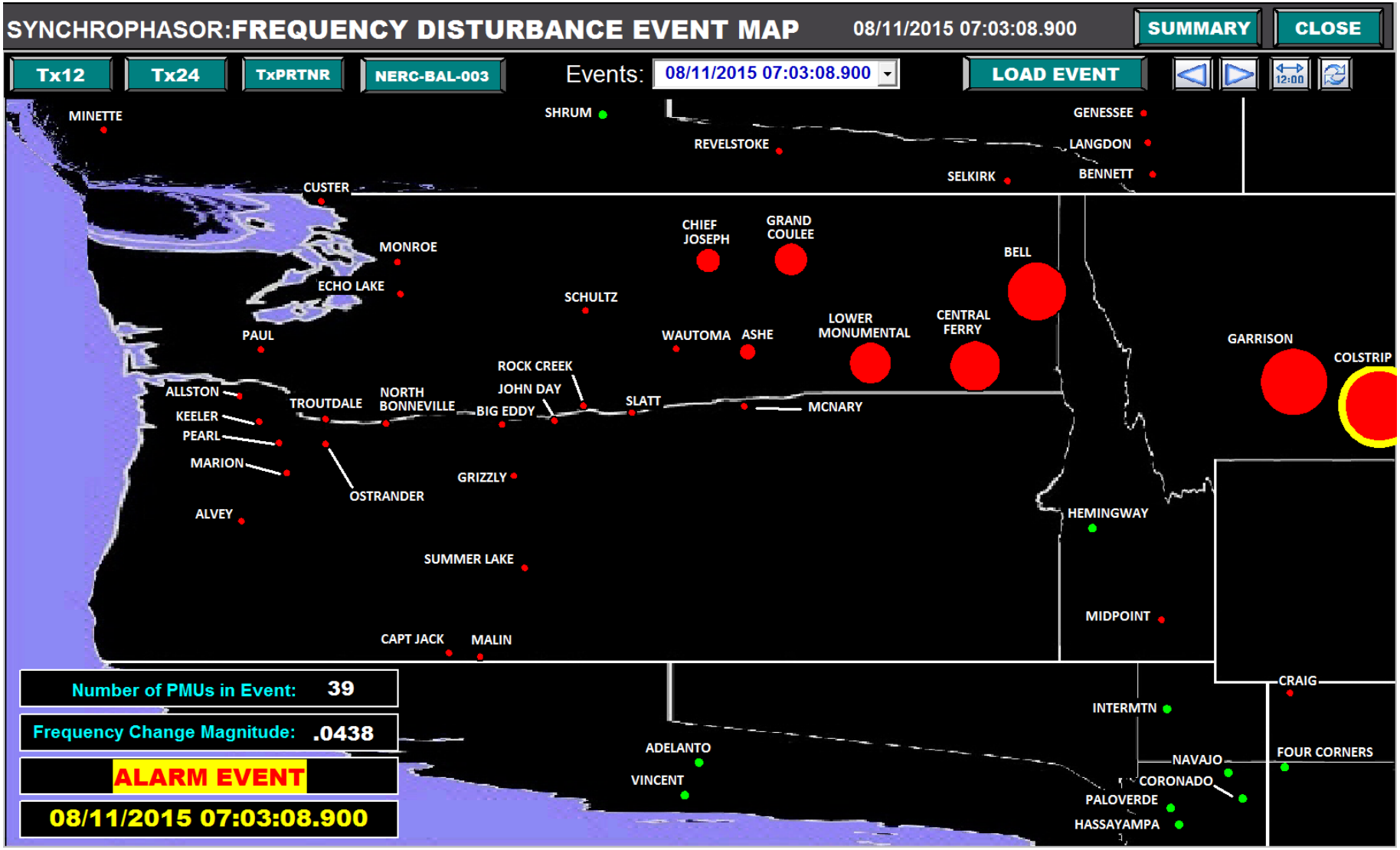
# Outside our BA – Down in Desert SW



# Outside our BA - Up in Canada

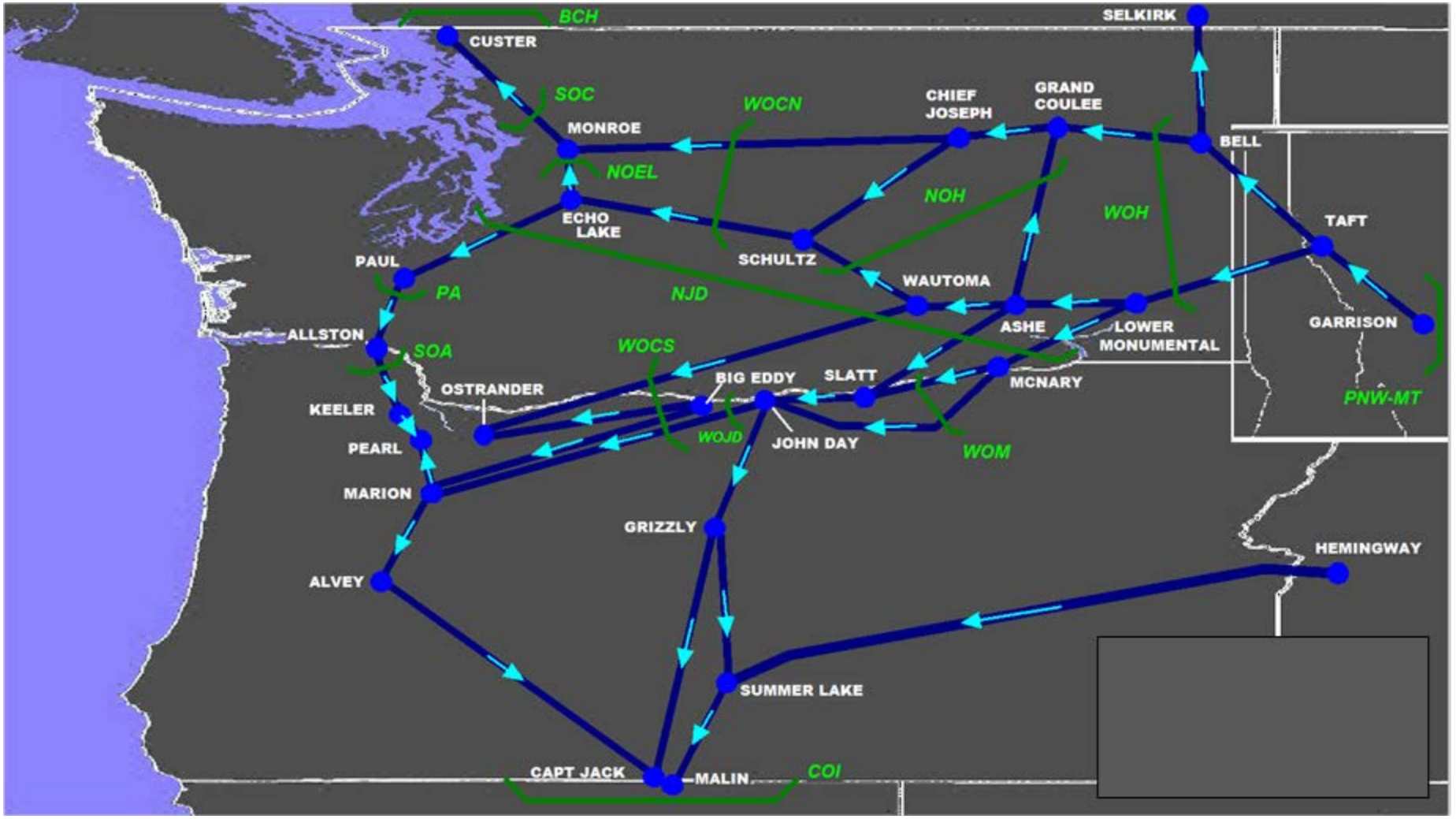


# Outside our BA - Over in Montana



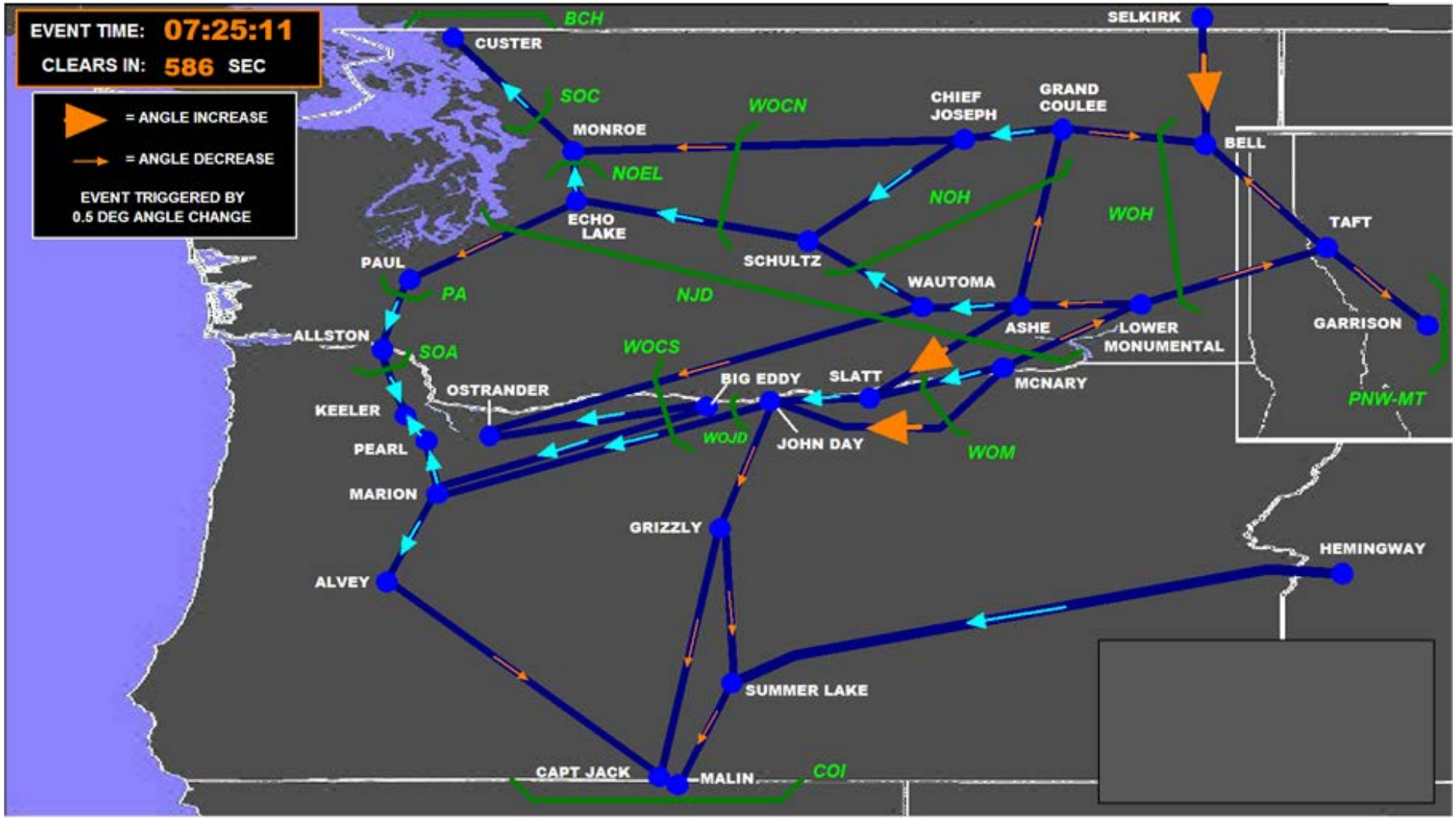
# How did event impact MW flow on the grid?
# Did flows increase or decrease on lines?

Power Flows from higher to lower phase angle

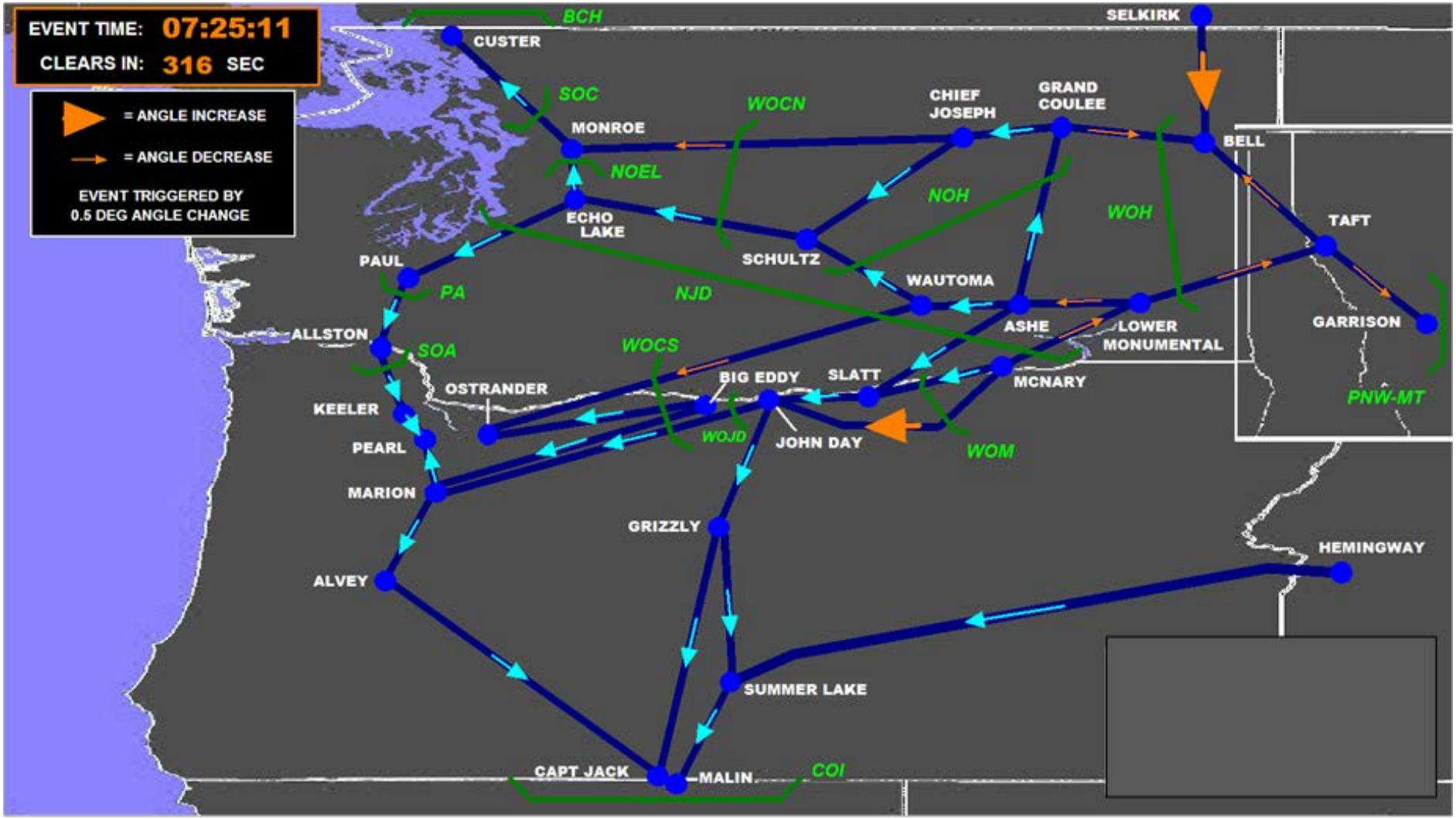


# 14 seconds after Gen drop at Colstrip

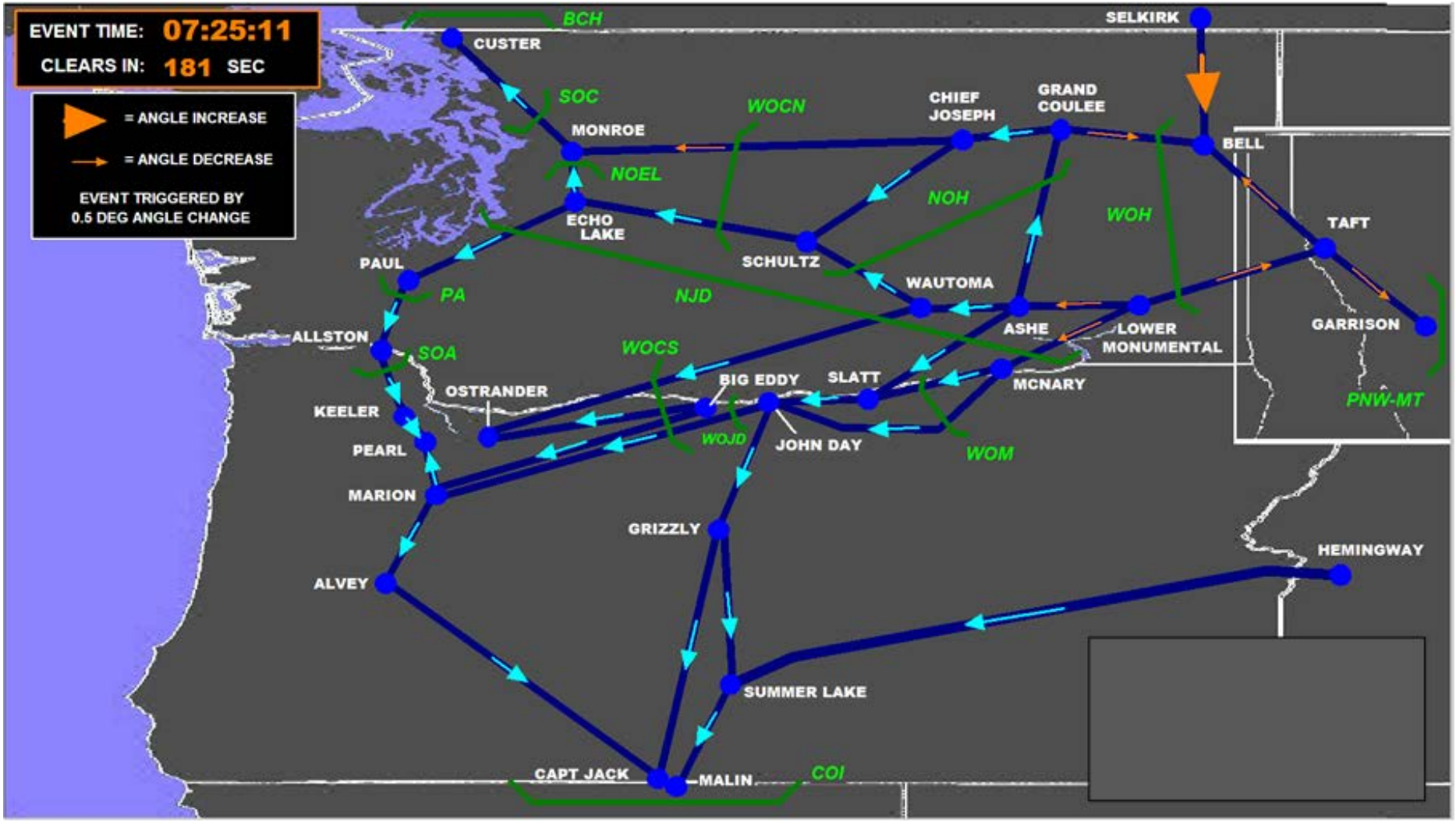
Large arrow (angle increased more than 0.5 degrees)
Small arrow (angle decreased more than 0.5 degrees)



# 4 mins 44 seconds into event



# 7 minutes into it.
# In 10 minutes display returns to normal



# What dispatchers say

- “This information helps dispatch in assessing the impacts of the event on our balancing area and helps us posture our response in a more informed and timely manner.” - Curtis Holland, BPA Senior Dispatcher

# For Engineers
# 20 seconds after the event I get an email

- The Synchrophasor Frequency Deviation Module (FDM) detected an alarm event at 9/8/2015 5:10:20 AM Pacific Daylight Time (GMT-07:00:00)
- Rank1 PMU = W036COLSTRIP__01
- Number of PMUs Affected = 44
- Frequency Change Magnitude = 0.04257038

# I call up the event on my Laptop

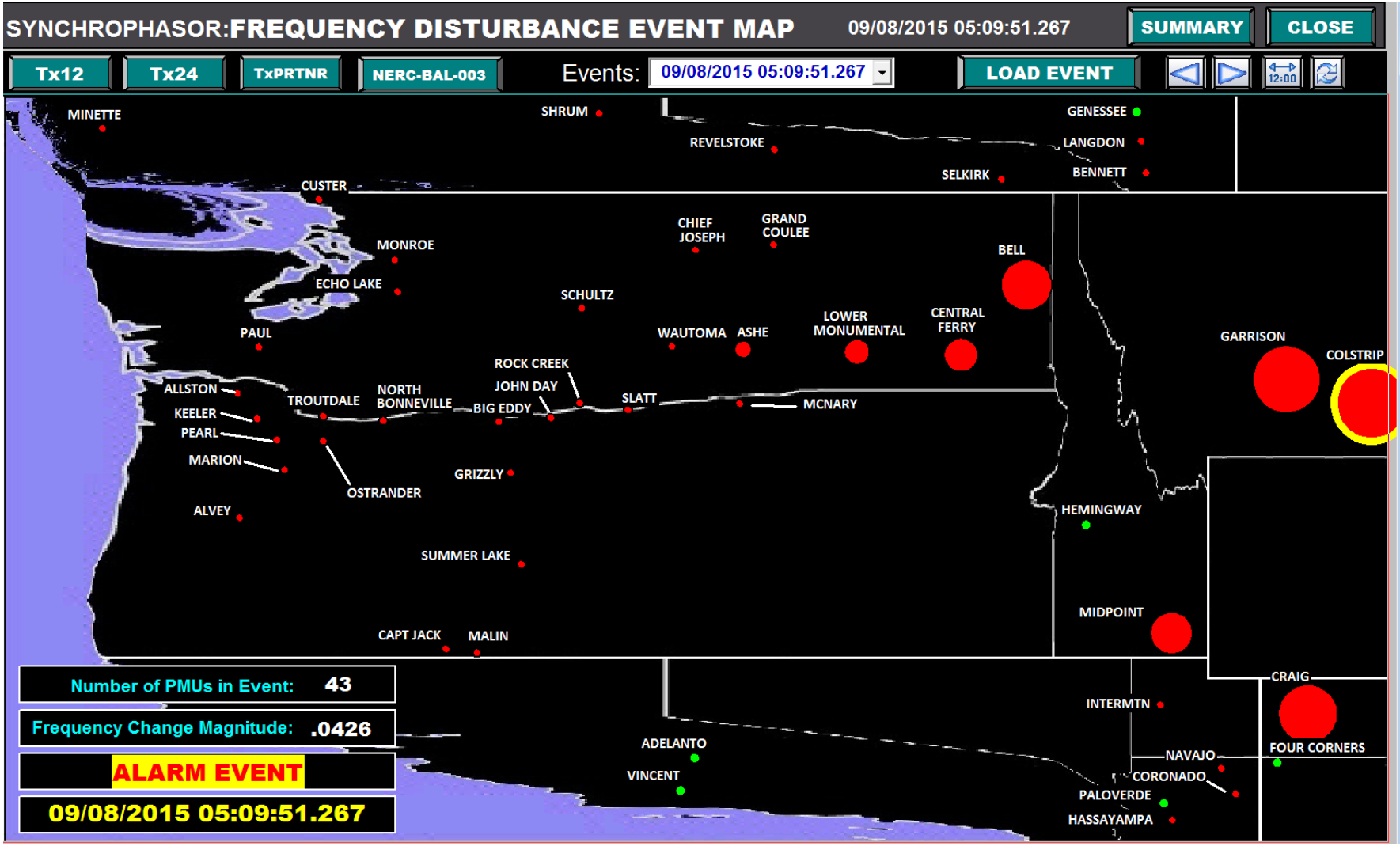
# List of Events

SYNCHROPHASOR: **FREQUENCY DISTURBANCE SUMMARY** 10/2/2015 3:34:00 PM CLOSE

LOAD MAP

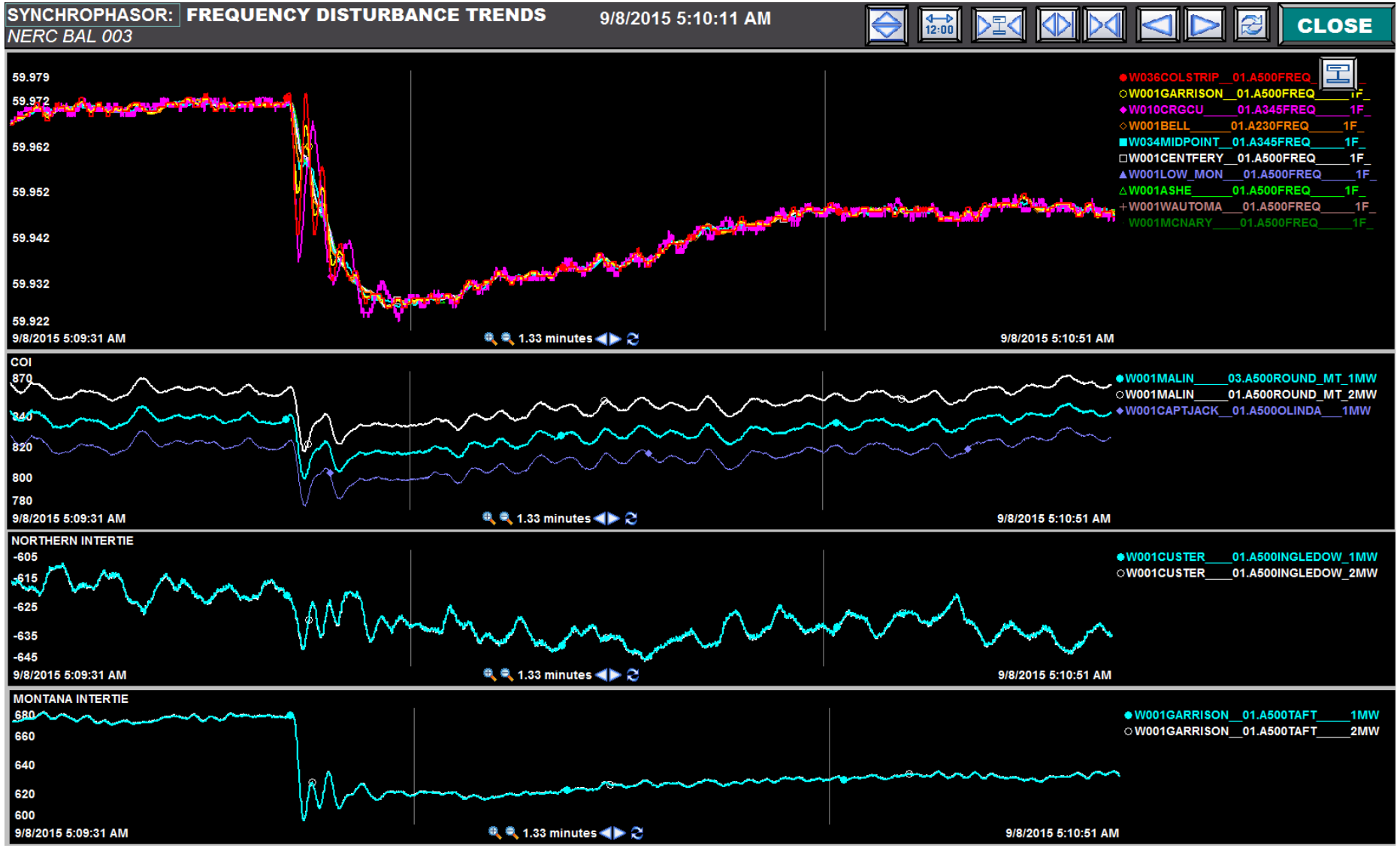
| Event Time | Magnitude (Hz) | Rank1 PMU | PMU Count | Alarm Event |
|---|---|---|---|---|
| 09/08/2015 15:26:16.417 | .0282 | BCH:Minette | 43 | |
| 09/08/2015 05:09:51.267 | .0426 | NWE:Colstrip | 43 | Alarm |
| 09/05/2015 07:25:11.300 | .1425 | AESO:Bennett | 44 | Alarm |
| 09/05/2015 06:57:05.517 | .0003 | Garrison | 3 | |
| 09/03/2015 13:09:28.433 | -.0025 | Garrison | 3 | |
| 09/03/2015 07:48:18.483 | .0831 | TSGT:Craig | 44 | Alarm |
| 09/02/2015 20:48:52.667 | .0343 | TSGT:Craig | 44 | |
| 09/02/2015 19:37:17.150 | .0582 | LADWP:Intermountain | 44 | Alarm |
| 09/02/2015 15:43:38.417 | .0126 | AESO:Langdon | 8 | |
| 09/02/2015 14:25:03.050 | .0301 | BCH:Revelstoke | 40 | |
| 09/01/2015 18:03:29.517 | .0343 | SRP:Hassayampa | 40 | |
| 09/01/2015 10:30:12.333 | .0767 | APS:Navajo | 44 | Alarm |
| 08/31/2015 07:32:17.633 | .0559 | BCH:Revelstoke | 44 | Alarm |
| 08/30/2015 18:04:23.217 | .0465 | IPCO:Midpoint | 40 | Alarm |
| 08/29/2015 21:48:03.217 | .0320 | IPCO:Midpoint | 39 | |

**I click on Load Map**




# Then click on NERC-BAL-003

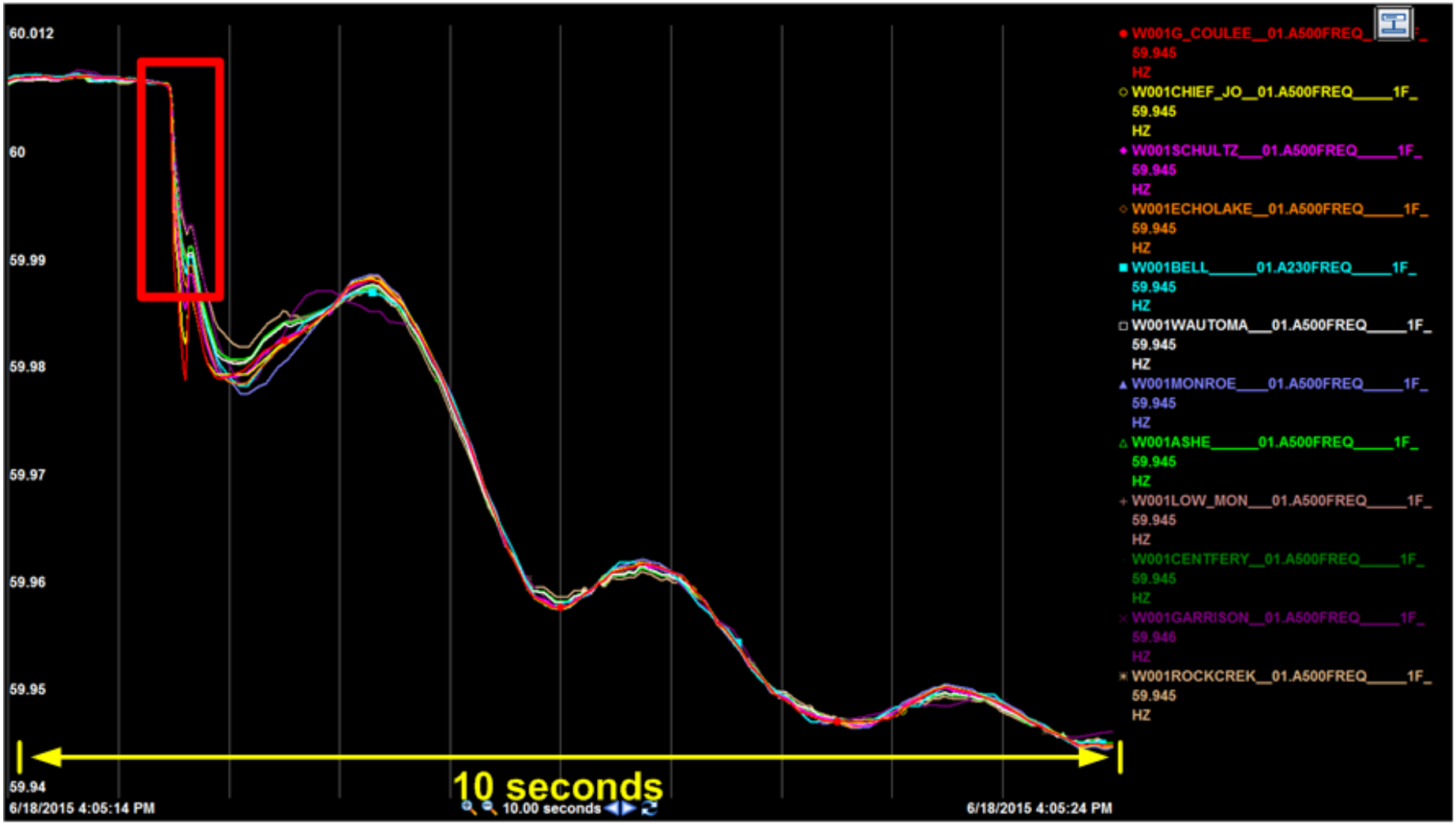
# Freq and Major Interties



# How the App works

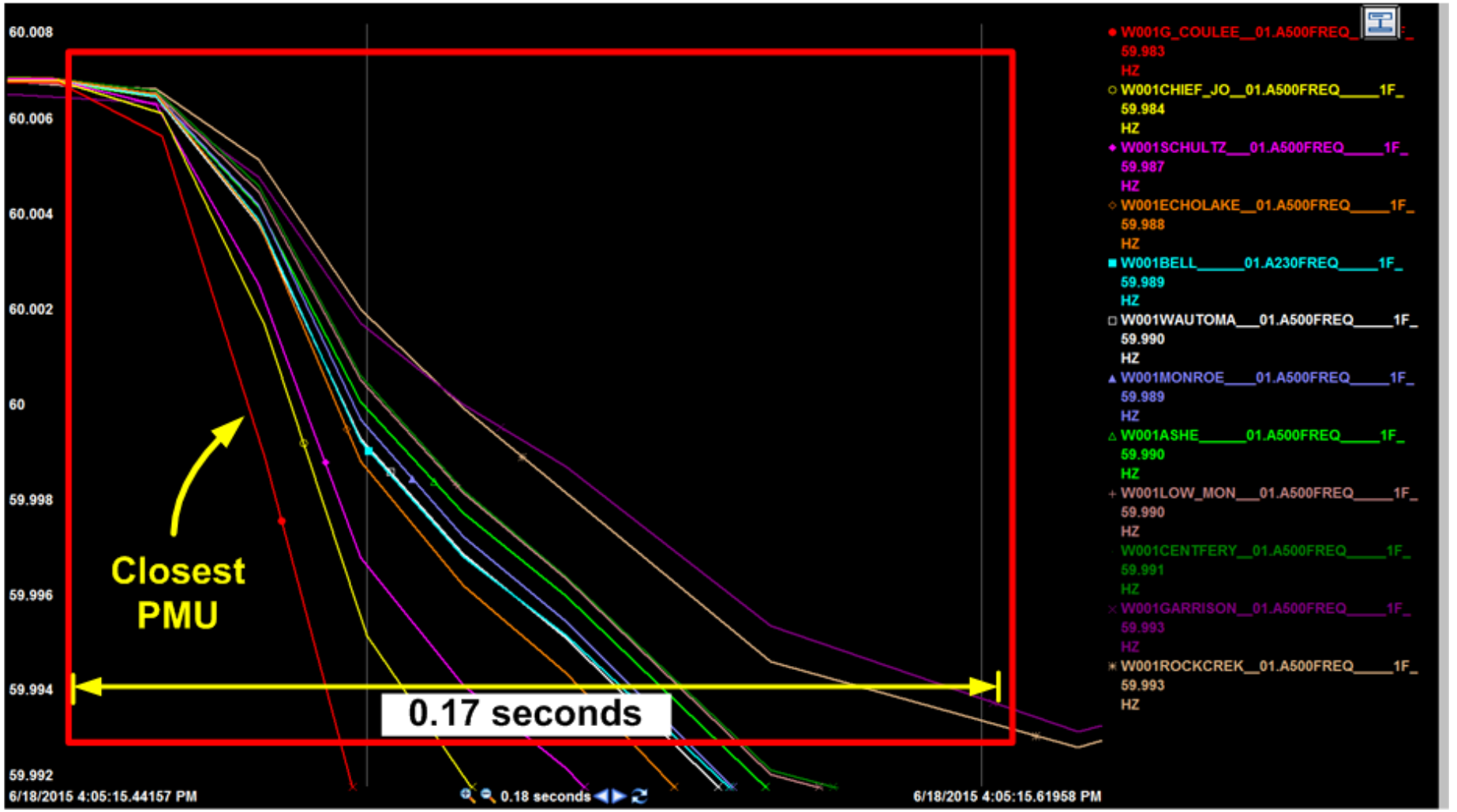
Example with a Grand Coulee 600 MW Gen drop, but app works with any freq change (positive or negative)

# First ½ second of freq data is used to find location



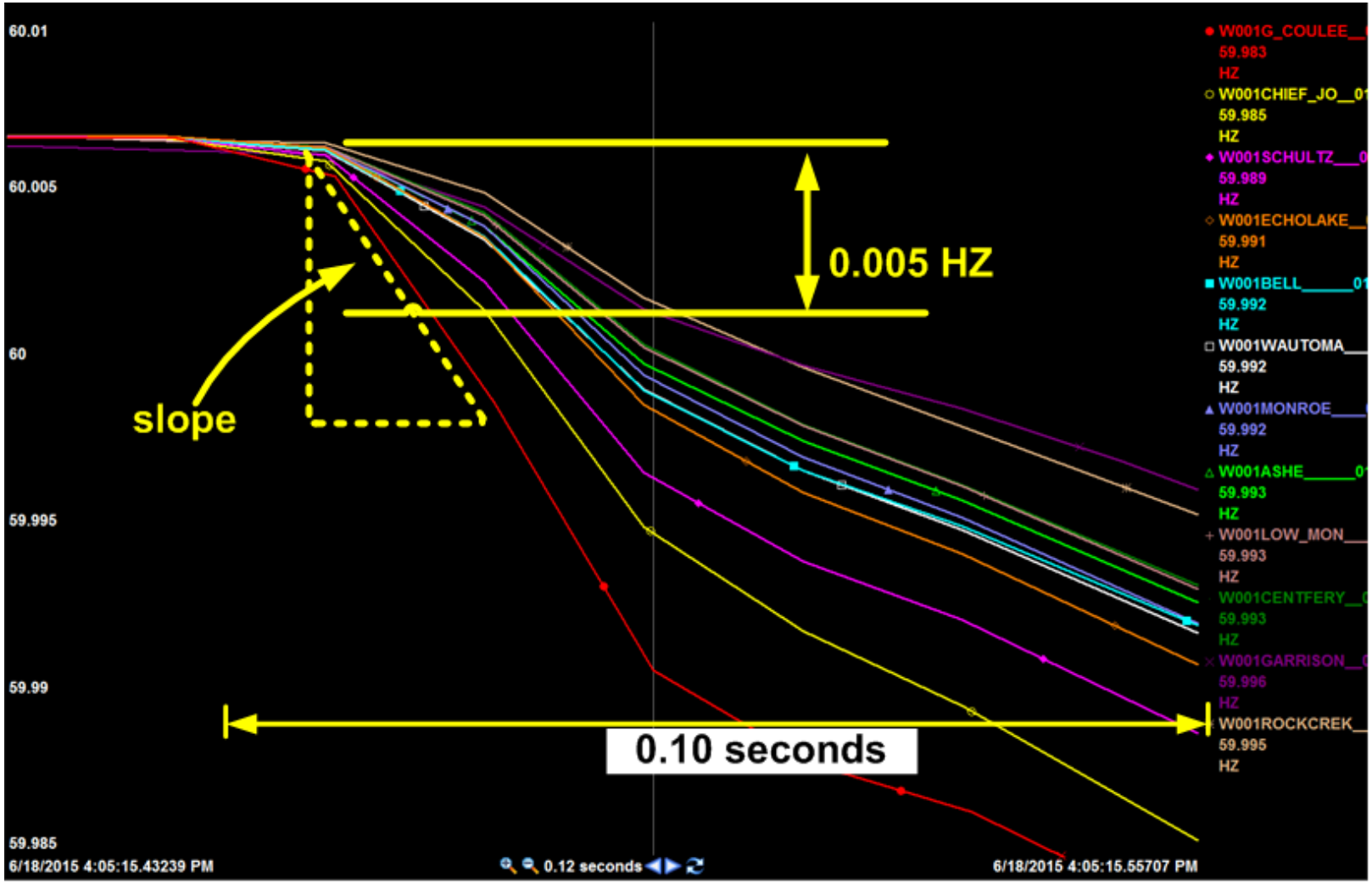
# Zooming in shows PMU freqs drop at different rates

The Freq that drops the quickest (has the steepest slope) is the closest to the disturbance

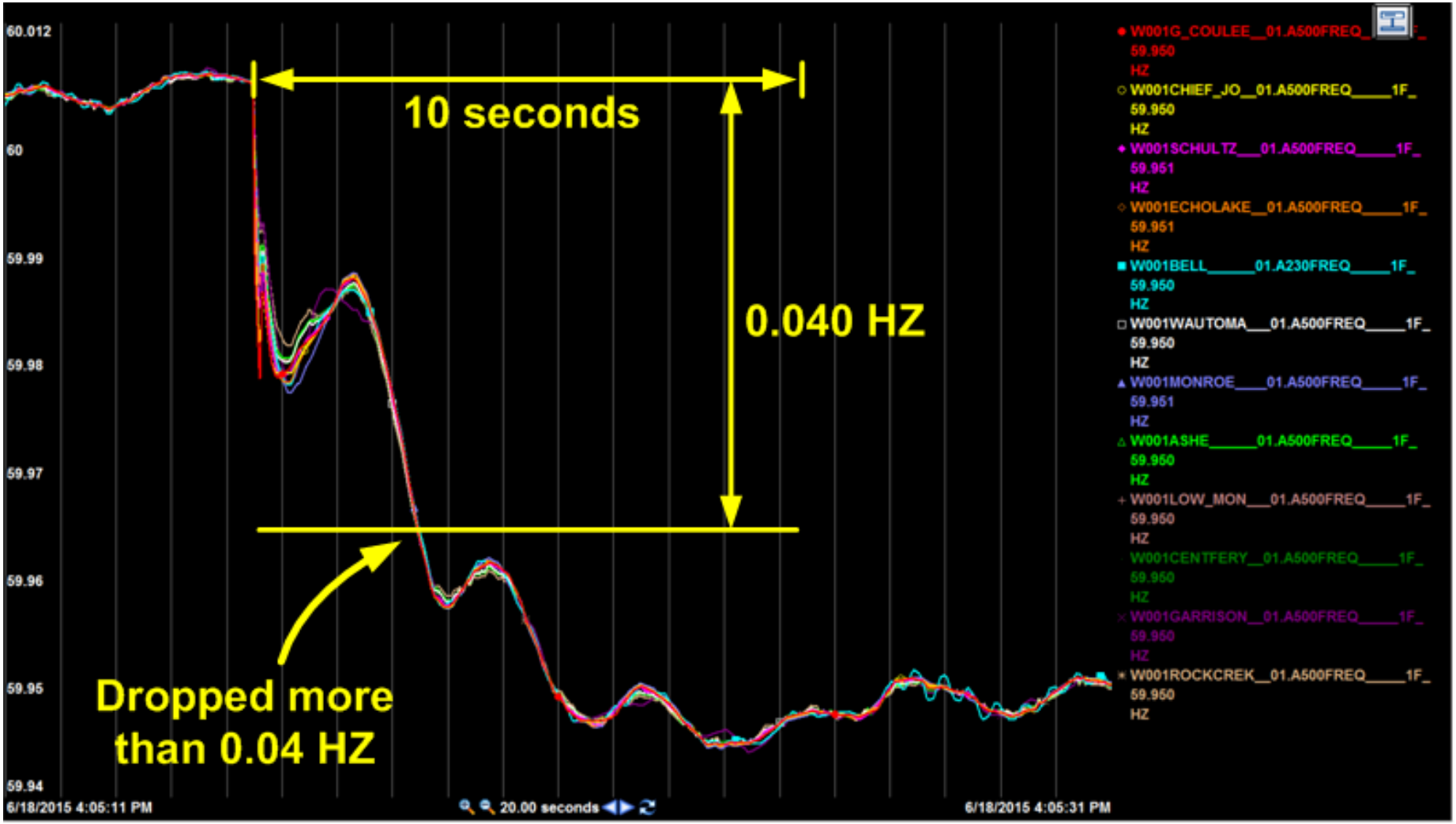


**Have found that best results are obtained when calculating the freq rate-of-change (slope) after a relatively small freq drop .**

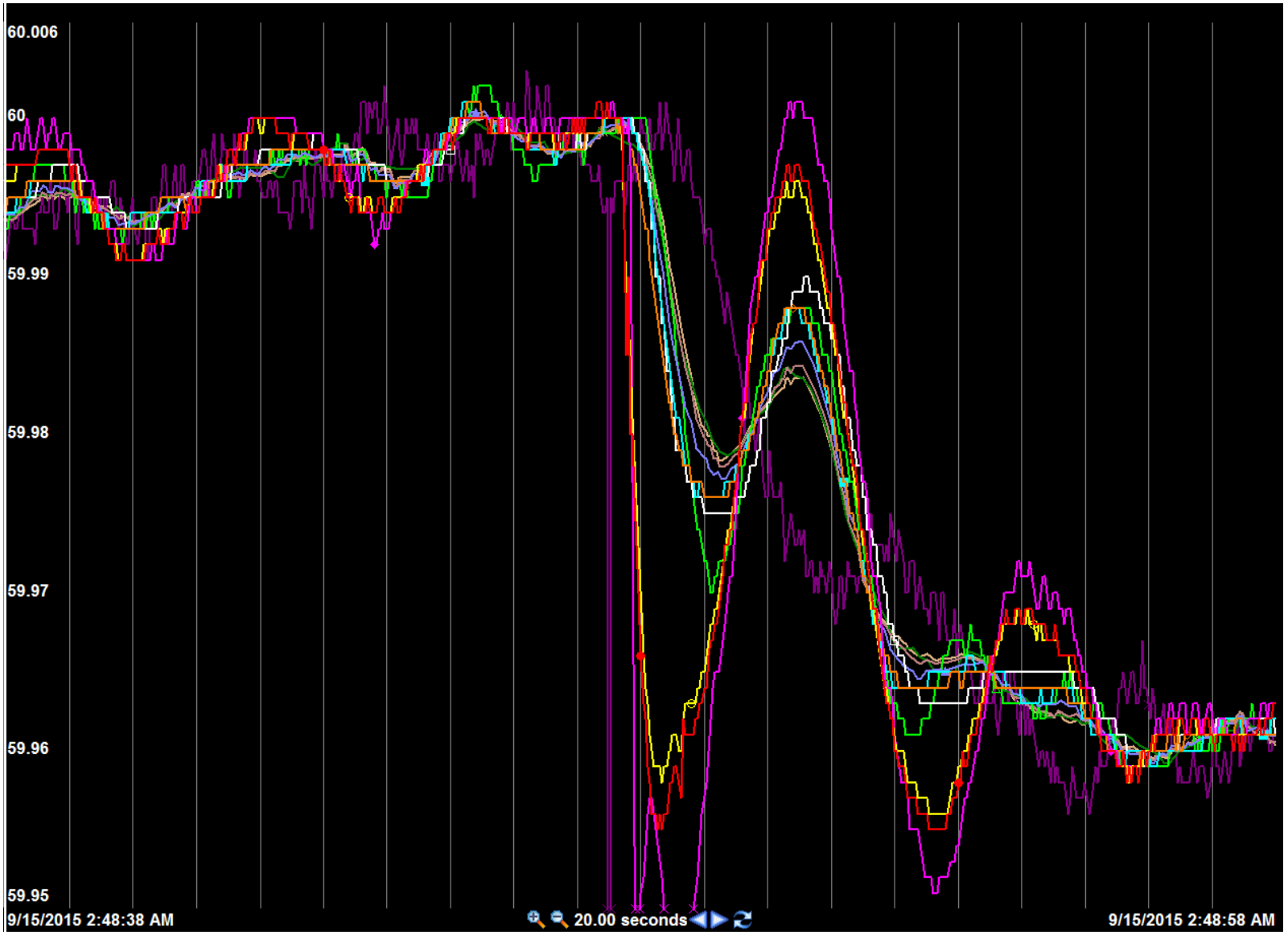
**We calculate slope using the first freq sample after a drop of 0.005 Hz.**



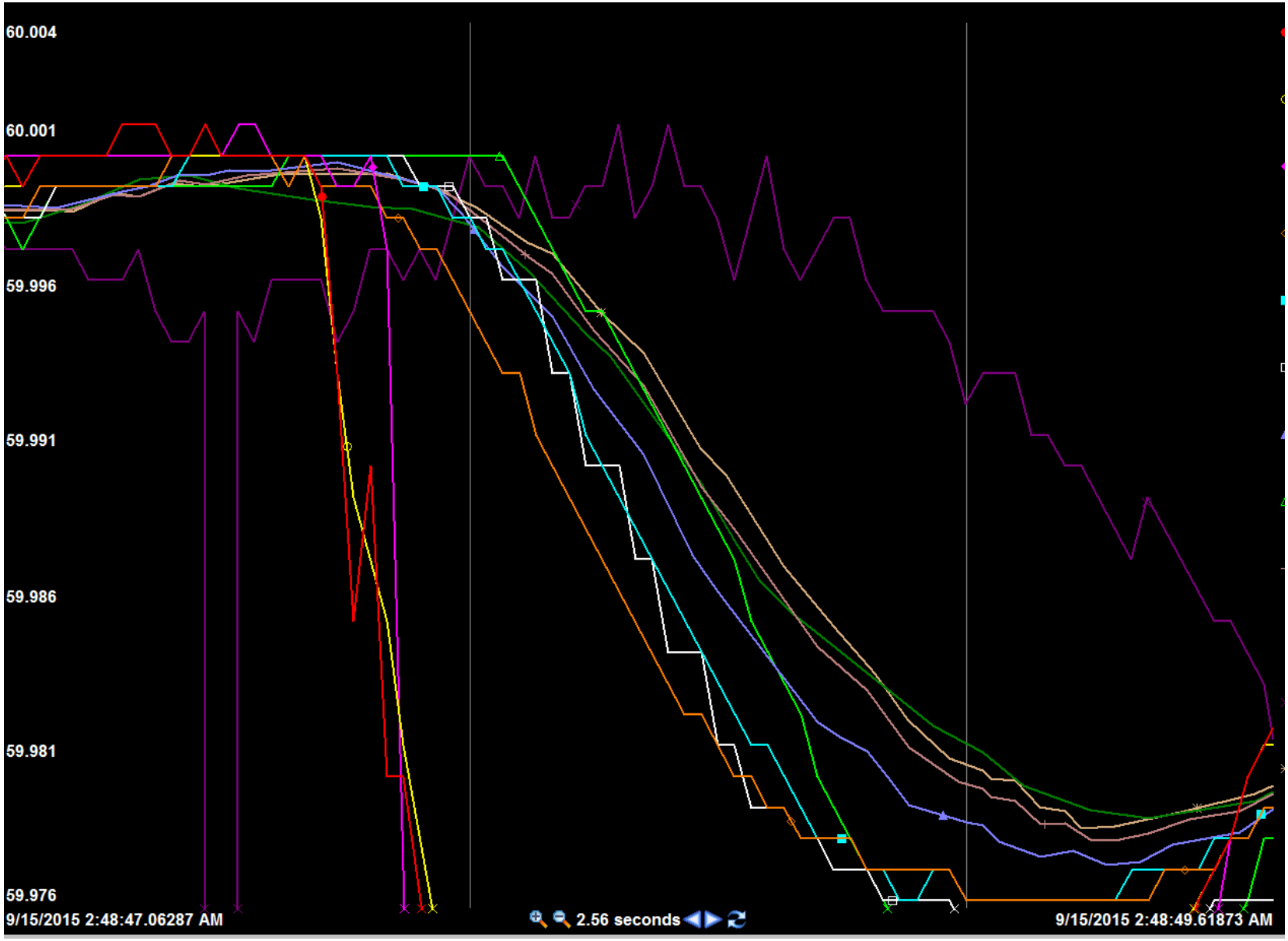
# Dispatchers only care about relatively large freq deviations. We picked a 0.04 Hz drop within 10 seconds as an alarmable event



# Some events are more of a challenge



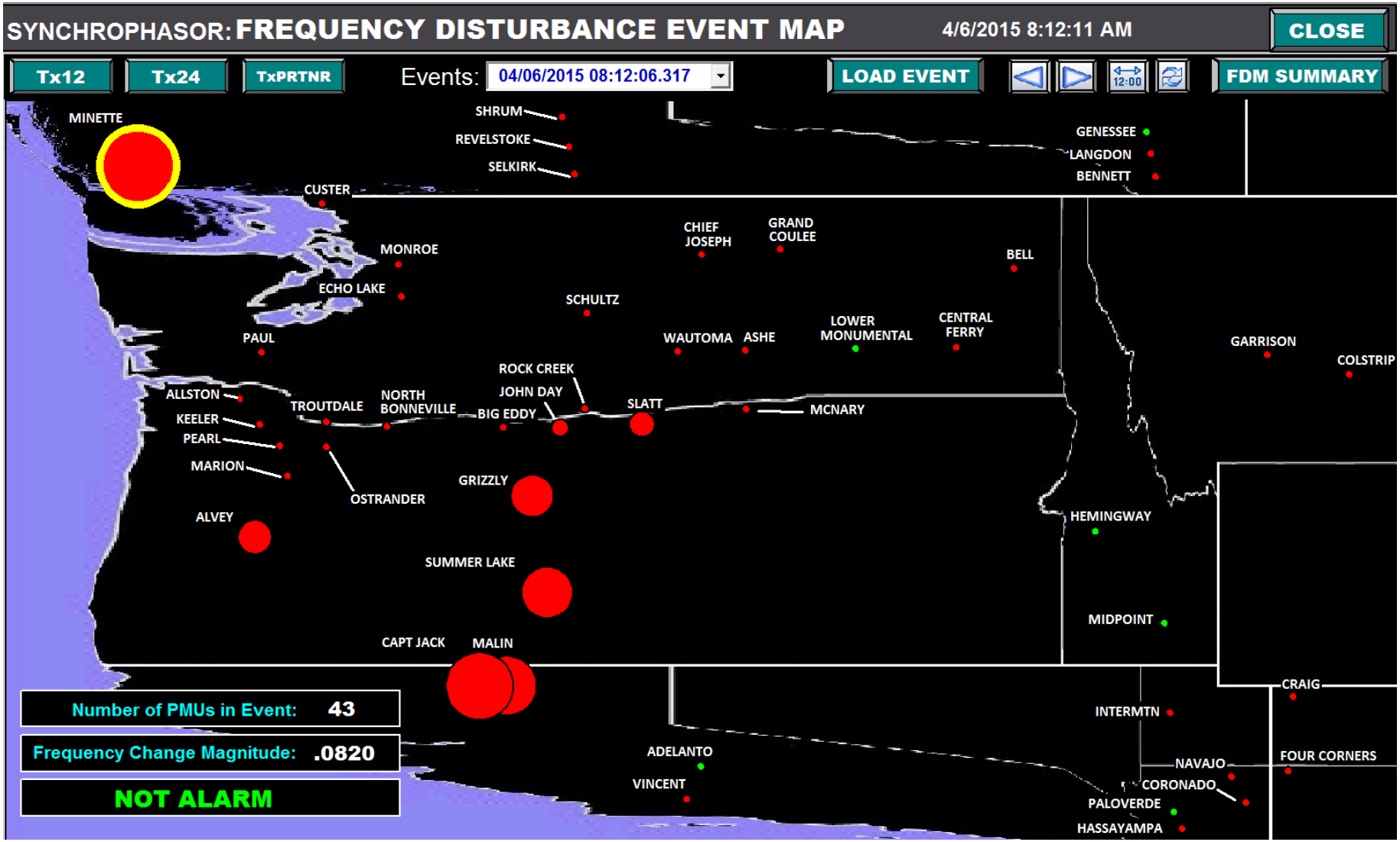
# Zoomed in data used by app



# Data error problems

- PMU time tags for Frequency are not that consistent
  - PMU vendors use different methods to calculate frequency.
  - Can’t say that a PMU that changes freq sooner is closer to the fault
  - Application uses calculated rate-of-change of freq only to rank PMU closeness
- PMU data dropouts
  - Missing PMU data can skew results
  - We use multiple PMU in an area as backups
  - Recently started sending automated daily emails to partners with bad data.

# Showing multiple bubbles has helped to rule out unreasonable results



# Results - caveats

- Have been fine tuning app for over a year.
- Major improvements made in late August.
- Latest update Oct 5th.
- Goal is to identify:
  - Inside or outside BPA BA
  - If outside, which BA outside (not which substation)

# Results as of Aug 29th

- Have had 19 alarmable events
- 6 event results were validated by reports (WECCNet, Partner published)
- 9 events were validated by evaluating the frequency trends, noting rate-of-change
- 3 events gave the wrong location (all were outside the BPA BA), but the Oct 5th software update should fix the mis-identification

# Operational Status

- Displays are shown in real time at the Dittmer Control Center
- Dispatchers use it as an early indicator. A place to start looking for the cause of the event using other tools, if necessary

# Conclusions

- Real time Situational Awareness tool for dispatchers. Location identified in 15 seconds and updated on Video Wall
- Identifies the responsible BA
- Alerts/emails engage Engineers
- Nicely packaged source of historical freq events with easy access to data

# Questions?