Showing the Location of a Frequency Disturbance using PMU data

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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 within 15 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

Number of PMUs in Event: 39
Frequency Change Magnitude: 0.0438
ALARM EVENT
08/11/2015 07:03:08.900
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**

<table>
<thead>
<tr>
<th>Event Time</th>
<th>Magnitude (Hz)</th>
<th>Rank1 PMU</th>
<th>PMU Count</th>
<th>Alarm Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>09/08/2015 15:26:16.417</td>
<td>0.0282</td>
<td>BCH:Minette</td>
<td>43</td>
<td></td>
</tr>
<tr>
<td>09/08/2015 05:09:51.267</td>
<td>0.0426</td>
<td>NWE:Colstrip</td>
<td>43</td>
<td>Alarm</td>
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<tr>
<td>09/05/2015 07:25:11.300</td>
<td>0.1425</td>
<td>AESO:Bennett</td>
<td>44</td>
<td>Alarm</td>
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<tr>
<td>09/05/2015 06:57:05.517</td>
<td>0.0003</td>
<td>Garrison</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>09/03/2015 13:09:28.433</td>
<td>-0.0025</td>
<td>Garrison</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>09/03/2015 07:48:18.483</td>
<td>0.0831</td>
<td>TSGT:Craig</td>
<td>44</td>
<td>Alarm</td>
</tr>
<tr>
<td>09/02/2015 20:48:52.667</td>
<td>0.0343</td>
<td>TSGT:Craig</td>
<td>44</td>
<td>Alarm</td>
</tr>
<tr>
<td>09/02/2015 19:37:17.150</td>
<td>0.0582</td>
<td>LADWP:Intermountain</td>
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<td>Alarm</td>
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<tr>
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<td>AESO:Langdon</td>
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<td></td>
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<tr>
<td>09/02/2015 14:25:03.050</td>
<td>0.0301</td>
<td>BCH:Revelstoke</td>
<td>40</td>
<td></td>
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<tr>
<td>09/01/2015 18:03:29.517</td>
<td>0.0343</td>
<td>SRP:Hassayampa</td>
<td>40</td>
<td></td>
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<tr>
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<td>Alarm</td>
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<tr>
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<td>Alarm</td>
</tr>
<tr>
<td>08/30/2015 18:04:23.217</td>
<td>0.0465</td>
<td>IPCO:Midpoint</td>
<td>40</td>
<td>Alarm</td>
</tr>
<tr>
<td>08/29/2015 21:48:03.217</td>
<td>0.0320</td>
<td>IPCO:Midpoint</td>
<td>39</td>
<td></td>
</tr>
</tbody>
</table>

I click on **Load Map**
Then click on **NERC-BAL-003**
How the App works

Example with a Grand Coulee 600 MW Gen drop, but app works with any freq change (positive or negative)
First $\frac{1}{2}$ 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.

0.17 seconds
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 5\textsuperscript{th}.
- 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?