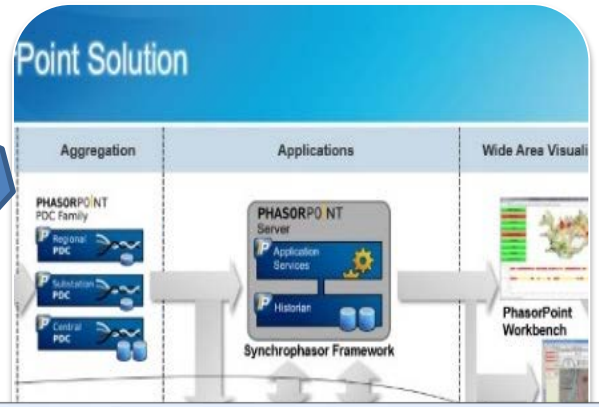
Synchrophasor Technology Advancement at Peak

- Peak has been working on Synchrophasor technology since 2012
- Peak is turning focus to control room solution (CRS) implementation

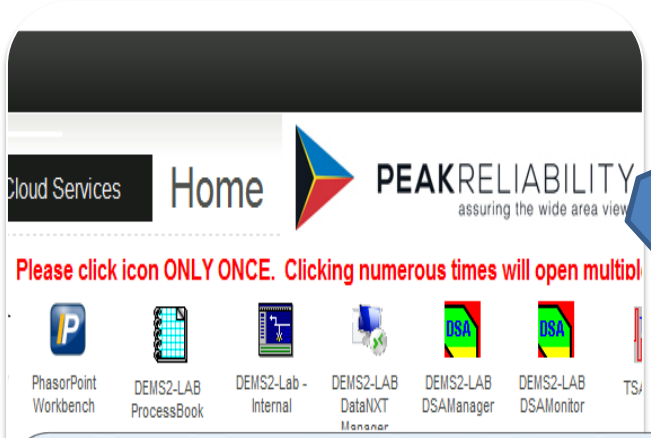
1



WISP ($108M DOE Grant, 2012-14)

- Install Synchro phasor Infrastructure
- Install and test Alstom WAMS Tools
- Integrate MontanaTech MAS in real-time
- Build Phasor PI for PMU Data storing
- Develop RT-VSA Tool from V&R POM

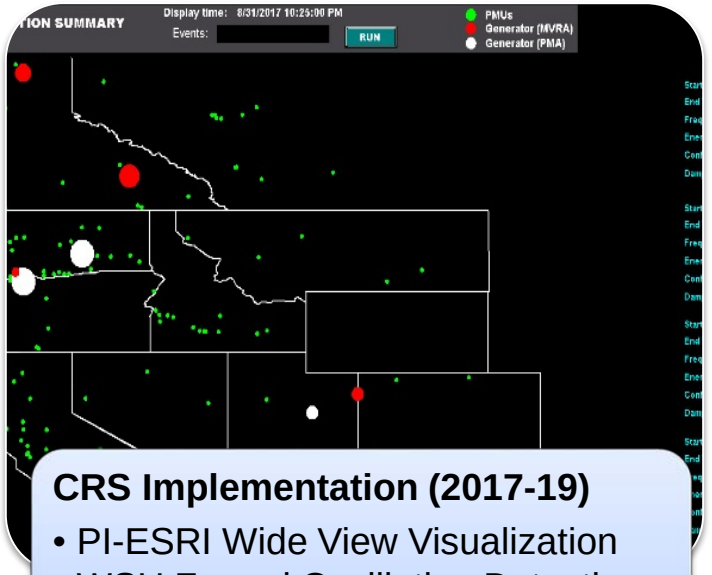
2



PRSP ($12.4M DOE Grant, 2015-16)

- Validate & improve PMU data quality
- Integrate PMU data in EMS
- Operationalize RT-VSA tool
- Upgrade MontanaTech MAS
- Build Engineering Lab & Validate WSU Oscillation Detection software
- Develop V&R LSE software

3



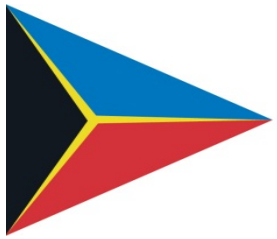
CRS Implementation (2017-19)

- PI-ESRI Wide View Visualization
- WSU Forced Oscillation Detection and Source Locating (FODSL) tool
- MAS 2.0/Mode Meter RT-Monitor
- LSE based PMU data conditioning
- Wide Angle Separation Monitoring

Success Story Spotlight

- Receive 400 PMUs live data from entities and down sample PMU raw signals and calculated line flows into EMS for Grid Resilience and a Hybrid SE Solution.
- Proven successful in System Model Validation (MOD-033) using PMU by Peak online TSAT and offline GE/PSLF tools.
- Integrated MontanaTech MAS tool in GE-Alstom PhasorPoint (PP) and send online PP/MAS results in EMS. Enable calculating major inter area oscillation modes in real time for Mode Meter baselining.
- Develop Forced Oscillation Detection and Source Location (FODSL) tools in collaboration with WSU. Capture oscillation events and source units effectively.
- Collaborated with V&R Energy to develop Real-time-Voltage Security Analysis (RT-VSA) tool-Peak ROSE for monitoring IROLs in Control room.

PMU Data Availability Statistics and Practical Utilization



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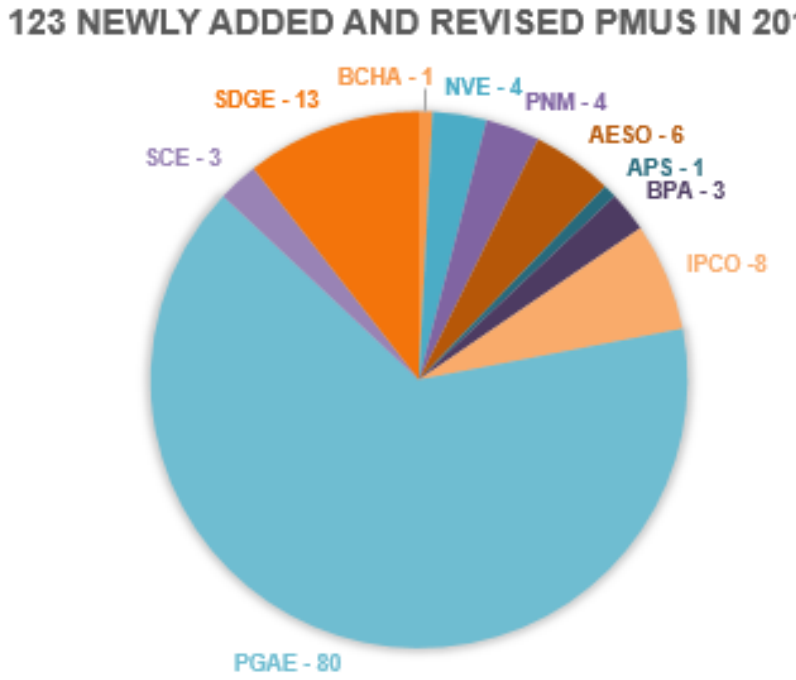
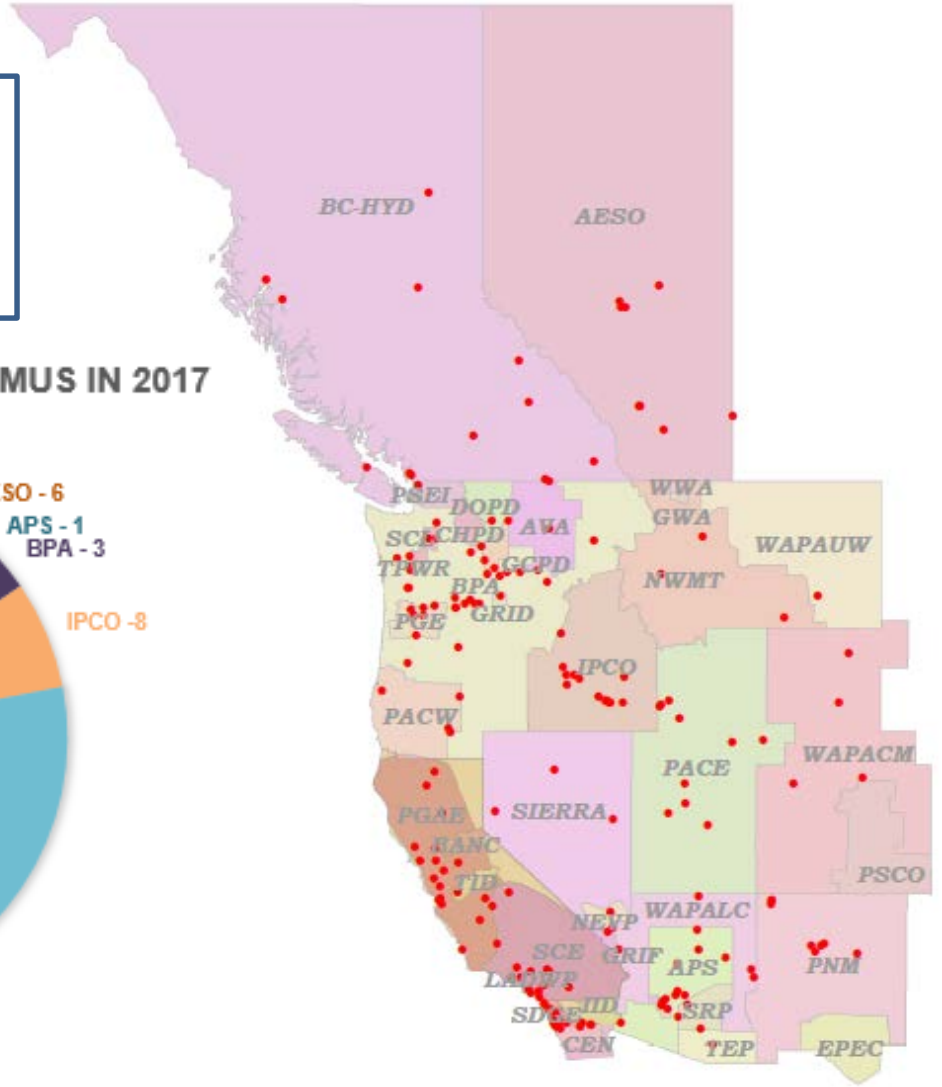
Peak PMU Map, Statistics and Additions in 2017

~thousands of PMU raw signals and 960 PMU based line MW/Mvar flows are down sampled in EMS





Entities	Number of PMUs		
	Van OpenPDC	Lov OpenPDC	Registry
AESO	42	42	43
APS	17	17	18
BCHA	11	11	13
BPA	64	64	76
IPCO	27	27	29
LDWP	15	15	15
NVE	13	13	18
NWE	3	3	3
PAC	-	-	8
PGAE	80	80	103
PNM	6	6	6
SCE	31	31	19
SDGE	71	71	118
SRP	7	7	9
TEPC	2	2	2
TSGT	2	2	2
WAPA	5	5	13
Grand Total	396	396	495

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Integrating PMU Data into EMS

- SE is solving with hybrid measurements: ICCP and DS-PMU

Telemetered PMU BUS Data | All | KVM | KVA | Telemetered Network Data

Time: 19-May-2017 14:32:25 RTNET REALTIME VALID SOLUTION

Station	Device Type	Device	Analog	Quality SCADA / Estimated	Value SCADA / Estimated	Enable	Primary	Weighted Residual	Standard Deviation	Bias	
G_COULEE	BUS	230_MAIN_SEC_2	KVA	Good / Available	28.45 / 28.09	☑	☐		0.630	0.223	
G_COULEE	BUS	230_MAIN_SEC_1	KVA	Good / Available	28.37 / 28.09	☑	☑	0.305	0.630	0.137	Row
HANFORD	BUS	900	KVA	Good / Available	15.50 / 15.31	☑	☑	0.203	0.620	0.063	Row
HANFORD	BUS	901	KVA	Good / Available	15.45 / 15.31	☑	☑	0.157	0.621	0.023	Row
JOHN_DAY	BUS	500_EAST	KVA1	Good / Available	8.56 / 8.47	☑	☐		0.618	-0.030	
JOHN_DAY	BUS	500_EAST	KVA	Good / Available	8.56 / 8.47	☑	☑	0.098	0.620	-0.030	Row
JOHN_DAY	BUS	500_WEST	KVA1	Good / Available	8.54 / 8.47	☑	☑	0.070	0.618	-0.056	Row
JOHN_DAY	BUS	500_WEST	KVA	Good / Available	8.51 / 8.47	☑	☐		0.620	-0.084	
JOHN_DAY	BUS	230KV_WEST	KVA	Good / Available	8.78 / 8.69	☑	☑	0.102			
MINETTE	BUS	404	KVA	Suspect / Available	25.74 / 25.26	☑	☑	0.530			
KEELER	BUS	500_PMU	KVA	Good / Available	0.00 / 0.14	☑	☑	0.151			
KEELER	BUS	230_MAIN_SEC_1	KVA1	Good / Available	-2.18 / -2.05	☑	☑	0.143			
KEELER	BUS	230_MAIN_SEC_1	KVA	Good / Available	-2.19 / -2.05	☑	☐				
KEELER	BUS	203	KVA1	Good / Available	-2.16 / -2.05	☑	☑	0.119			
KEELER	BUS	203	KVA	Good / Available	-2.19 / -2.05	☑	☐				

DS PMU Voltage Angle from SCADA vs SE Estimated Bus Voltage Angle

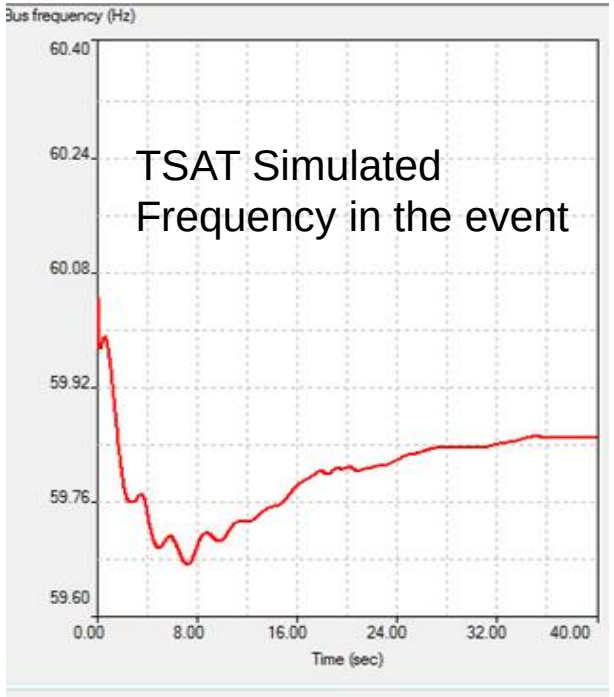
DS PMU based Line Flows from SCADA vs SE Estimated Line Flows

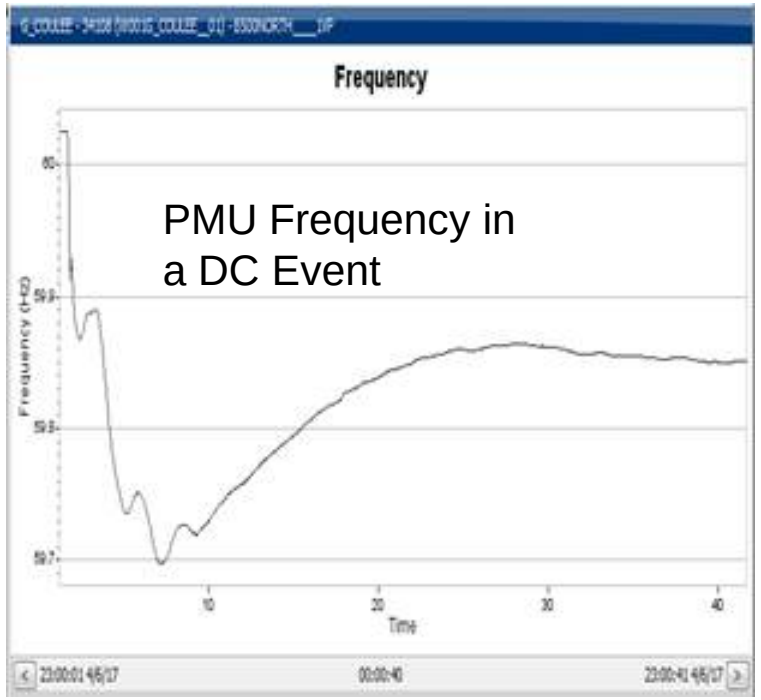
Last Solved: 17-Sep-2017 12:48:13 | Enable All Stations | RTNET REALTIME VALID SOLUTION

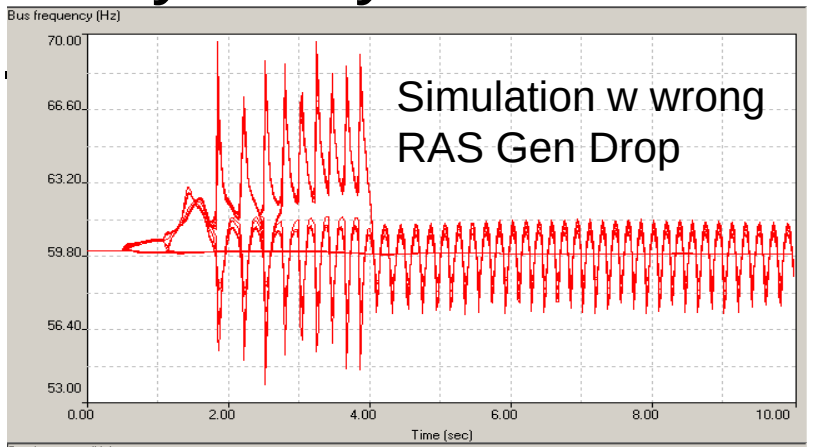
Device Name	Quality SCADA / Estimated	Value SCADA / Estimated		Enable	Primary	
MALIN				☑		
Line MALN_RNDM_2500 Seg (A)	Good / Disabled	611.92	612.18 PMW	☐	☐	
Line MALN_RNDM_2500 Seg (A)	Good / Available	612.90	612.18 MW	☑	☑	Row
Line MALN_RNDM_2500 Seg (A)	Good / Disabled	-63.19	-37.42 PMV	☐	☐	
Line MALN_RNDM_2500 Seg (A)	Good / Available	-58.50	-37.42 MV	☑	☑	Row
Line MALN_RNDM_1500 Seg (A)	Good / Disabled	600.15	600.44 PMW	☐	☐	
Line MALN_RNDM_1500 Seg (A)	Good / Available	607.50	600.44 MW	☑	☑	Row

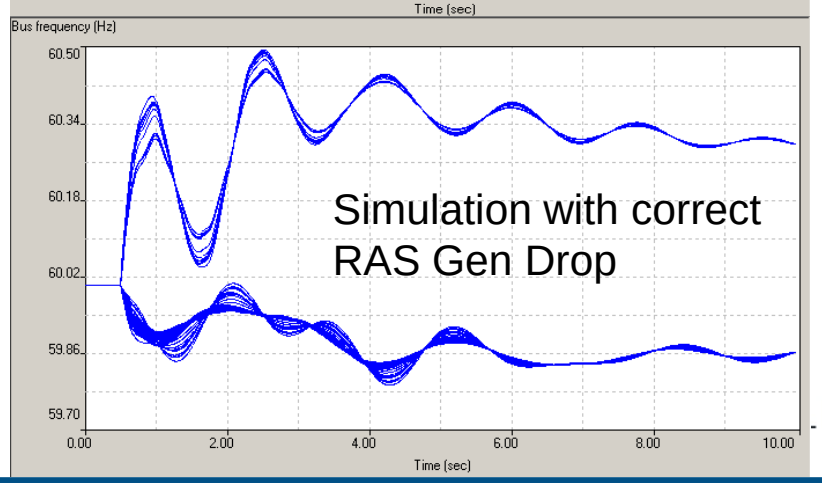
System Model Validation (MOD-033) Practice

- Peak used online WSM-TSAT/PSLF to validate many system events against PMU recording. We were able to identify many RAS, network and dynamic modeling issues and fix them.

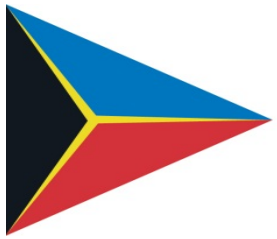








System Oscillation Detection Implementation at Peak



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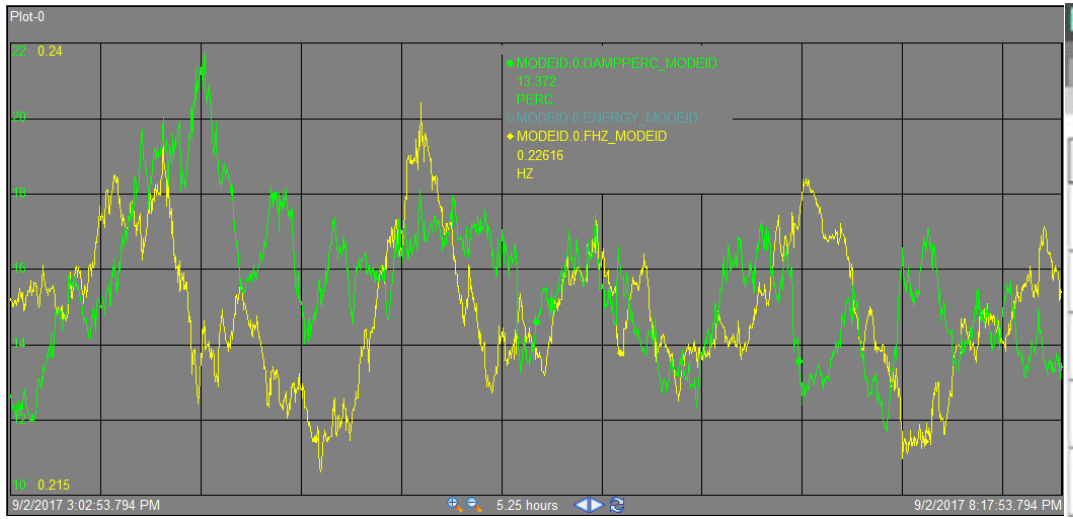
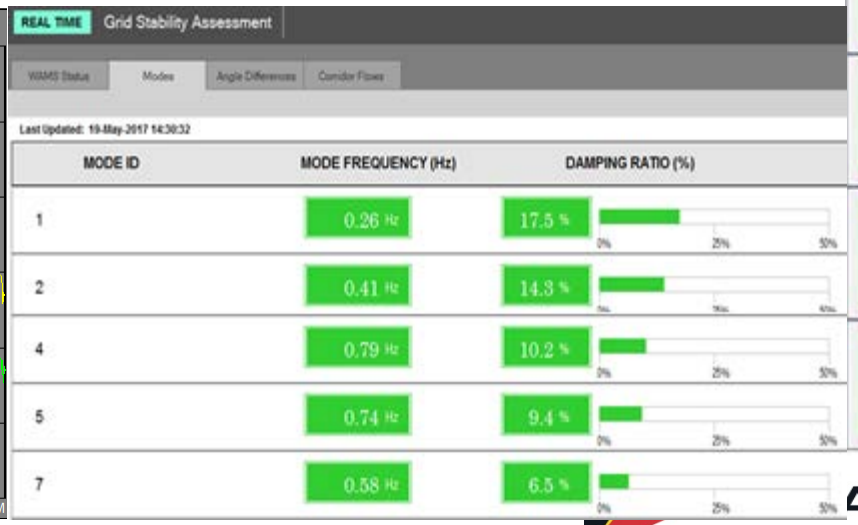
assuring the wide area view

Monitoring Inter Area Modes in Real-Time

- Peak implemented MontanaTech MAS engine in GE PhasorPoint (PP) and integrated PP/MAS solution results into EMS via Grid Stability Assessment (GSA).
- MAS is configured to monitor multiple inter area modes.
- All MAS results are available in EMS and PI Historian.

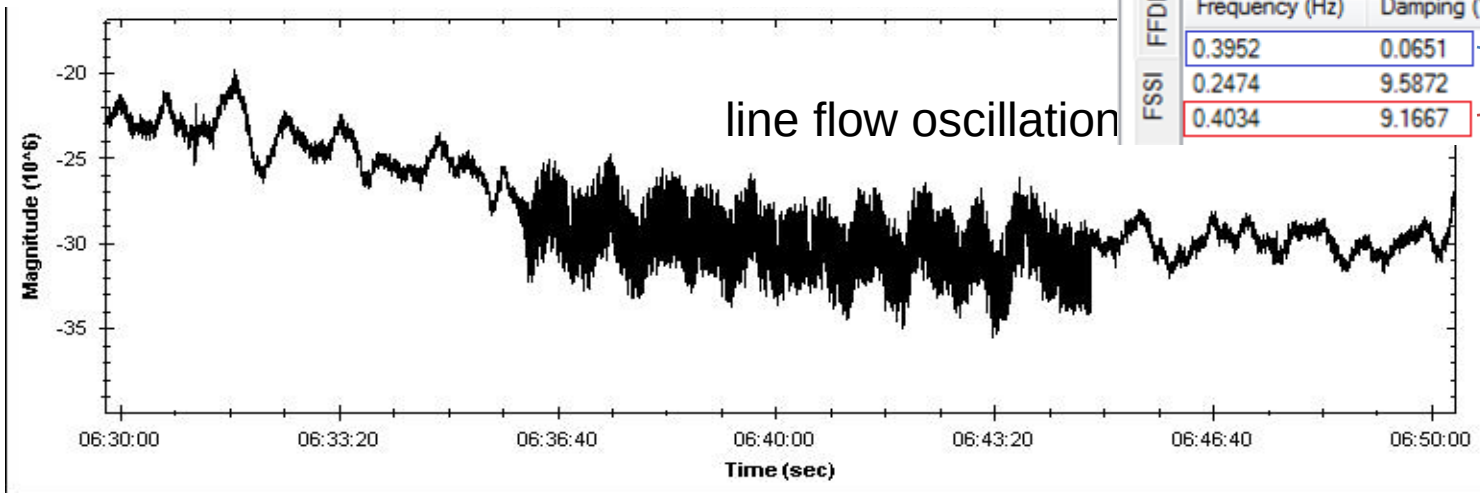




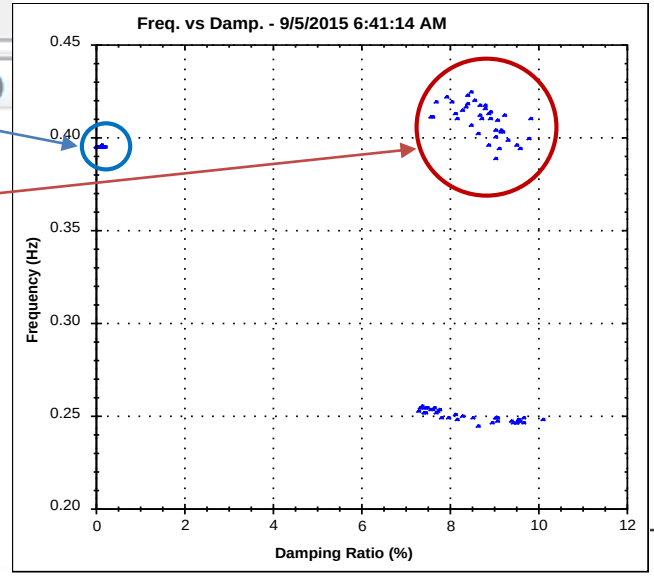
AKRELIABILITY

Forced Oscillation Detection & Source Locating

- Peak implemented WSU Oscillation Monitoring System (OMS) tools in Engineering Lab for forced oscillation detection in real-time.
- We collaborated with WSU to develop original algorithms for source locating by SCADA measurements: PMA and MVRA.
- The tools were used to find various forced oscillations, including one Resonant Oscillation on COI.



line flow oscillation



Real-Time FODSL Results Summary

(08/18/2017-09/07/2018)

- From the FODSL tool at Engineering Lab, we noticed hundreds of oscillation event alarms in Fig-1. By filtering those with damping <3% and confidence level>75%, we identified a subset of likely sustainable oscillations in Fig-2. We chose one 1.23 Hz oscillation event in Fig-3.

Fig-1:

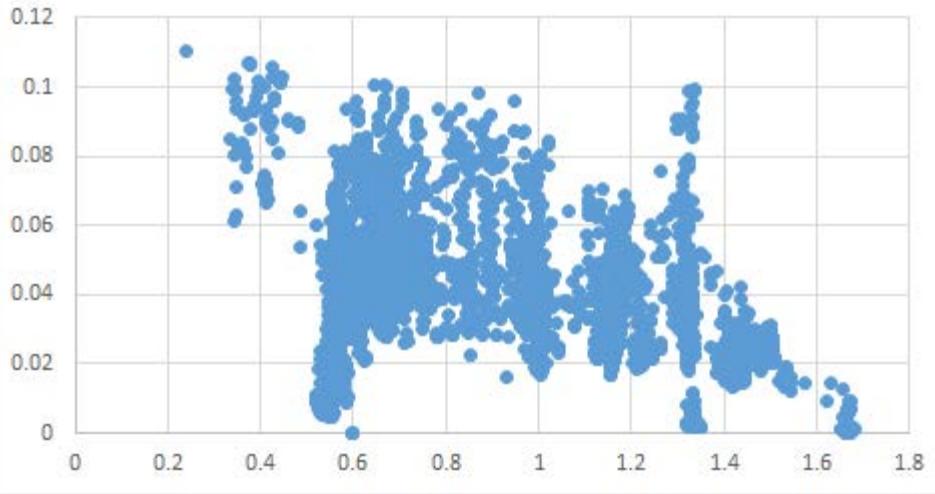


Fig-2:

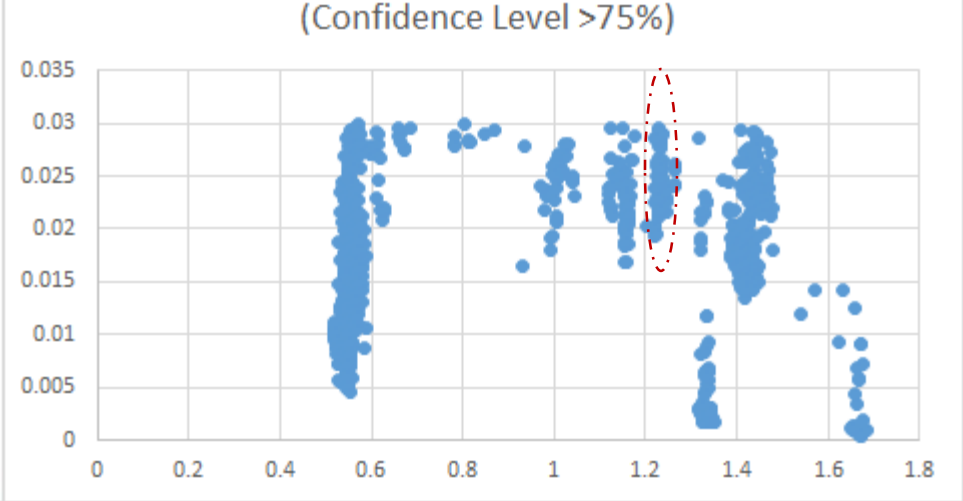
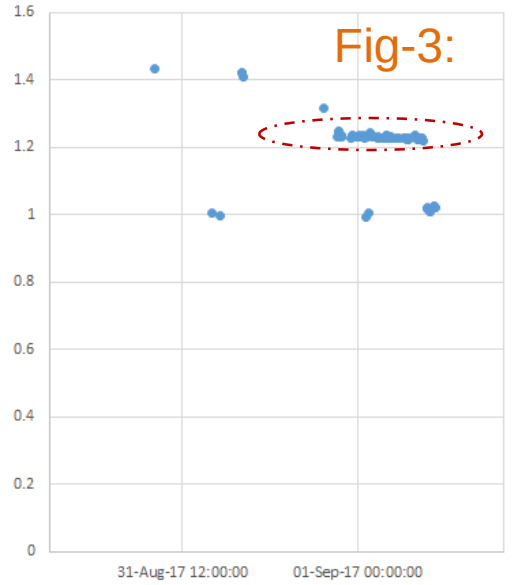


Fig-3:



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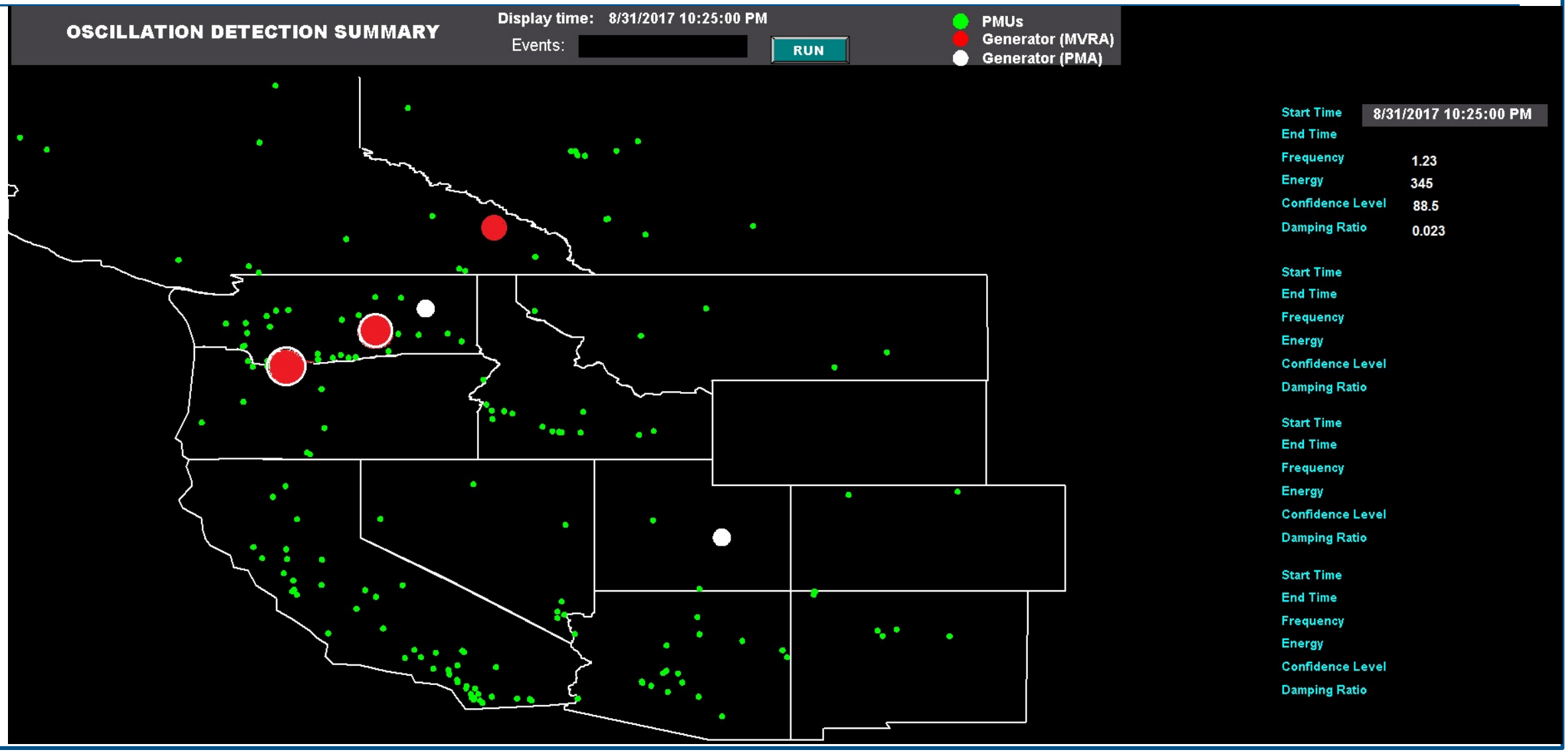
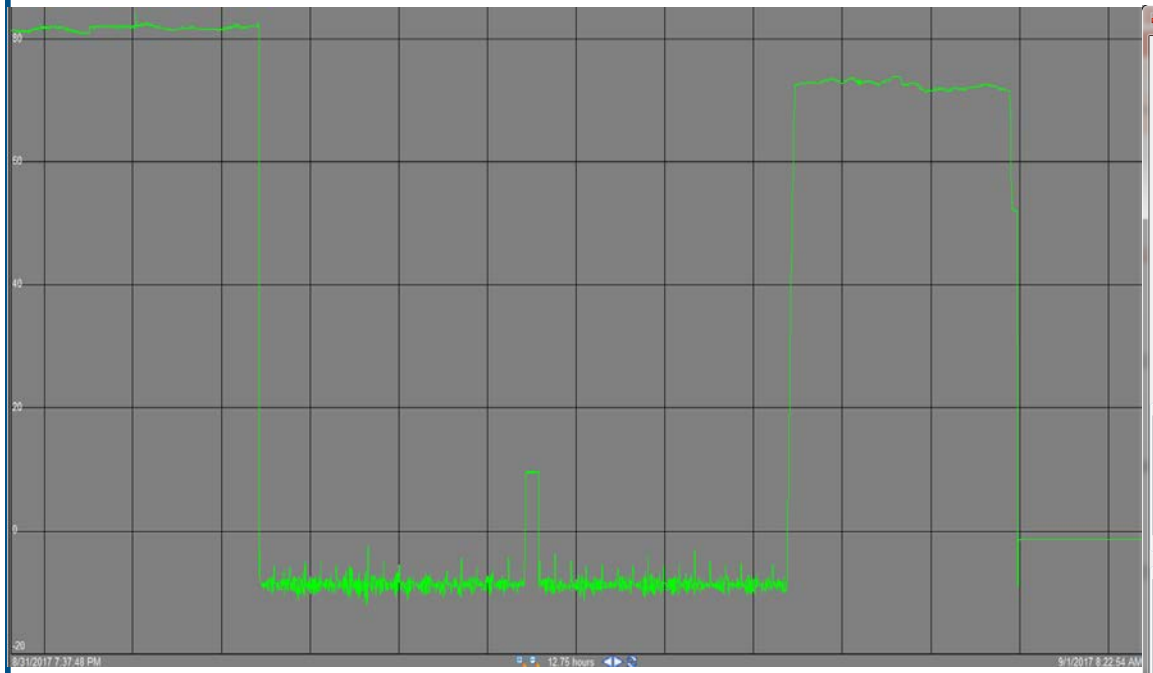
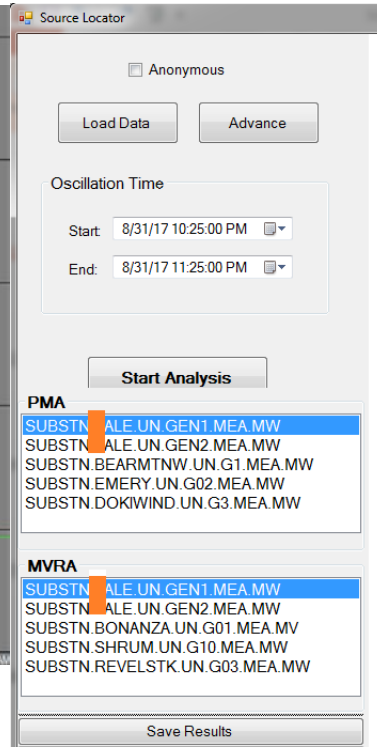
FODSL PI Processbook Visualization Tool

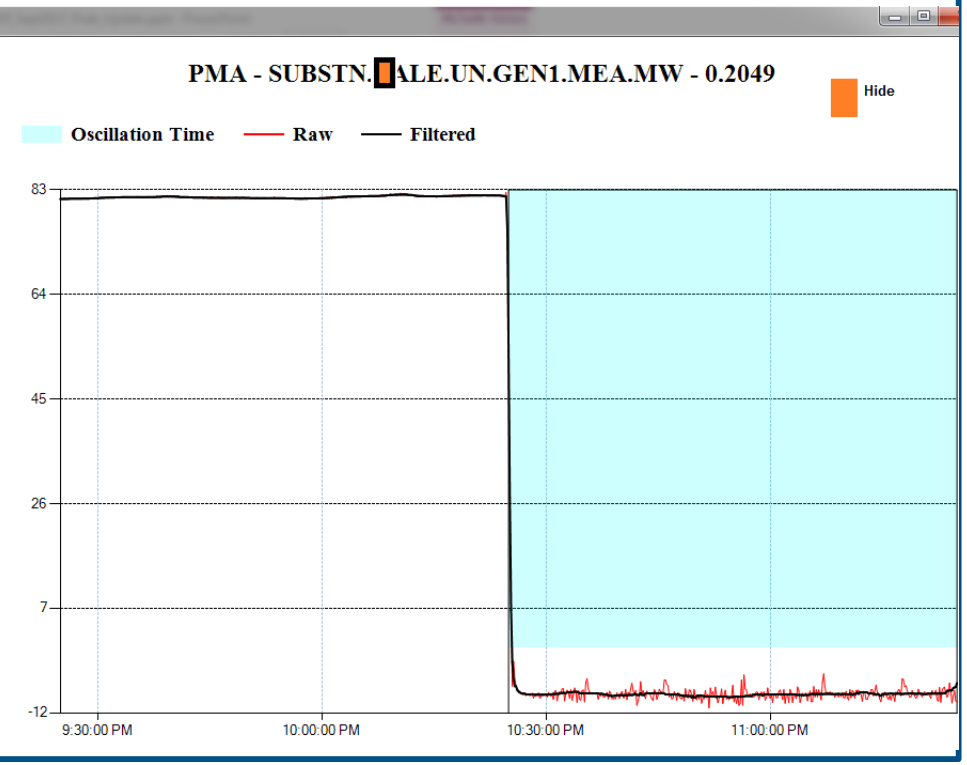


Offline Case Study by the PMA and MVRA Tools

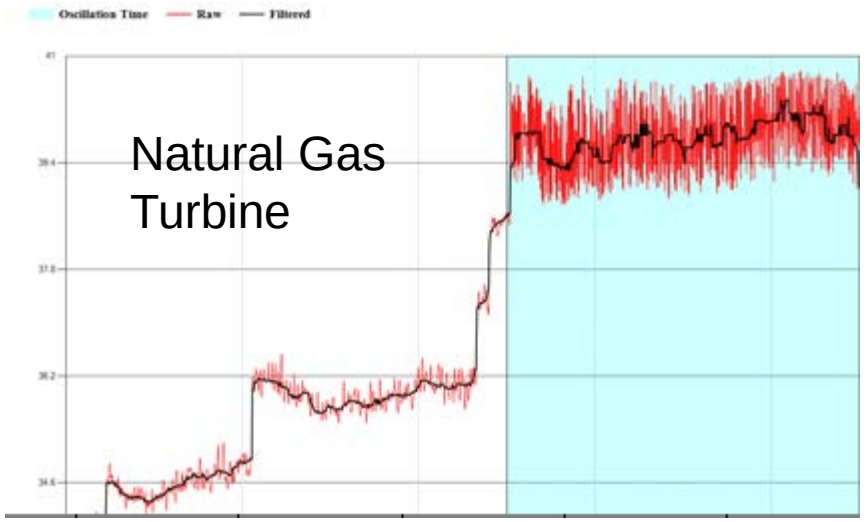
- This 1.23 Hz oscillation event was captured by both BPA MAS/ODM and Peak WSU-FOD tools. Both PMA and MVRA tools identified the same source unit. It was on motoring mode with PSS turned on during the incidence. BPA and Peak contacted the unit owner and confirmed the root cause of oscillation.

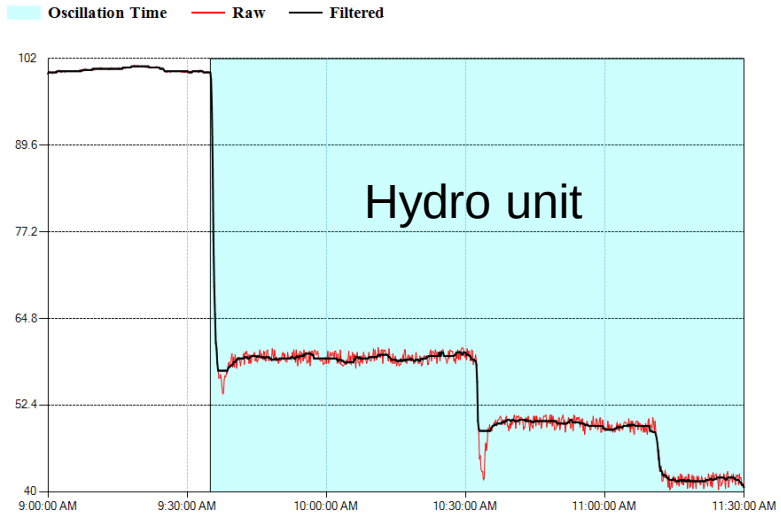


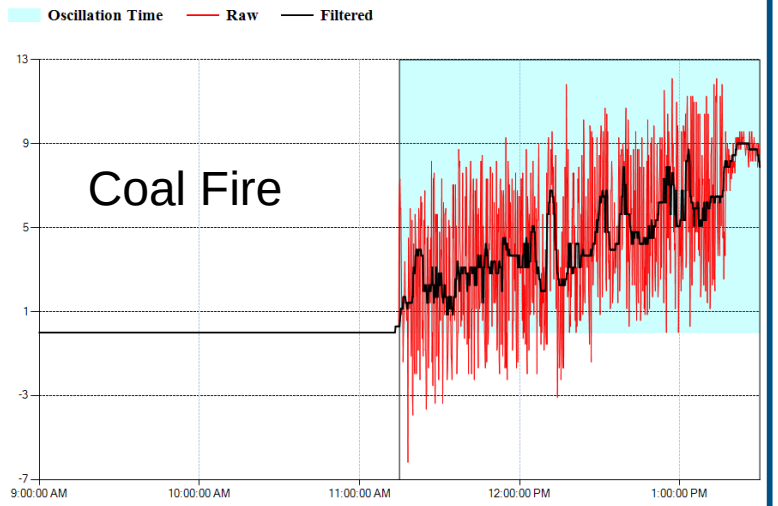


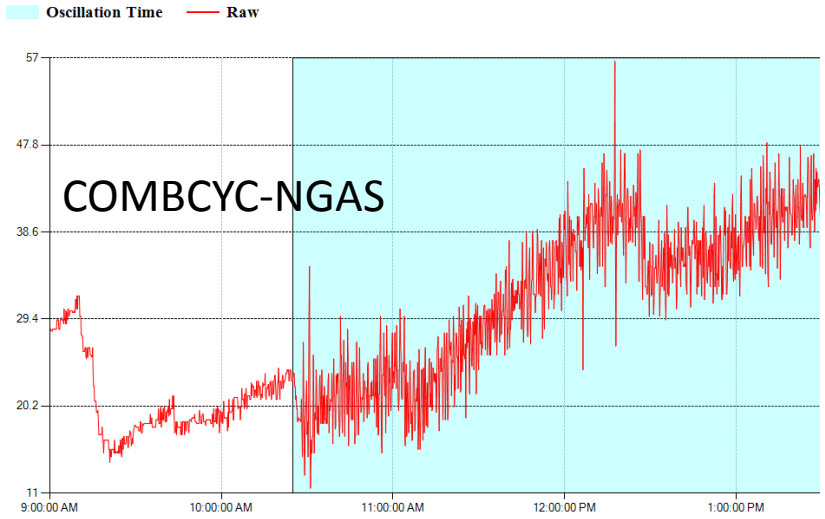


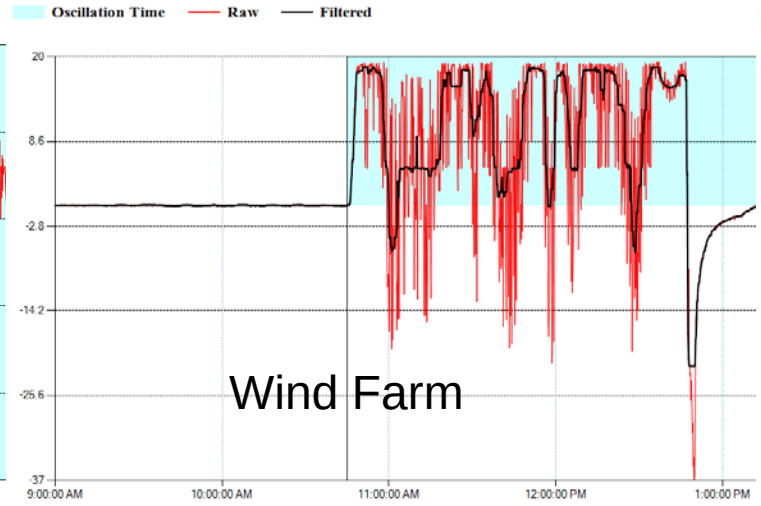
More Possible Oscillations to be Investigated

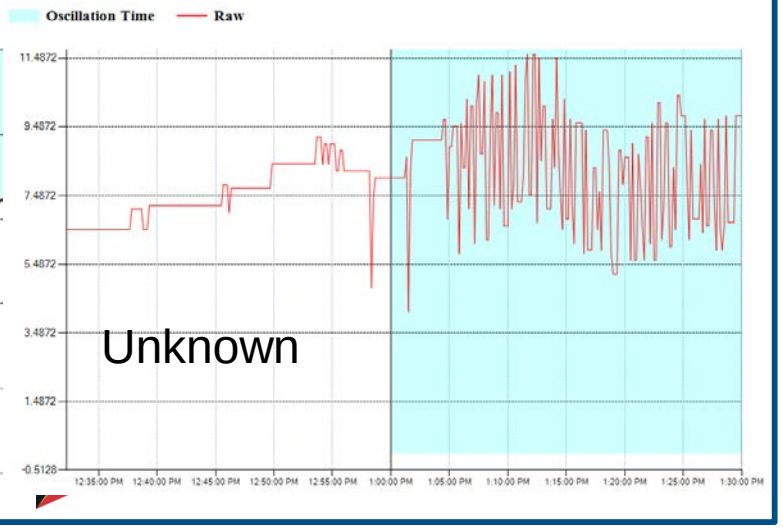




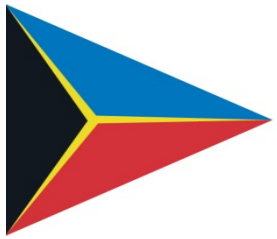








Linear State Estimator (LSE) online Implementation at Peak



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LSE Implementation Practice: V&R LSE under PRSP

- Peak RC supported V&R Energy to develop LSE in collaboration with Idaho Power, SCE, SDGE, and CAISO on the PRSP project.
- The tool is intended to perform real-time LSE analysis for
  - Bad data detection and conditioning combined with Kalman filtering
  - Identifying PMU observable parts of the system
  - Creation of PMU-based WECC-wide state estimator case
  - Performing voltage stability analysis using PMU-based case
- The tool was applied for offline analysis for optimal PMU placement at IPCO.
- The V&R LSE software is being installed at Peak RC for initial online testing.

VR ENERGY

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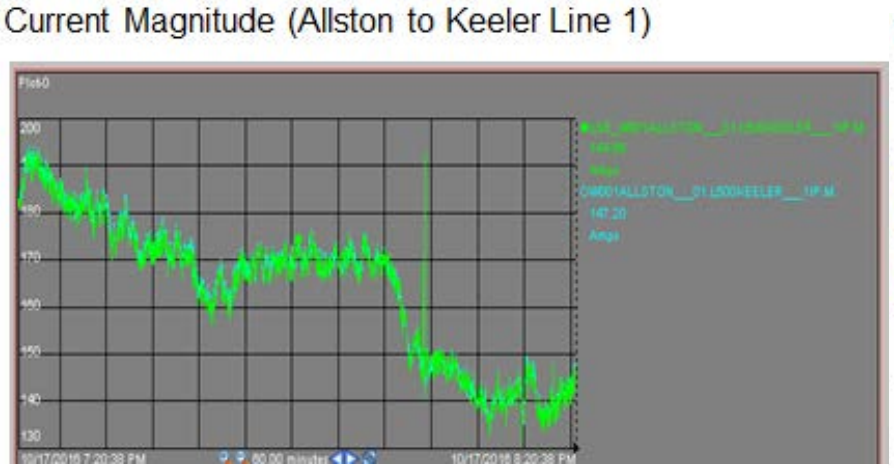
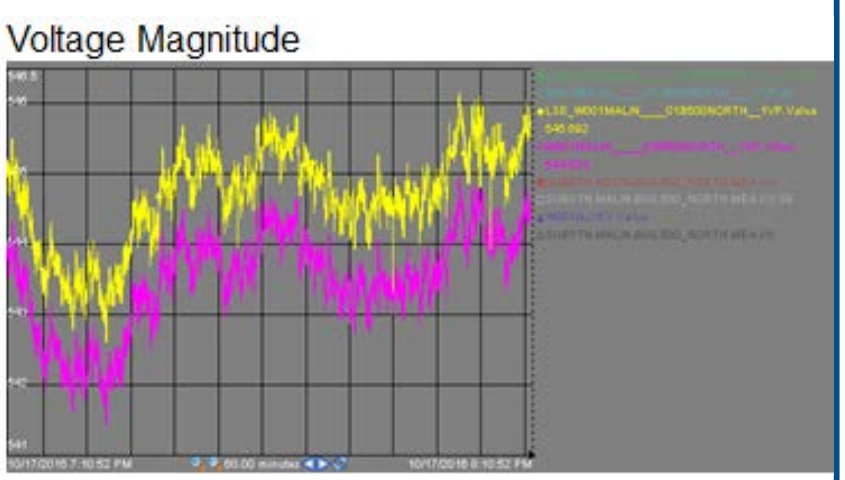
LSE Implementation Practice: EPG eLSE Project

- Peak started a EPG-eLSE Pilot project in May 2016. The eLSE has been running with 64 BPA PMUs for 1-yr at Engineering Lab for validation test. The tool was verified with a few key features:
  - Highly robust and accurate
  - Fast solution speed e.g. 30 runs per second
  - Bad data detection
  - Data conditioning
  - Multi-islanding
  - Topology process
  - Pseudo PMU





Electric Power Group

PEAKRELIABILITY

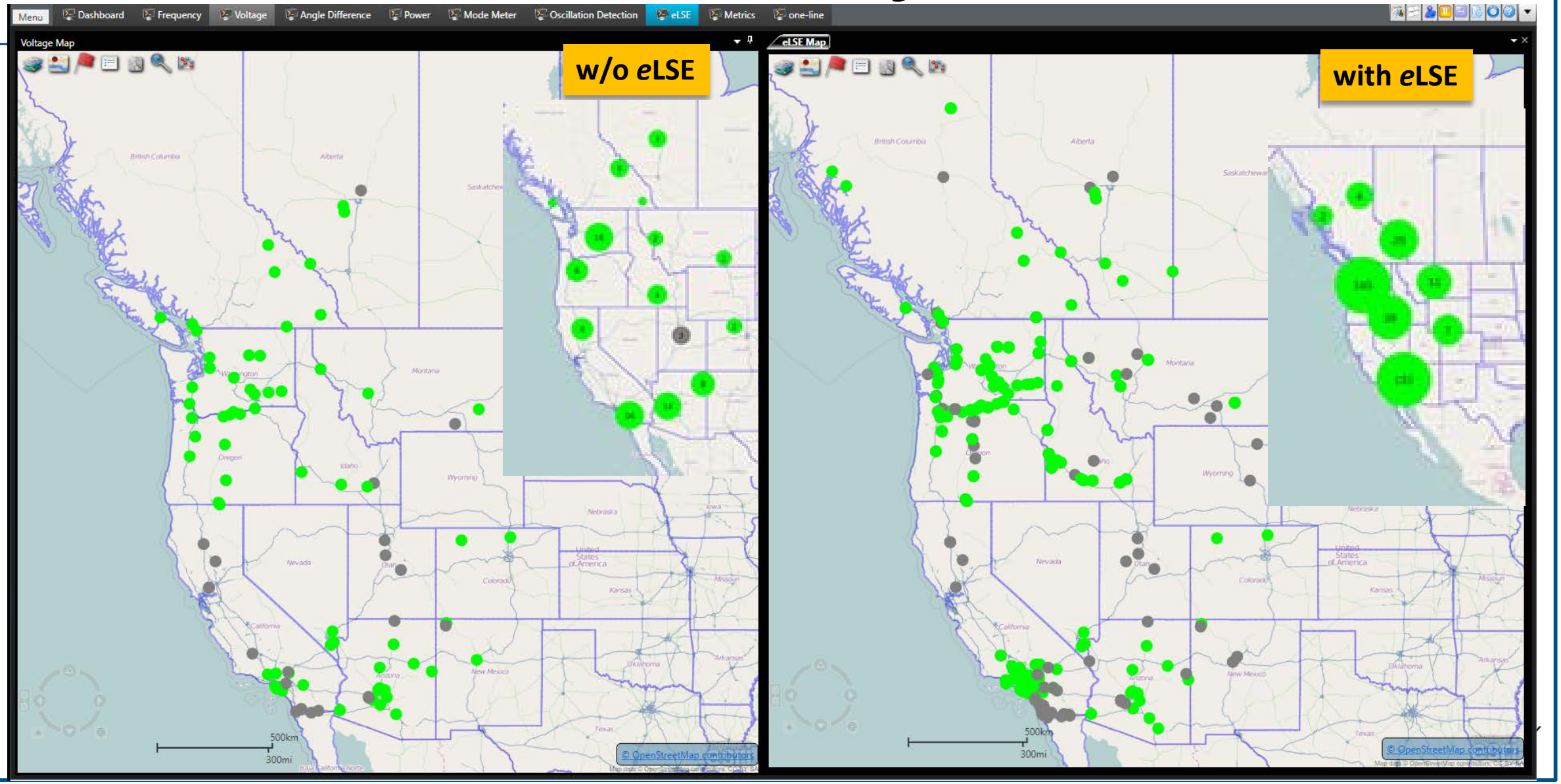
LSE Implementation Practice: Multiple Islands

- Peak recently expanded the LSE coverage from BPA to BC Hydro, Idaho Power, Northwestern Energy and Southern California Edison.
- Next step is to deploy EPG-eLSE in Test and Production for Grid Resilience in addition to EMS tools.

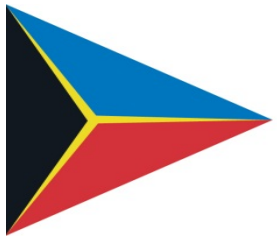
Number of	BPA	BC Hydro	Idaho Power	NWE	SCE	Total
PMUs	64	11	27	3	28	133
Substations with PMU(s)	35	9	13	2	14	73
Observable Substations in LSE	108	37	26	12	54	237

Peak EPG-eLSE Observability

Electric Power Group



PI-ESRI Visualization Tool for Control Room Solution at Peak



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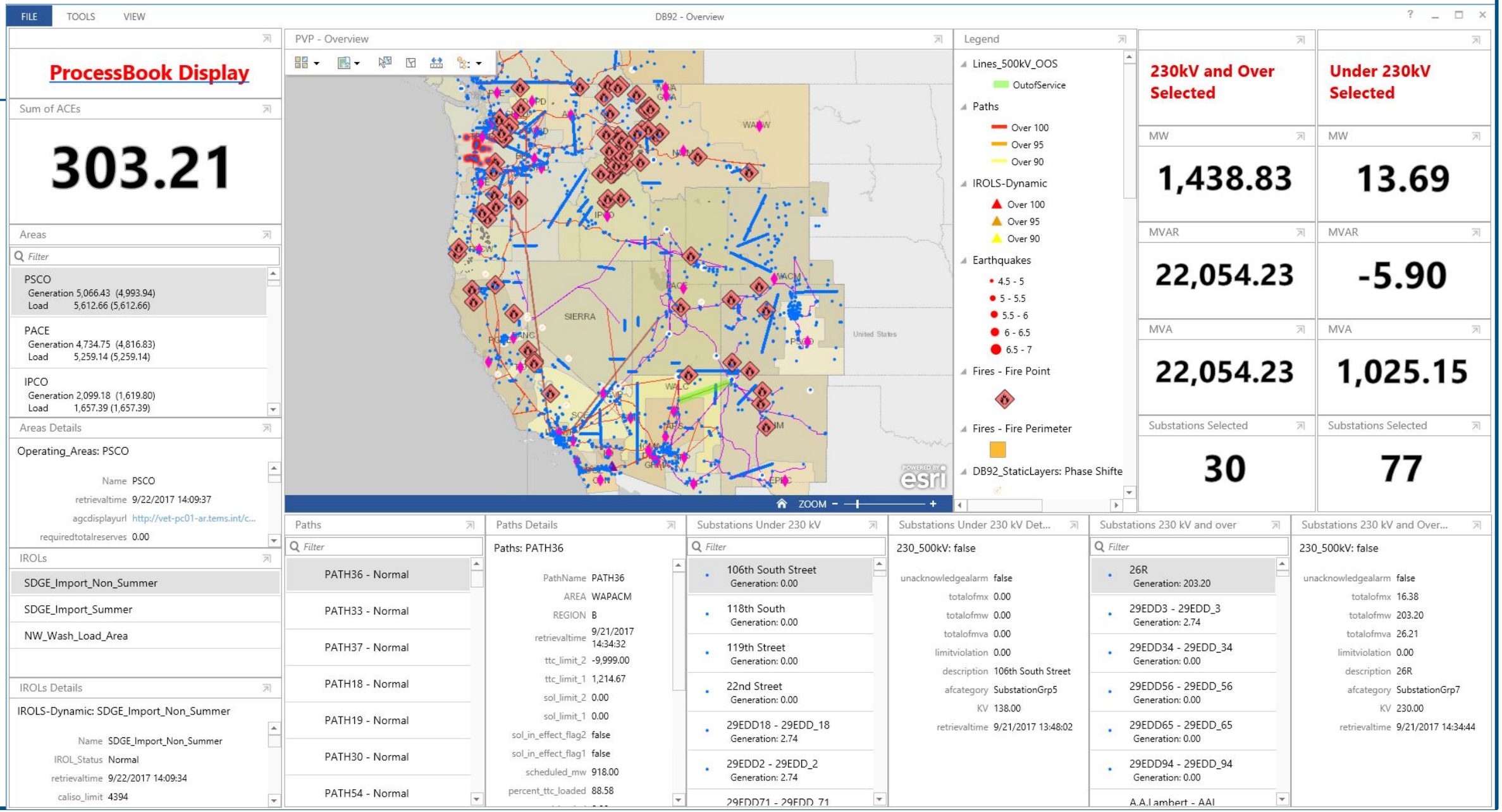
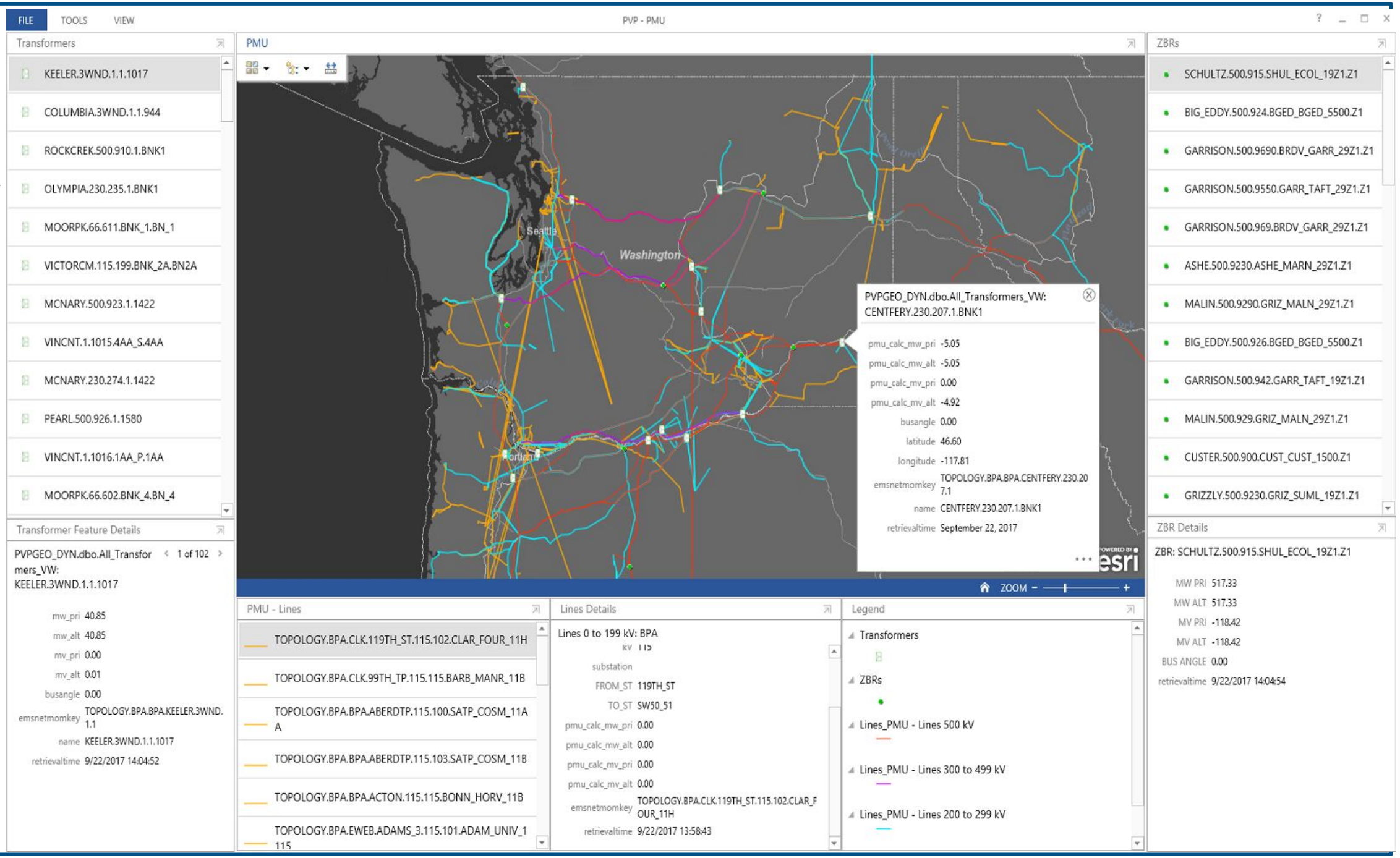
Visualization Platform Development-PI ESRI

- **Purpose**
  - Increase Situational Awareness
  - Easily Maintained Displays –Data-driven Map Creation
  - Geospatial Visualization (using Precise GIS mapping)
  - Weather Visualization (live weather feeds)
  - Fast Power System Analysis / Comprehension of System Conditions
  - Integrated with West-wide System Model –Model-Based Platform
- **Content Available**
  - Environmental Factors
  - SOL / IROL Information
  - Transmission Lines
  - Phase shifters
  - Substations
  - Alarms
  - Gas Facilities
  - PI Coresight
  - Base maps
  - RT Disaster Report
  - PMU Line Flows (in progress)

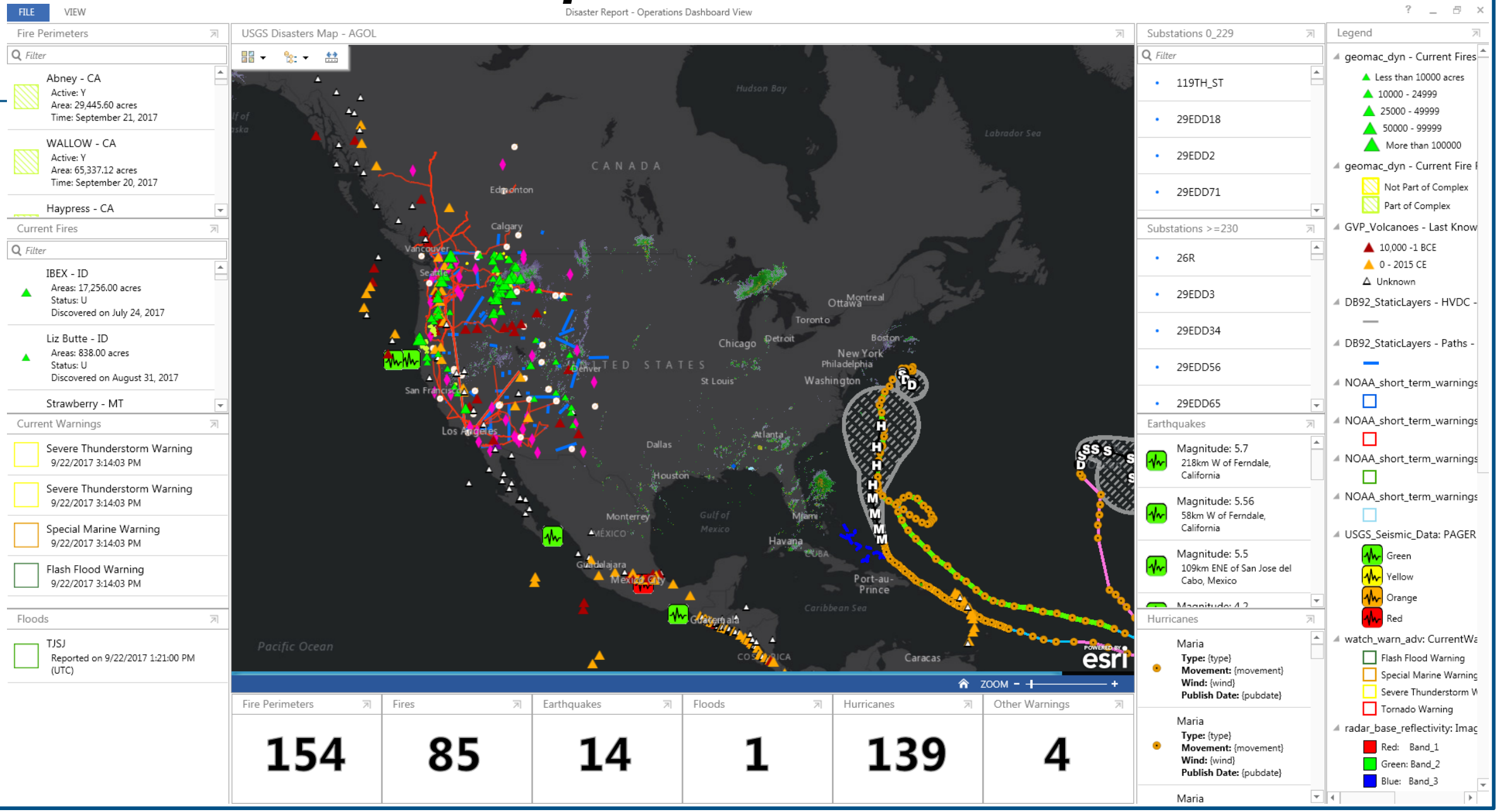
PVP Overview



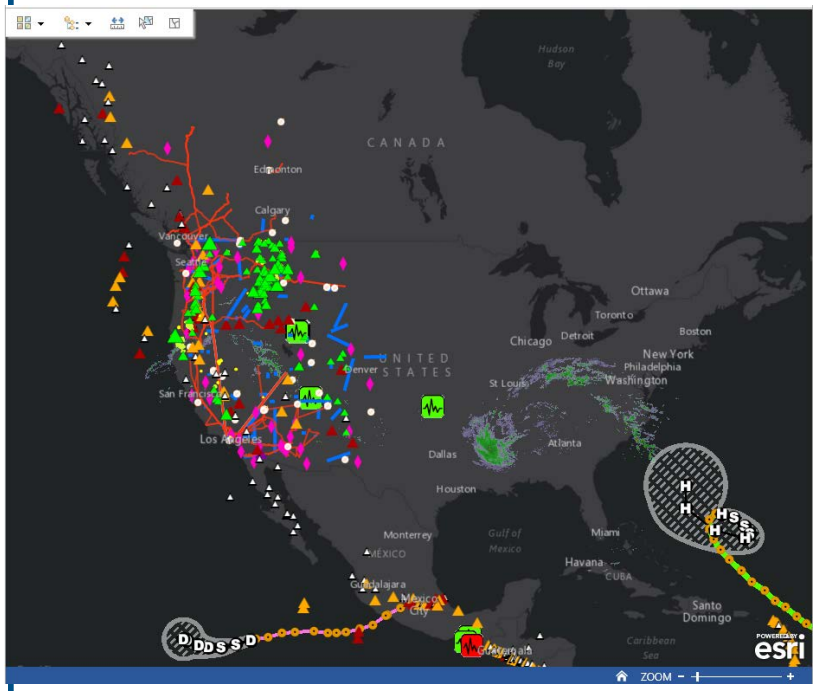
PMU Line Flow

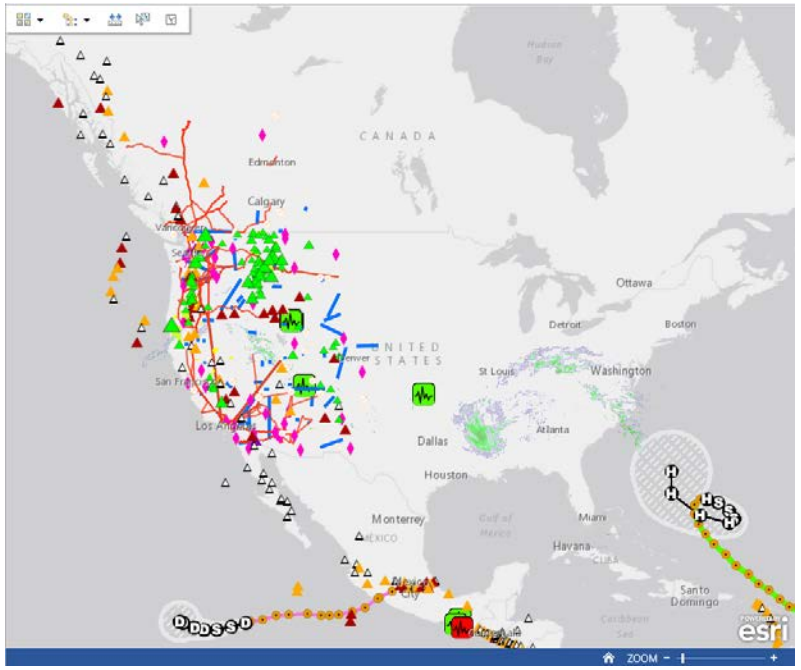


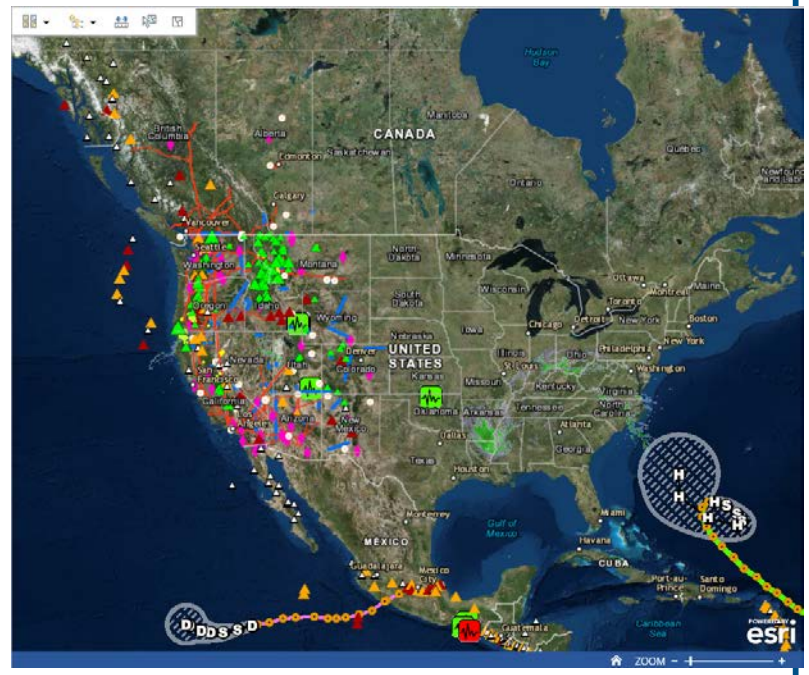
Real-time Disaster Report



Basemaps







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ESRI-PVP Project Roadmap

- Current State:
  - Perform Prod System Upgrade
  - Fifteen (15) use cases completed / partially completed
  - Real-time Disaster Report (e.g. earthquake, lightning)
- Next Steps:
  - Deploy new hardware to prepare for Prod migration
  - Complete additional identified use cases. For examples:
    - **Raw PMU /LSE solved Line Flows, RTCA, RT-VSA and online TSAT, Mode Meters, Frequency Events and Forced Oscillation Detection**

Conclusion

- Demonstrated values of Synchrophasor technology and use cases from WISP/PRSP/Pilot projects in collaboration with Vendors, universities and utilities.
- Next step is to mature Synchrophasor tools and integrate them into Peak custom control room solutions.
- Support NERC and WECC to develop new standards or guidelines for Synchrophasor applications.
- Work with entities for Synchrophasor Value demo & training.

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