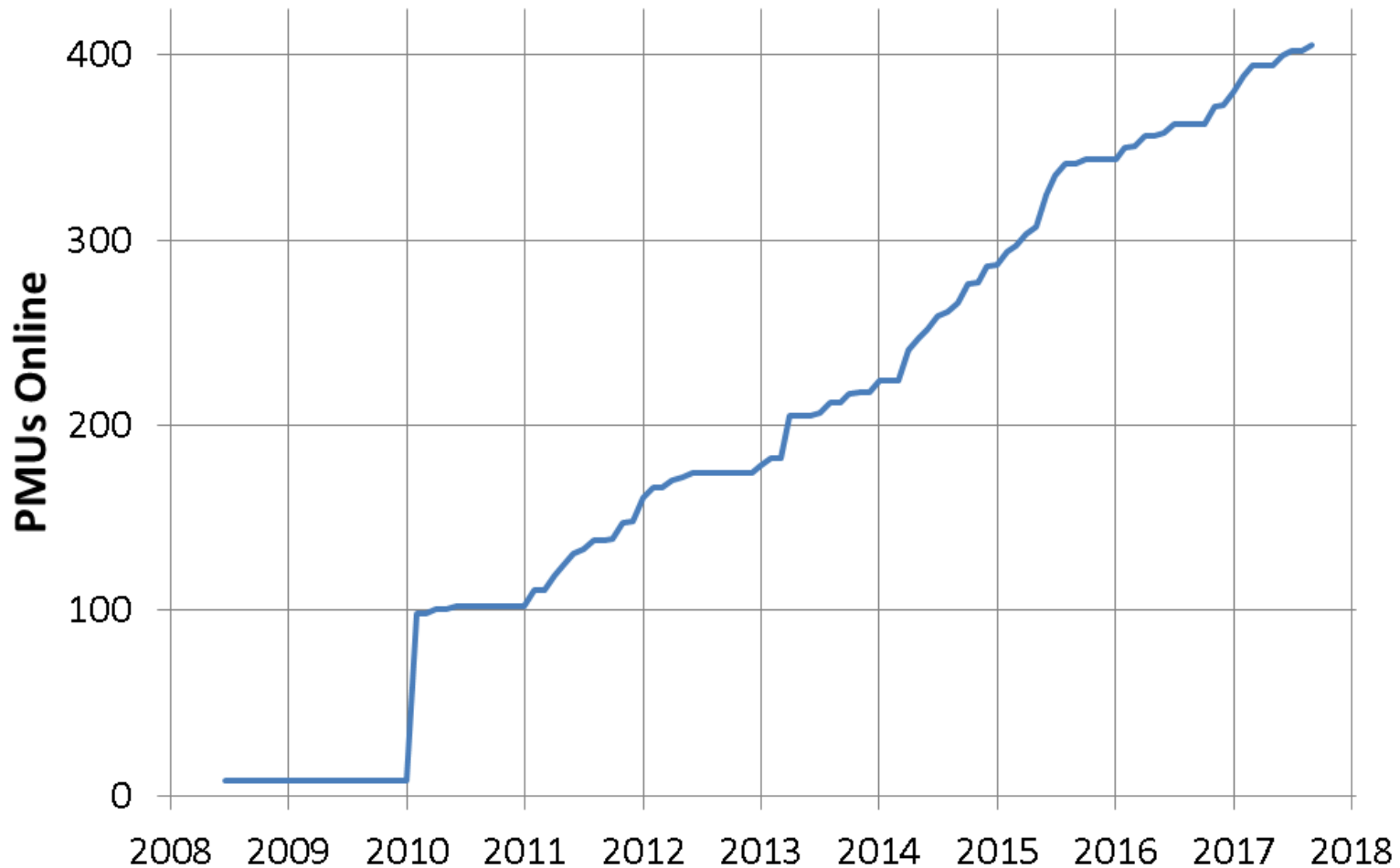


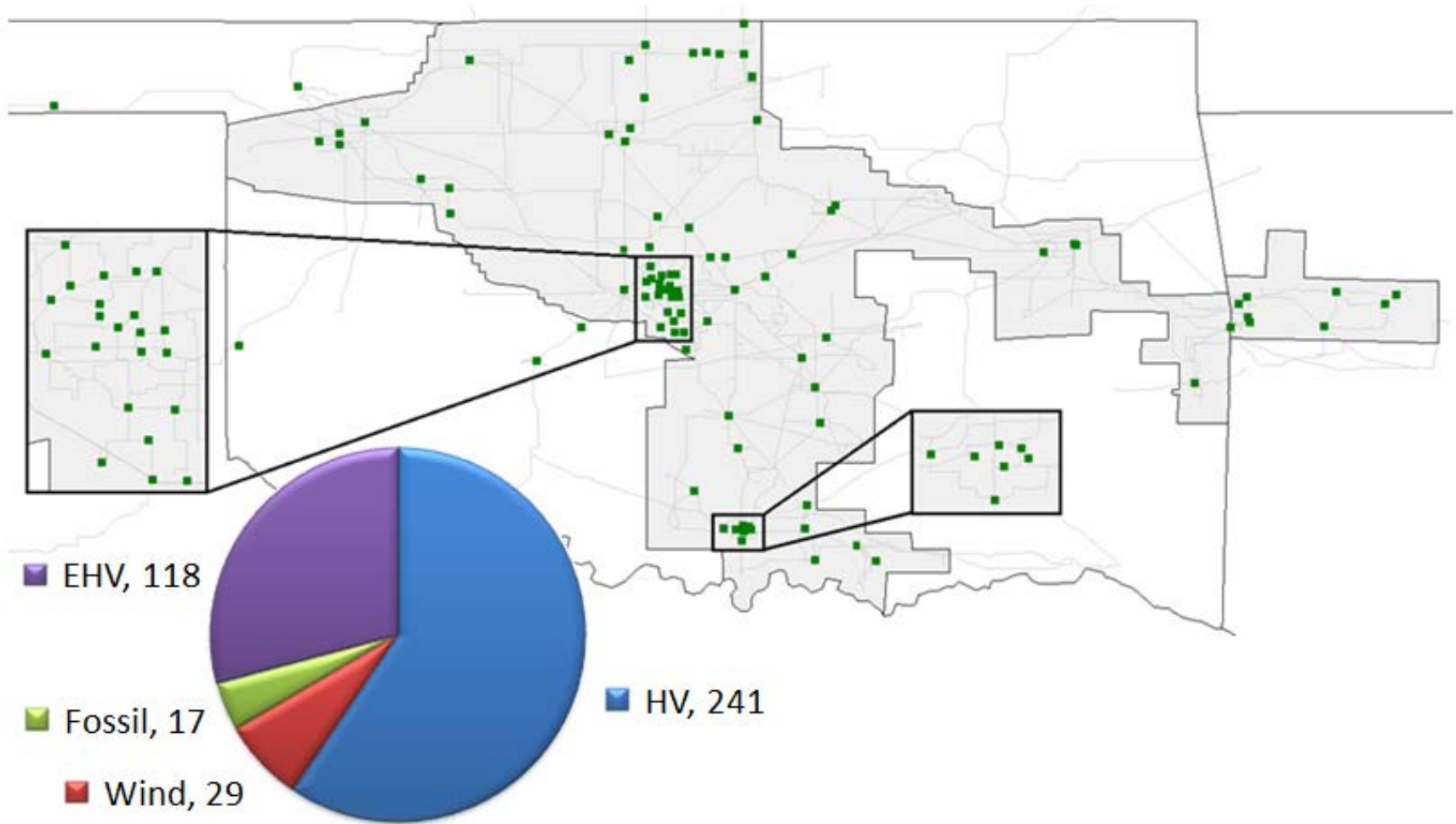
Synchrophasor Activity Update at **OG+E**

Austin White P.E., Steven Chisholm P.E.
Oklahoma Gas & Electric Company
NASPI 9/26/2017

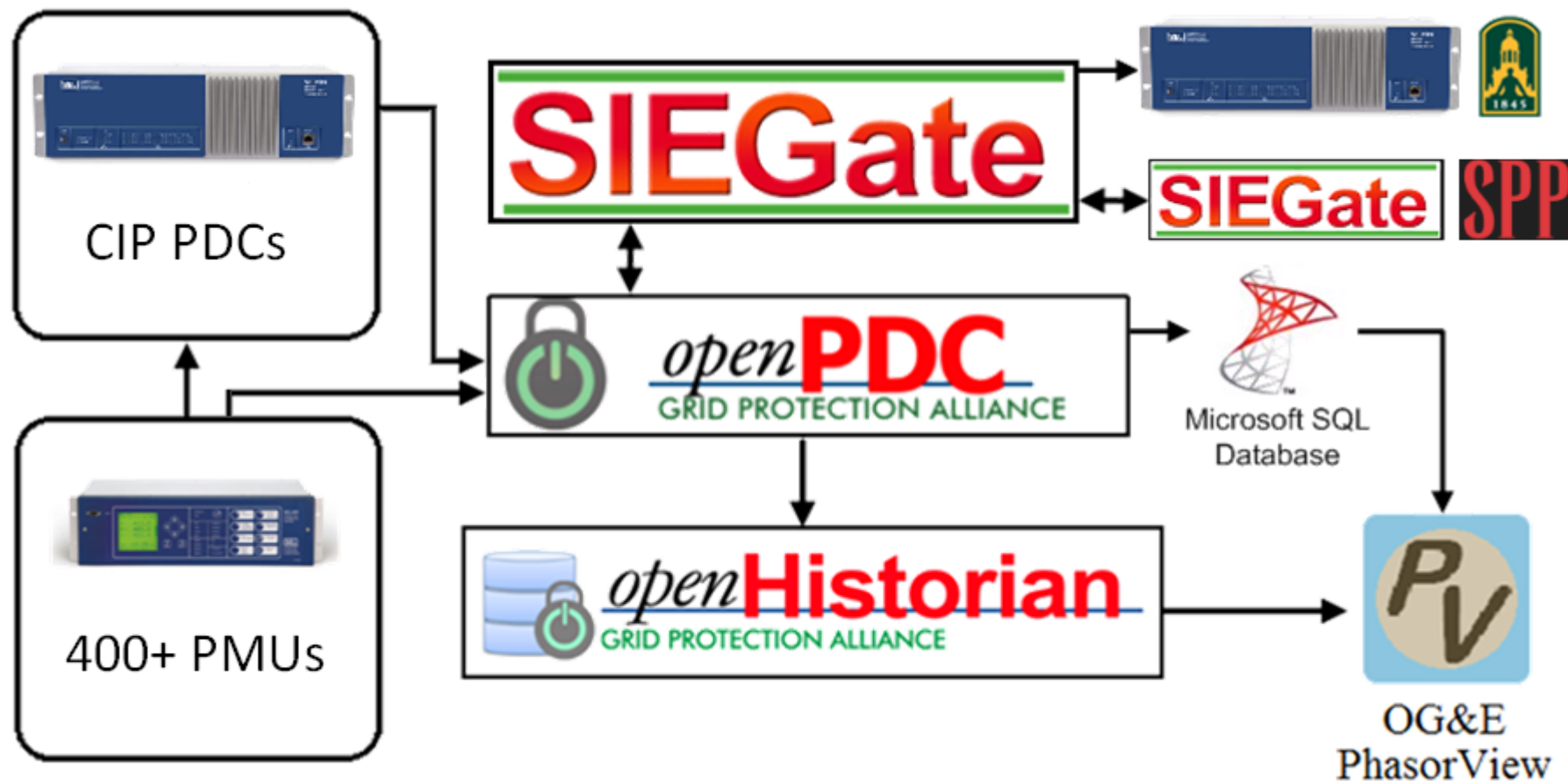
PMU Deployment 2008-2017



PMU Locations



Simplified Architecture



Archive Size

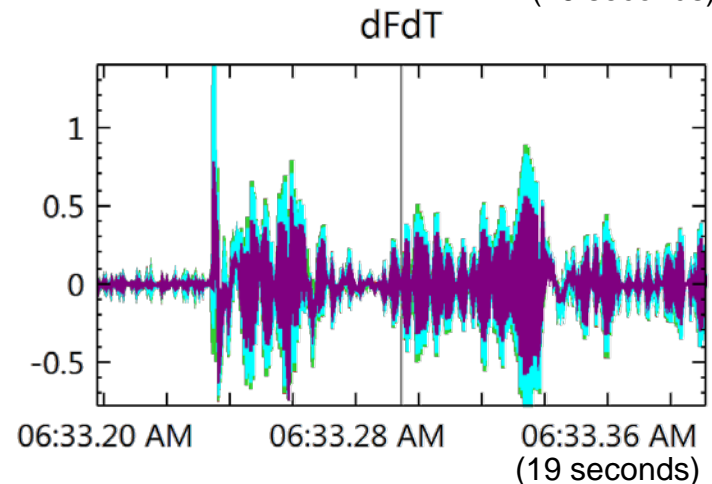
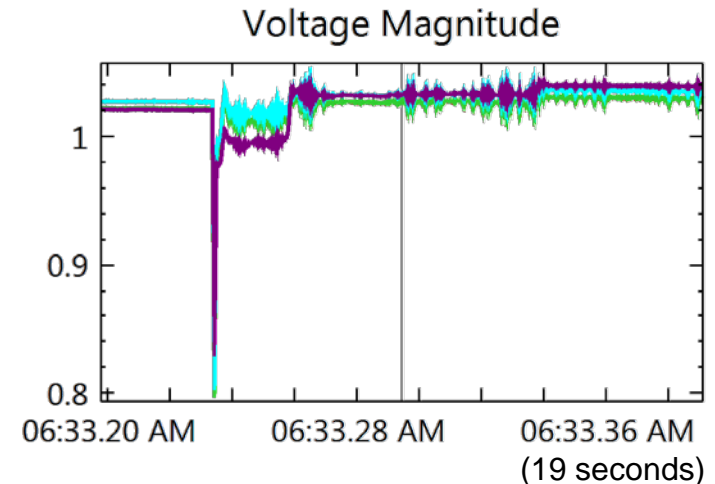
Data Type	Measurement Count	Starting Date
3 Phase	3.9 Trillion	Aug 2016
+ Sequence	12.9 Trillion	Jan 2009

Why 400 PMUs?

- Oscillation Monitoring
- Equipment Health Monitoring
- Disturbance analysis
- Industrial Load PQ Issues

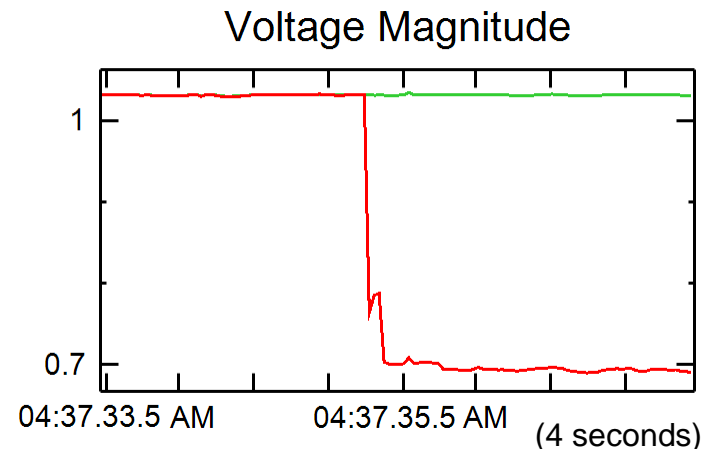
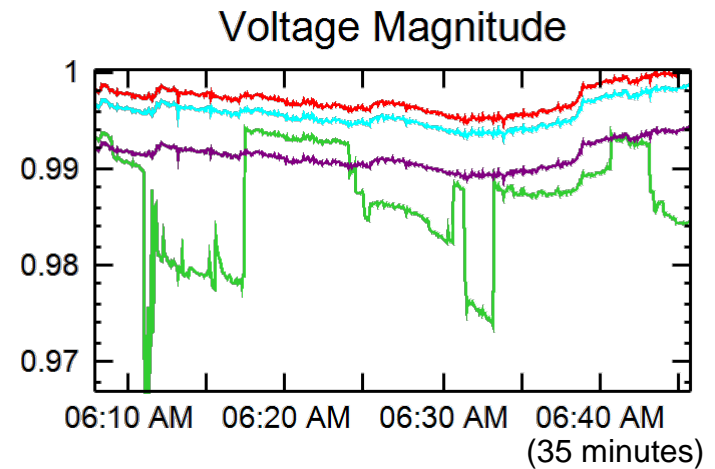
Oscillation Monitoring

- Since 2009 Forced Oscillations discovered at four power plants
- 1 CC Gas, 3 wind
- About 100 individual events
- Lots of curtailments required

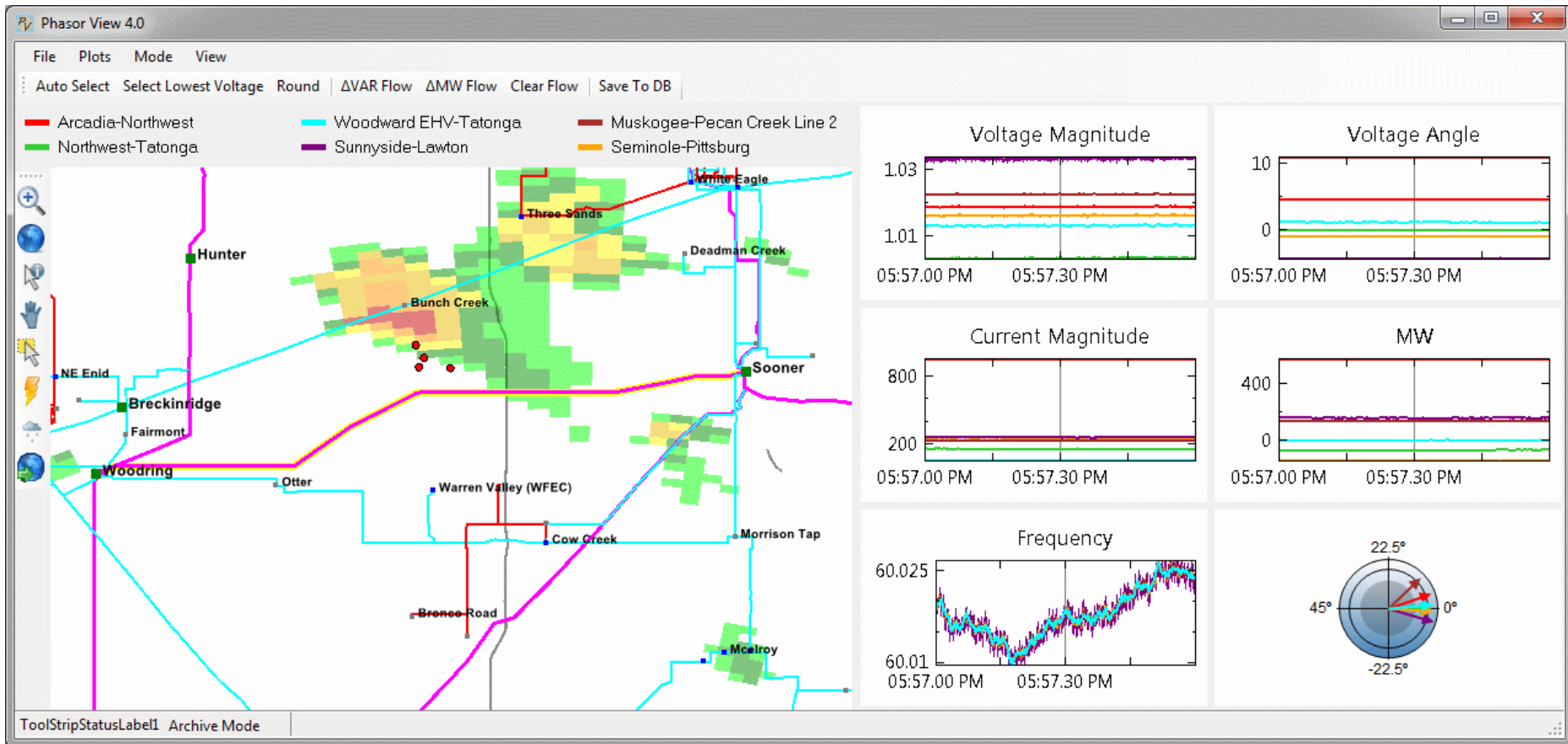


Discovery of Failing Equipment

- Discovered many loose connections in the potential circuits at fuses or terminal blocks
- This has caused misoperations in the past (relays get confused)
- Proactively finding these helps prevent future outages and misoperations

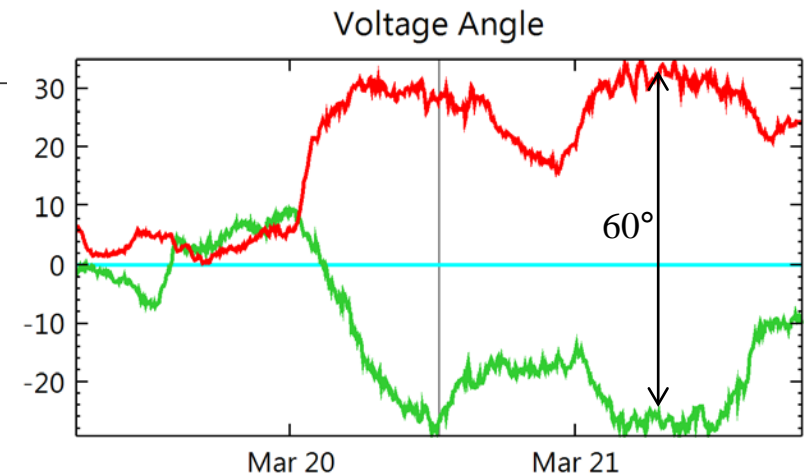
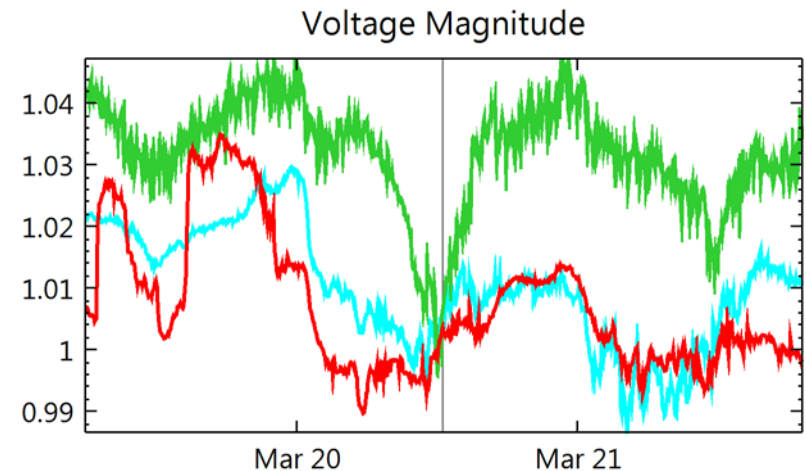
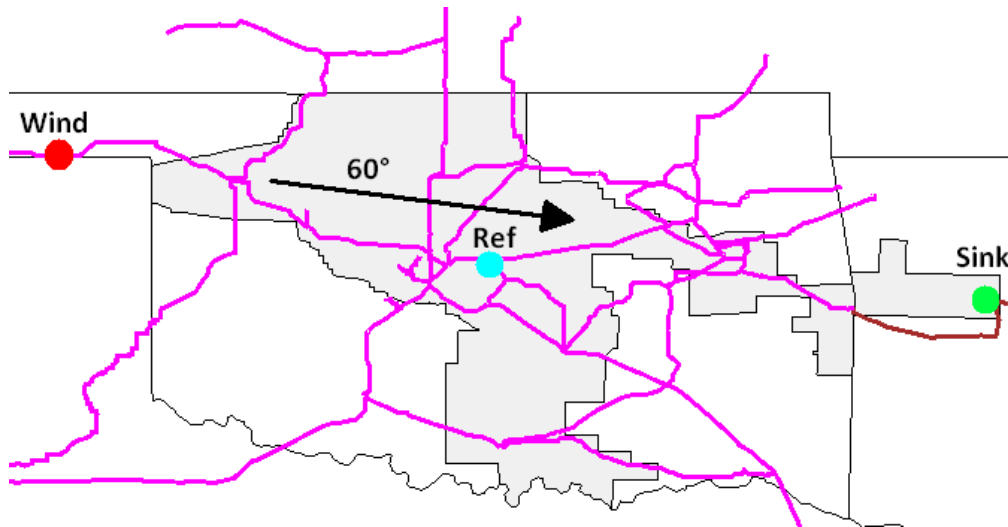


Situational Awareness



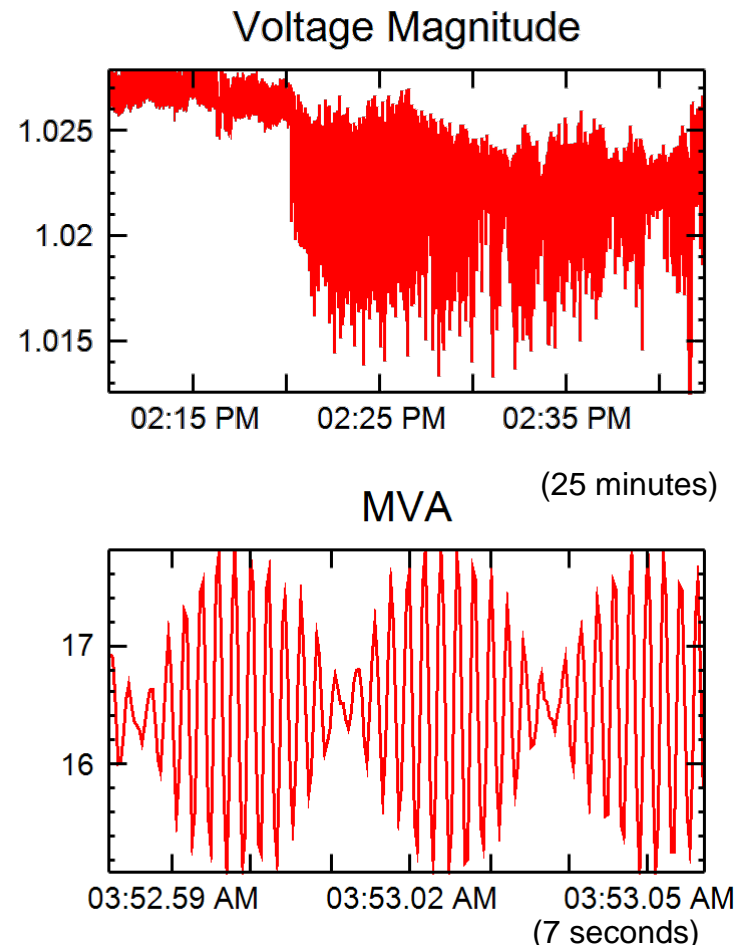
OG&E Wind Penetration > 5400MW

- SPP record peak of 45% and 10,783MW on 3/21/2016
- 60° angle spread across OG&E from west to east



Monitoring Power Quality

- It has been observed that large loads inject noise onto the system
- Large refineries and arc furnaces are the worst offenders
- Synchrophasors allow for real time power quality monitoring

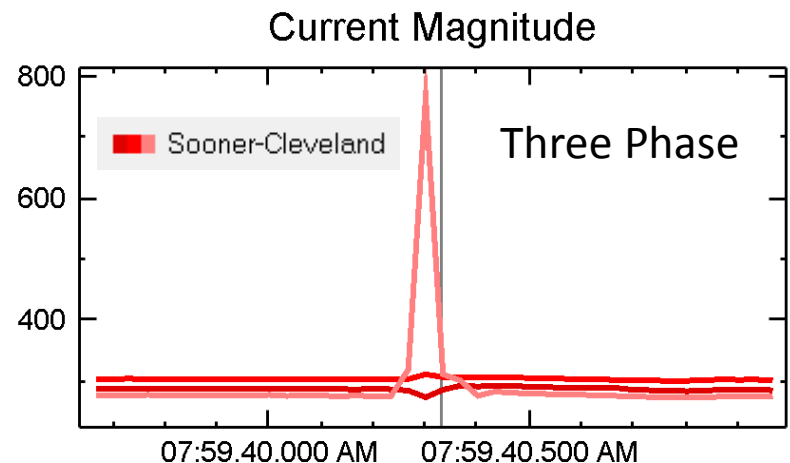
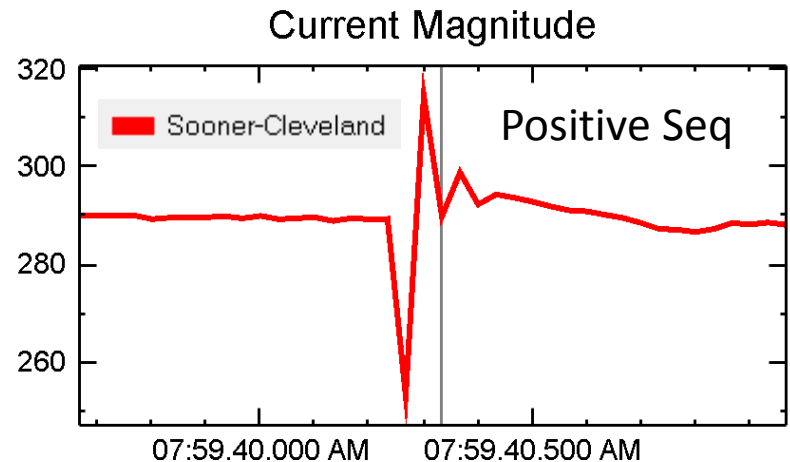


What Have We Been Doing?

- Moved from Positive Sequence to 3 Phase
 - Overcome Vendor Software Performance Issues
 - Mitigated Storage Growth Issues
 - Reworked Our Visualization Tools
- Identified Disturbances
 - Statistics
 - Events

Why Move To 3 Phase?

- Enabled to help with PRC-002-2 Compliance
- Easily Identify Faulted phase(s)
- Calculate negative and zero sequence
- Tell if ground is involved
- Calculate impedance



Hurdles to Cross

1. Our existing deployment was already pushing the boundaries of our 5 year old hardware. (Limited IT Budget (i.e. \$0))
2. Existing storage growth could not be sustained.
3. None of our in house tools were built with 3 phase in mind.

Hurdle #1: CPU Burden

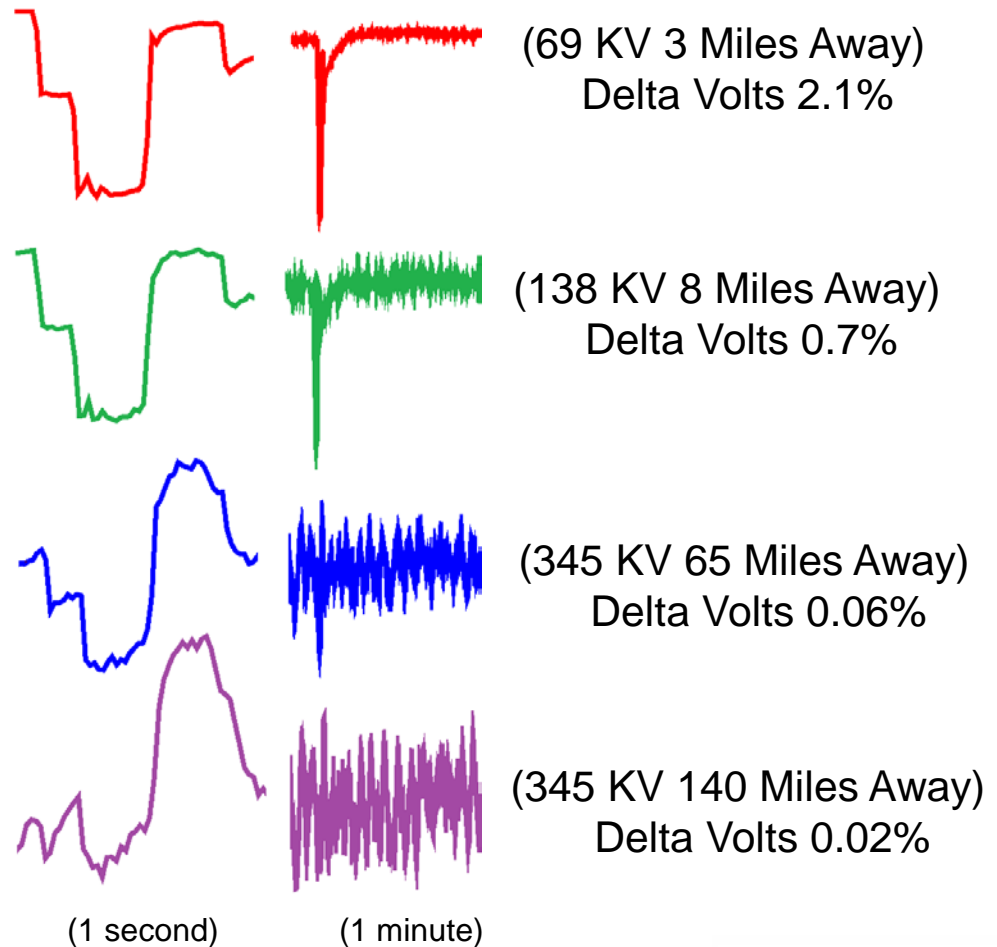
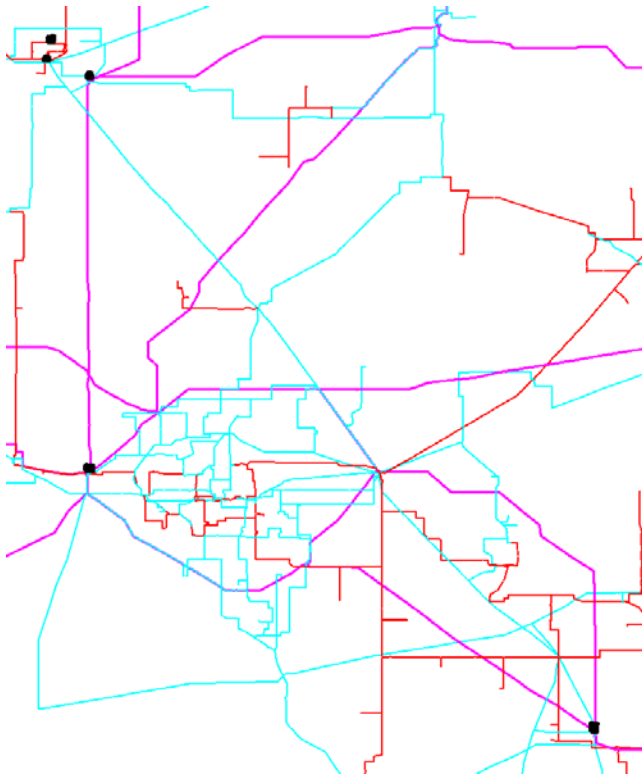
- Performance tuned openPDC and lowered CPU requirements from 45% down to 3% of our Server.
- Switched to Lossy-ish compression to reduce growth
- Made our in house tools measurement based instead of frame based.

Hurdle #2: Storage

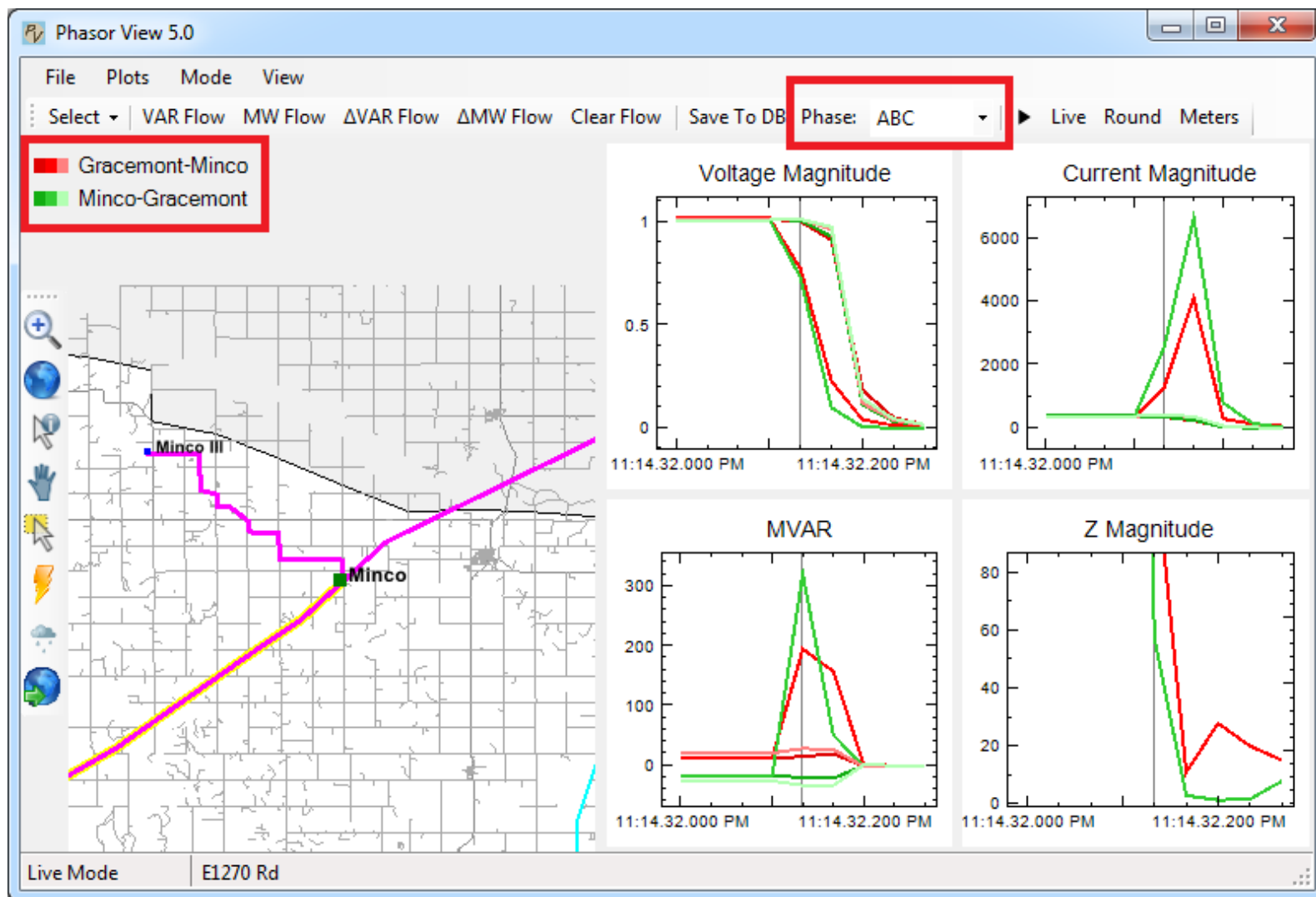
	Bytes per Measurement		Savings over RAW
Method	+	ABC	
(SQL) 1 Measurement Per Row	25	25	0%
(SQL) 1 Terminal Per Row	7.2	6.0	74%
(OGE) OpenHistorian 2.0 Lossless	2.2	3.2	89%
(OGE) OpenHistorian 2.0 Lossy-ish	1.5	2.1	93%
(WIP) OpenHistorian 3.0 Lossy-ish	0.9	1.3	96%

Fault Visibility

- 0.7 Second, 12.5kV Distribution Fault

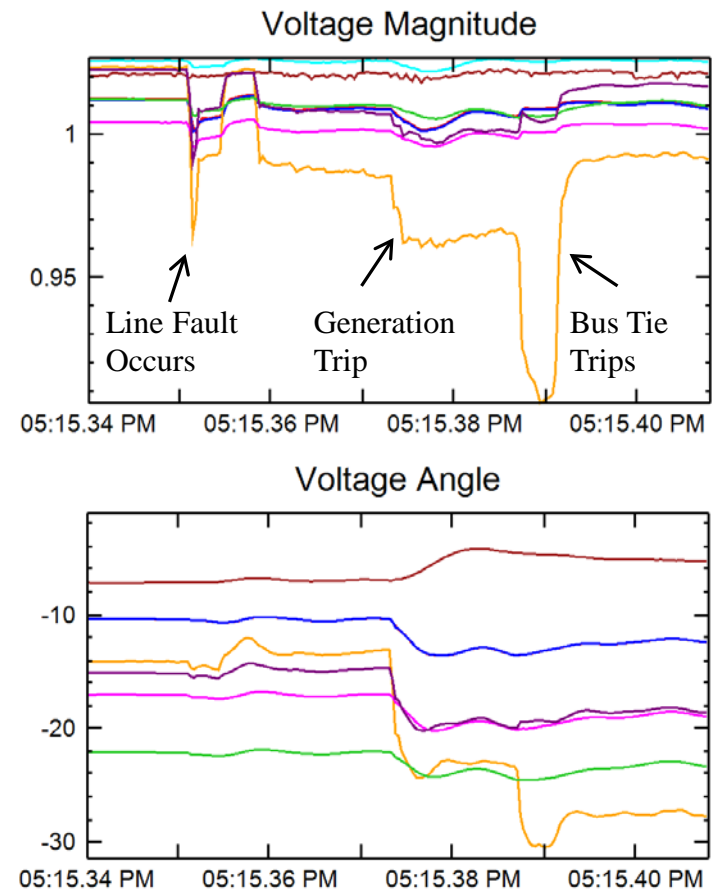


Hurdle #3: Software Backend



Identifying Disturbances

- Reasons for the change:
 - SCADA doesn't catch everything
 - Moving towards automating the operator's disturbance log.



Statistics

- We capture on a 1 minute resolution 139 statistics on PMU data. Min, Max, Avg, Largest Change, Average Change, Bits Changed for
 - ABC Phases, +-0 Sequence,
Volts/Amps/Watts/Vars/Impedance/Freq/dFdT

GPS/Availability Stats

- Daily stats:
 - System down time
 - Max PMUs
 - 100% availability
 - 100% GPS
 - Triggers
- Select 1 day:
 - PMU down time
 - PMU GPS down time
 - PMU Trigger time

Date	Down Time	Minutes	Max PMUs	100% Avail	100% GPS	Triggers
1/8/2017	0	1440	383	322	372	14
1/9/2017	0	1440	387	310	366	47
1/10/2017	0	1440	387	295	373	34



Terminal	Down Time	GPS Down Time	Trigger Time
Fixico-Forest Hills/Maud Tap	15.27s	3.83m	1.37s
Fixico-Weleetka	15.27s	3.85m	2.57s
Forest Hills-Fixico/Maud Tap	15.27s	3.83m	1.37s
Fort Smith Transformer 1 (500-345kV)	1.00d	0	0

GPS/Availability Detail

- Stats per PMU for selected date range
- Can view data for selected PMU by
 - Day
 - Hour
 - Minute

Wednesday, January 04, 2017 Refresh

Wednesday, January 11, 2017

Terminal	Down Time	GPS Down Time	Trigger Time
Oak Grove-Drumright	2.21m	867.00ms	33.00ms
Oak Grove-Greenwood	2.06m	633.00ms	33.00ms
Oak Park-Massard	0	0	100.00ms
Oak Park-Third St	0	0	100.00ms
Oak Park-VBI	0	0	100.00ms
Open Sky-Kay Wind*	3.03m	0	0



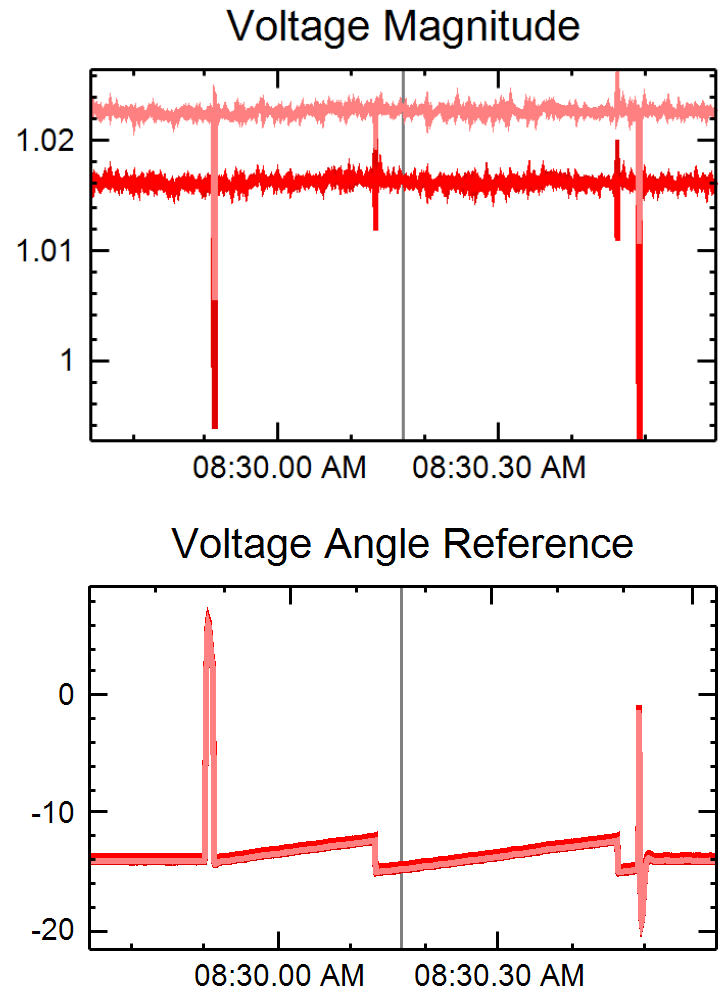
Date	Down Time	GPS Down Time	Trigger Time
1/4/2017	233.00ms	867.00ms	0
1/5/2017	2.20m	0	0
1/6/2017	0	0	0
1/7/2017	0	0	33.00ms
1/8/2017	0	0	0
1/9/2017	0	0	0
1/10/2017	0	0	0

Event Algorithm

- 10 times greater than the 95% change. Rise or fall in Voltages/Currents. ABC, +-0.

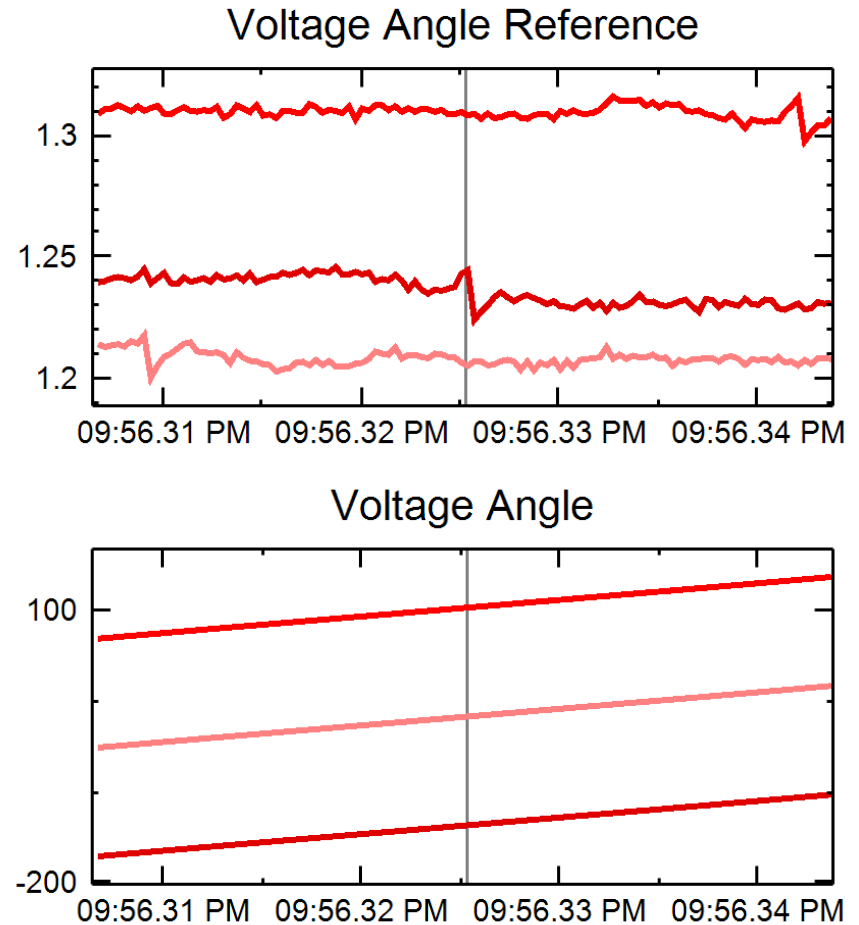
PMU Bug 1

- Discovered an issue with a certain model of PMU using new stats
- GPS outage causes spikes in voltage and current magnitude
- Misleading/erroneous data - looks like a fault
- Vendor is looking into the problem



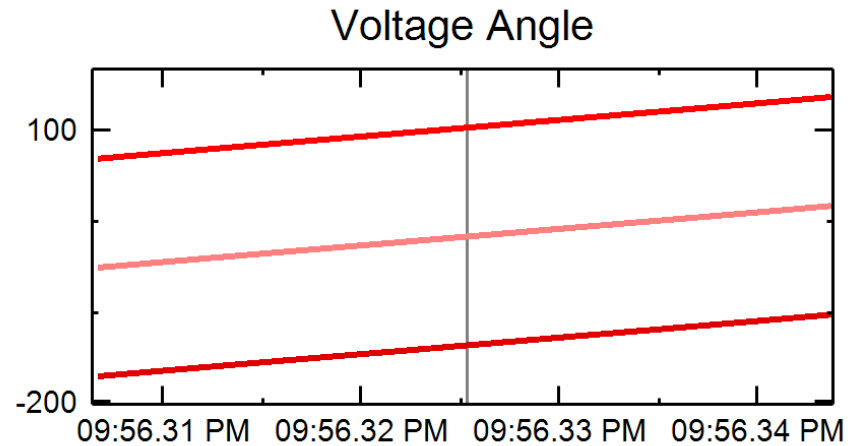
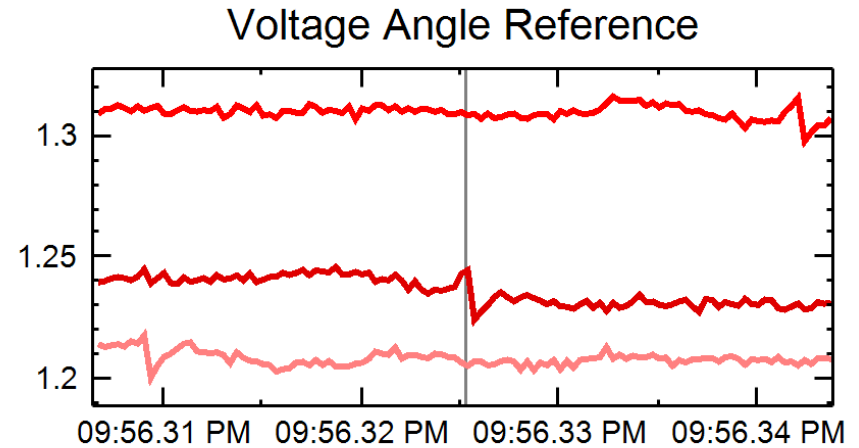
PMU Bug 2

- Another issue with a different model of PMU
- Spikes occur in the voltage angle when the angle passes through ± 45 and ± 135 degrees
- Vendor is looking into the problem



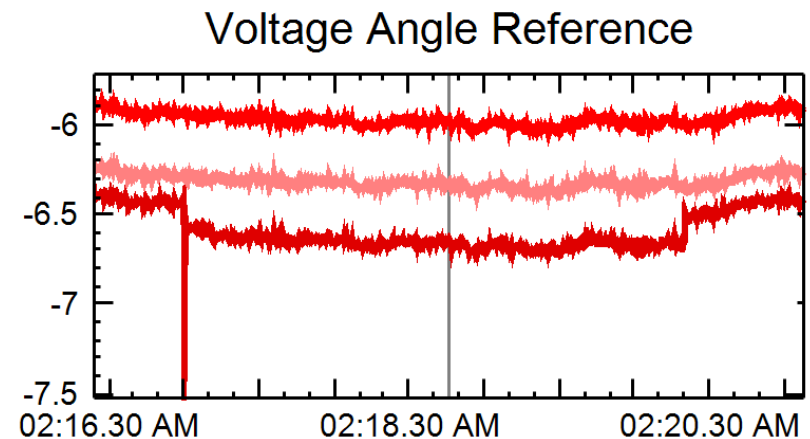
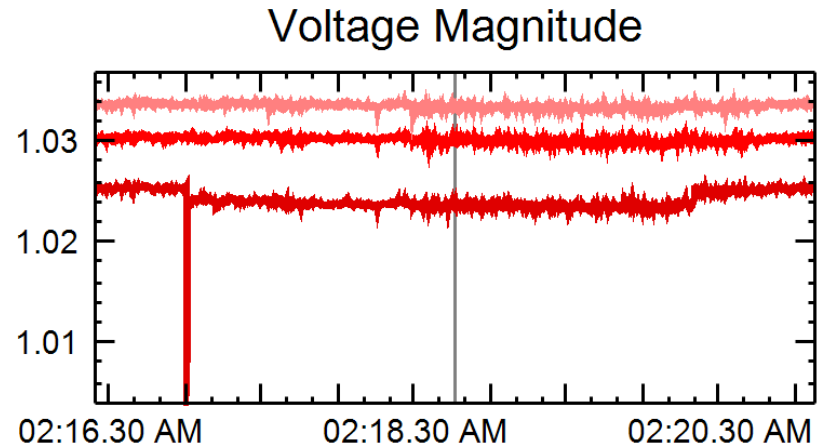
PMU Bug 3

- Improper STAT frame with GPS sync



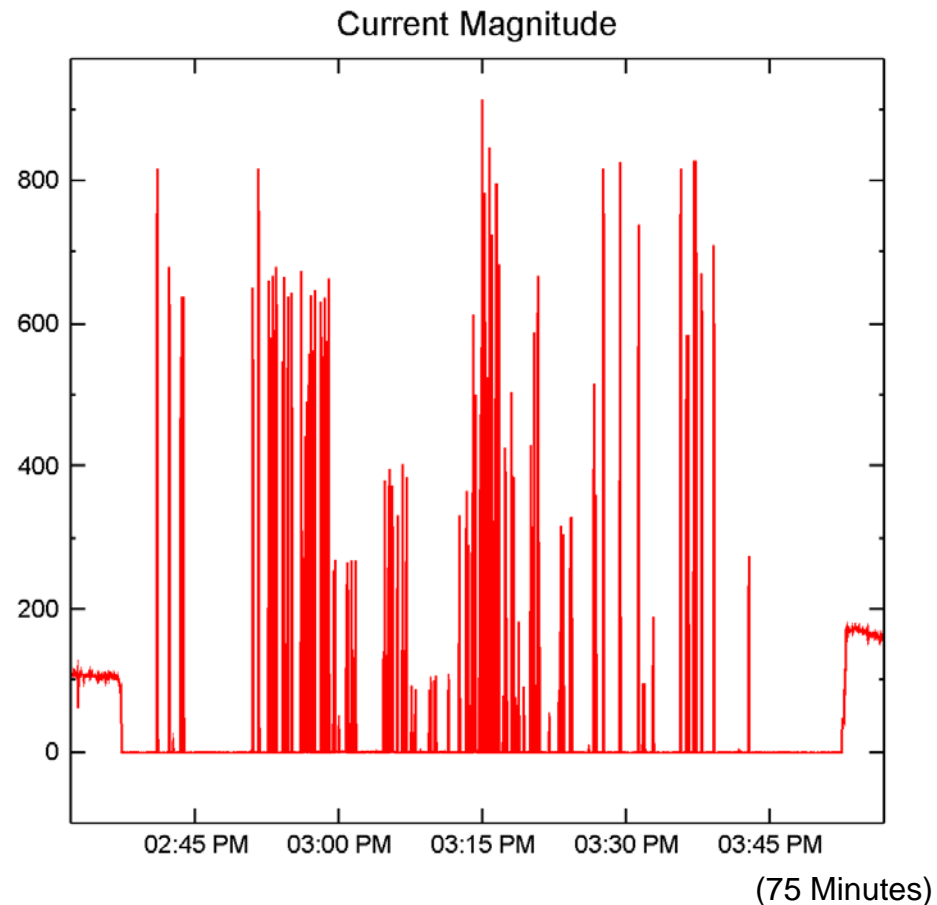
SSVT

- Some stations have SSVTs, so we see substation AC and Heater load show up in the Negative and Zero Sequence plots.



Relay Testing

- Seen lots of relay testing that we have to throw out.



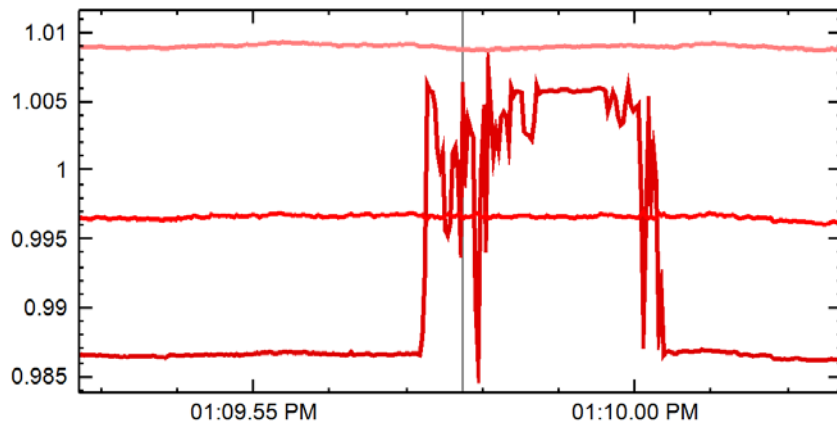
Loose Connection

Event Log Per Device						
	Terminal	Event Count				
▶	Cimarron Transformer 2 (345-138kV)	19942				
	Mustang Solar South	8205				
	Event Time	MeasurementN:	Change	Duration	Confidence	Threshold
▶	08/30/2017 0...	V_MPU_A	0.009532947...	0.033299999...	2.705967426...	0.003522934...
	08/30/2017 0...	V_MPU_A	0.009532947...	0.033299999...	2.705967426...	0.003522934...

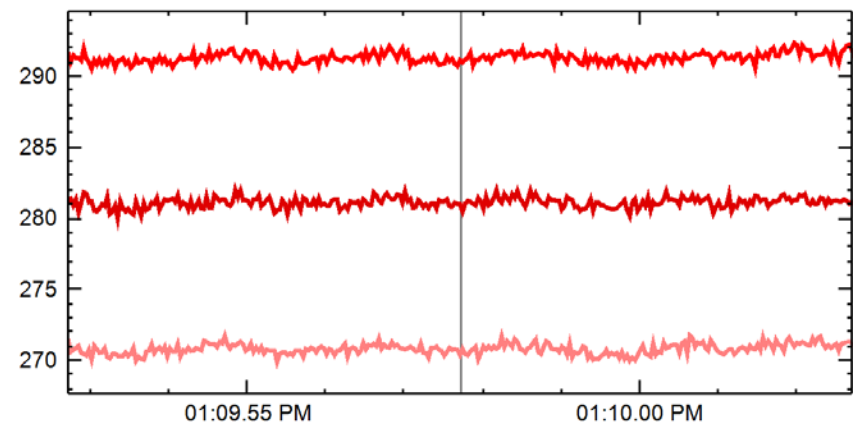
Time Range: 8/30/2017 2:58:31 PM to 9/23/2017 11:10:47 AM

Find

Voltage Magnitude

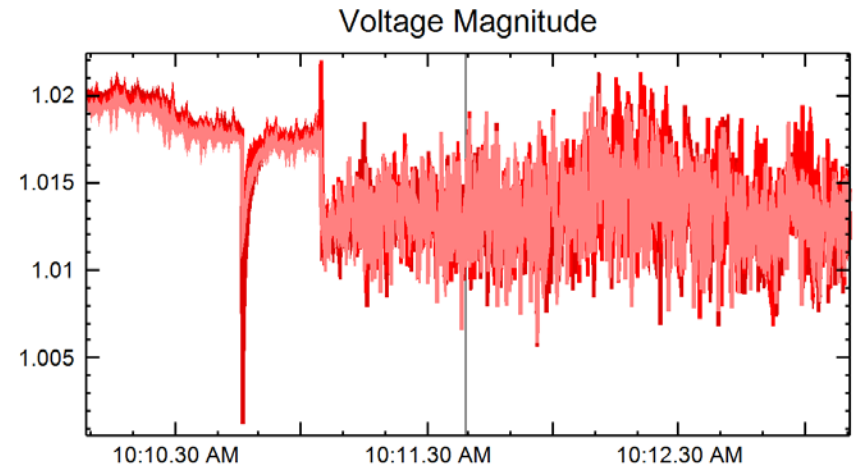
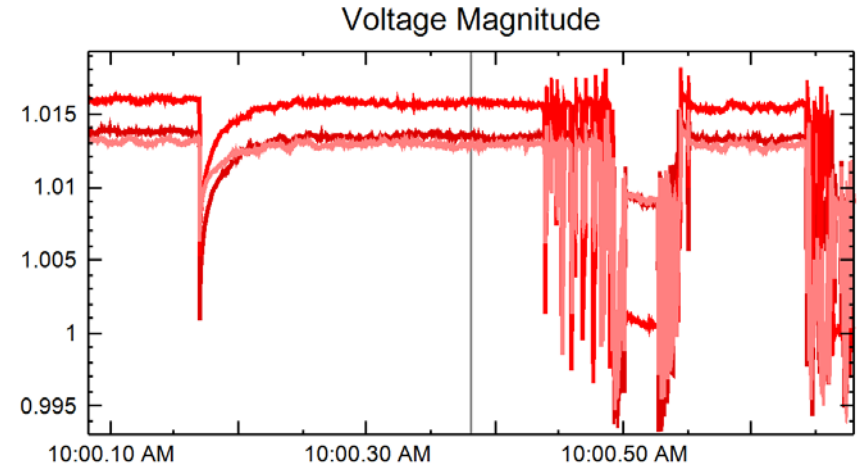


Current Magnitude



Arc Furnace

- We also pick up arc furnaces.

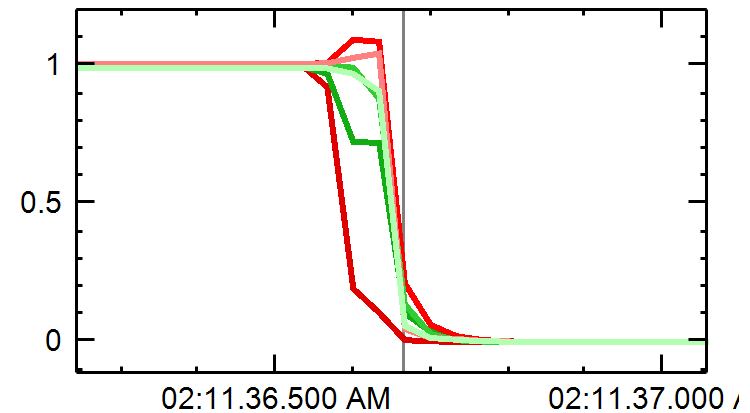


Fault Detection Algorithm

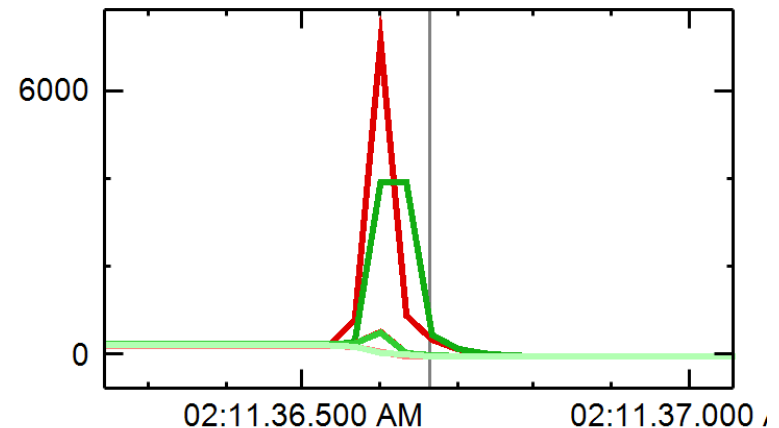
- Multiple substations have to detect the condition.
- It must have changes of XYZ.

Event Log			
	Event Time	Event Duration	Terminal Count
▶	10/05/2016 02:11:36.433 AM	0.938	242
	Term	MeasurementName	Change
▶	Woodring-Mathewson	I_M_A	6899.2...
	Mathewson-Woodring	I_M_A	4136.3...

Voltage Magnitude



Current Magnitude



Questions?

- Thanks! Feel free to contact us if you have any questions.
 - Austin White
 - whitead@oge.com (405-553-5996)
 - Steven Chisholm
 - chishose@oge.com (405-553-5917)