Automated Fault Detection With PQ Monitors

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Presentation Outline

- Background
- Case Studies (5)
- Needs
- Tools
- Conclusion

Background

- ~1200 Metering Devices
  - DFR
  - PQ Meter
  - Revenue Meter w/PQ Capability

- Multiple Download Frequencies
  - Daily
  - Hourly
  - Sub-Hourly

Data Quantity By The Numbers...

DFR

- 251 Devices
- ~80 Channels / Dev
- ~3 MB / Event
- 1 Event / Day
- > 750 MB / Day
- > 20k Channels

PQ Meter

- 1069 Devices
- 300 Channels / Dev
- ~3 MB / Day
- 144 Points / Day
- > 3200 MB / Day
- > 320k Channels
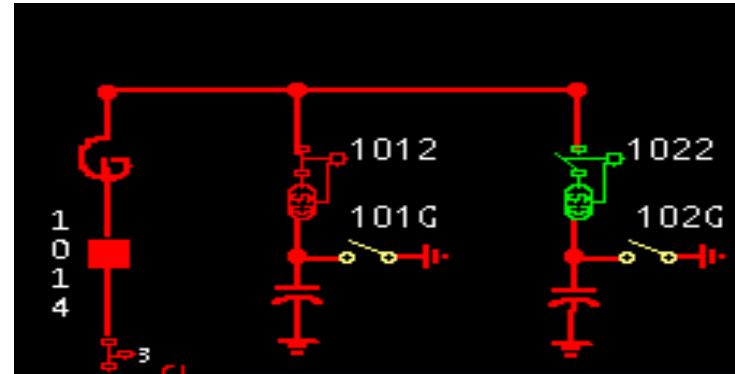
Cap Bank Switch Failure
aka "The Good"

Pre-insertion inductors mounted on 138-kV Vertical-Break Style Mark V Circuit-Switcher.

An S&C Mark V switch is opened to take the Cap Bank Off Line.

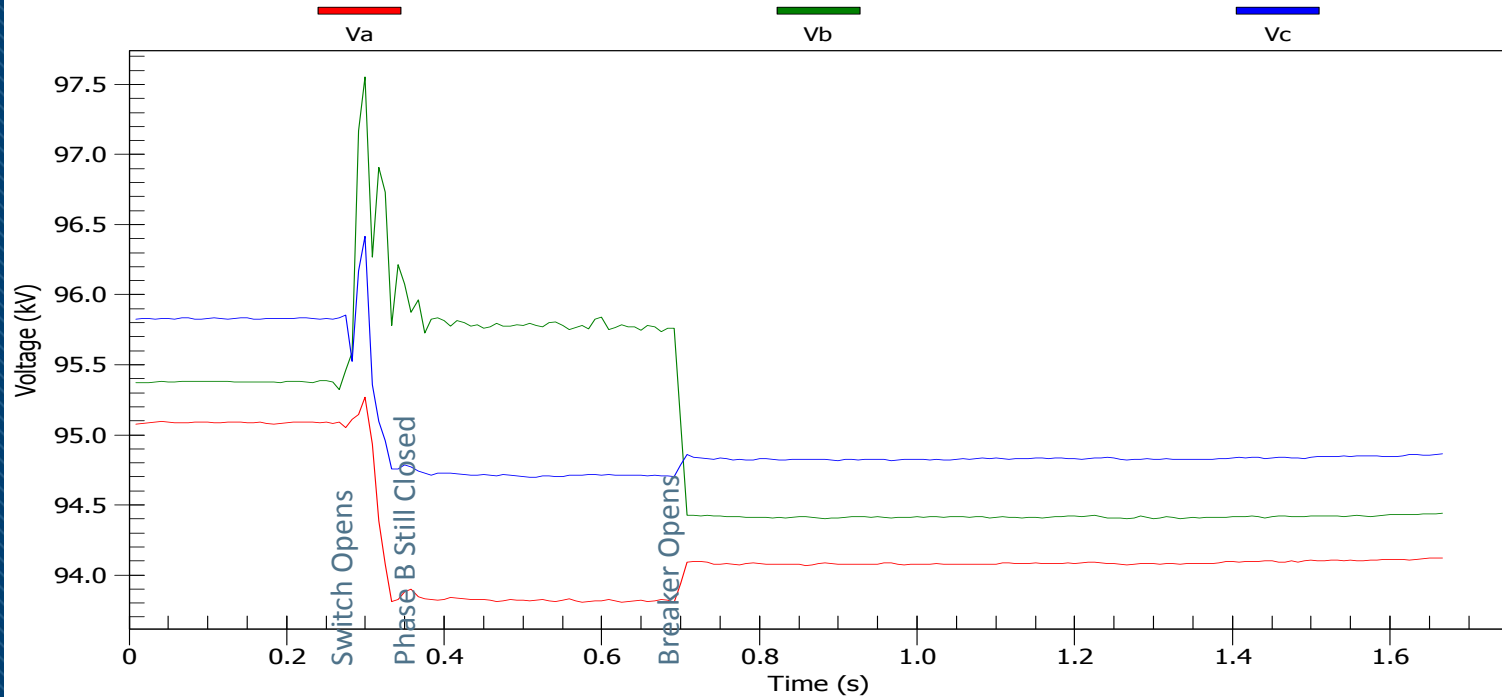About 6 cycles later the breaker protecting the bank trips.

PQ asked to investigate why…

The Good (Continued)...

Cap Bank - 09/05/2012 20:24:27.1454

The Good (Continued)…

- No flashover occurred (luck).

- PQ Group suggested low SF-6 as likely reason for the failed open attempt.

- Field personnel found that the B-Phase bottle was empty.

Mark V Capacitor Bank Switcher and SF-6 Gas Indicator

Isolating Arm

SF-6 Bottle

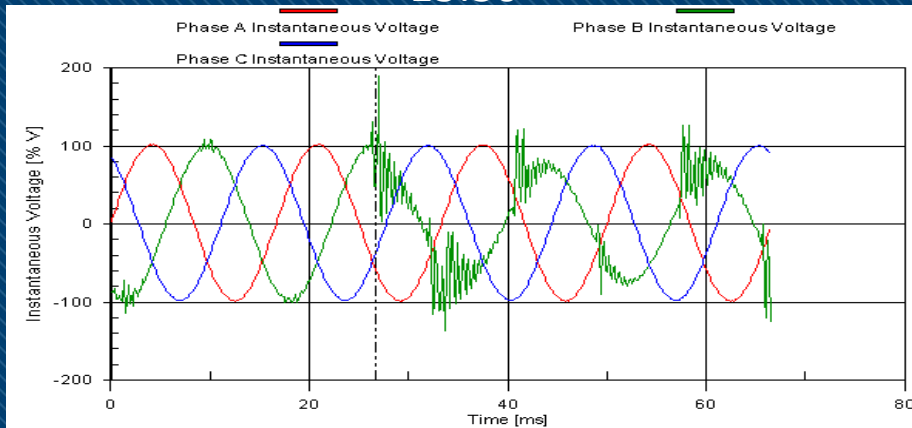Visual Indicator Of Low SF-6 Gas Pressure

TVA

PT Failure - aka "The Bad"

The Bad (Continued)…

A PQ monitor receives voltage inputs from the 161kV Main Bus VTs. The PQM recorded a series of voltage transients indicating arcing on B-phase in the minutes prior to the VT failure on 01/03/2013. These incipient waveforms were recorded from 13:29CT up until failure at 13:53CT.

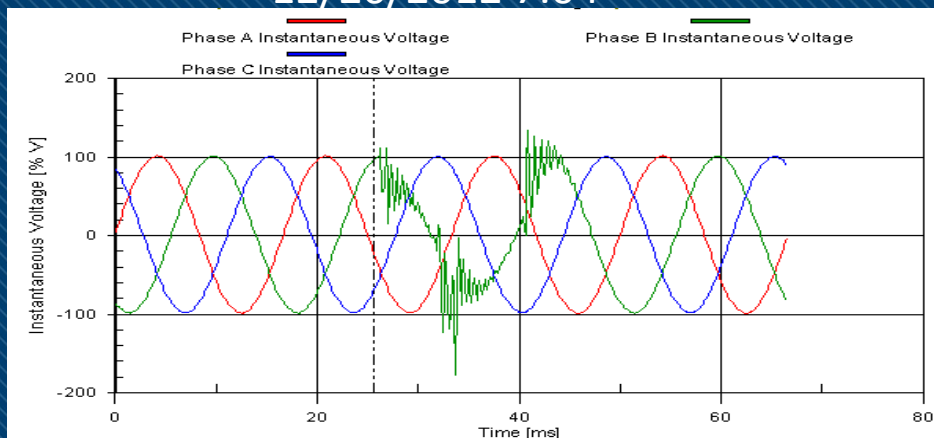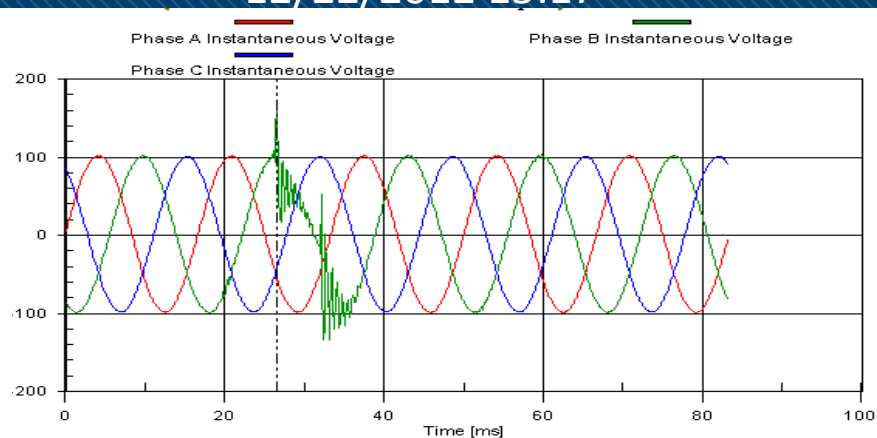13:30   13:45
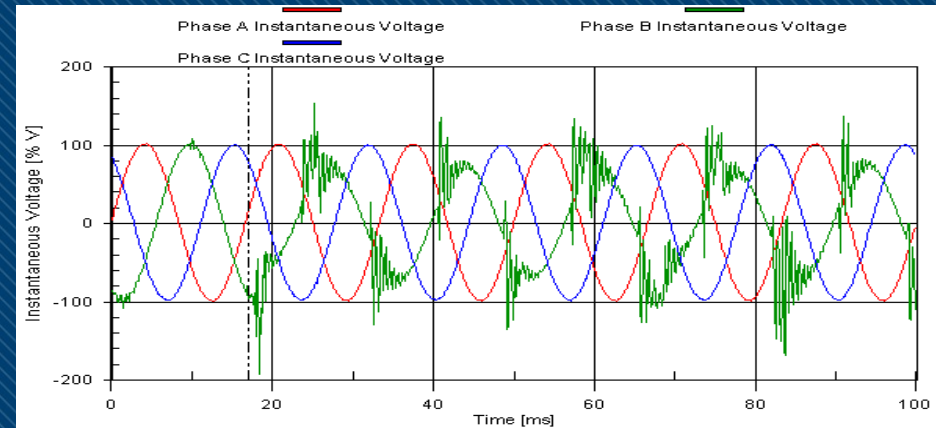
The Bad (Continued)…

Waveforms with similar transient disturbances on the B-phase voltage indicating arcing were also recorded on 12/20/2012 from 07:04CT to 07:05CT and on 12/22/2012 from 15:17CT to 15:18CT. Thus, indications of a problem existed up to two full weeks before the VT failure.
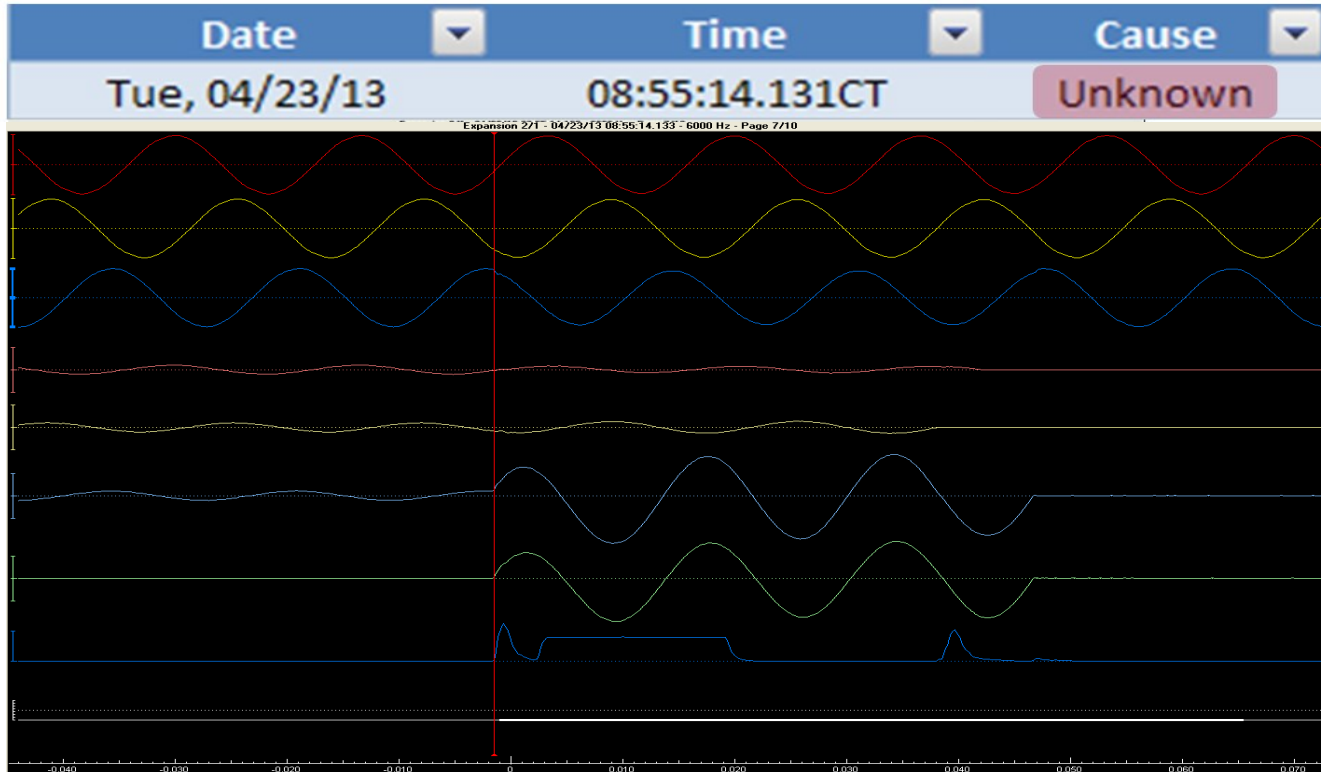
12/20/2012 7:04   12/22/2012 15:17

Transmission Lines Unknown Events aka "The Ugly"

CG Fault

Insulation Breakdown

The Ugly (Continued)…

Date ▼	Time ▼	Cause ▼
Tue, 04/23/13	08:55:14.131CT	Unknown
Thu, 07/21/11	05:40:47.367CT	Unknown
Tue, 02/22/11	01:48:00.450CT	Unknown
Sat, 08/14/10	00:14:41.028CT	Unknown
Wed, 02/24/10	05:31:57.753CT	Unknown
Wed, 01/20/10	09:00:44.350CT	Unknown

The Ugly (Continued)...

Date	Time	Cause	Phase
Tue, 04/23/13	08:55:14.131CT	Unknown	C
Thu, 07/21/11	05:40:47.367CT	Unknown	C
Tue, 02/22/11	01:48:00.450CT	Unknown	C
Sat, 08/14/10	00:14:41.028CT	Unknown	A
Wed, 02/24/10	05:31:57.753CT	Unknown	C
Wed, 01/20/10	09:00:44.350CT	Unknown	C

The Ugly (Continued)…

| Date	Time	Cause	Phase	Structure A	Structure B	Fault Av
Tue, 04/23/13	08:55:14.131CT	Unknown	C	135	132	
Thu, 07/21/11	05:40:47.367CT	Unknown	C	129	125	
Tue, 02/22/11	01:48:00.450CT	Unknown	C	129	128	
Sat, 08/14/10	00:14:41.028CT	Unknown				
Wed, 02/24/10	05:31:57.753CT	Unknown	C	139	121	
Wed, 01/20/10	09:00:44.350CT	Unknown	C	133	121	

Outlier

There appears to be a problem between Structure 127 and 134!
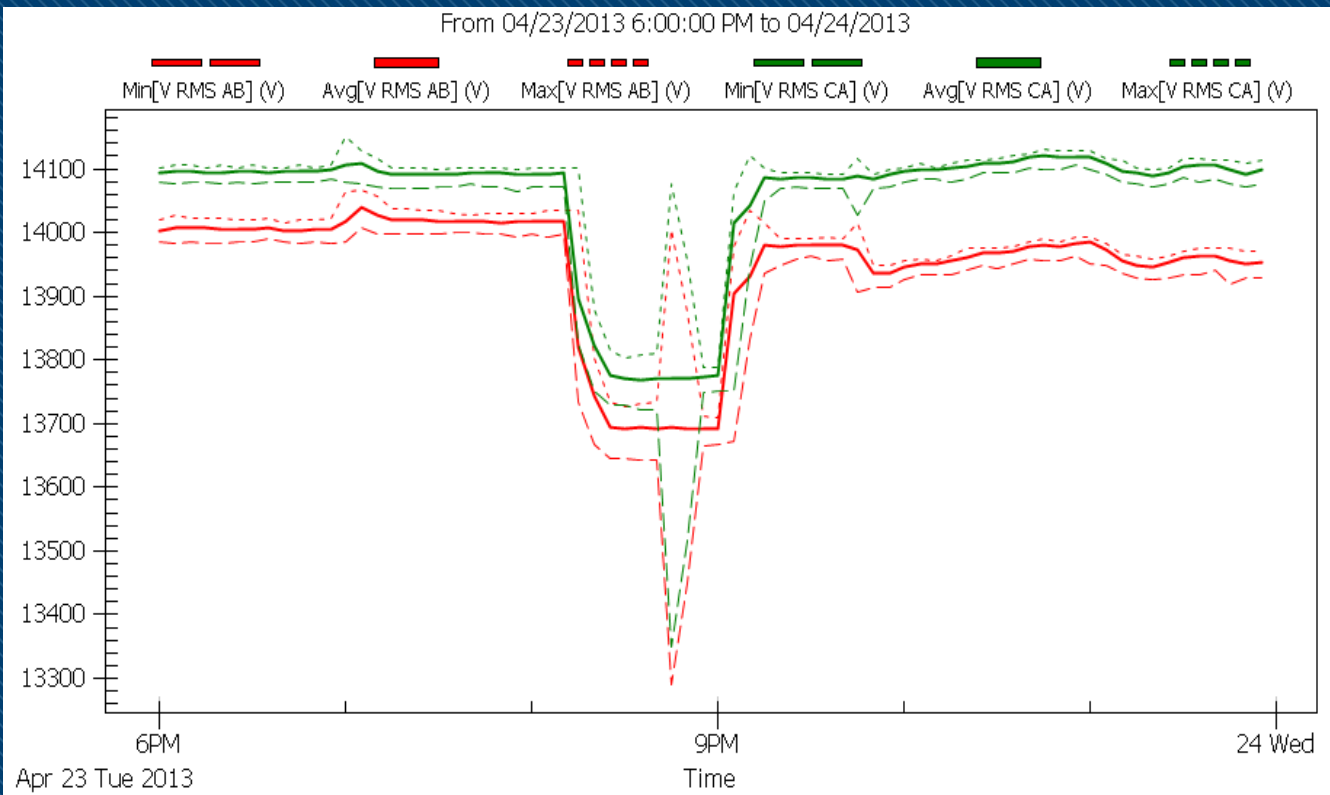
Field Inspection Reveals 2 Broken Insulators.

The Weird!
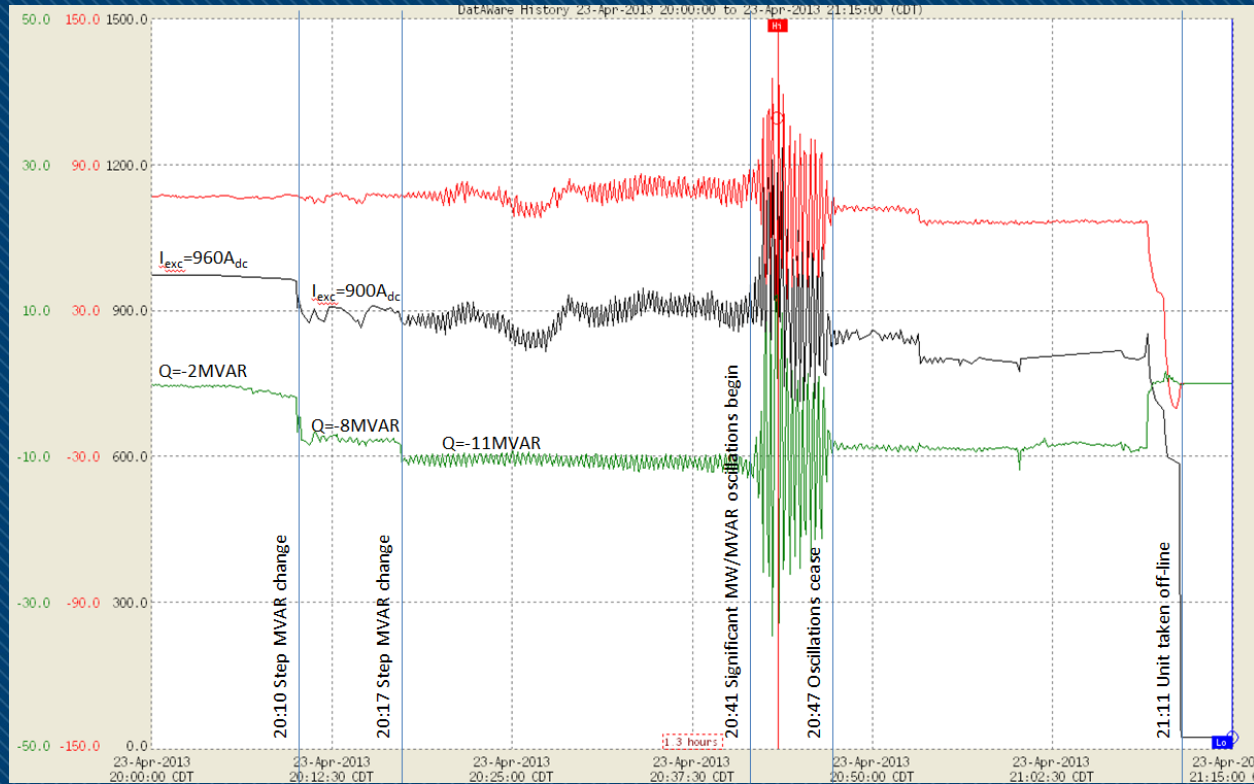
100 MW Oscillations detected across Eastern Part of Tennessee.

Observed at Hydro and Nuclear units at same time.
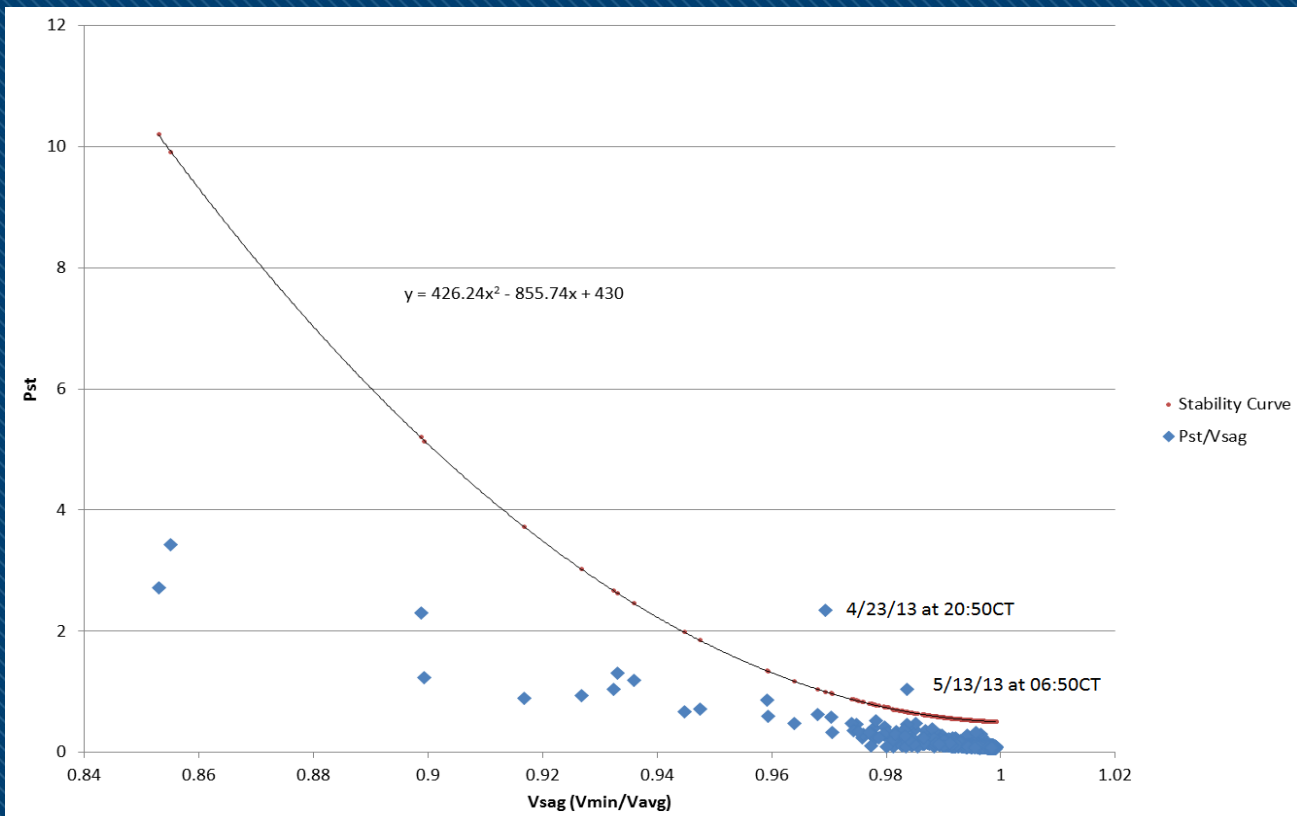
The Weird! (Continued)

From 04/23/2013 6:00:00 PM to 04/24/2013

Min[V RMS AB] (V) Avg[V RMS AB] (V) Max[V RMS AB] (V) Min[V RMS CA] (V) Avg[V RMS CA] (V) Max[V RMS CA] (V)

PQ monitors show a minimal impact to voltage (< 5% of nominal).

No devices "triggered", because there was no "fault" on the system.

The Weird! (Continued)

$$y = 426.24x^2 - 855.74x + 430$$

- Stability Curve
- Pst/Vsag

4/23/13 at 20:50CT

5/13/13 at 06:50CT
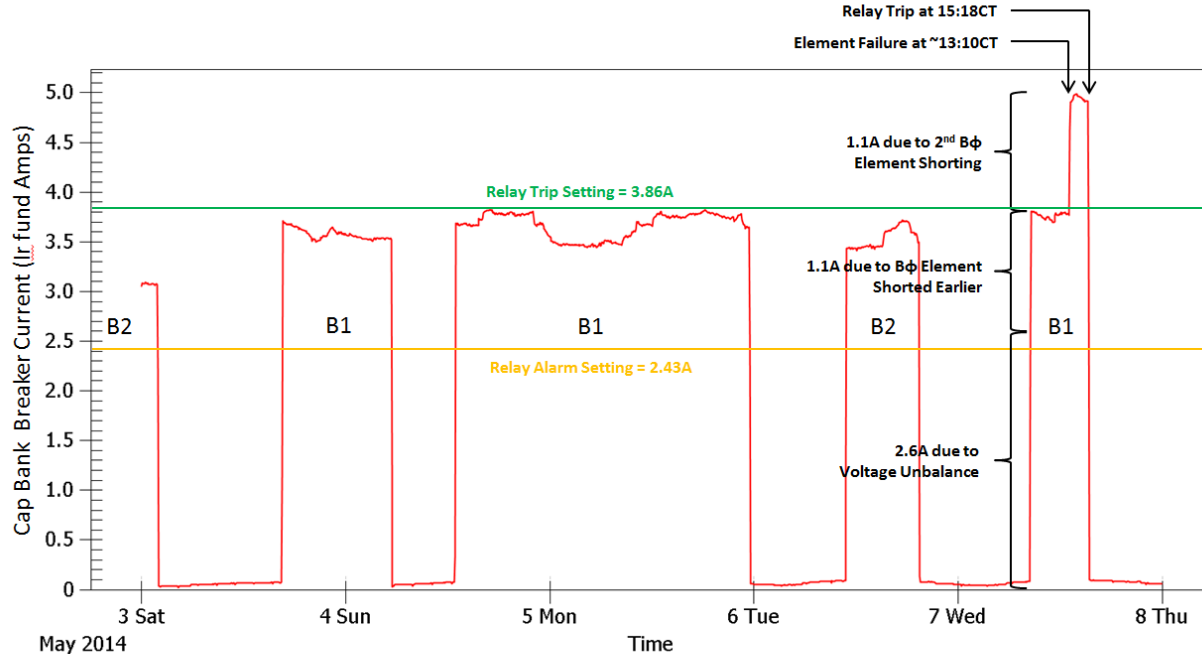
Pst

Vsag (Vmin/Vavg)

What if we developed an algorithm to detect increased PST levels when there was not any indication of a fault on the system?

Then we could alarm on that and make operators aware of this area-wide issue!

The Headscratcher…

Why was there a 2hr 8min delay between the 2nd element failure and the bank trip?

The relay is set to trip when 4 elements in same string fail. However, relay trips with only the 2nd element failure.

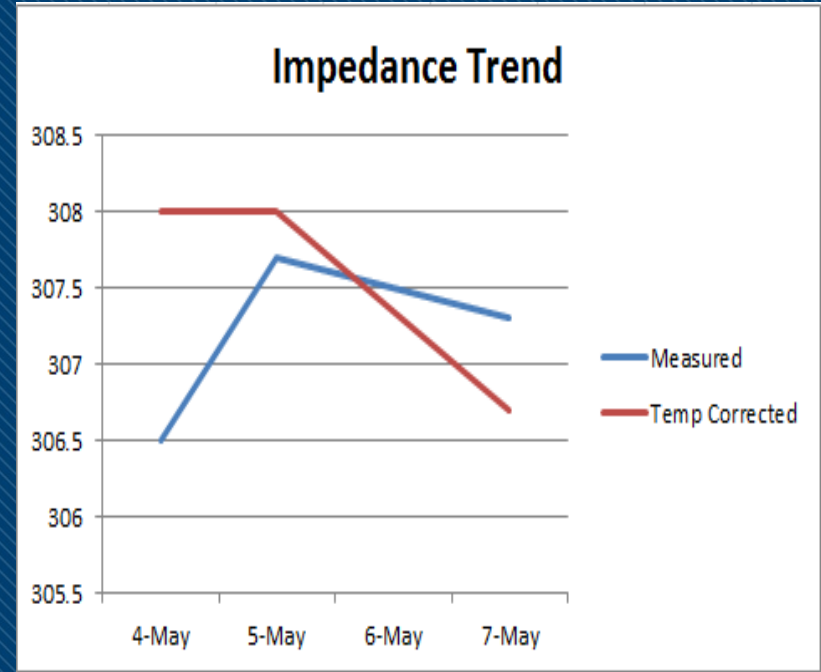Voltage unbalance makes it appear as though two other elements had also failed.

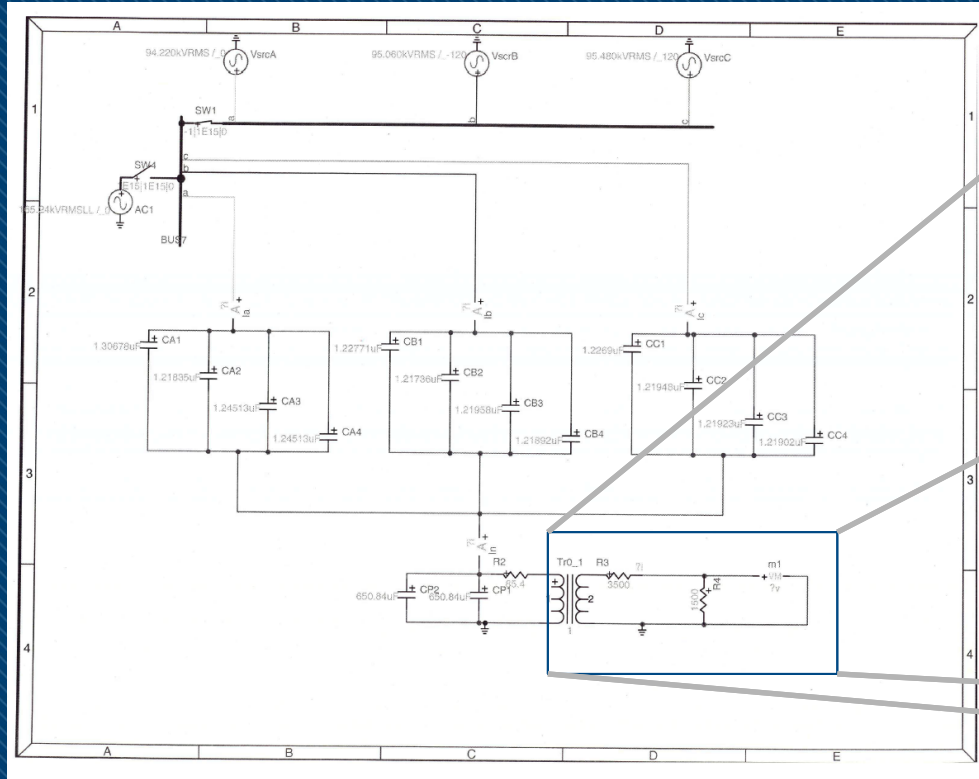# The Headscratcher (Continued)…

Issues that influence cap bank imbalance:

- – Impedance
  - • Temperature
  - • Tolerance
- – Voltage Imbalance

Could we make a system that incorporates all of these factors to assess the health of the system?

The Headscratcher (Continued)…

Needs

- Automated mechanism to analyze data.

- Distill "interesting events" to the top.

- An interesting event database that captures all relevant information about a given event.

Weather
System Conditions
SCADA Data
System Model
PMU Data
DFR / PQ
Historical Performance

TVA

Tools

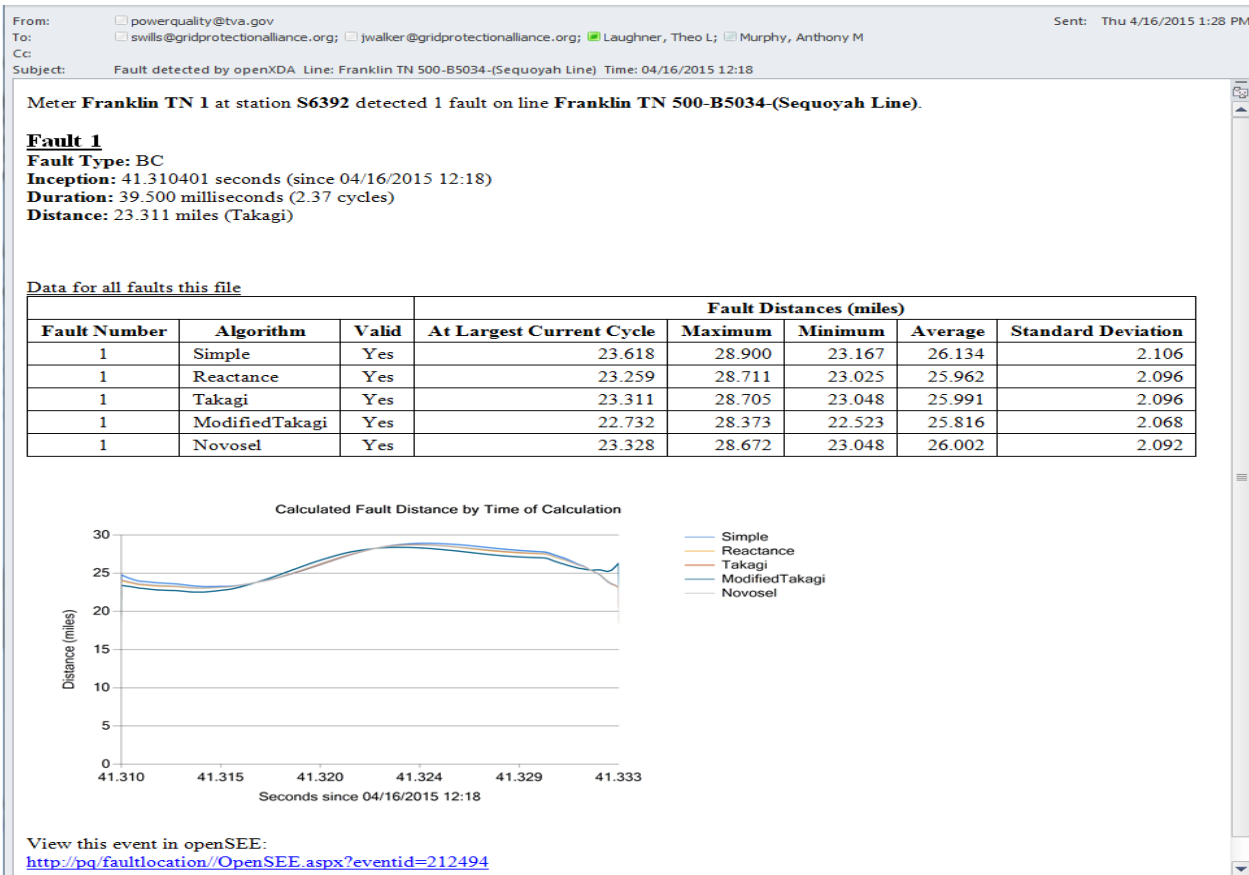To address these concerns, two platforms have been developed: openXDA and PQ Dashboard.
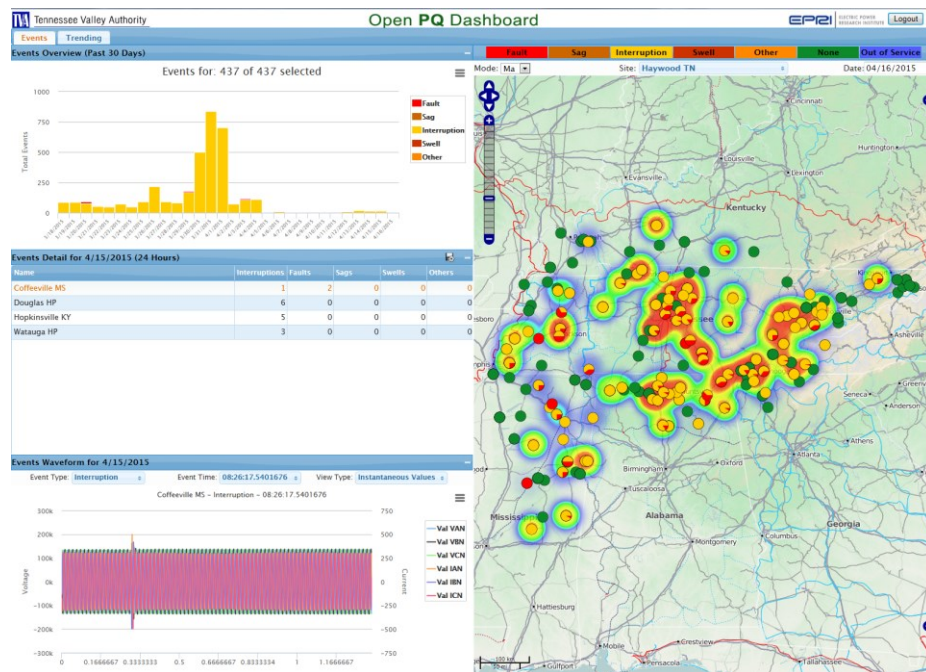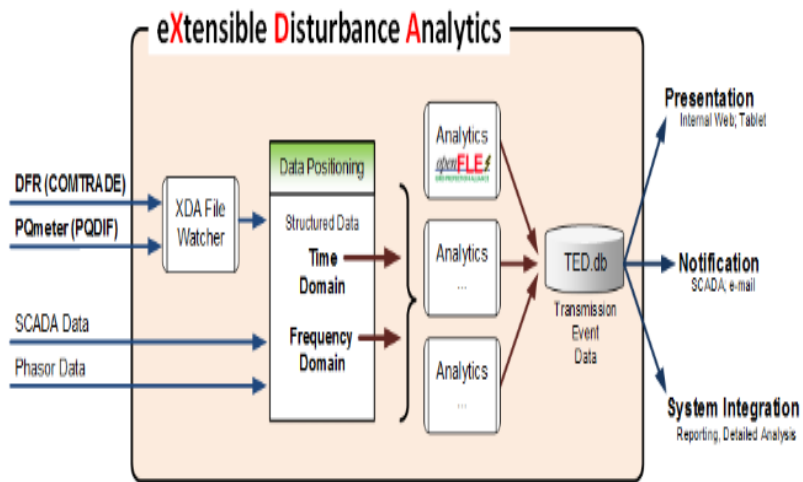
openXDA

- OpenXDA is an extensible platform for performing analytics on waveform data.

- The waveform data can come from a variety of sources: digital fault recorders, relays, power quality monitors, etc.

- After analysis an email is sent letting relevant users know what has happened.

Sample Email

The email quickly alerts staff to the fact there was an issue.

A variety of algorithms are run on the data and a summary of them is shown.

A link to a more detailed page is provided.

From: powerquality@tva.gov   Sent: Thu 4/16/2015 1:28 PM
To: swills@gridprotectionalliance.org; jwalker@gridprotectionalliance.org; Laughner, Theo L; Murphy, Anthony M
Cc:
Subject: Fault detected by openXDA Line: Franklin TN 500-B5034-(Sequoyah Line) Time: 04/16/2015 12:18

Meter **Franklin TN 1** at station **S6392** detected 1 fault on line **Franklin TN 500-B5034-(Sequoyah Line)**.

Fault 1
Fault Type: BC
Inception: 41.310401 seconds (since 04/16/2015 12:18)
Duration: 39.500 milliseconds (2.37 cycles)
Distance: 23.311 miles (Takagi)

Data for all faults this file

Fault Number	Algorithm	Valid	Fault Distances (miles)				
			At Largest Current Cycle	Maximum	Minimum	Average	Standard Deviation
1	Simple	Yes	23.618	28.900	23.167	26.134	2.106
1	Reactance	Yes	23.259	28.711	23.025	25.962	2.096
1	Takagi	Yes	23.311	28.705	23.048	25.991	2.096
1	ModifiedTakagi	Yes	22.732	28.373	22.523	25.816	2.068
1	Novosel	Yes	23.328	28.672	23.048	26.002	2.092

Calculated Fault Distance by Time of Calculation

Simple
Reactance
Takagi
ModifiedTakagi
Novosel

Distance (miles)

Seconds since 04/16/2015 12:18

View this event in openSEE:
http://pq/faultlocation//OpenSEE.aspx?eventid=212494

Detailed Web Page

The detailed web report shows:
- ✓ Picture of the structure
- ✓ GIS map
- ✓ Line parameters
- ✓ Historical event analysis
- ✓ Links to other relevant information (Drawings)

open PQ Dashboard

- The dashboard provides visualizations to quickly convey the location of a variety of issues.

- Provides displays that summarize alarm types for various time windows: day, month, etc.

- Provides statistical process control of trended quantities for a given site to emphasize abnormal conditions.

- Provides waveform data for a given event.

Dashboard

Grid indicating sites with issues over timeframe selected.

Historical performance of system is shown.
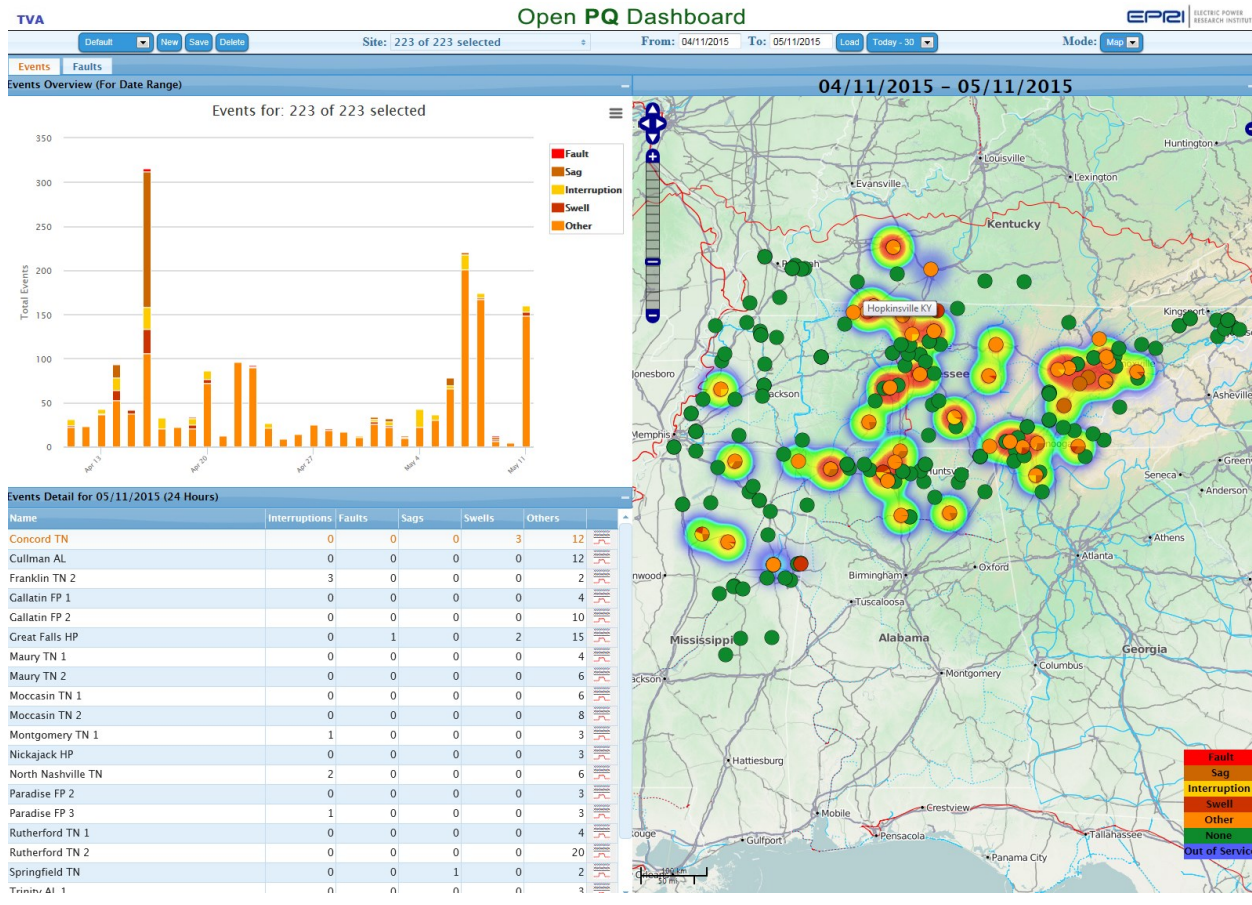
Links to individual station/data is available.

Dashboard (Continued)

Geographic Information System (GIS) view.

Map indicating sites with issues over timeframe selected.

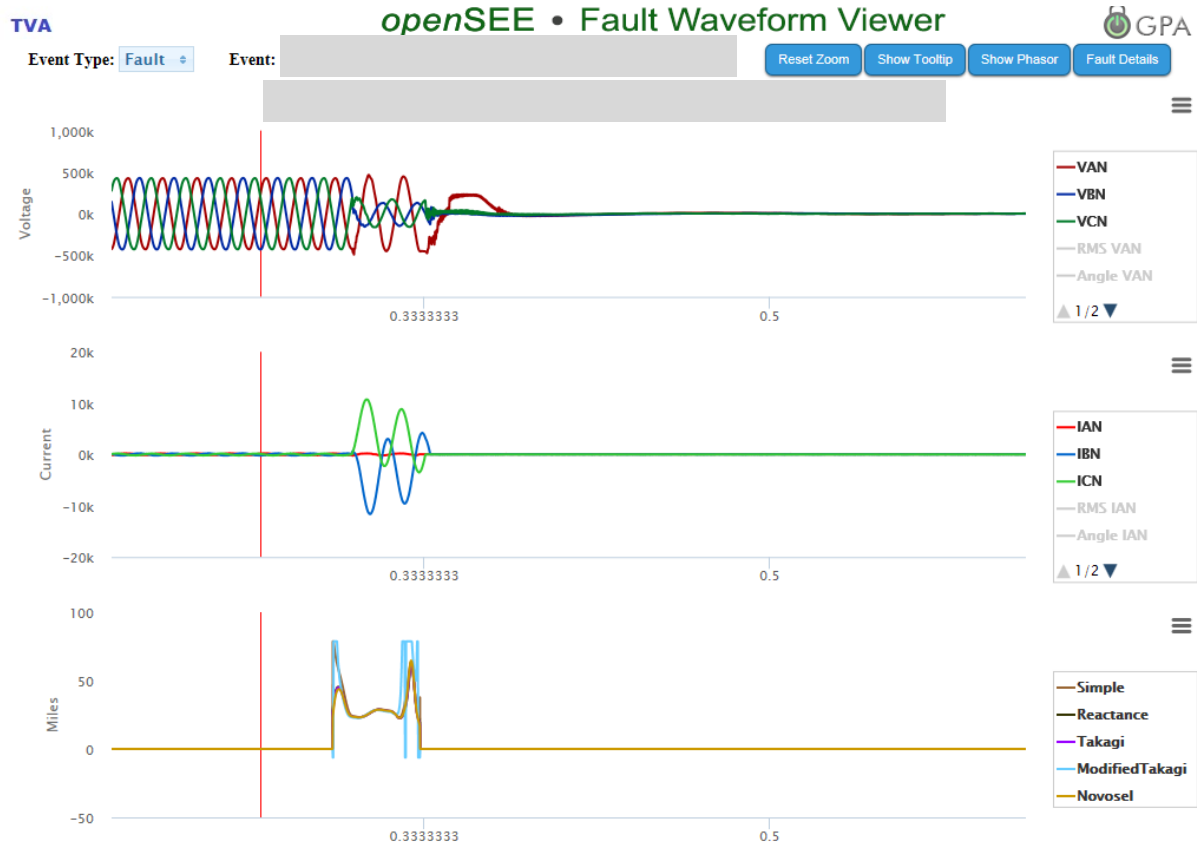Heat map highlights areas with the most potential issues.

Dashboard (Continued)

Waveform viewer.

Provides web based viewing of waveform data and the resulting fault calculations.

Development Under Way

- Validation Of Data

- Cap Bank Health Assessment

- Dashboard Enhancements

Conclusions

- Valuable Information Buried In Data
  - We could be proactive!
  - Save PTs, Cap Banks and Customer Interruptions

- Automated Analysis Is Necessary
  - Too Much Data To Perform Manually

- Automated Analysis Is Here
  - Fault Location Ready
  - Additional Algorithms for "Interesting Events" Need To Be Developed

Questions?