Using SynchroPhasor Data To Diagnose Grid Events

North American SynchroPhasor Initiative Working Group Meeting

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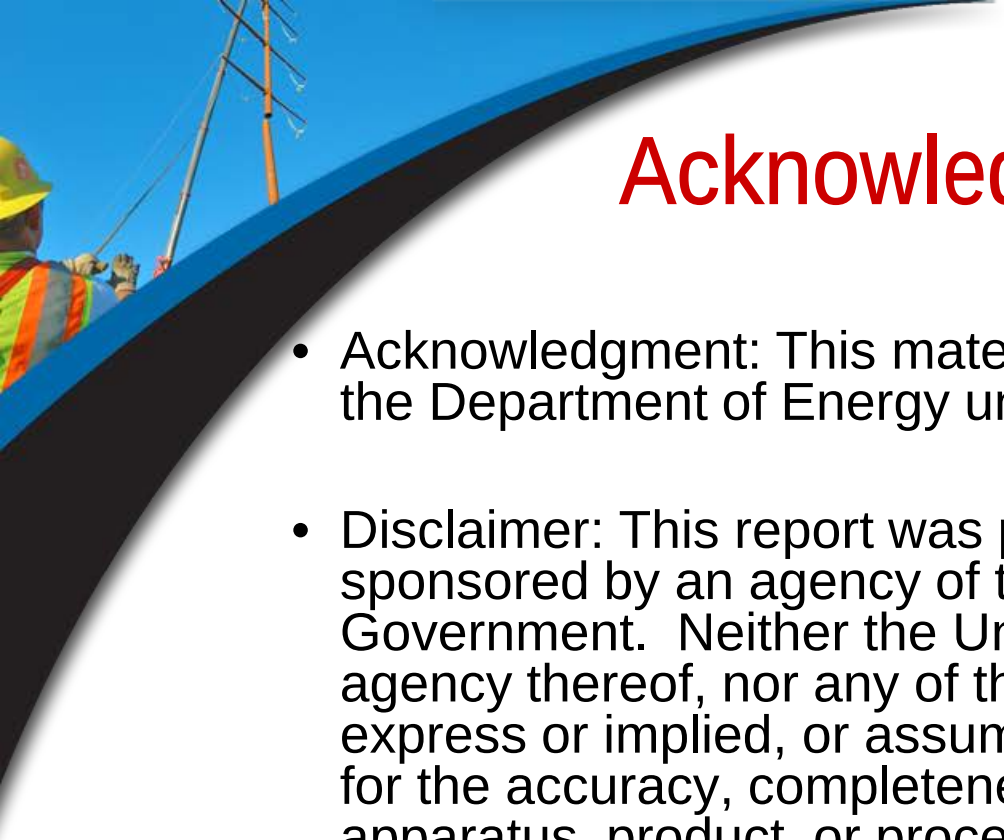

Acknowledgment and Disclaimer

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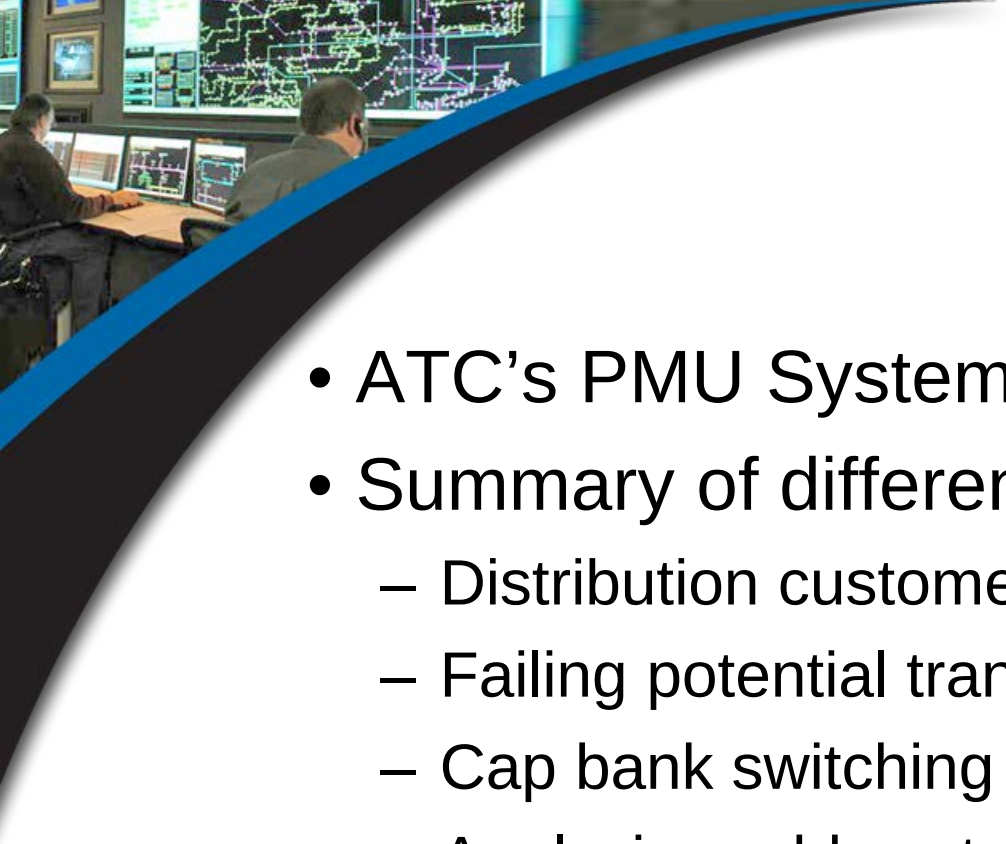
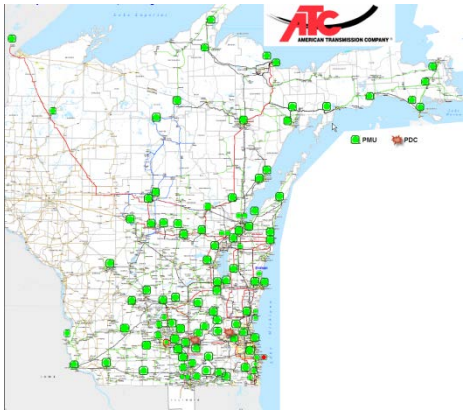


Overview

- ATC's PMU System Overview
- Summary of different uses for our PMU data
  - Distribution customer voltage issue analysis
  - Failing potential transformer
  - Cap bank switching issue
  - Analyzing odd customer outages
  - Identifying issues with open phases on breakers
  - Negative sequence concerns
- Quick Summary
- Questions?

ATC PMU System Overview



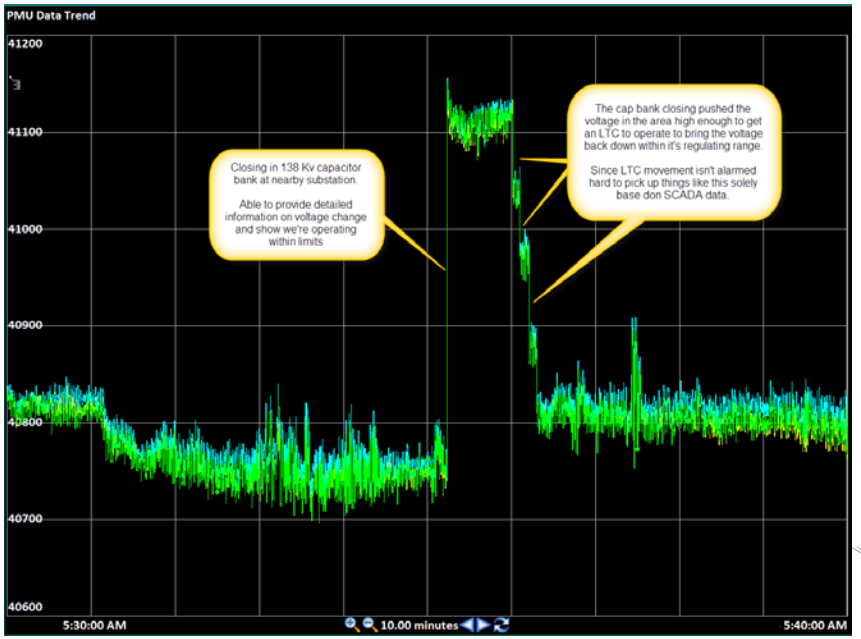
- 107 PMUs in service providing data
- Devices spread across the state of Wisconsin and the Upper peninsula of Michigan. Higher concentrations in metro areas.
- Synchrophasor data is being used to fill in a visibility gap between 4 second scan rate data and high speed fault recording equipment because DFRs don't always trigger when you need higher resolution data

Distribution customer voltage Issue analysis

- Customers on the distribution side are installing more sophisticated monitoring tools and asking more questions about system events they see
- PMU data allows us to assess the impact of an event on a wide area and answer questions with certainty
- Easy to determine if voltage dips are distribution or transmission sourced with enough PMUs in place

Distribution customer voltage Issue analysis – Event 1

- Distribution customer monitoring equipment generating events when we closed a local capacitor bank for area voltage support
- Able to show them the actual change in system voltage on all phases related to the cap being placed into service

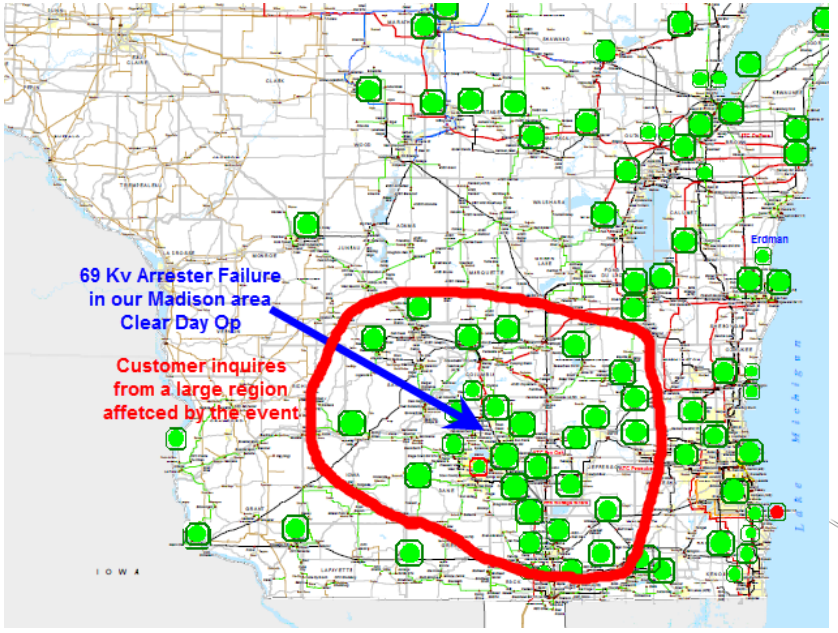


2013 @ 5:32:00 AM CST
509.4V (106.1%)
480.0V
8ms (0.48 cycles)
Transient
60.0 Hz

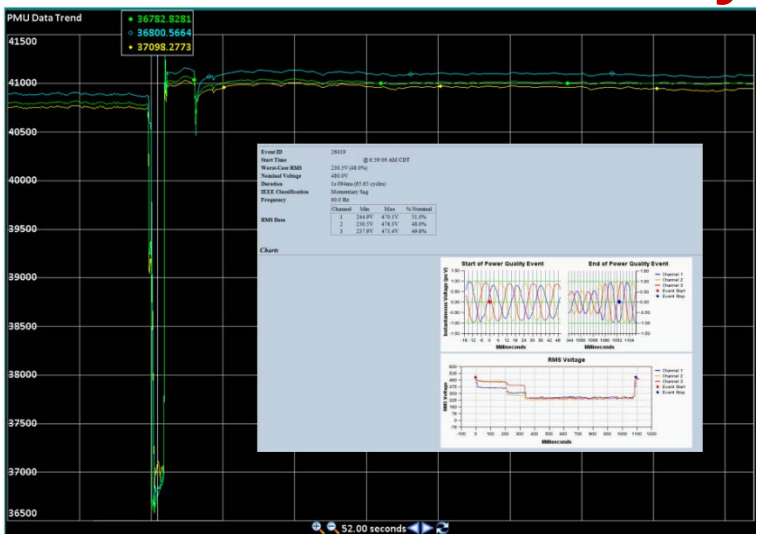
Channel	Min	Max	% Nominal
1	494.2V	509.4V	106.1%
2	491.8V	505.4V	105.3%
3	489.8V	505.4V	105.3%

Distribution customer voltage Issue analysis – Event #2

- 69 Kv arrester failure on a clear day caused short duration (10 cycle) depressed voltage to a wide area of our system
- Able to provide customer service personnel with info on duration of the event and effect on local system using data from PMUs across the system

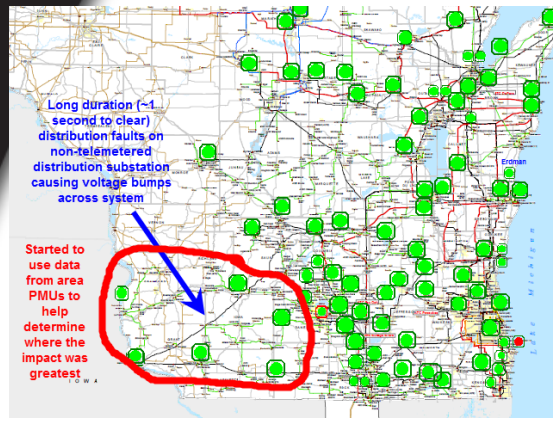


Distribution customer voltage Issue analysis – Event #3



- Voltage dips observed by customer equipment. They reached out to customer service to better understand source of problem affecting their equipment
- PMU data showed 3 phase voltage dip lasting ¾ second but no cause found
- We were able to show detailed impact of the event on the transmission system

Distribution customer voltage Issue analysis – Event #4



- Voltage dips observed across our SW Wisconsin system caused by faults on an un-telemetered distribution substation
- Intertied with another transmission entity in the area and we do not have SCADA indication on intermittent events on their system so no clear understanding of source
- Started using PMUs to determine stations most affected and eventually hoping to triangulate location of problem (not enough PMUs in this case to locate but in other areas we might be able to)

Failing potential transformer

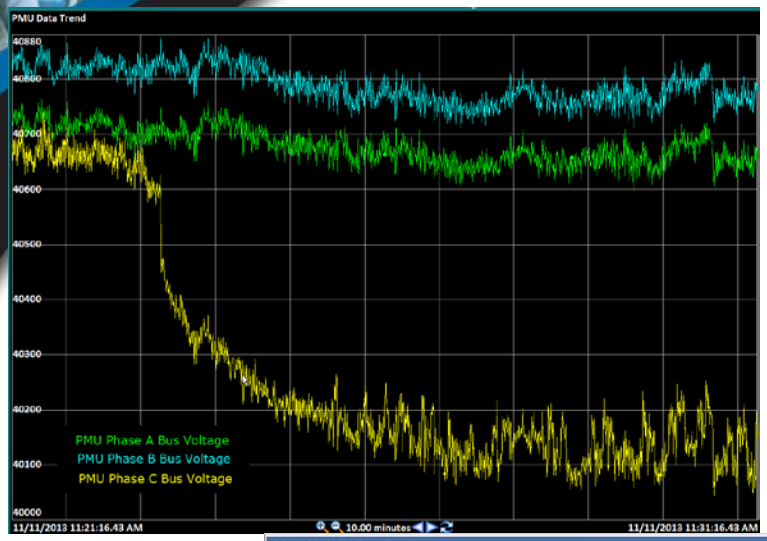
Background:

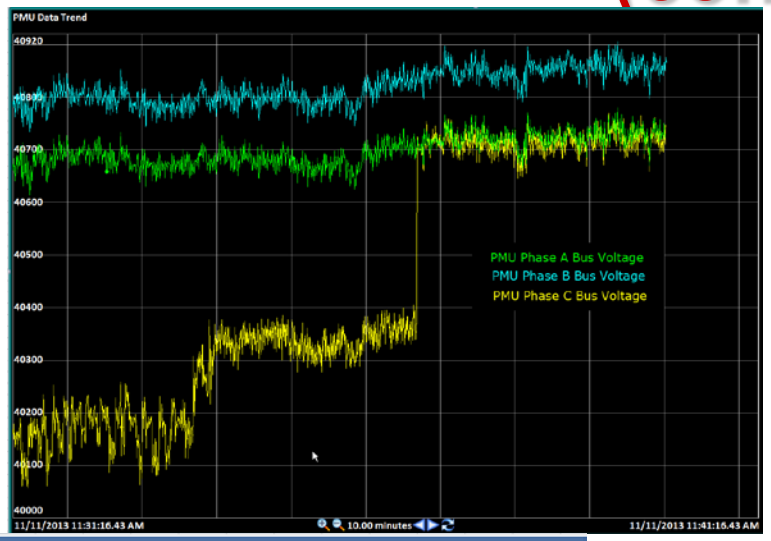
- Stumbled across odd voltage signature from a PMU monitoring one of our 69 Kv substations while reviewing fault operations
- Slow voltage decay on one phase which eventually jumped back to “normal”
- Confirmed same issue present on both secondary windings for the PT. Determined it was an issue with primary winding.
- All connections verified good so determined this was an internal primary winding issue on the PT

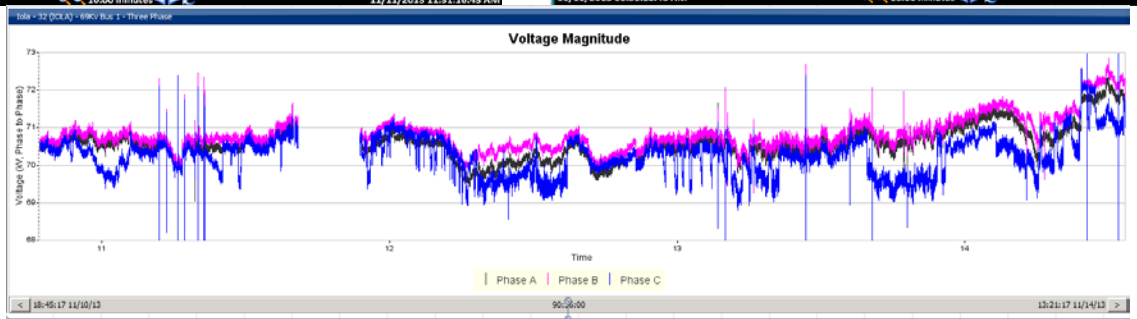
Failing potential transformer (cont'd)

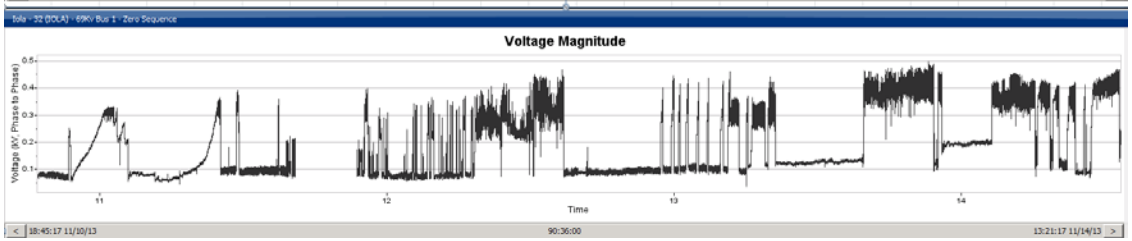
- Decision made to replace defective PT before it failed
- Substation could not be back fed from distribution system so we were able to schedule a mobile transformer and serve the load while we replaced the unit before we had a failure
- We believe we avoided an extended outage by catching this before it failed and saved money as we were able to replace during normal work hours
- Disclaimer – The high level tests we did on the suspect PT did not show an obvious issue but we were not certain it would due to the intermittent nature of the failure/short

Failing potential transformer (cont'd)





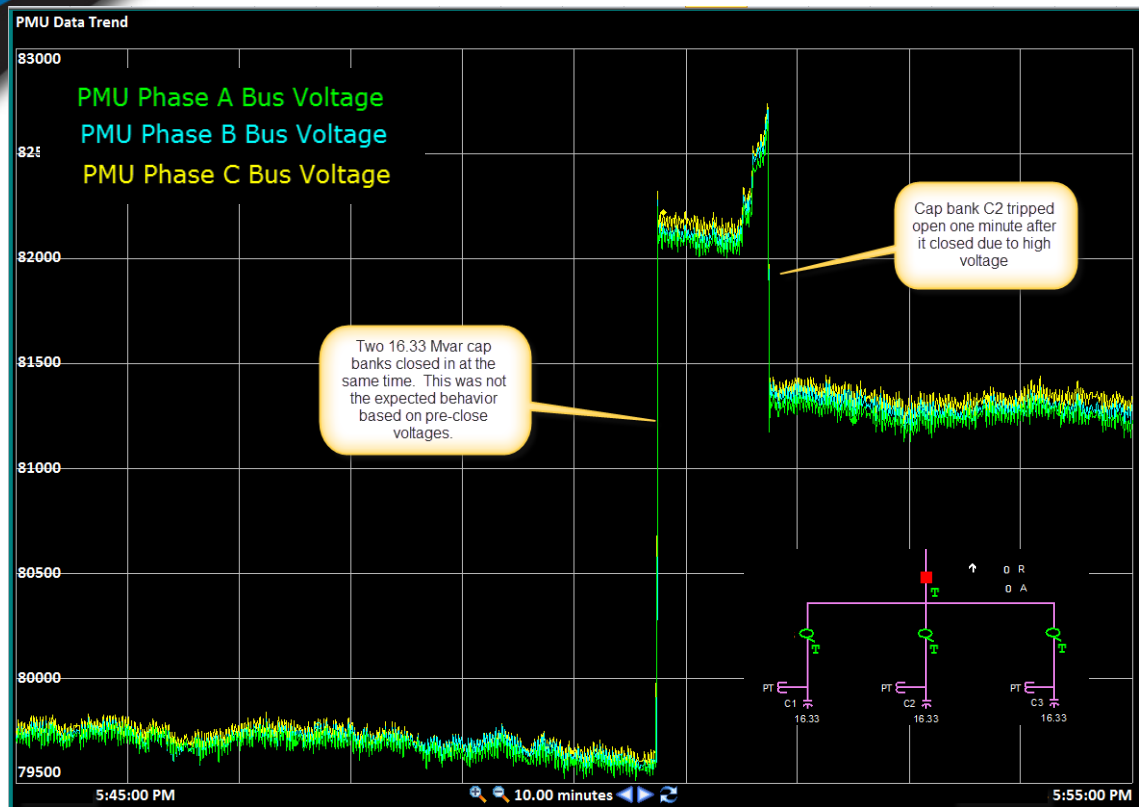




Cap bank switching issue

- Multiple 138 Kv connected cap banks at station closed in at same time under normal operation.
- Cap closing should be staged with delays between closes
- System protection personnel had questions if we had experienced voltage dips in the area prior to the closes but relays did not record enough pre-event data to analyze properly
- Able to better analyze the relay operation based on the additional data that would not have been available using SCADA or relay event records

Cap bank switching issue (cont'd)



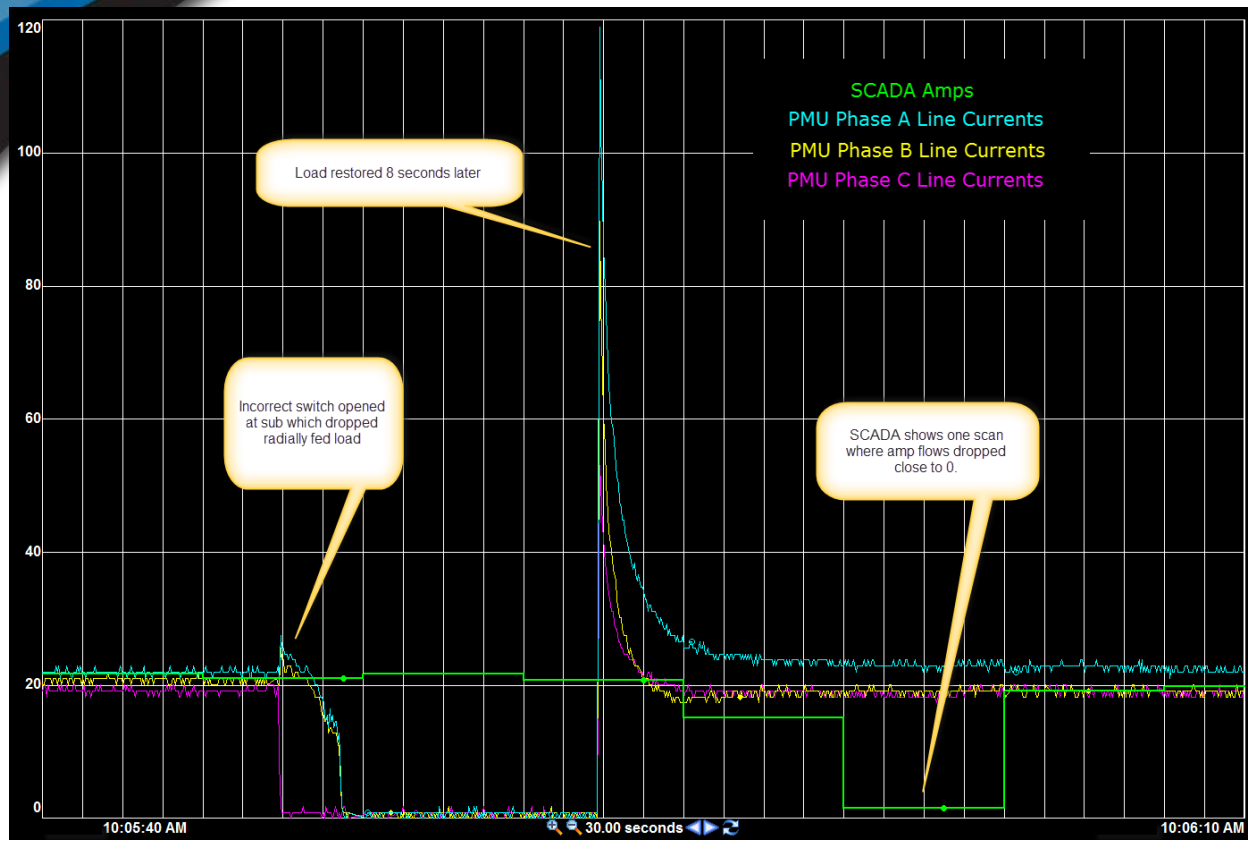
- Since PMU data is "always on" we were able to determine there were no abnormal voltage swings that caused the undesired dual close operations.

Analyzing odd customer outages

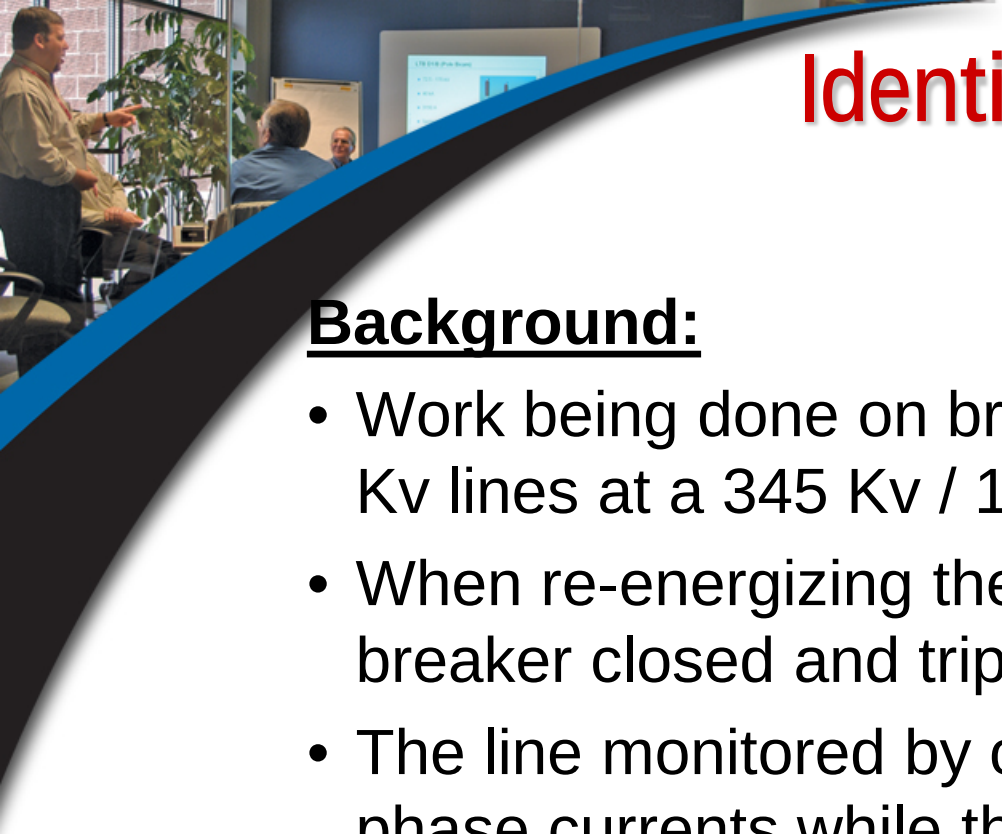
Background:

- 138 Kv tapped line open at one end for maintenance
- Feeding minimal (~2 MW) tapped load radially
- Received customer complaints fed from the station being served radially that they had experienced a short duration outage
- Nothing on the transmission side to indicate the load had been disconnected
- SCADA shows decrease in flows for one scan but not enough detail to know if noise or actual event.

Analyzing odd customer outages (cont'd)



- PMU data monitoring line to the sub clearly showed a disconnect and reconnect. Again SCADA showed similar trend but limited detail.
- Eventually found that switchman at tap sub had incorrectly opened the wrong switch. No SCADA status so we had no idea the switch had opened and closed.

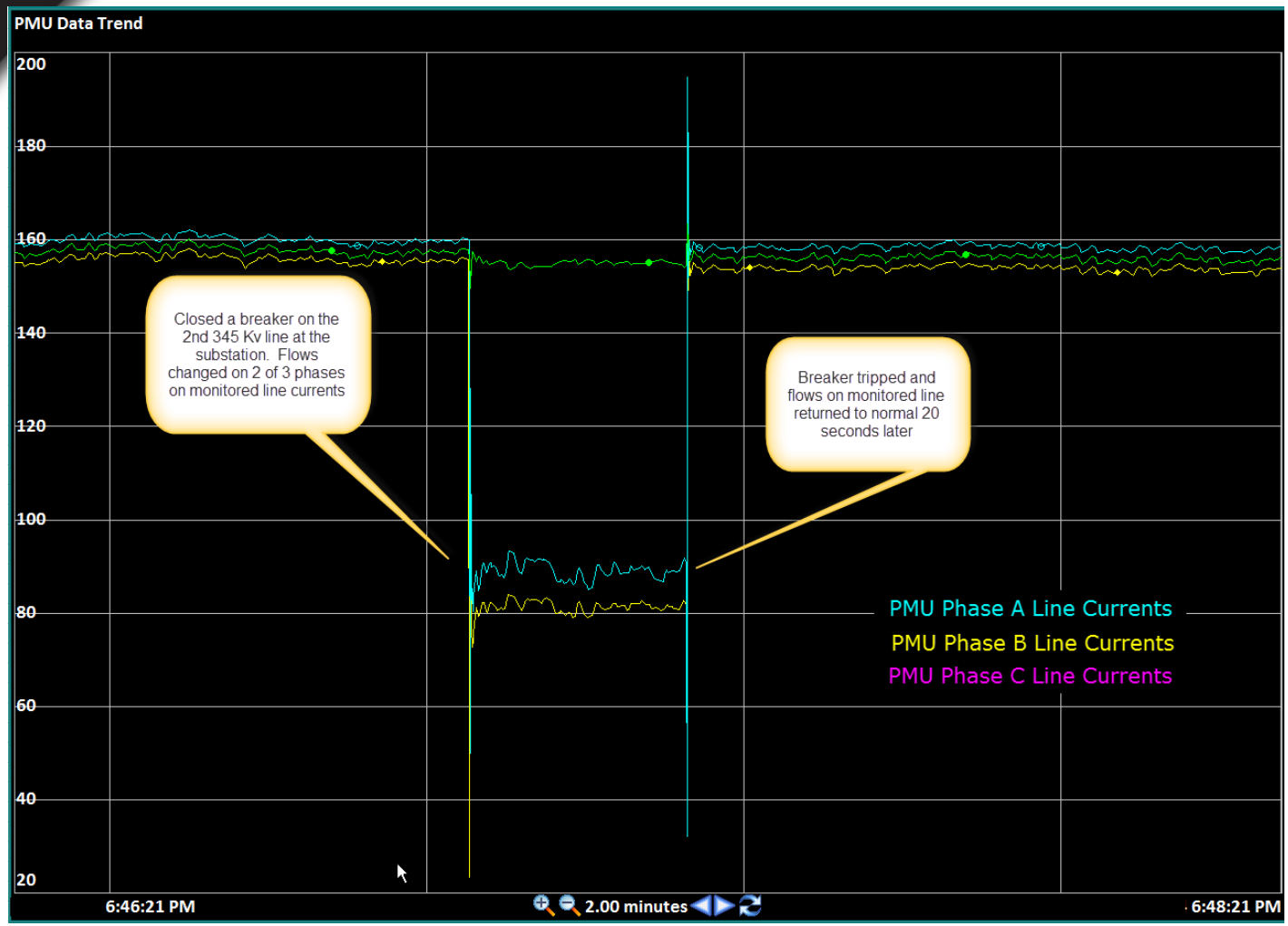


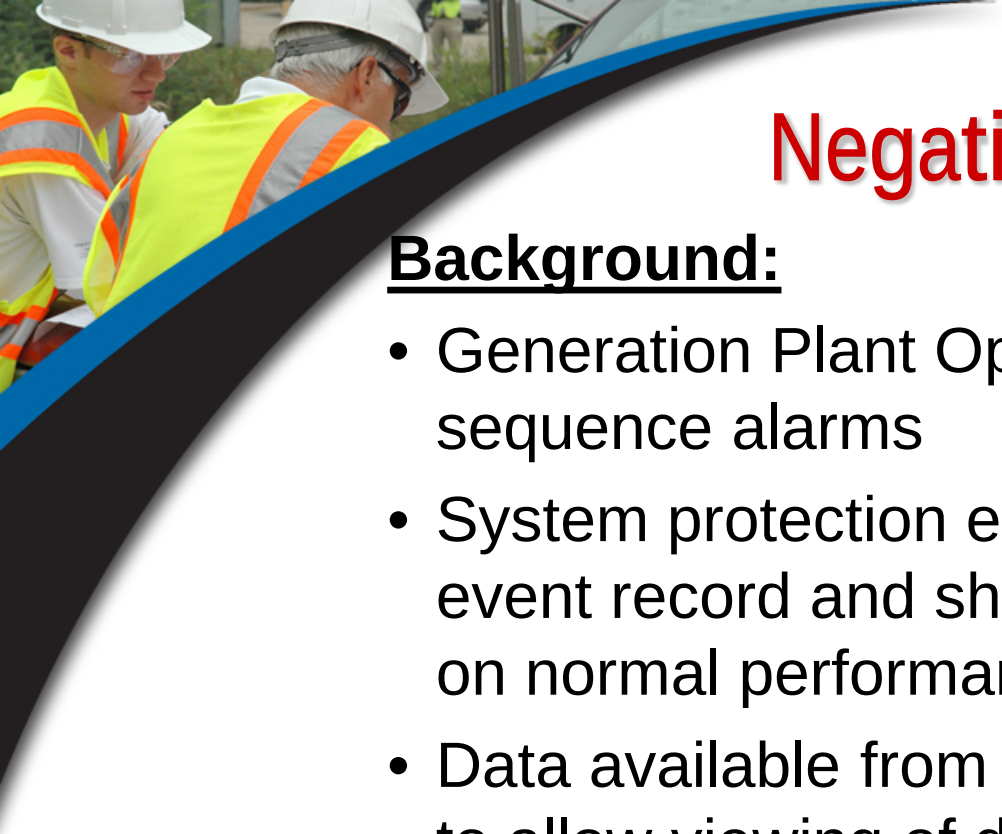
Identifying issues with open phases on breakers

Background:

- Work being done on breaker feeding one of two 345 Kv lines at a 345 Kv / 138 Kv substation
- When re-energizing the line and picking up load the breaker closed and tripped open within 20 seconds
- The line monitored by our PMU saw unbalanced phase currents while the other breaker was closed
- No digital fault recorders triggered for this. No relay event files available to explain what happened. One open phase alarm which we questioned initially based on the lack of data
- Very hard to troubleshoot without the PMU data

Identifying issues with open phases on breakers (cont'd)



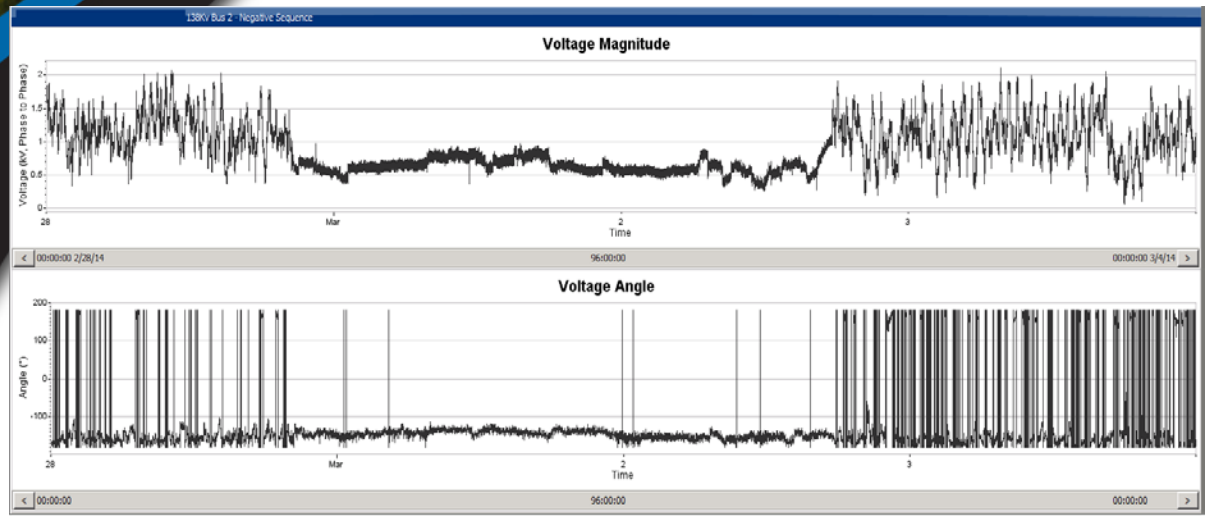


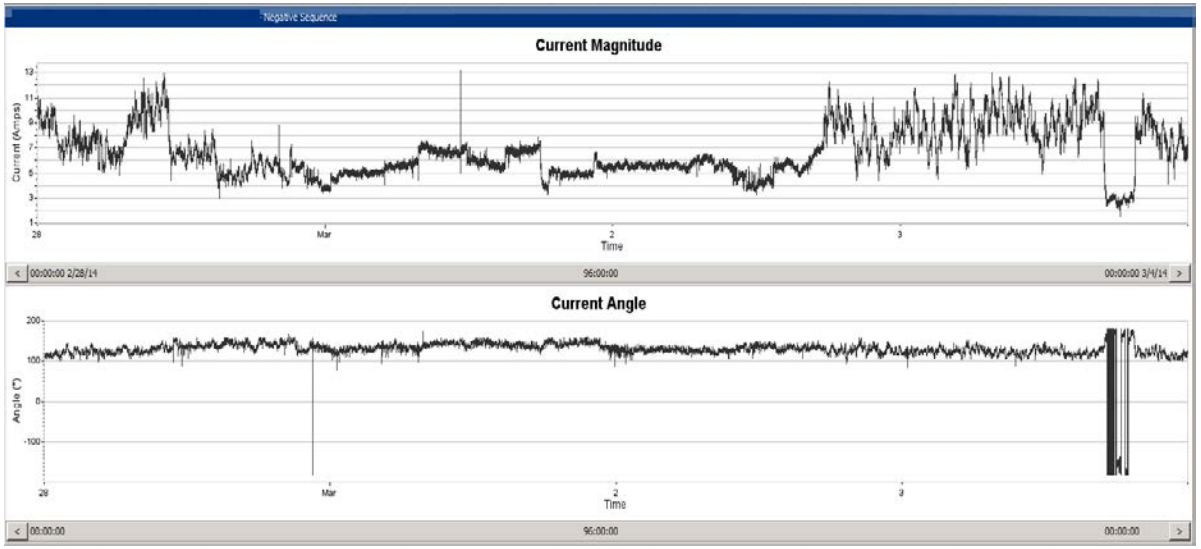
Negative sequence concerns

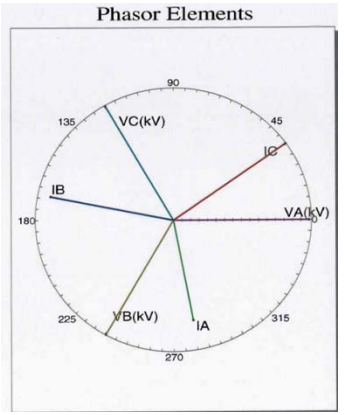
Background:

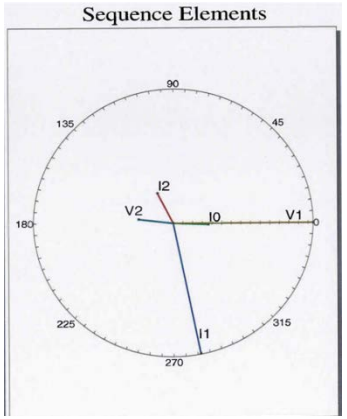
- Generation Plant Operator receiving negative sequence alarms
- System protection engineer able to trigger an event record and show unbalance but no history on normal performance
- Data available from interconnection station PMU to allow viewing of data over the weekend to identify any oddities in system
- Able to use PhasorPoint application to derive negative sequence data and plot to provide GO with clarity as to what was happening.
- Single phase arc furnace loads in area

Negative sequence concerns (cont'd)









Summary

- At ATC the use of synchrophasor data for post event analysis is gaining acceptance from our Ops Engineering and System protection groups (they know the data is there and ask for it…..)
- The little things we use the data for now will help pave the way for future development of tools using the data
- We will continue to find applications for the data we didn't envision especially when others understand what data is available

Questions?