Using Synchrophasor Data to Diagnose Equipment Mis-operations and Health

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Background and thesis of paper

Preview of a technical paper to be issued by the DOE SGIG program, to extract insights from the SGIG-SGDP synchrophasor projects

Thesis of paper

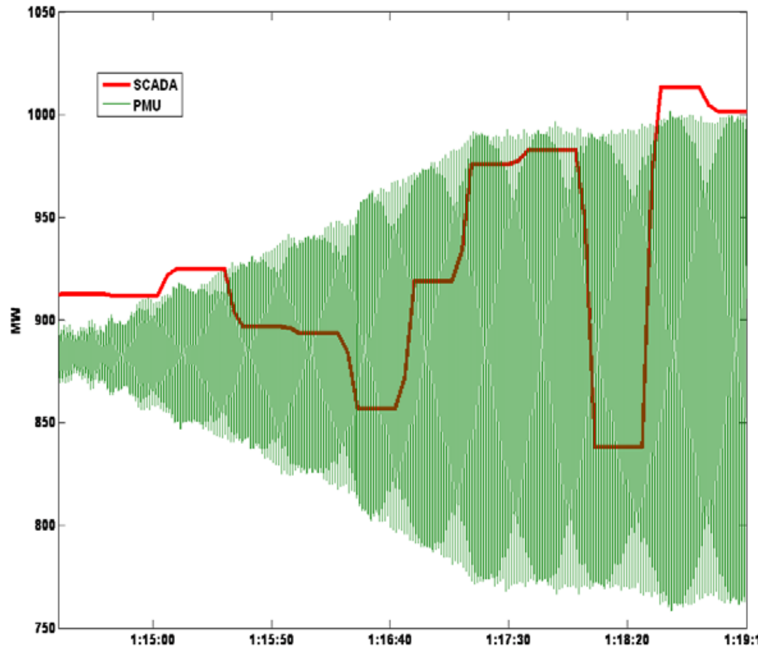
- Operating engineers are using synchrophasor data to identify and diagnose a wide number of generation and transmission events. This off-line use is producing tremendous value in terms of potential equipment damage avoided and potential outages averted.
- By documenting the examples and the diagnostic and deductive processes used for each case, the entire industry can learn how to implement this great synchrophasor value source.

Four main categories of diagnostic use to date

Based on observability improvement from combination of high time resolution and more detailed data collection at useful points across the grid

1. Generator settings and generating equipment failures
2. Wind plants and oscillations
3. Transmission events and equipment
4. Proactive uses of PMUs for equipment installation and protection

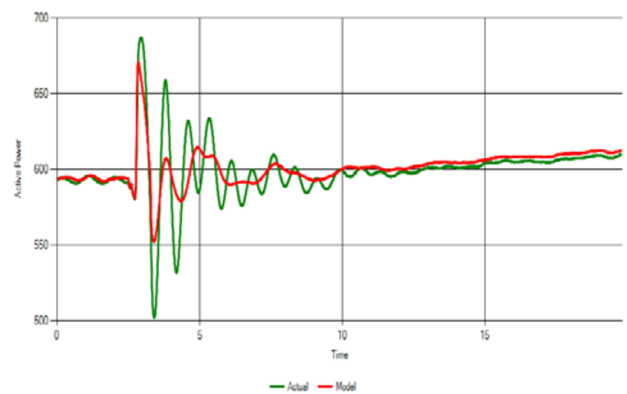
Twelve-minute oscillation at nuclear power plant
(Dominion VP)



Mis-operations examples

1) Generator settings and generator equipment failures

- Cumberland generator PSS setting (TVA)
- Malfunctioning generator PSS (NYISO)
- Malfunctioning generator AVR control system (NYISO)
- Redbud powerplant oscillations (OG&E)
- Voltage oscillations at nuclear plant (Dominion)
- Protecting power system stabilizers (Manitoba Hydro)
- Governor control malfunction in Alberta caused large power oscillations on California-Oregon lines (BPA, CAISO)
- Relay mis-operation causing generator trip (ATC)
- Faulty generator control card (ERCOT)
- Governor control issue (MISO)
- Figuring out governor settings (BPA)

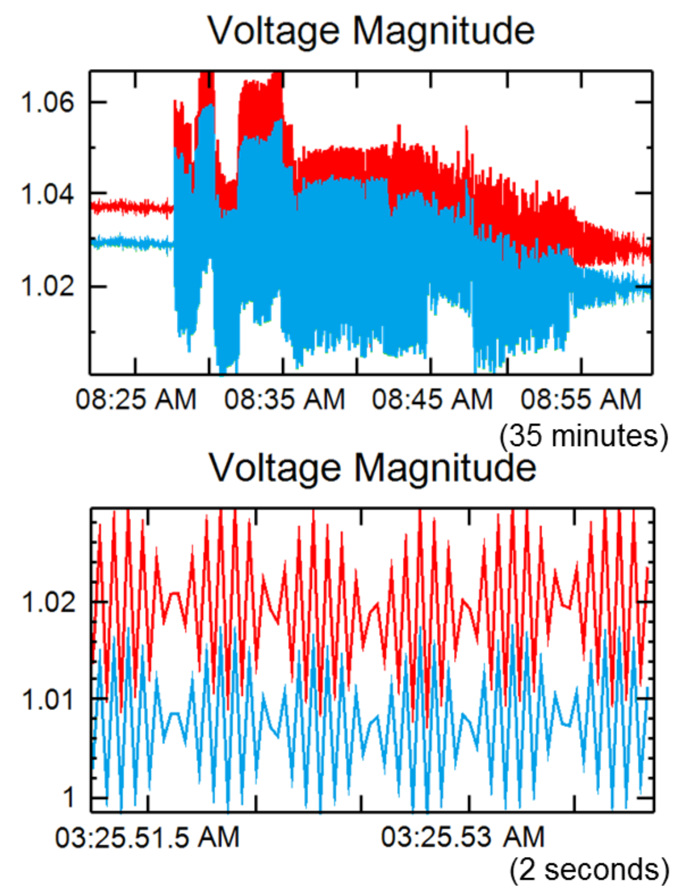


Mis-operations examples

2) Wind plants and oscillations

- Wind plant oscillations (OG&E)
- Wind controller software update flawed (ERCOT)
- Wind events and turbine controllers (ERCOT)
- Wind plant high frequency oscillation (BPA)

OG&E – wind plant oscillation



Mis-operations examples

3) Transmission equipment

- Controller oscillation at Pacific HVDC Intertie (BPA, SCE, CAISO)
- Failing potential transformer (ATC)
- Failing voltage transformer (Dominion)
- Finding loose connections in potential circuits at fuses and terminal blocks (OG&E)
- Identifying 69 kV arrester failure affecting customers (ATC)
- Voltage pull-downs linked to line communications carrier (OG&E)
- Monitoring harmonics and noise from new equipment (ATC)
- Finding open phases and unbalanced phase currents on breakers (ATC)
- PQ monitoring (OG&E)
- Negative sequence alarms (ATC)
- Transmission-level fault analysis (NYISO)
- Capacitor bank switching problem (ATC)

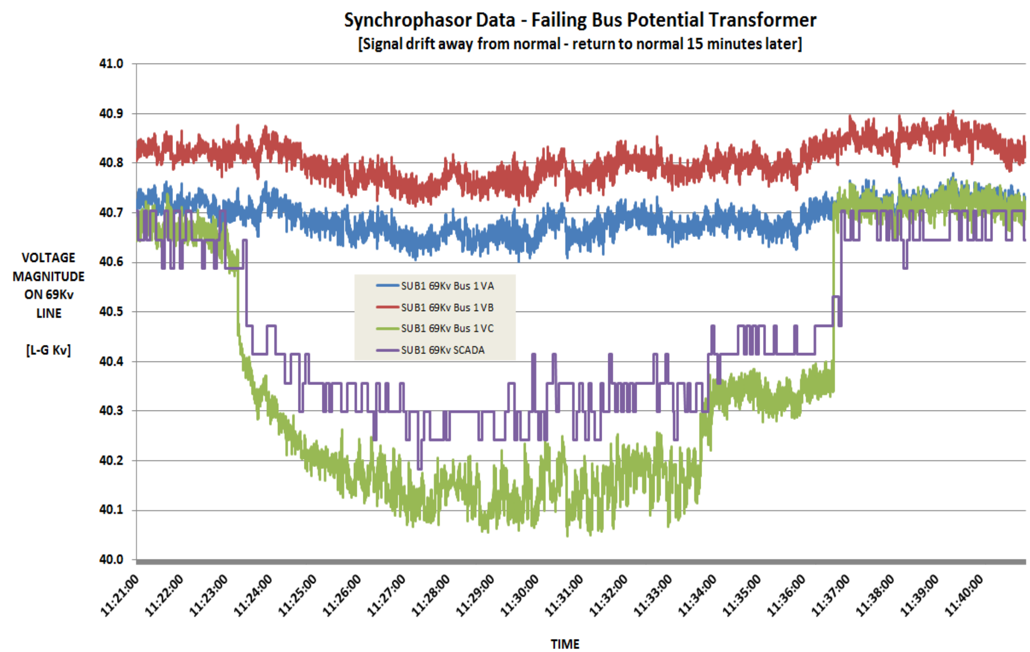
Mis-operations examples

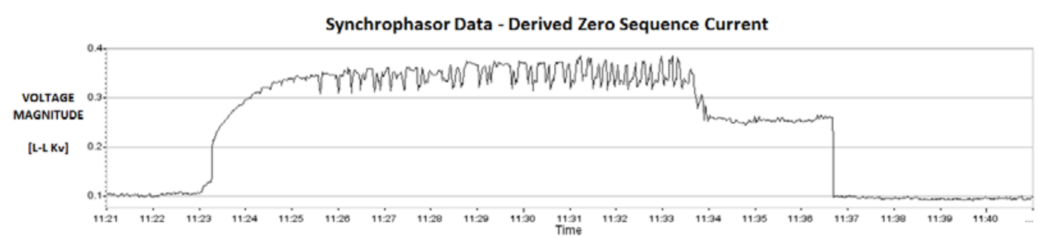
4) Proactive uses of PMUs for equipment installation and protection

- Commissioning power system stabilizers (Manitoba Hydro)
- Using PMUs to install equipment to verify phasing (ATC)
- Monitoring system current imbalance to protect large power generator rotors (Dominion)
- Using PMUs to install and calibrate instrument transformers (Dominion)
- Checking system protection device operation (ATC)

Failing bus potential transformer (ATC)

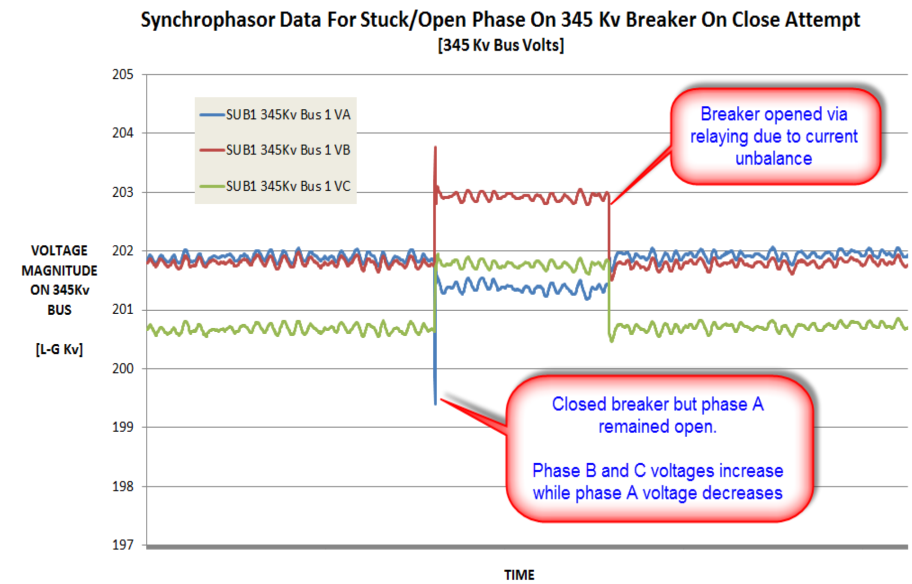
- If a PT connection is bad or the PT is failing, it may feed inaccurate voltages to the attached relays and cause a relay mis-operation. A failed winding in the PT could cause a catastrophic failure and break-up, damaging substation equipment.
- Because ATC spotted this failing PT winding through PMU data, it was able to take the bus out of service and replace the PT before it failed w/o emergency repairs or a customer outage.

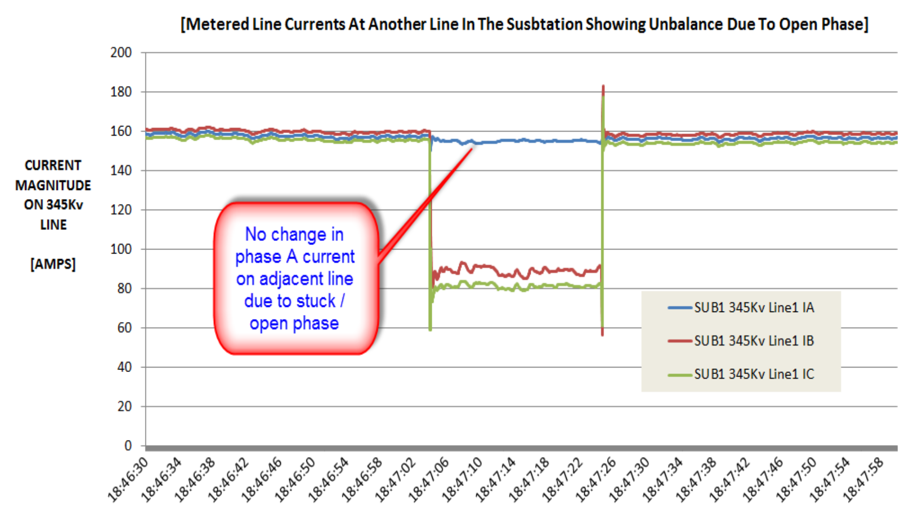




Finding open phases and unbalanced phase currents on breakers (ATC)

- When ATC crews working on a breaker feeding a 345 kV line re-energized that line, the breaker closed and tripped open within 20 seconds on unbalance as one phase remained open (flat blue line on current plot). PMUs saw unbalanced phase currents while the other breaker was closed, but there were no event files or DFR traces to show what happened.
- Based on the PMU data, ATC was able to easily confirm which phase did not close properly and address the problem (a close relay that was not operating in synch with other phases).

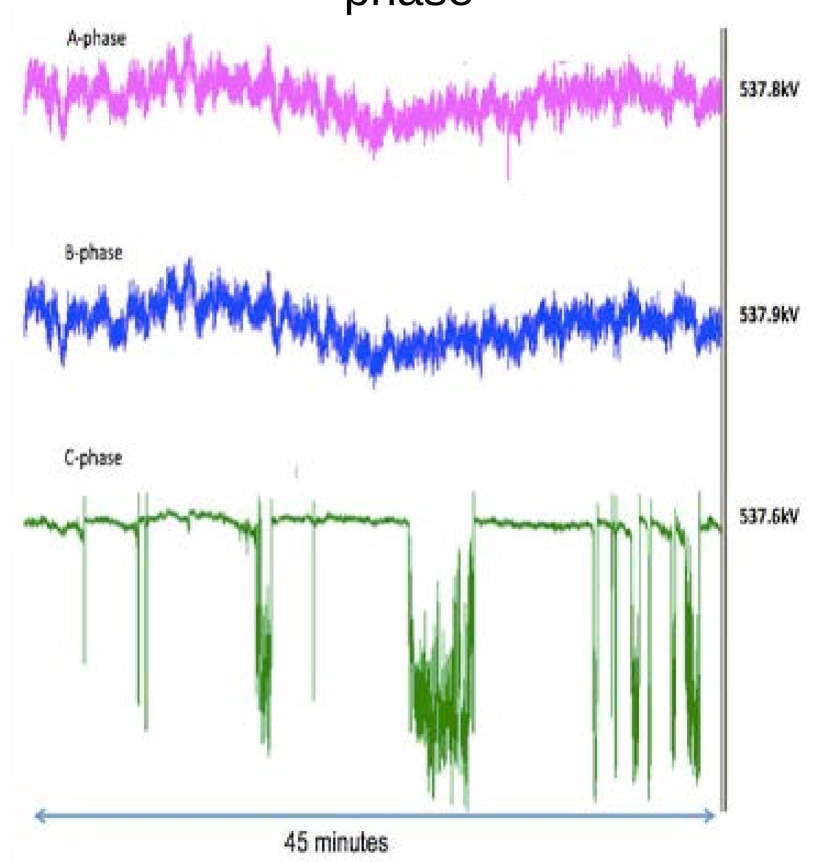




Identify failing voltage transformer before it fails (Dominion)

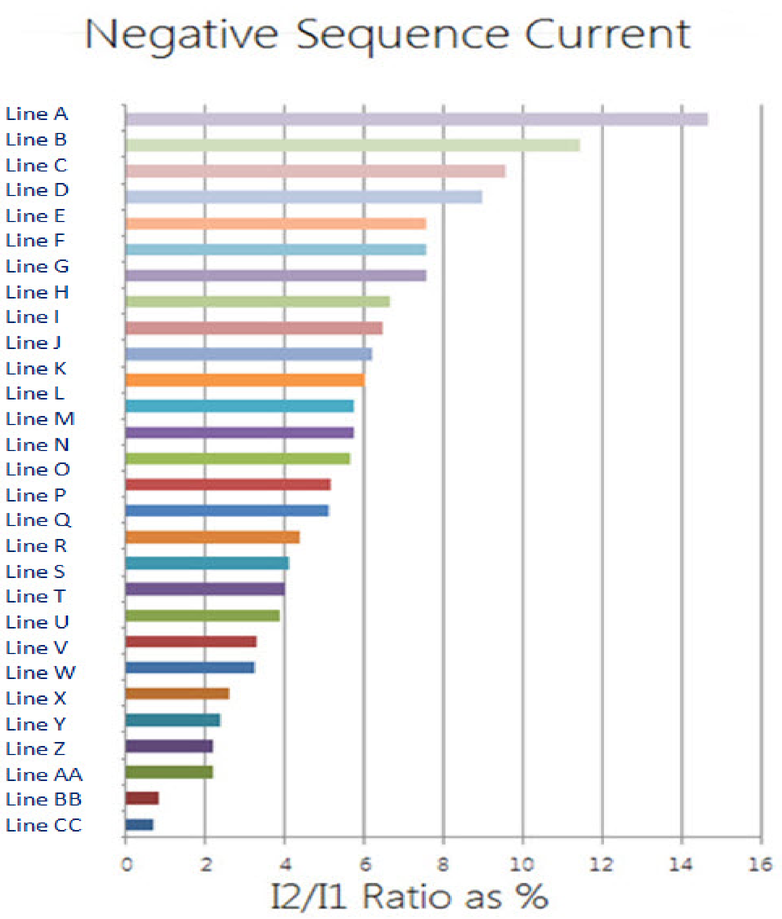
- CCVTs are used in many EHV installations – EHV buses, lines, transformers, generators. In a catastrophic failure, the capacitors in a CCVT can explode, with damaging shrapnel hurting equipment and personnel.
- Fluctuations in voltage on the C-phase indicated a failing transformer several days before the SCADA monitoring on the CCVT indicated imminent failure.

PMU recording for 500 kV voltage transformer, indicating problem on C-phase



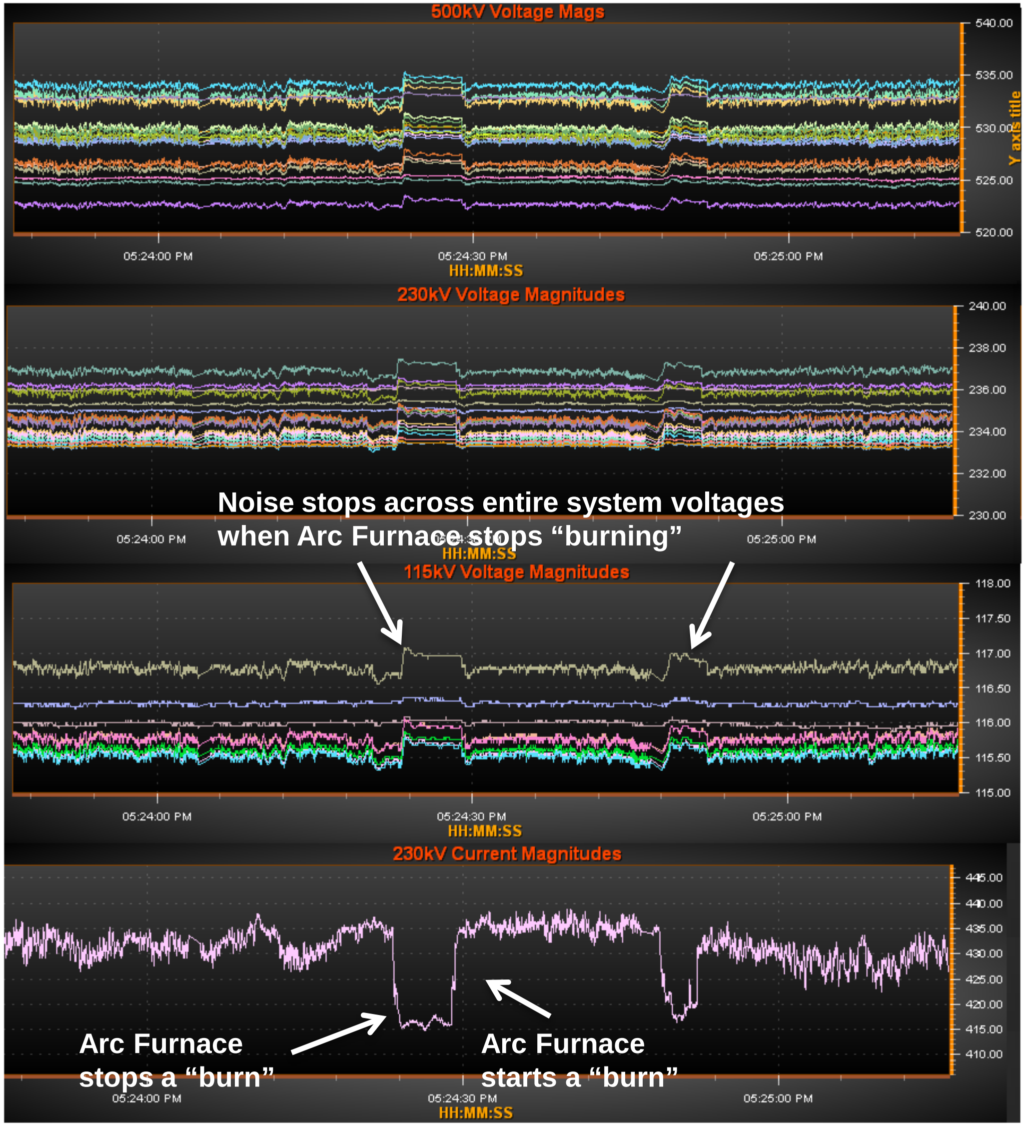
Monitoring system current unbalance to protect large generator rotors (Dominion)

- Negative sequence current on a transmission line can flow into a generator stator, causing its rotor to over-heat and break (long, expensive repair effort).
- Use PMUs to measure three phase currents on all transmission lines and calculate the symmetrical components to identify negative sequence current at each location.
- System alarms when the amount of actual negative sequence current entering a specific generator exceeds manufacturer limits.



Large arc furnace causes noise across system (Dominion)

- Both CCVT/PT failure examples show that by comparing the voltages & currents across multiple phases and multiple locations we can identify problems
- Recently noticed that a few voltage signals had significant noise. Plotted all voltage magnitudes and found the noise was present across the system.
- Found that noise was being created by a very large arc furnace load.



What happens next?

- Still collecting examples, writing paper, and fact-checking
- Start outreach campaign at NERC, NATF, NAGF, JSIS, and more
- We would like to build a library of synchrophasor data for these examples, that analysts can examine to look for event signatures for automated diagnosis
- Look at OG&E and others' automated reports and review habits to see if these practices and tools could be extended or undertaken by others
- Got more examples to share? Please let me know – alisonsilverstein@mac.com

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- MISO – Kevin Frankeny
- NYISO – Edwin Cano
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