IEEE Presentation
12KV Distribution Automation

Austin Walker, PE

12 kV DA Equipment

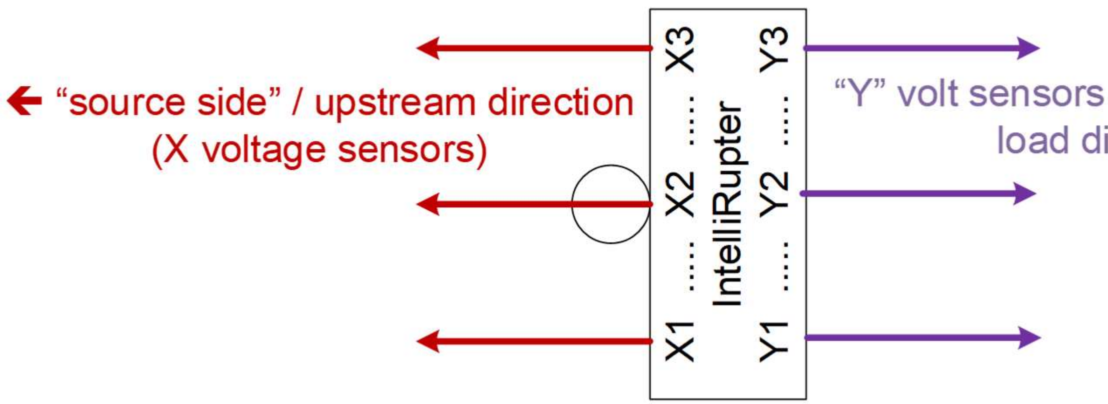
- Reclosers: ~1200
- Automation controllers: ~55
- Automated Switchgears: ~30

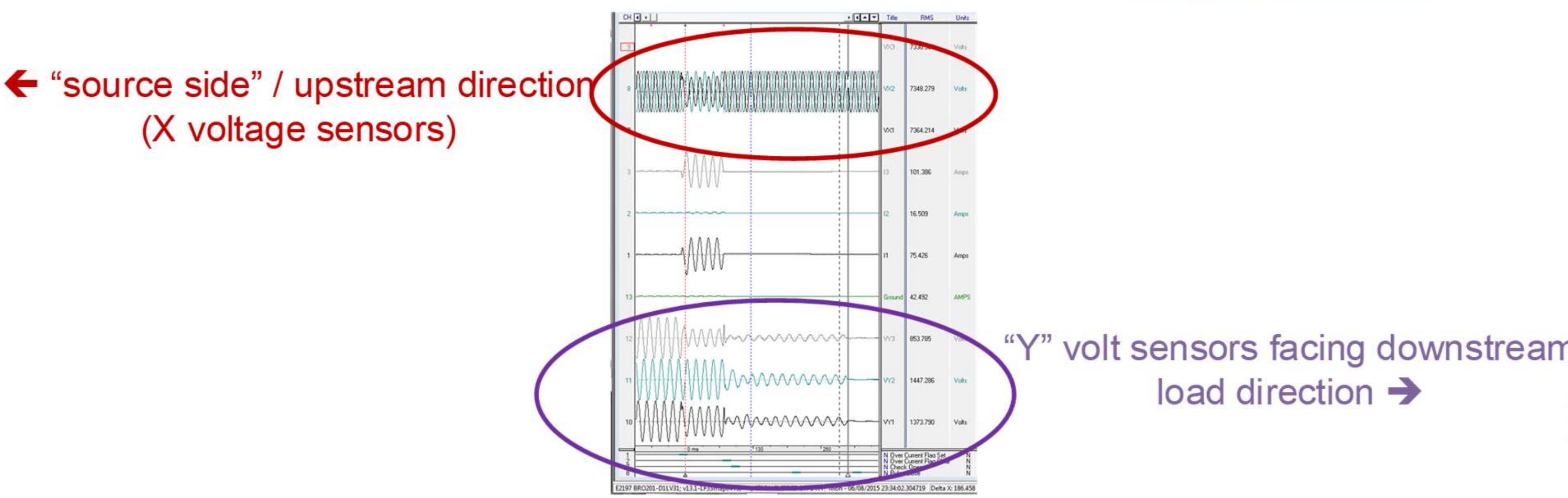
12 kV line recloser

EPB “XY” Orientation

- Source is on the “X” side of the recloser.

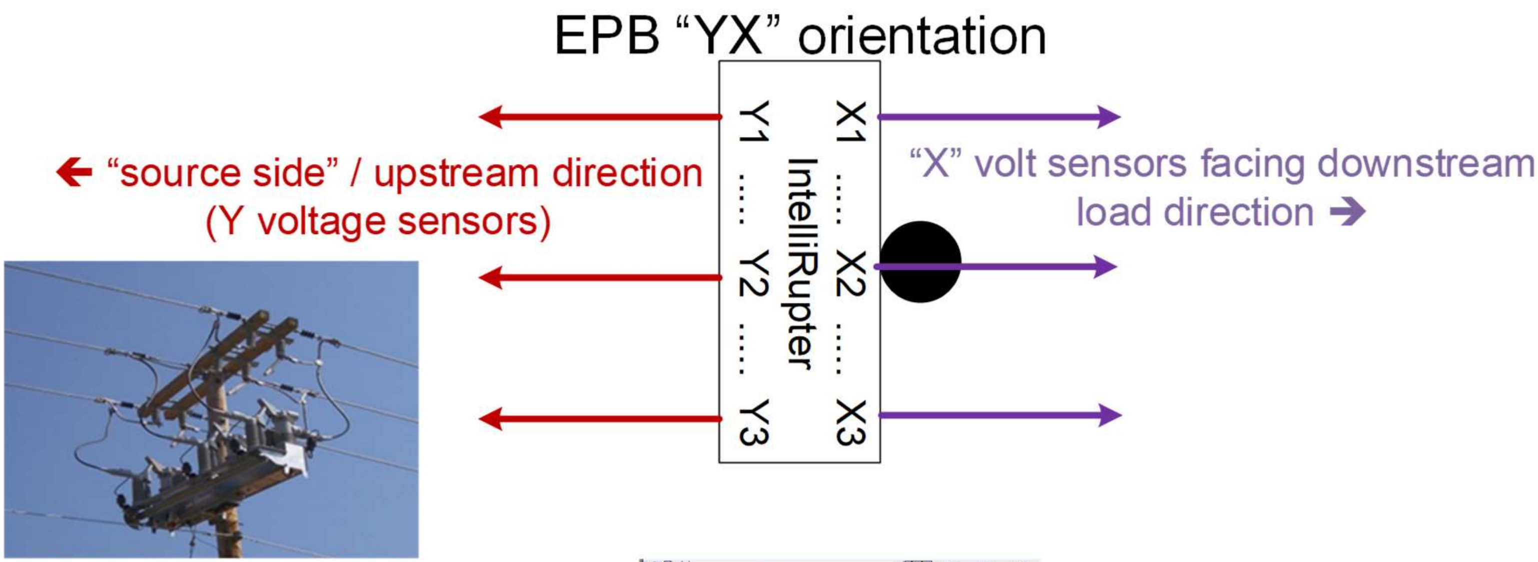
EPB “XY” orientation

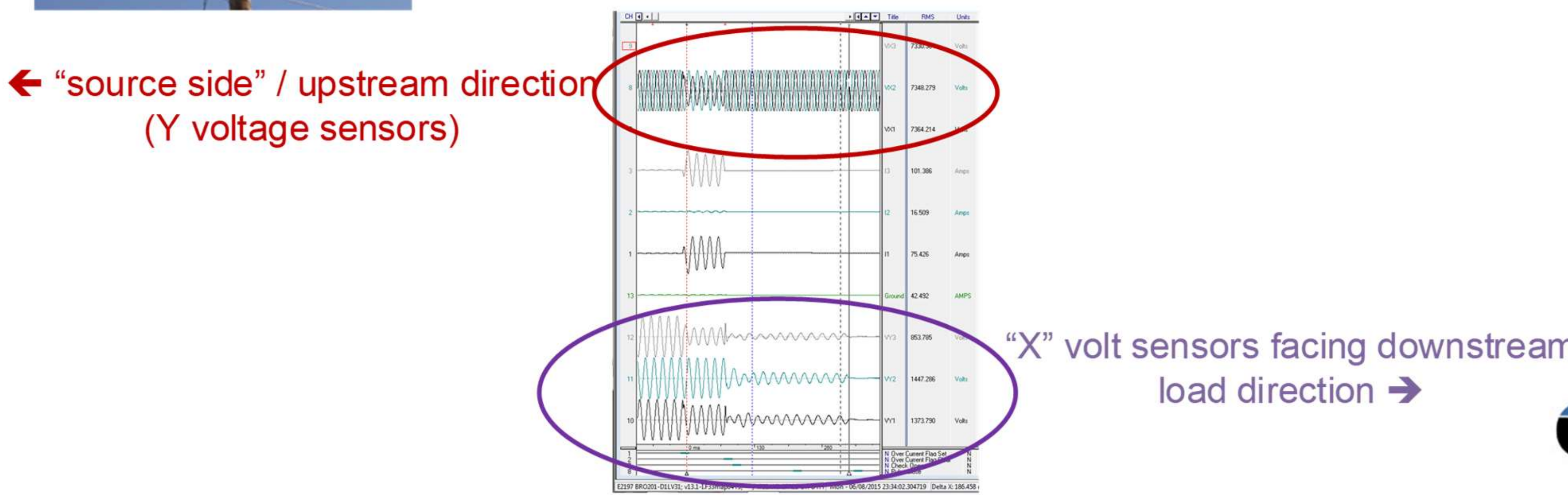




EPB "YX" Orientation

- Source is on the "Y" side of the recloser.



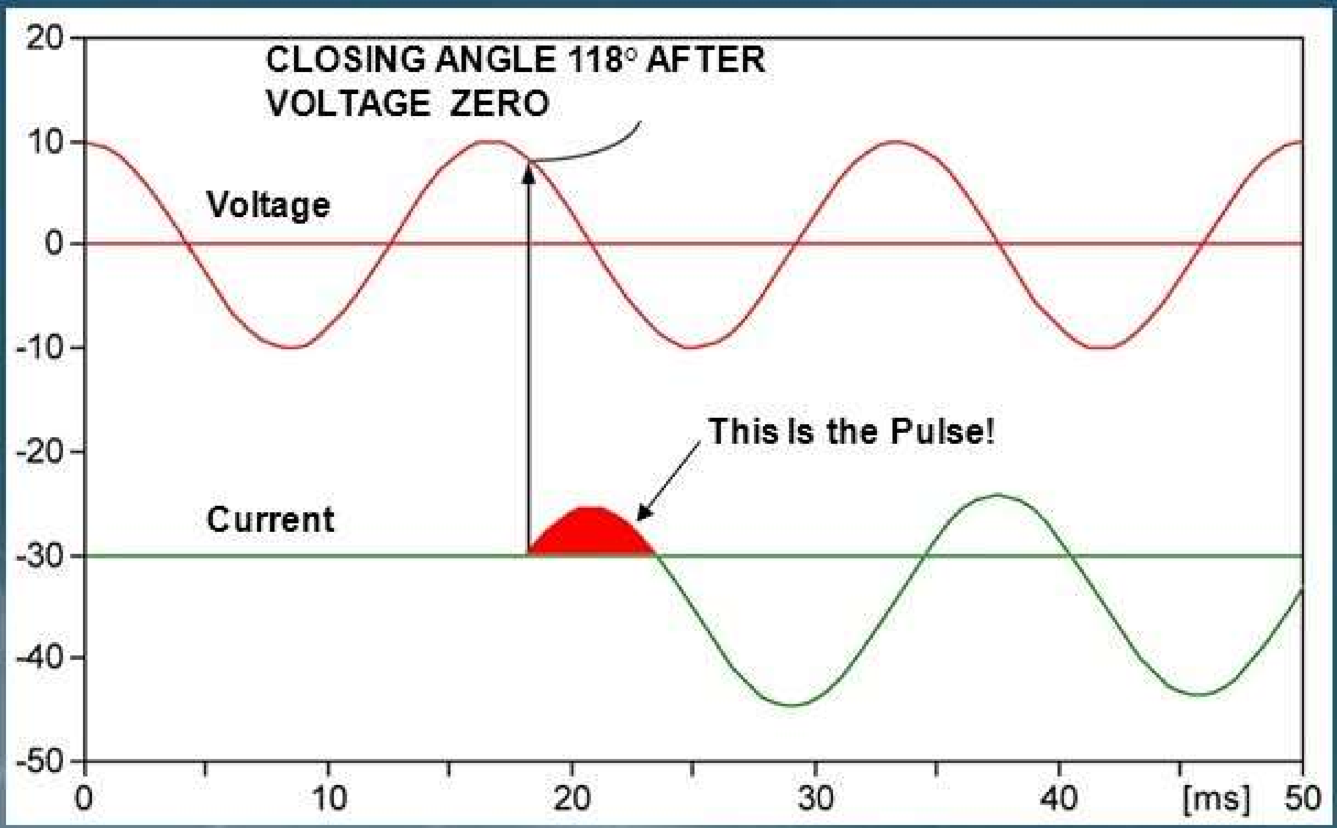


Protection and Switching

- Switching – SCADA control
  - Open or close protection device
  - Open or close switch remotely
- Protection
  - Trip = automatic open to clear fault
  - Reclose: automatic close, attempt to energize
    - Traditional – circuit breaker
    - Pulse close

Pulseclosing Technology

1. Test to see if the line is still faulted
2. Don't stress or damage the power system equipment
3. Don't cause voltage sags for upstream customers



EPRI / IREQ
Pulse test Let through energy

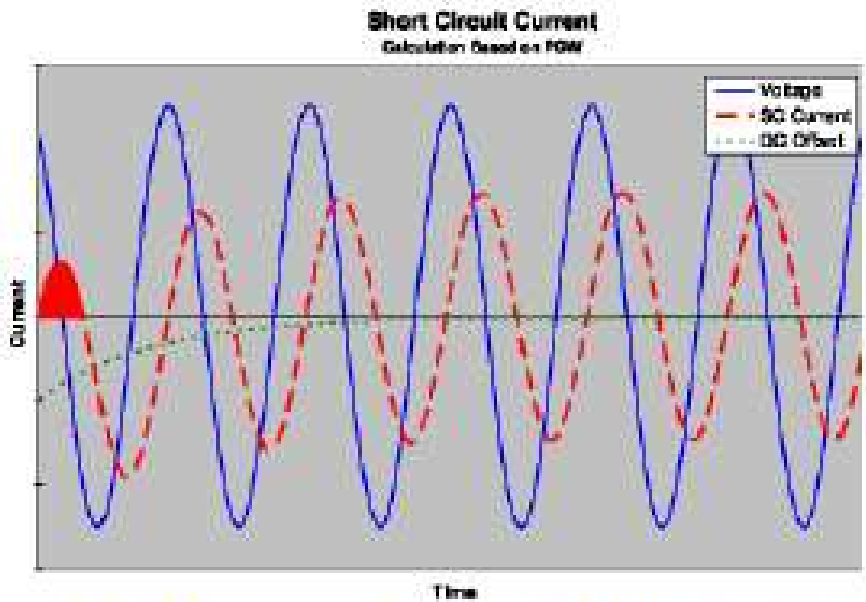


Figure 4. The pulse is a minor loop of fault current. Only the first minor loop of current (shaded area) is allowed to flow.

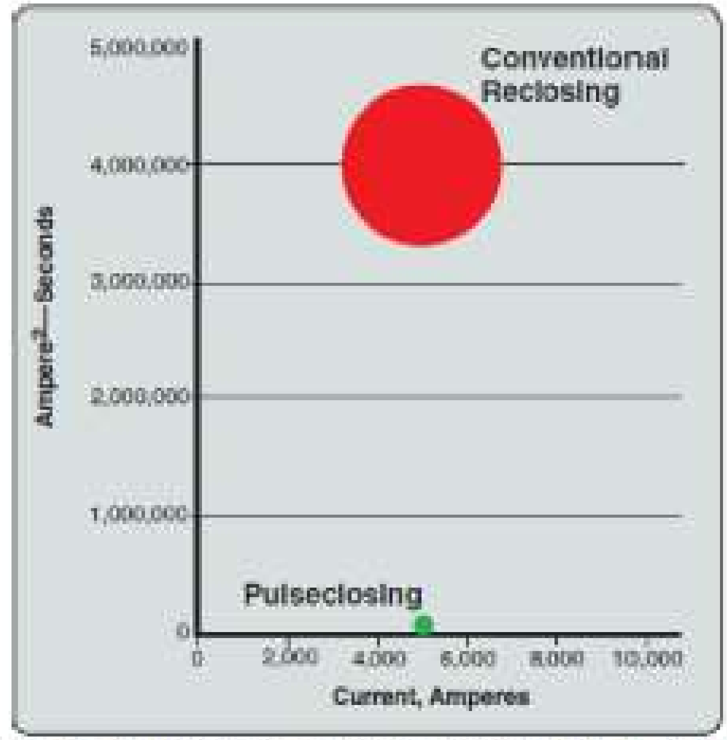


Figure 5. Relative let-through energy for a typical 5000 ampere fault.

Conclusion: < 2% typical

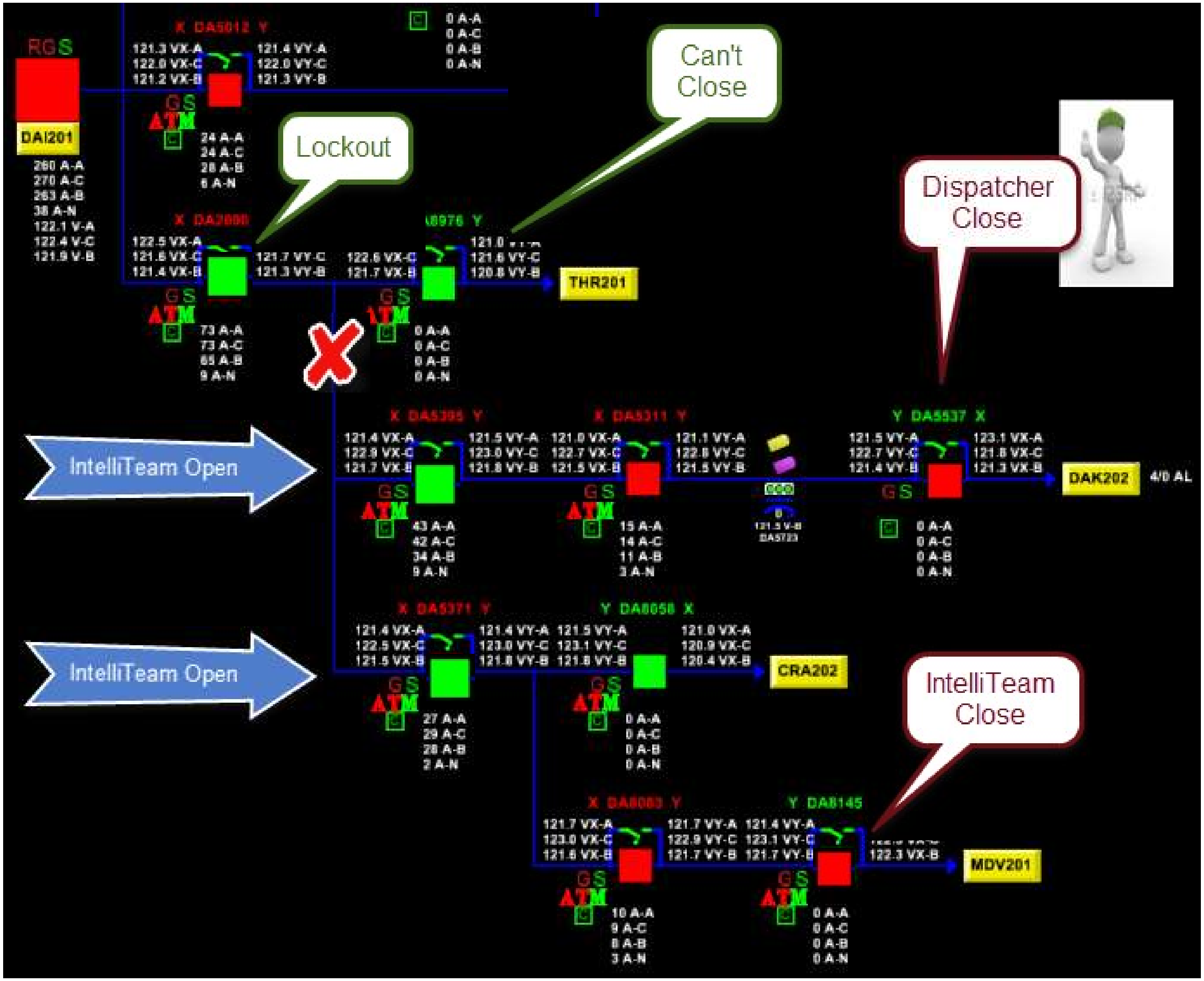
APPLICATIONS ASSESSMENT OF PULSE CLOSING TECHNOLOGY

A Joint Project of the Electric Power Research Institute and Hydro-Quebec

Let Through Energy (LTE)

- Measure of stresses on electric assets
  - Conductors, splices, jumpers, transformers, protective devices
- Energy (joules) = $I^2 \times R \times t$
- LTE (amps squared seconds) = $I^2 \times t$
- Which fault has higher LTE?
  - 2,500 amps for 25 cycles
  - 3,500 amps for 12 cycles

Service Restored – unfaulted sections



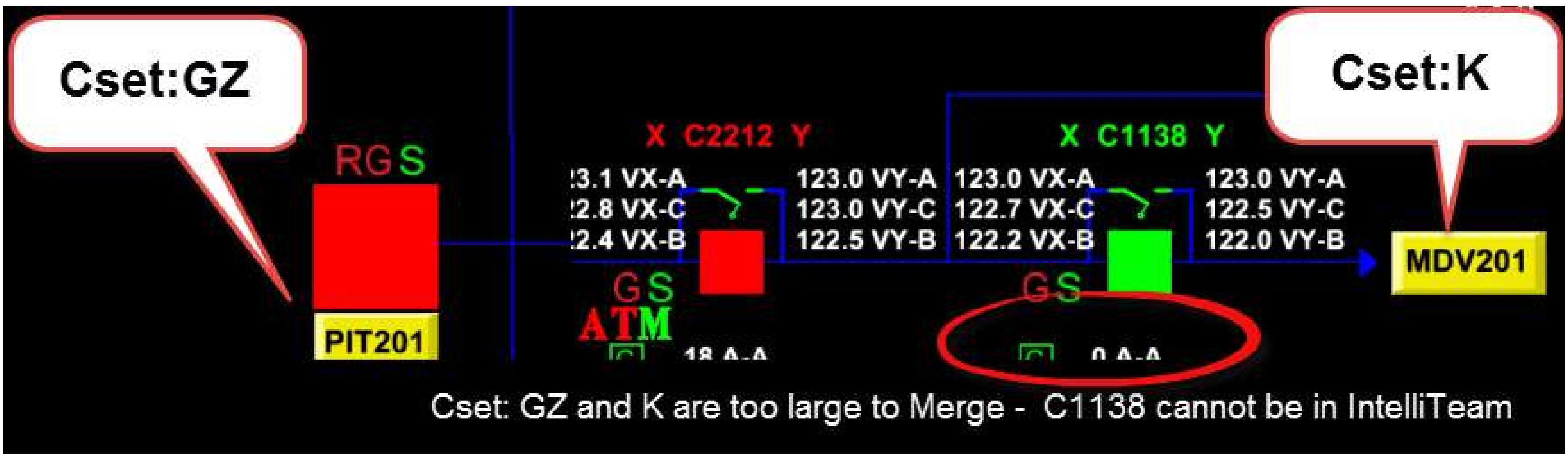
Devices not in automatic restoration model

- Restoration model has limitations on the number of devices included in one model.

- This necessitates that system is broken into different restoration groups.

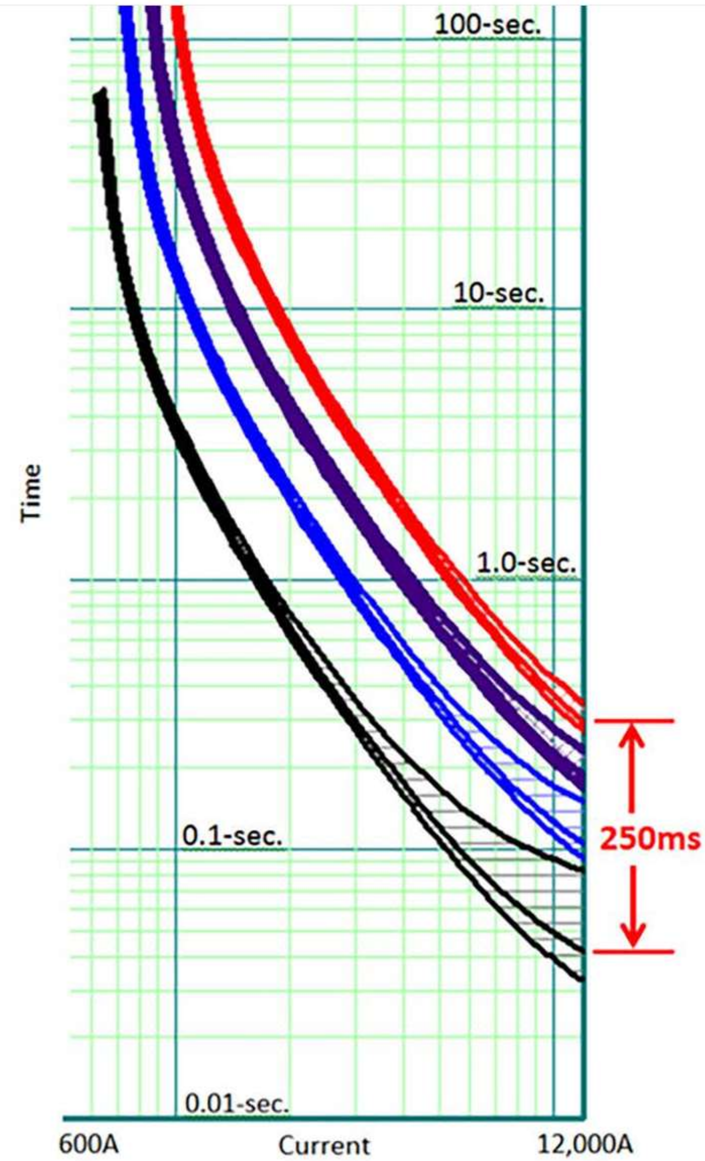
Devices not in automatic restoration model

- TIE that merges two restoration models.
  - Exceeds 128 limit

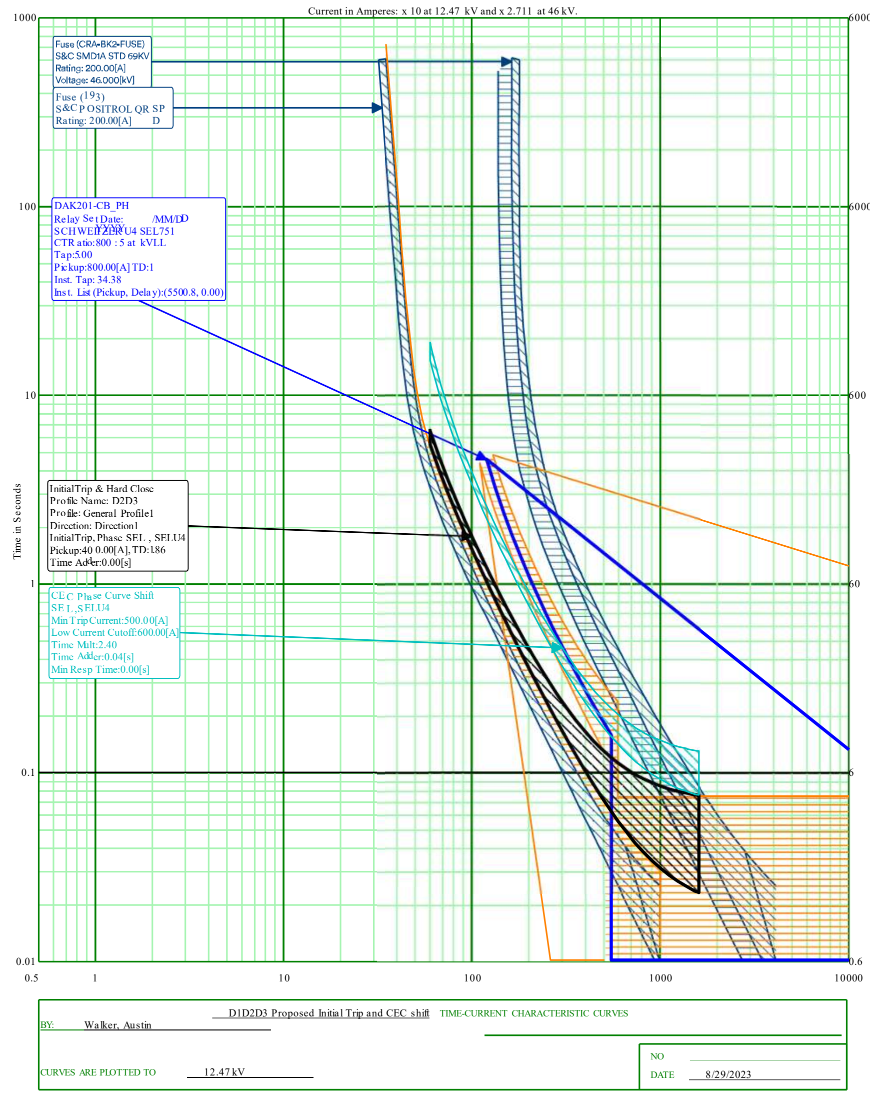


Coordination

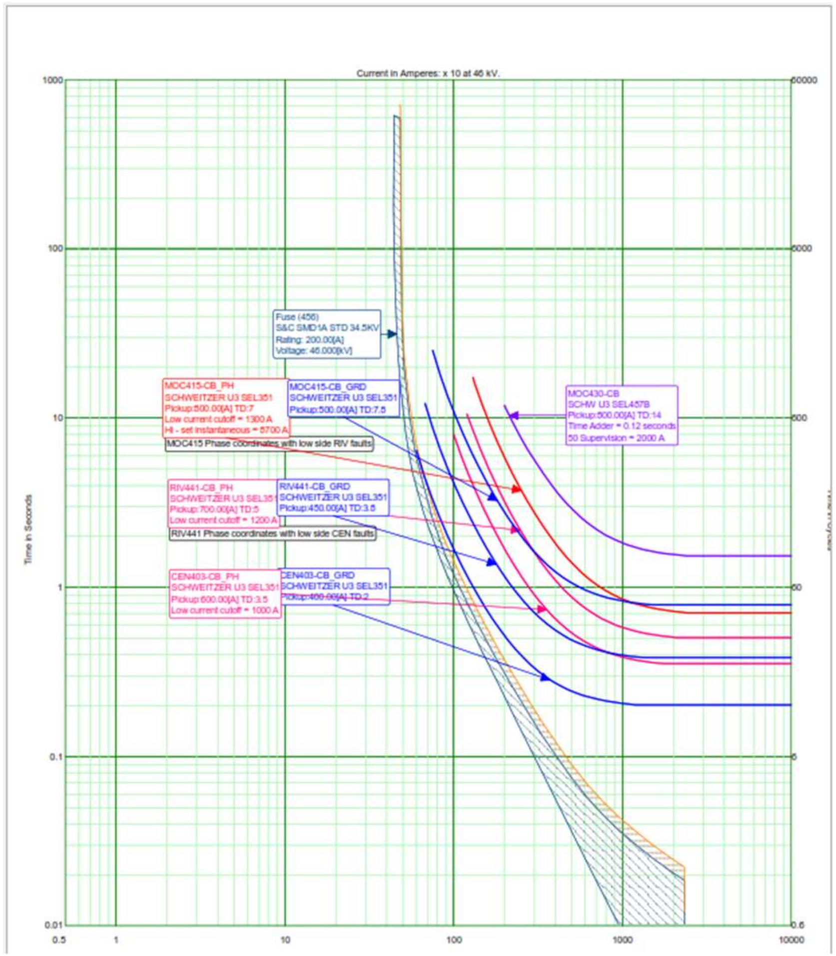
- Utilize tolerance performance bands to coordinate devices instead of CTI
- Consider fixed-time error, clearing time, overtravel (EM), etc.



Outdoor Station 12 kV Coordination

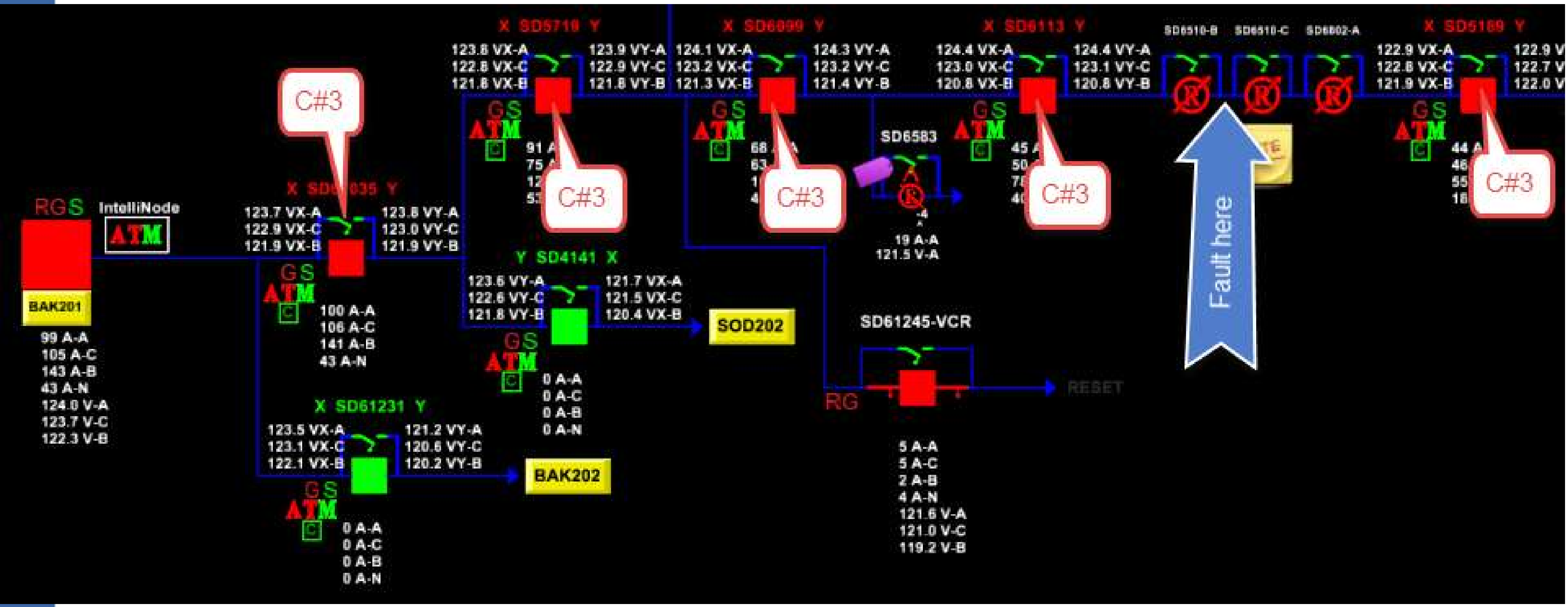


46 kV coordination

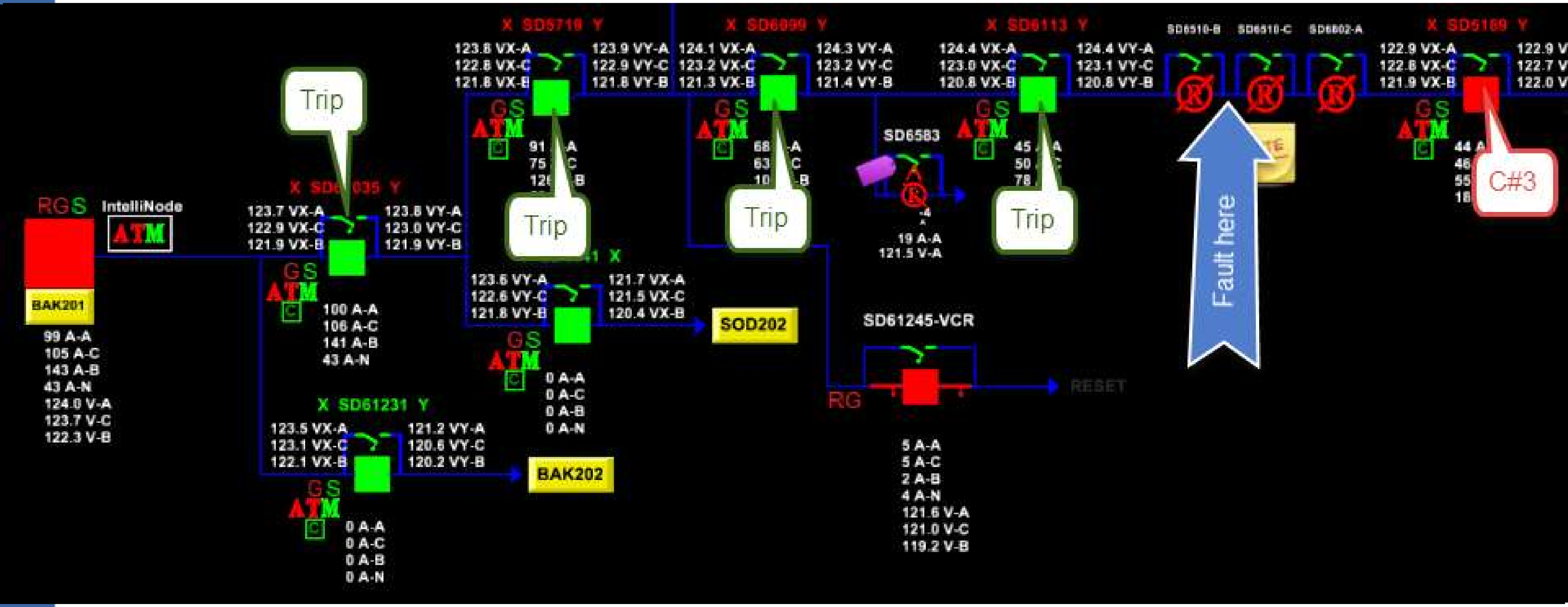


Mis-Coordination Problem

- Wrong device(s) trips



Mis-Coordination Example (animation)

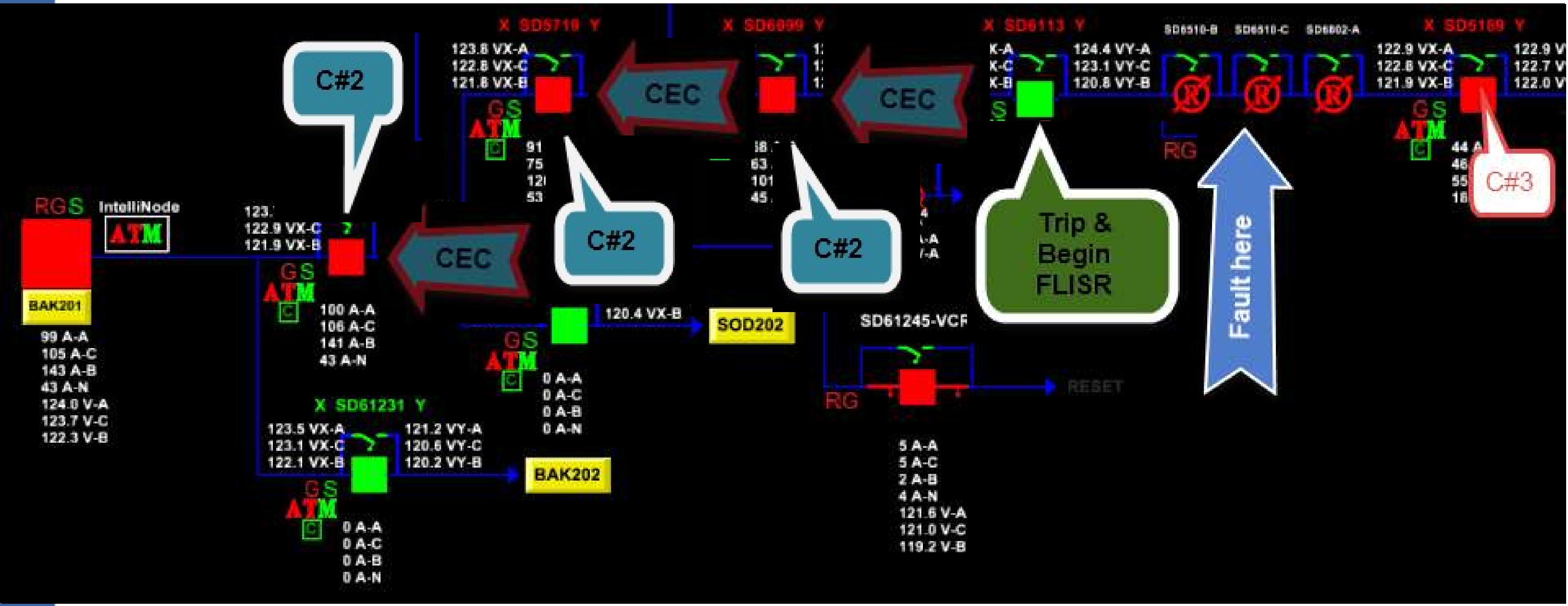


Mis-Coordination
How CEC can solve this problem

recloser detects fault

- Send CEC shift message to source recloser
- If CEC message is received, shift to a slower curve
- If no CEC message AND fault is present, then this device is closest to the fault
  - Trip on normal TCC curve

Mis-Coordination
How CEC can solve this problem



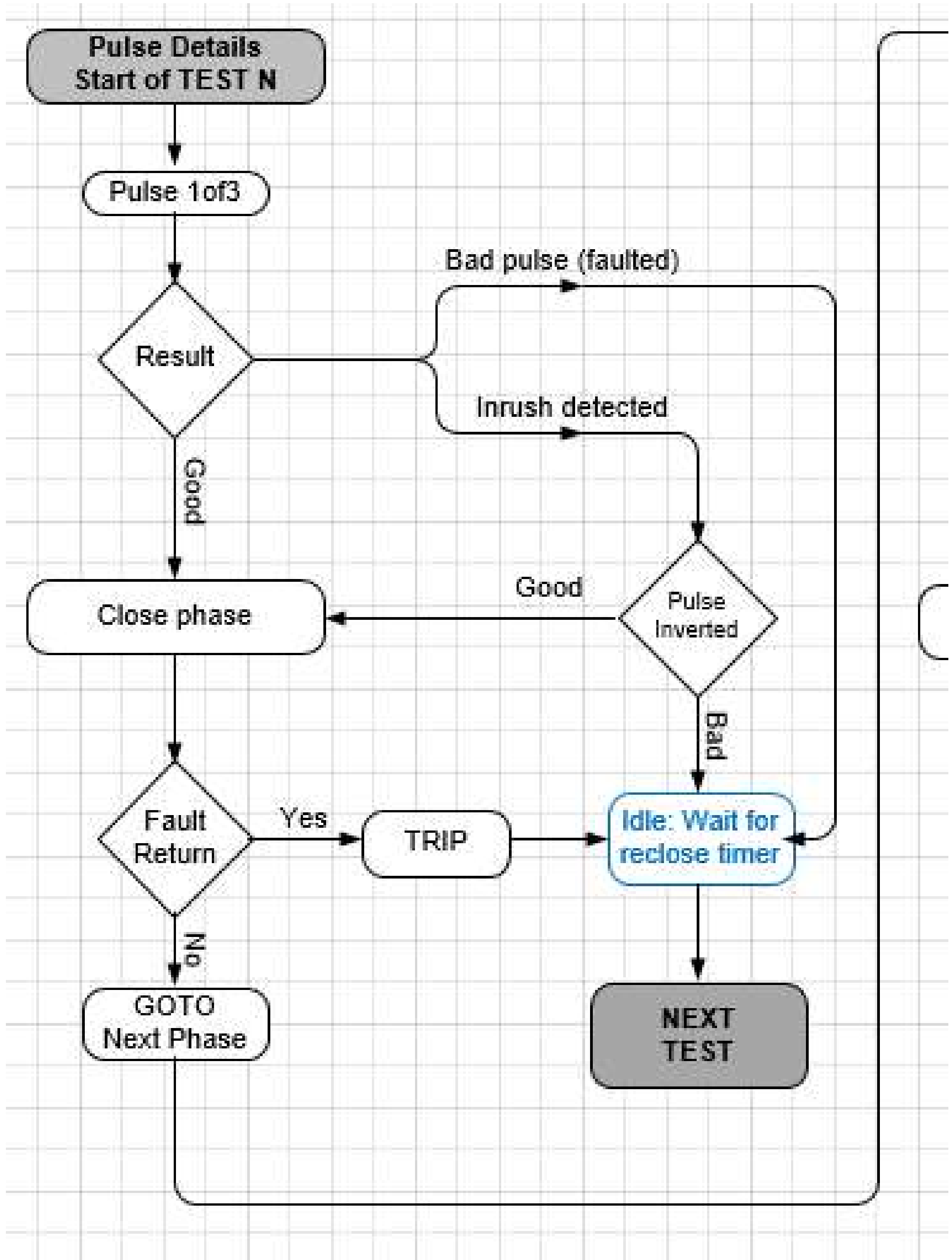
Common Fault Type

- Permanent
- Momentary – device trips (transient fault)
  - Typical transient causes
    - Conductor slap
    - Animal contact
    - Tree falls clear
    - Vegetation contact
- Returning faults
  - Conductor slap
  - unknown

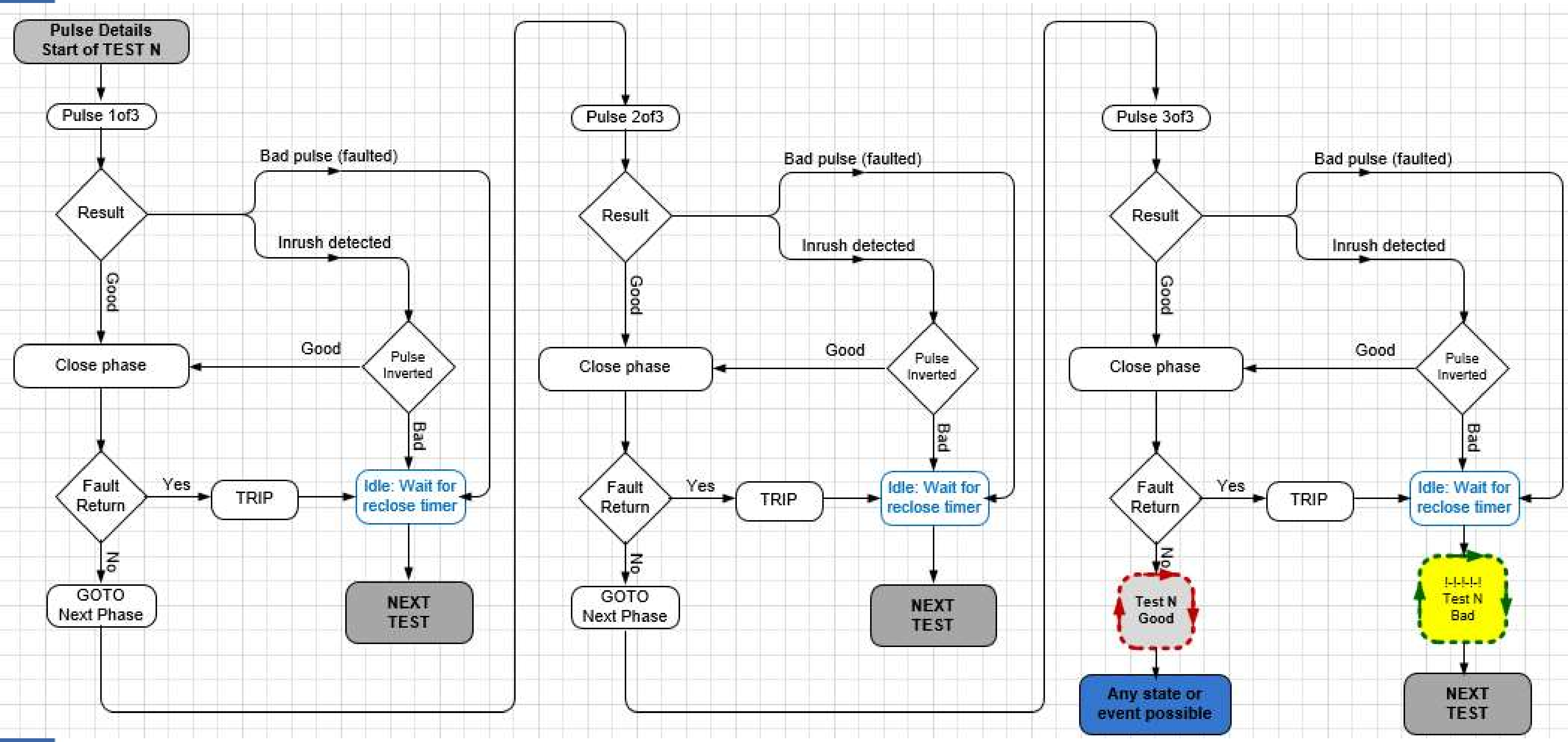
Recloser test configurations

- Hard Close (no pulse)
- Pulse Test – no fault detected
- Pulse Test – fault detected
- Pulse Inrush Test – (inverse pulse)
- Pulse Analysis Sequence – flow diagram
- Pulses reveal line conditions

Flow Diagram: one phase pulse



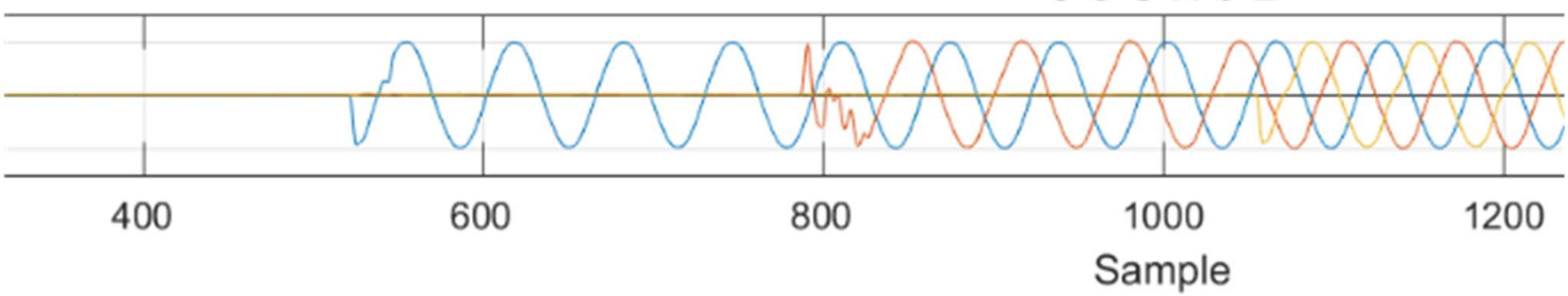
Pulse Analysis Sequence Flow Diagram



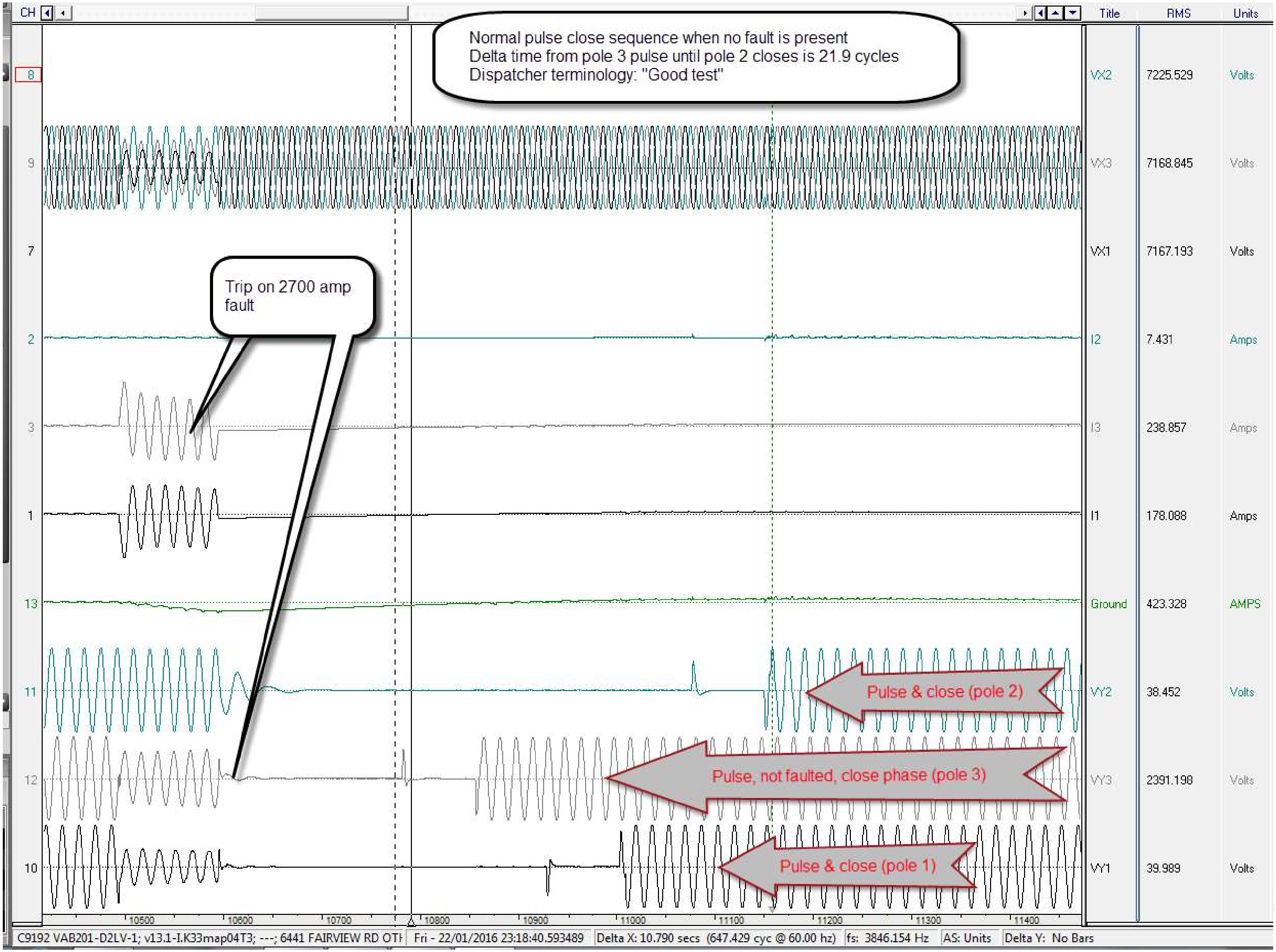
Traditional CLOSE: Conventional Circuit Breaker (CB)

Needs a way to mimic CB

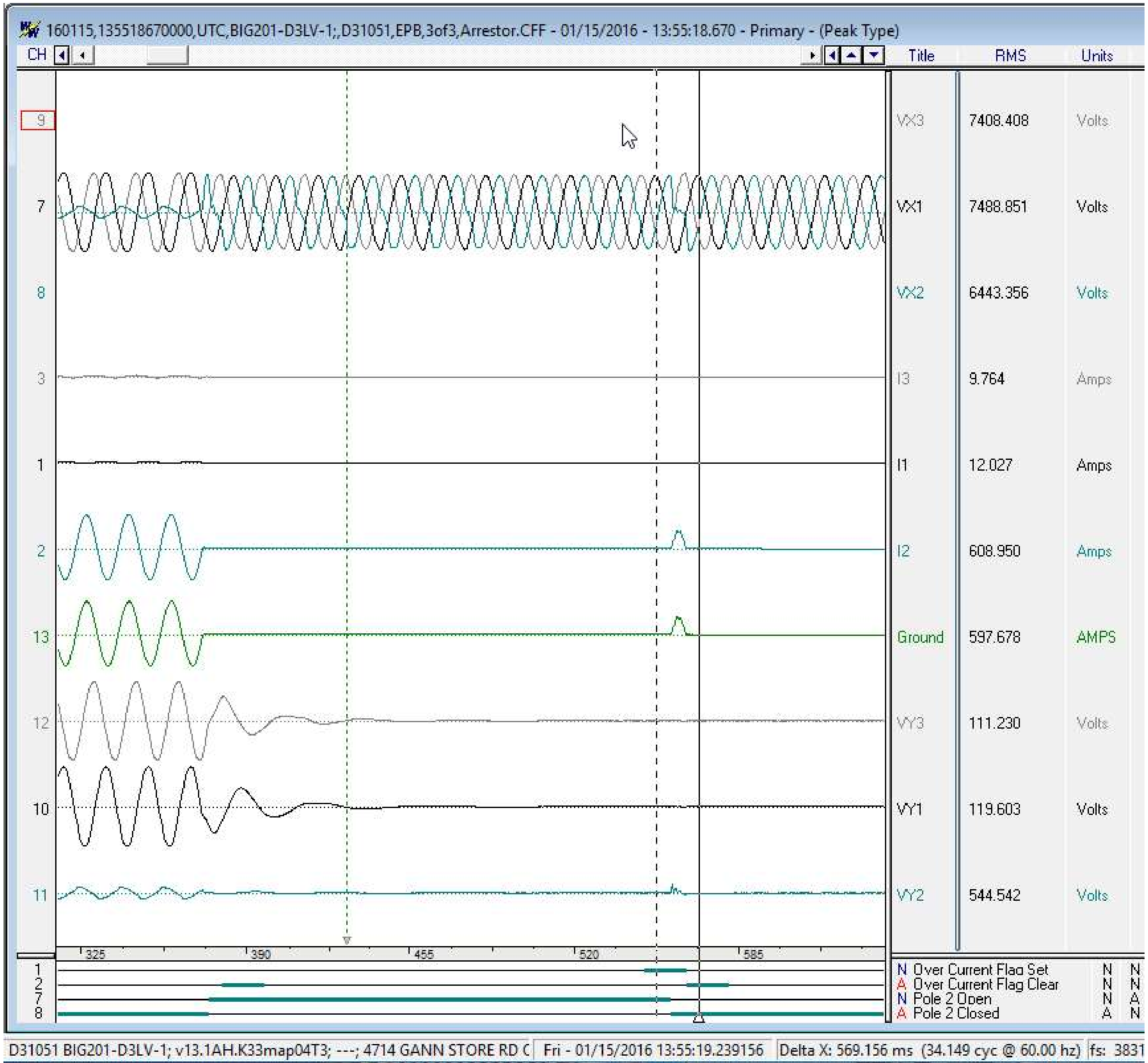
12 kV recloser ("Hard Close" = no pulse)



Pulse Testing – no fault detected

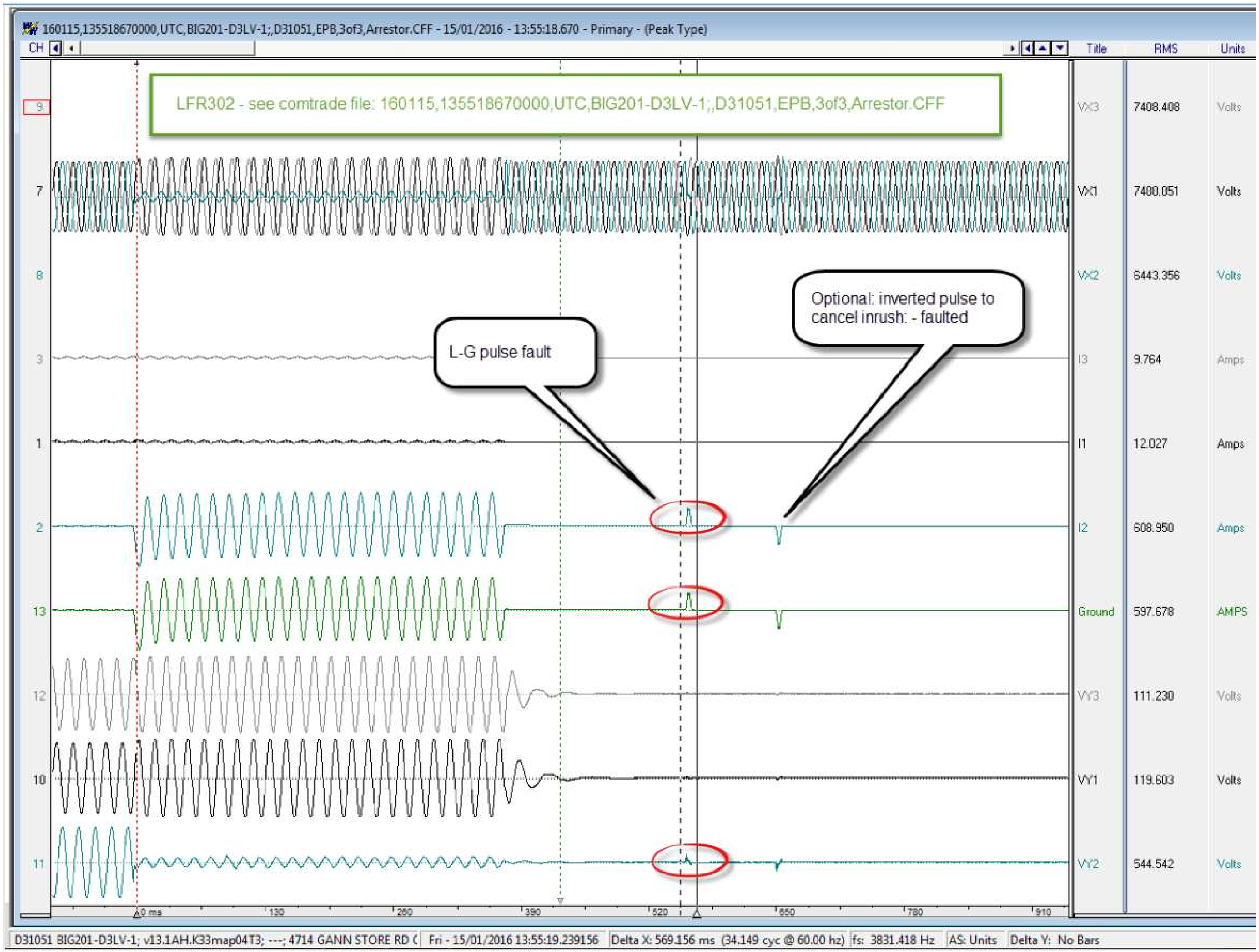


Pulse test: L-G fault detected

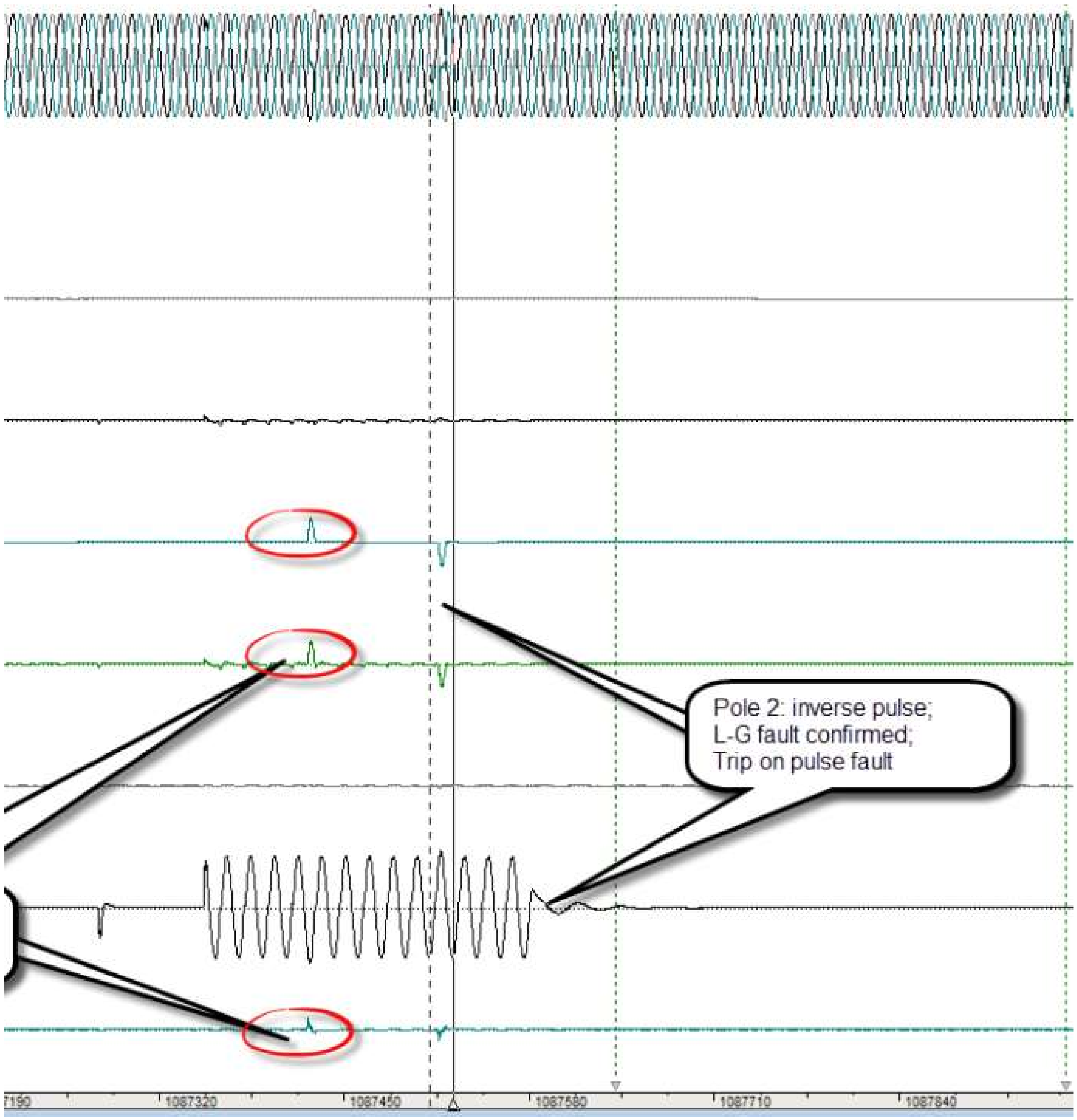


Pulse test: L-L detected

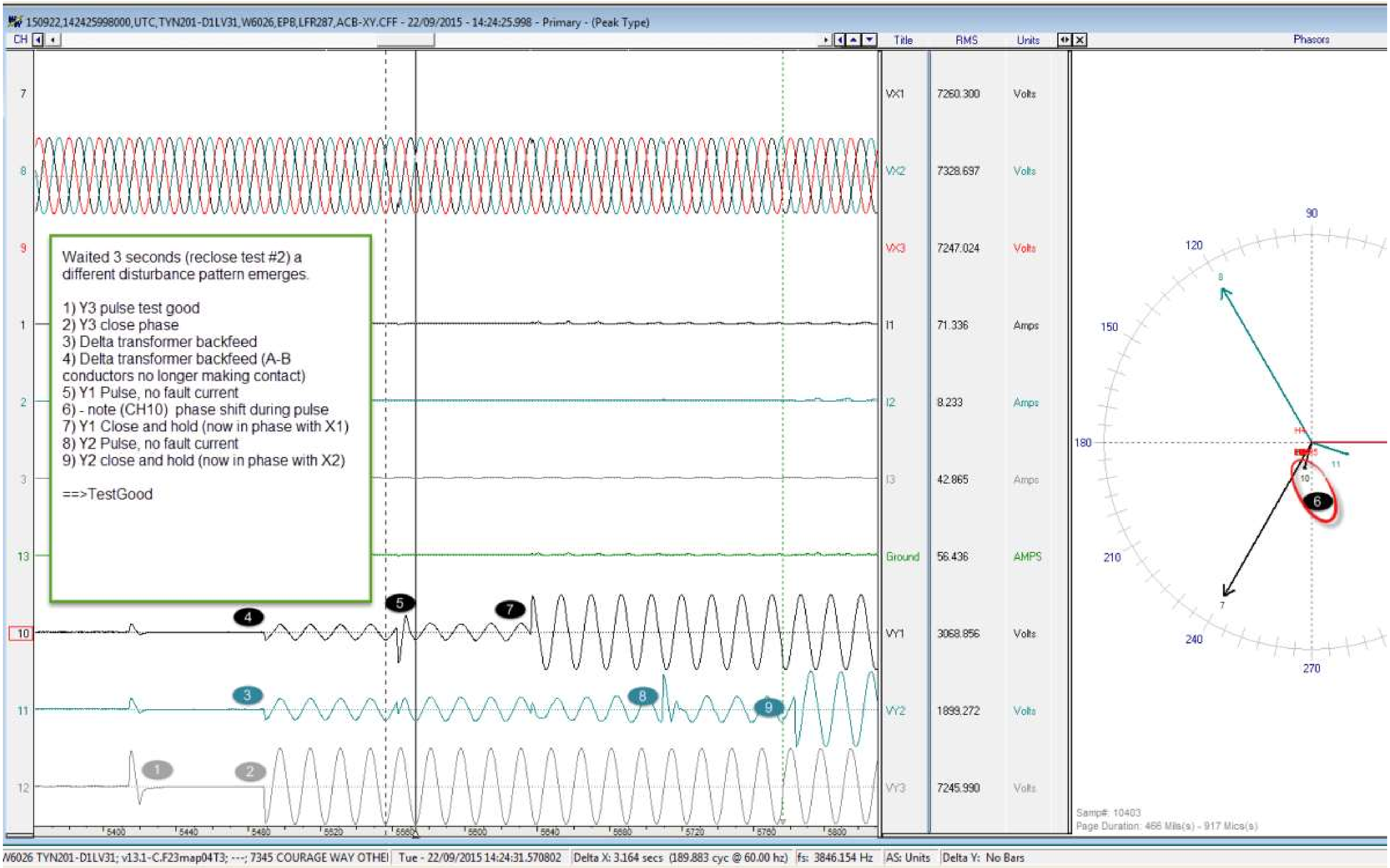
L-G Fault: Reclose#1 Inverted Pulse



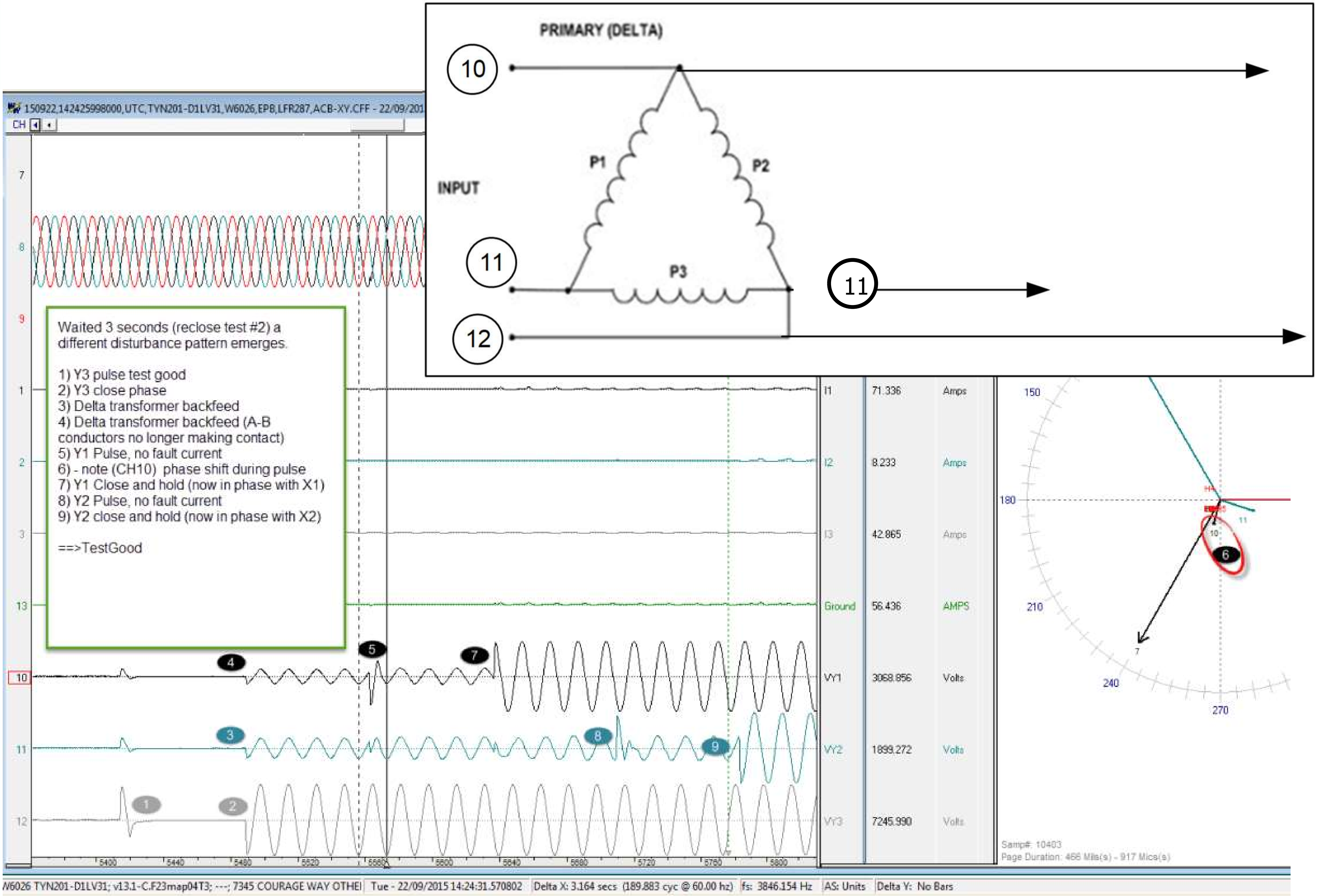
First phase: No Fault – Phase 2: L-G "Implies" the fault moved



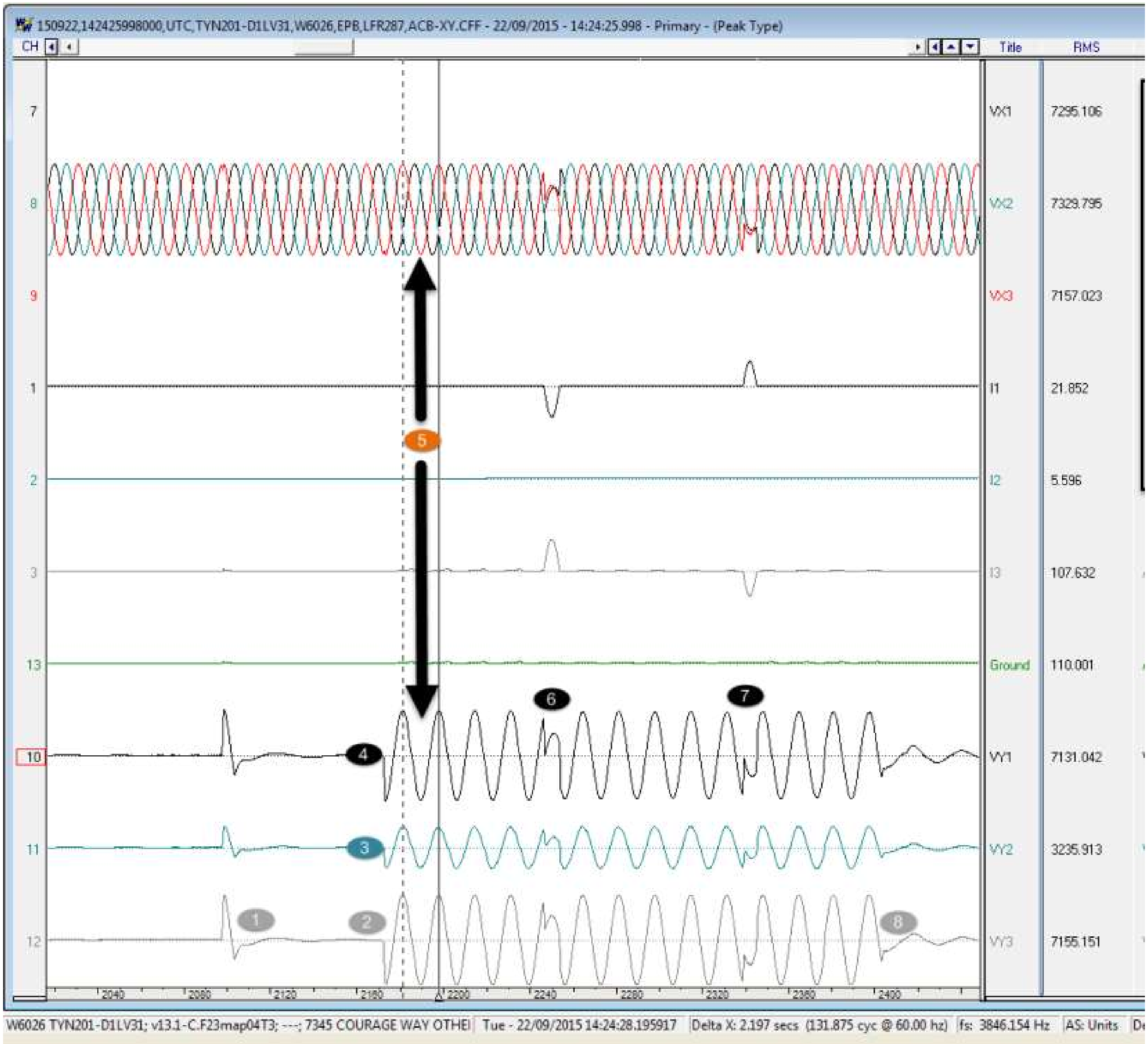
The Two-Phase Case



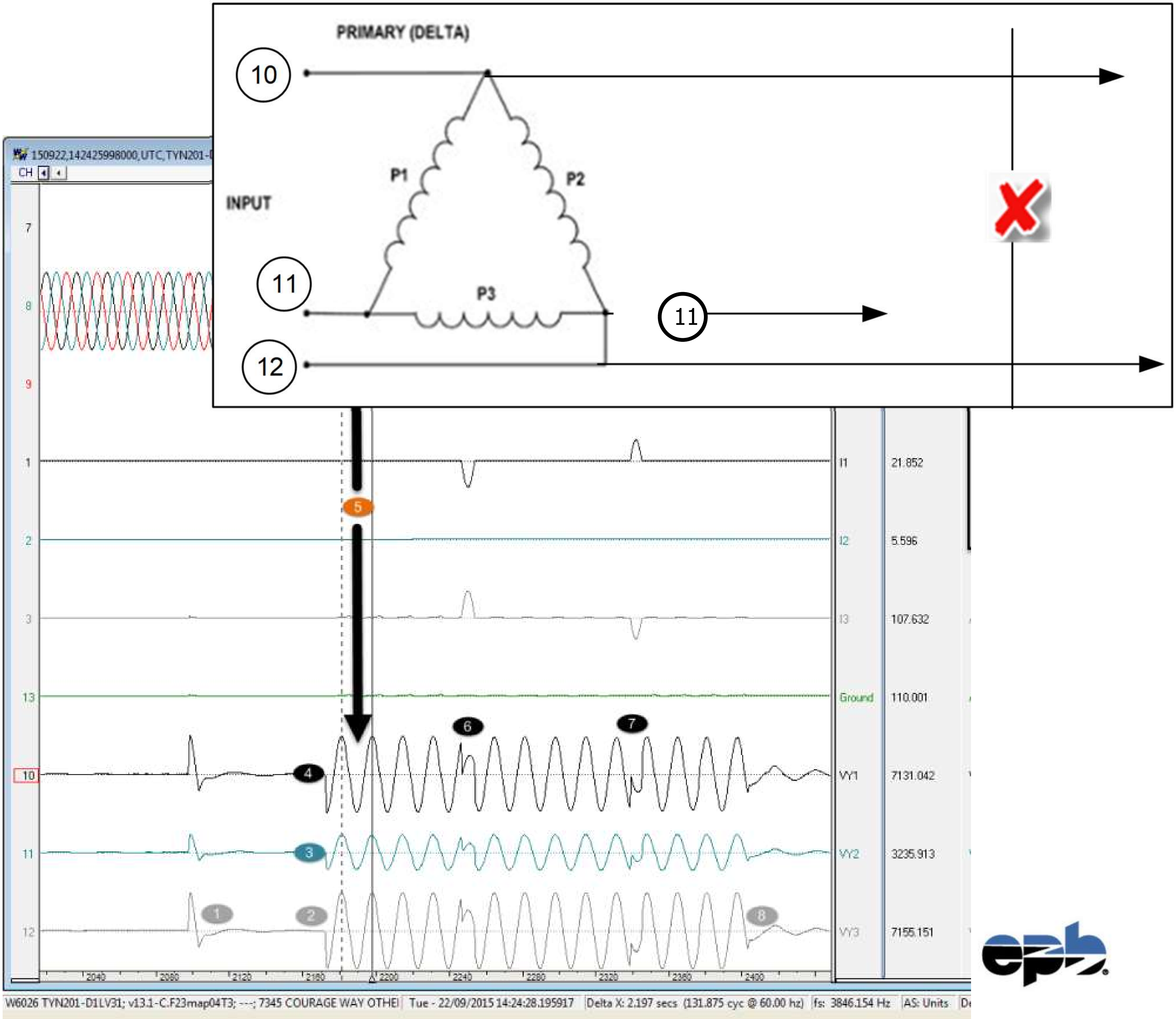
No Fault but Delta Response



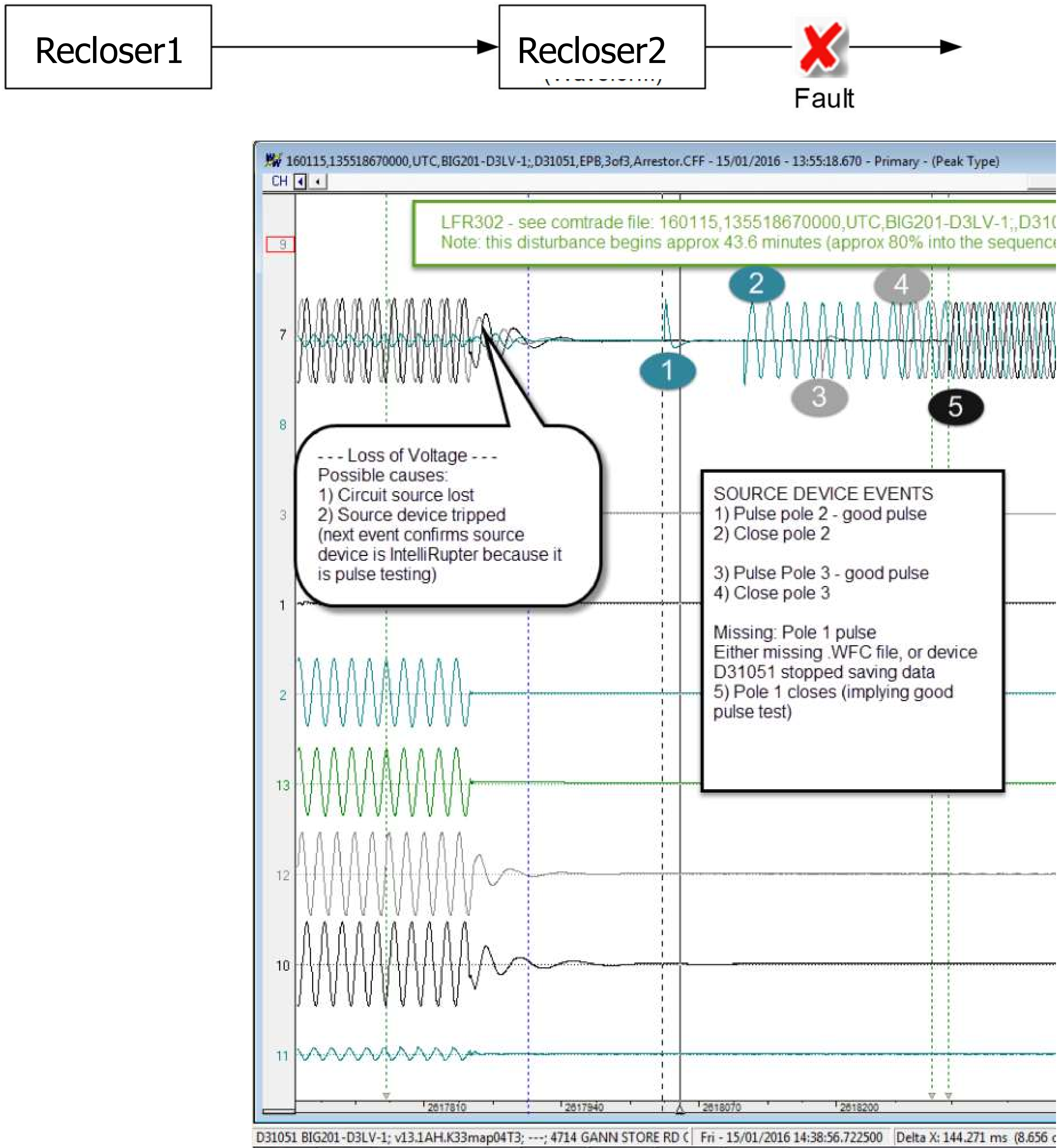
1 pulse but 3 responses



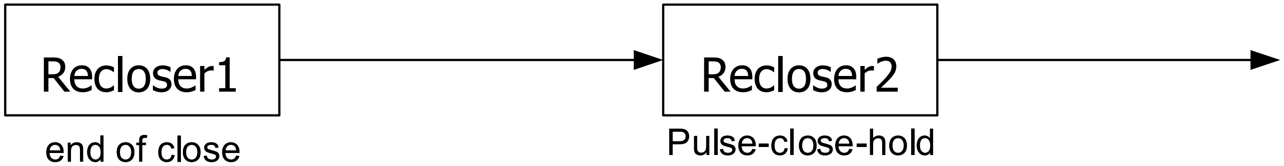
1 pulse but 3 responses

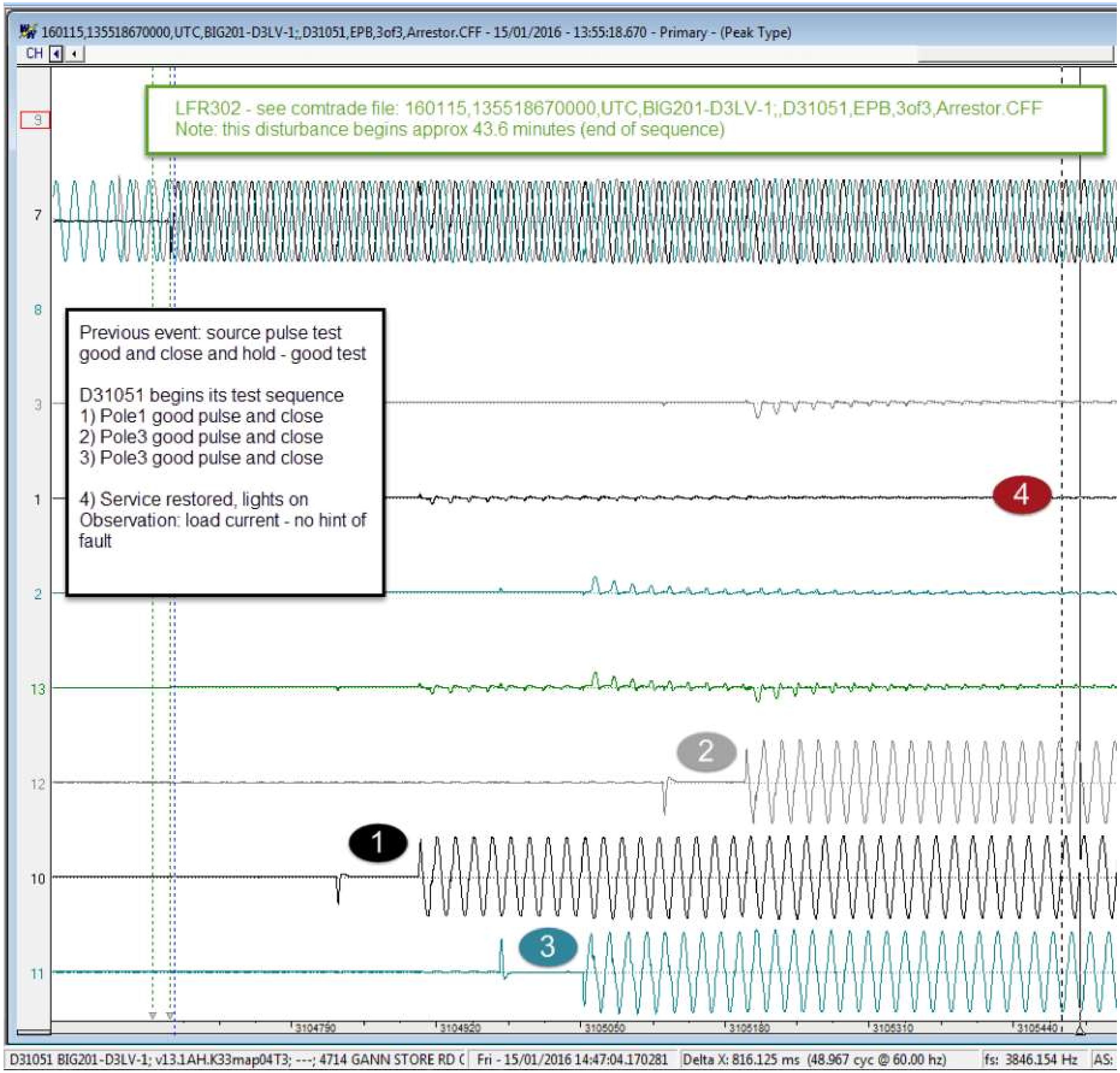


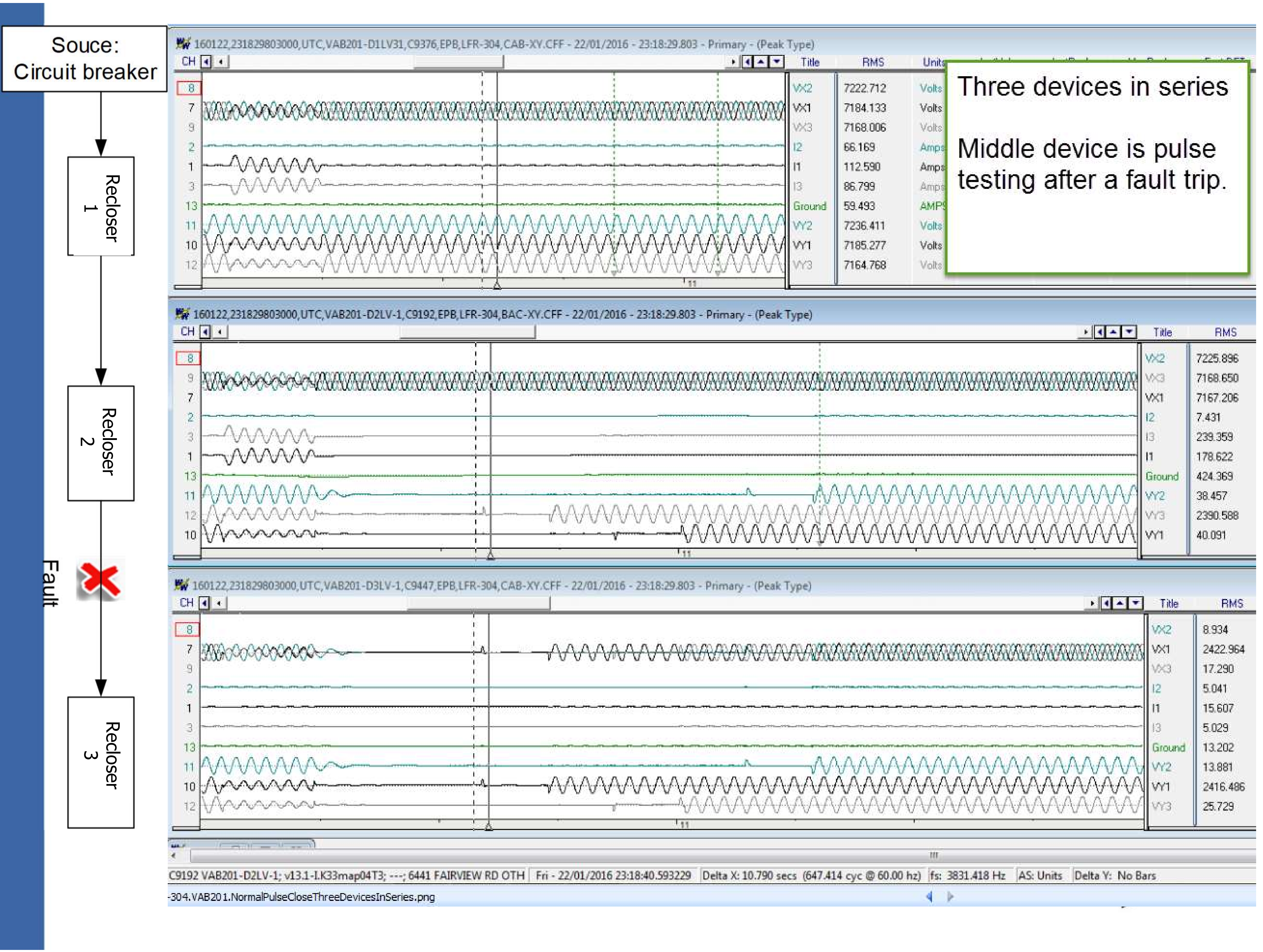
Two Devices in series MisCord TBC#1 trip / pulse and close



Source Return
Successful Pulse-Close



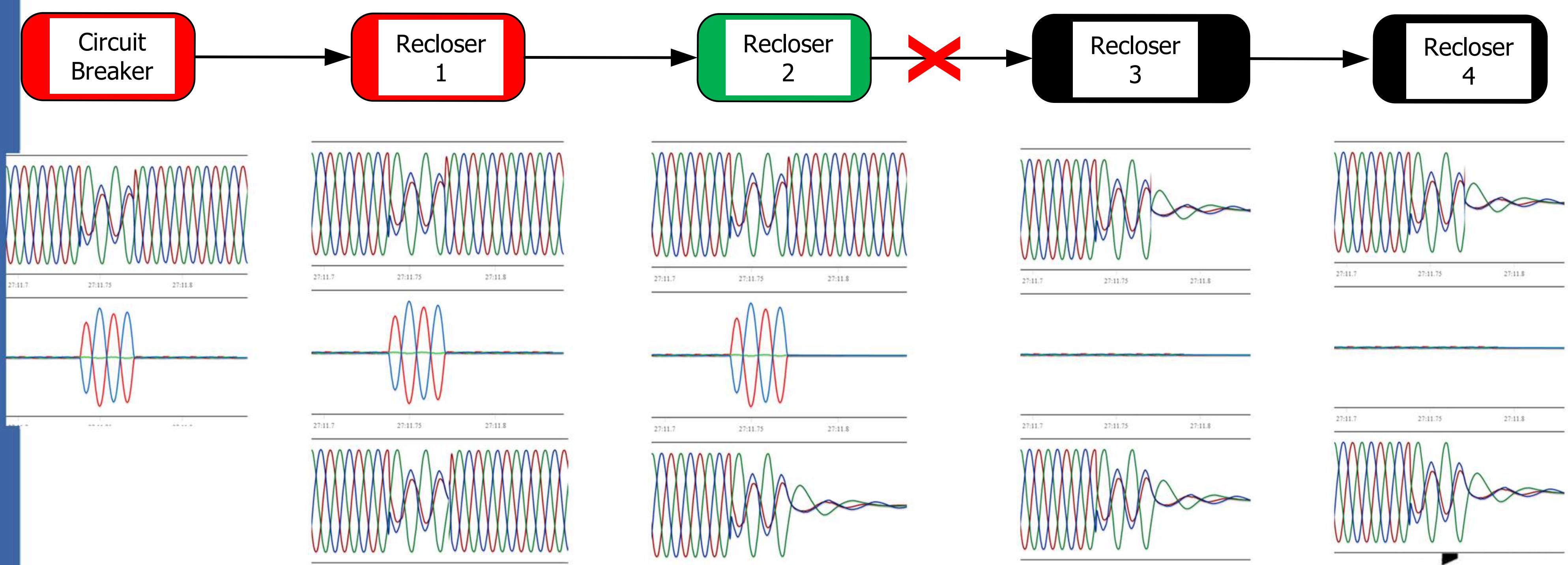




Souce: Circuit breaker
Recloser 1
Recloser 2
Fault
Recloser 3
Three devices in series
Middle device is pulse testing after a fault trip.
160122,231829803000,UTC,VAB201-D1LV31,C9376,EPB,LFR-304,CAB-XY.CFF - 22/01/2016 - 23:18:29.803 - Primary - (Peak Type)
160122,231829803000,UTC,VAB201-D2LV-1,C9192,EPB,LFR-304,BAC-XY.CFF - 22/01/2016 - 23:18:29.803 - Primary - (Peak Type)
160122,231829803000,UTC,VAB201-D3LV-1,C9447,EPB,LFR-304,CAB-XY.CFF - 22/01/2016 - 23:18:29.803 - Primary - (Peak Type)
C9192 VAB201-D2LV-1; v13.1-I.K33map04T3; ---; 6441 FAIRVIEW RD OTH
Fri - 22/01/2016 23:18:40.593229
Delta X: 10.790 secs (647.414 cyc @ 60.00 hz)
fs: 3831.418 Hz
AS: Units
Delta Y: No Bars
-304.VAB201.NormalPulseCloseThreeDevicesInSeries.png

L-L Fault on Main Line

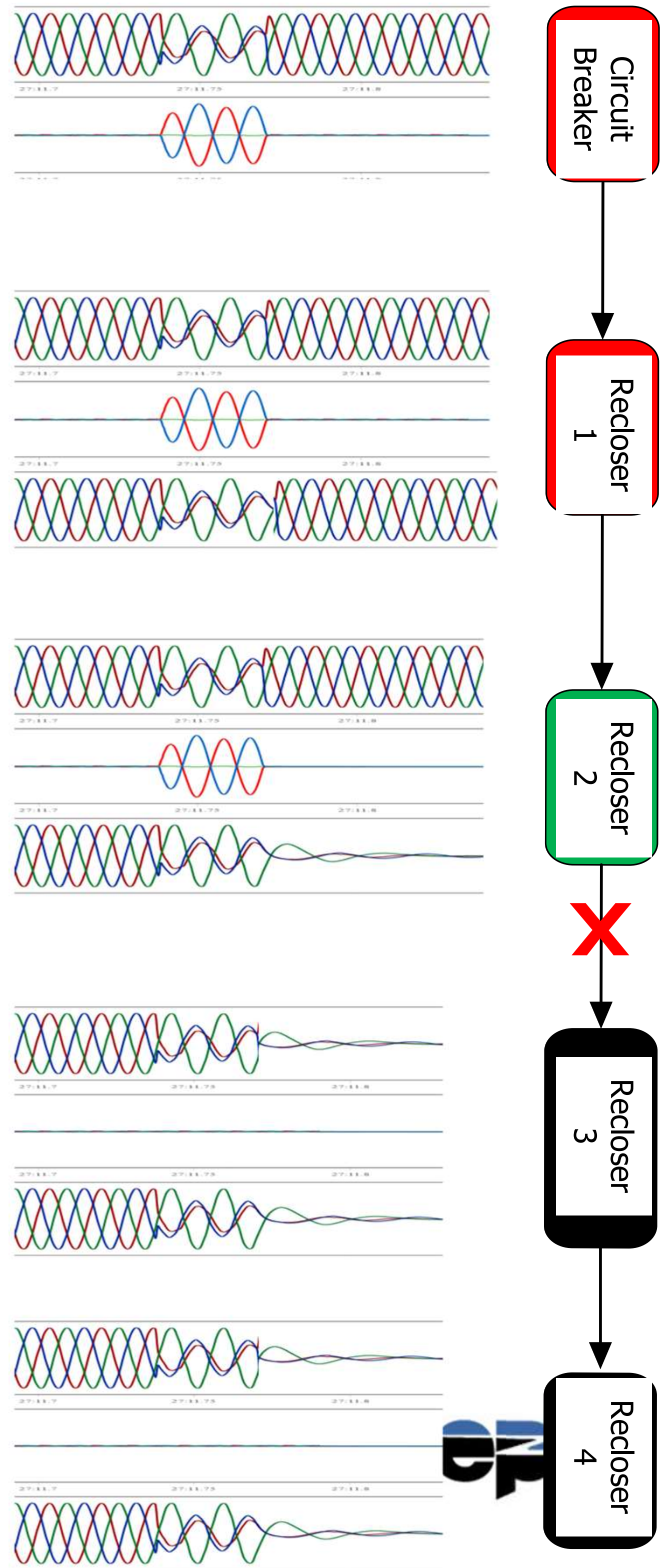
- Dev#3 (green line recloser) clears fault
- 4 distinct waveform patterns captured by 5 devices
- Difficult to align time in your mind



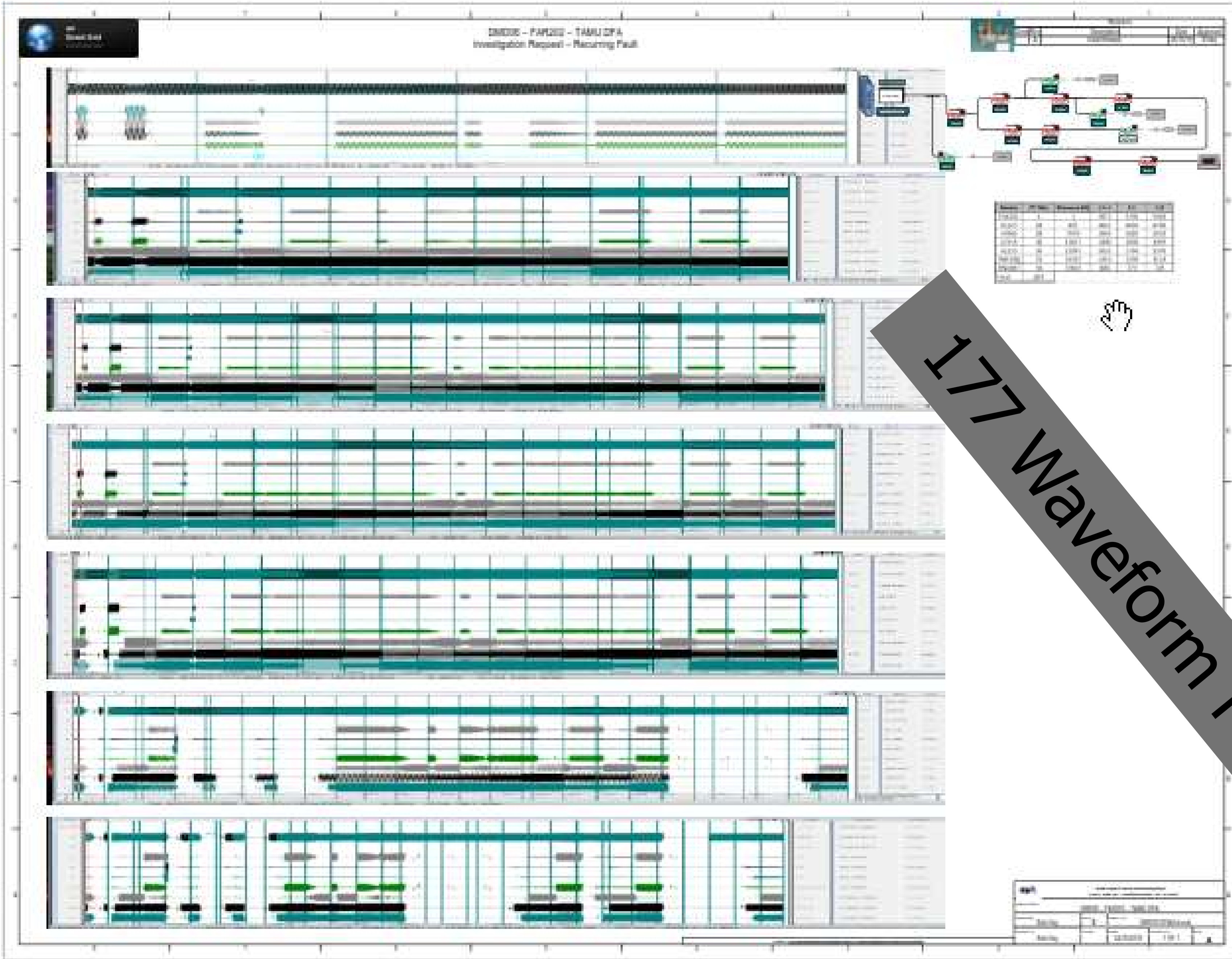
Same L-L Fault, Simple Case

Aggregation Benefits

- common time line
- sensors in "AFC" descending order
- easy to see time gaps
- see in seconds what many sensors recorded, this example
  - 27 voltage sensors
  - 15 current sensors
  - 5 comtrade files



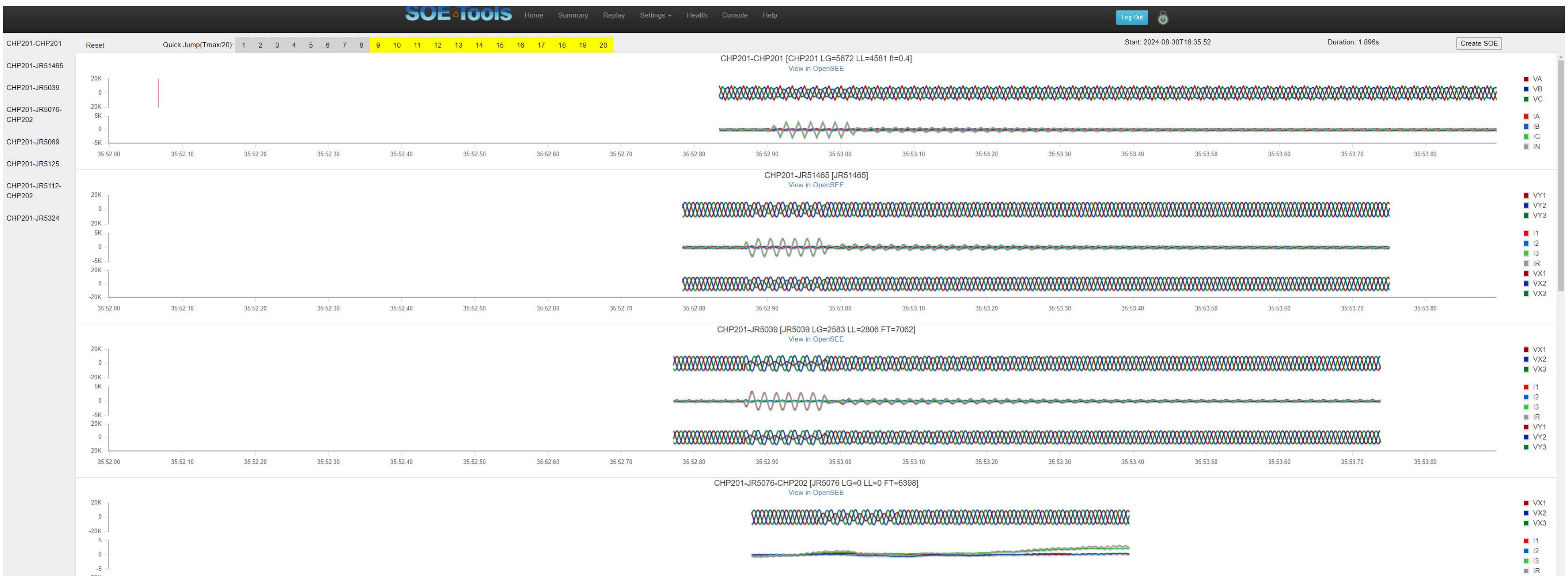
Old Problem: Labor = 5 hours



177 Waveform FILES

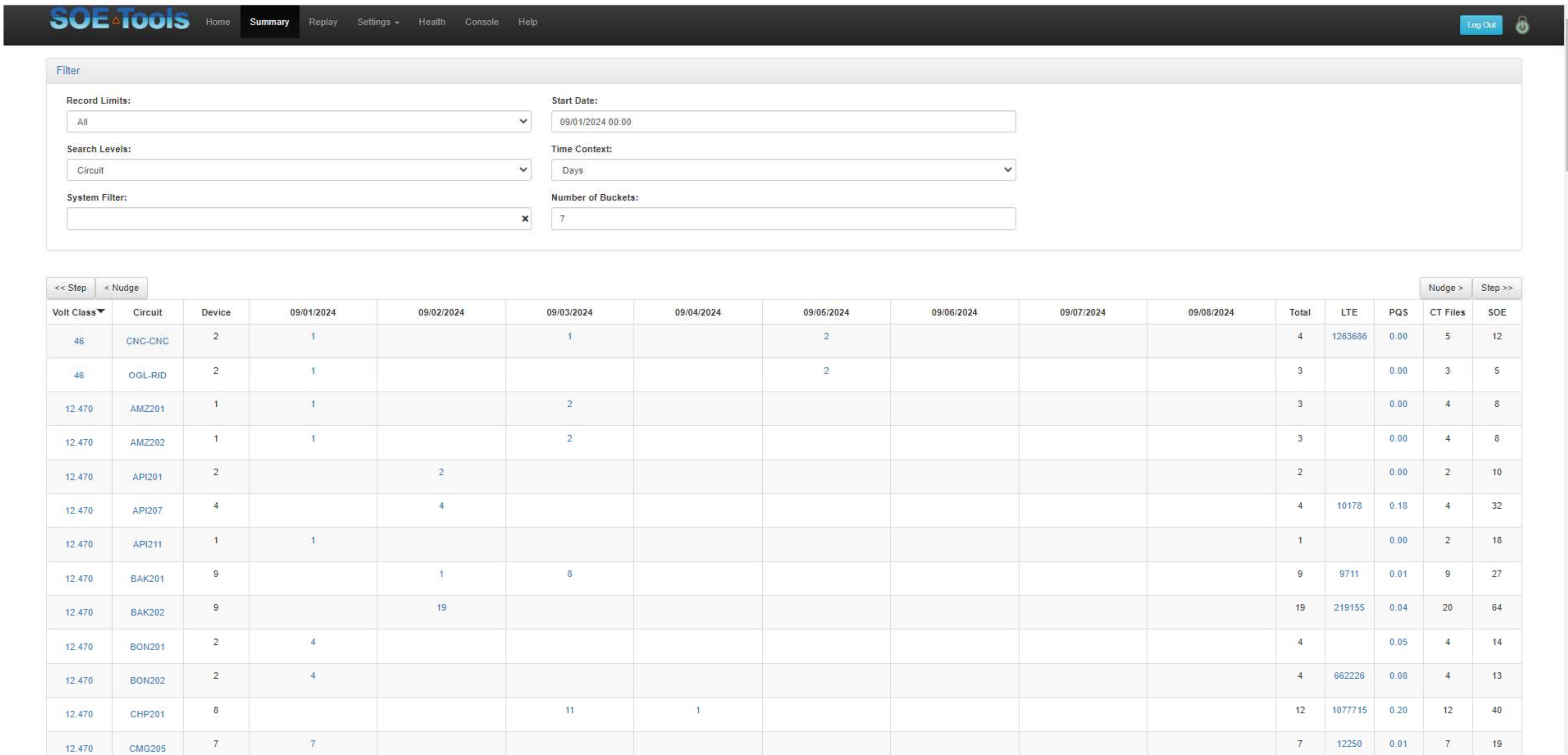
Tools - Grid Protection Alliance

- Includes oscillography from substation breakers and line reclosers.



Tools - Grid Protection Alliance

- Overview of oscillography available throughout a time range.


SOE Tools
Home
Summary
Replay
Settings
Health
Console
Help
Log Out

Filter

Record Limits: All

Start Date: 09/01/2024 00:00

Search Levels: Circuit

Time Context: Days

System Filter:

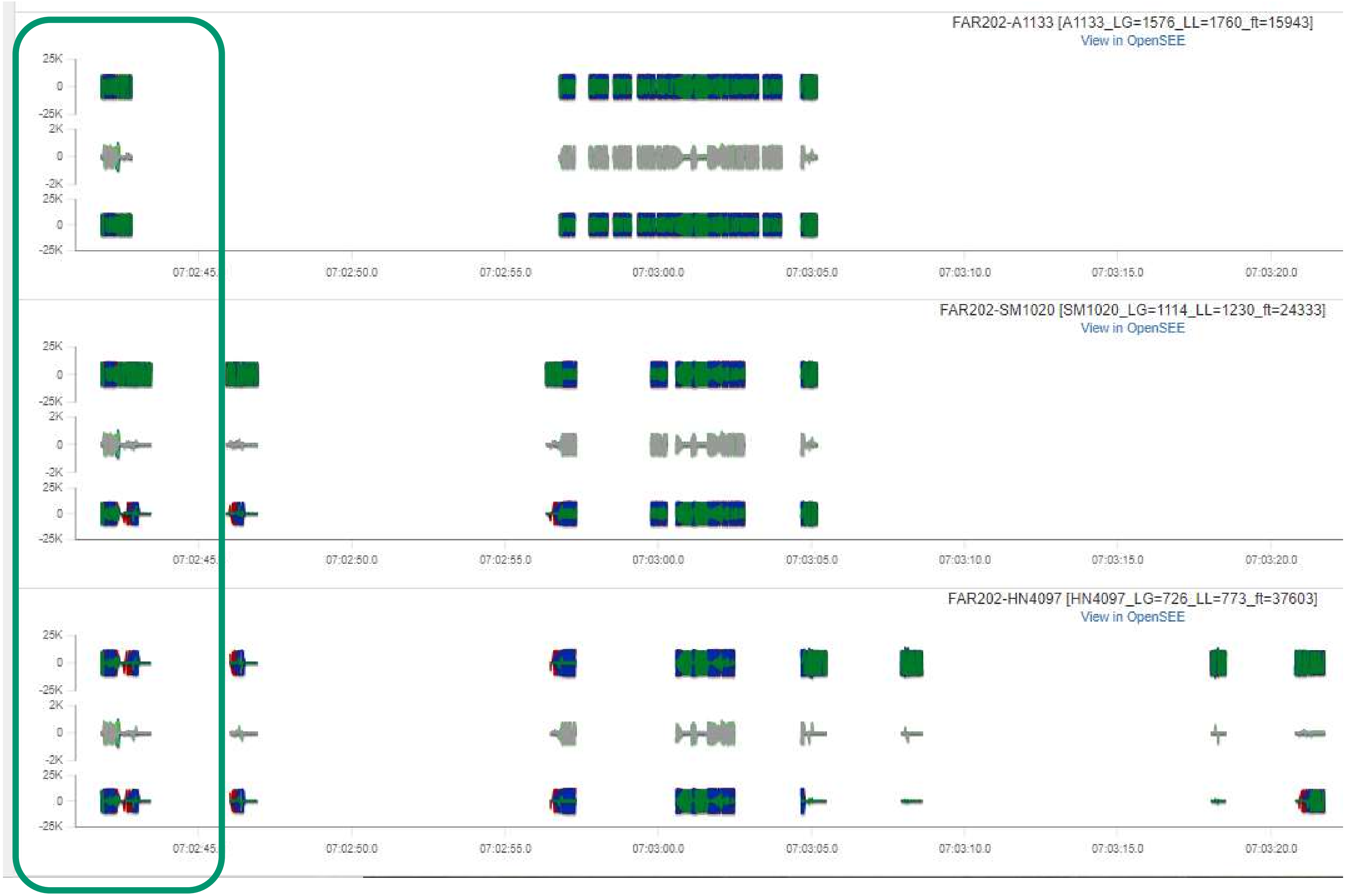
Number of Buckets: 7

<< Step | < Nudge | Nudge > | Step >>

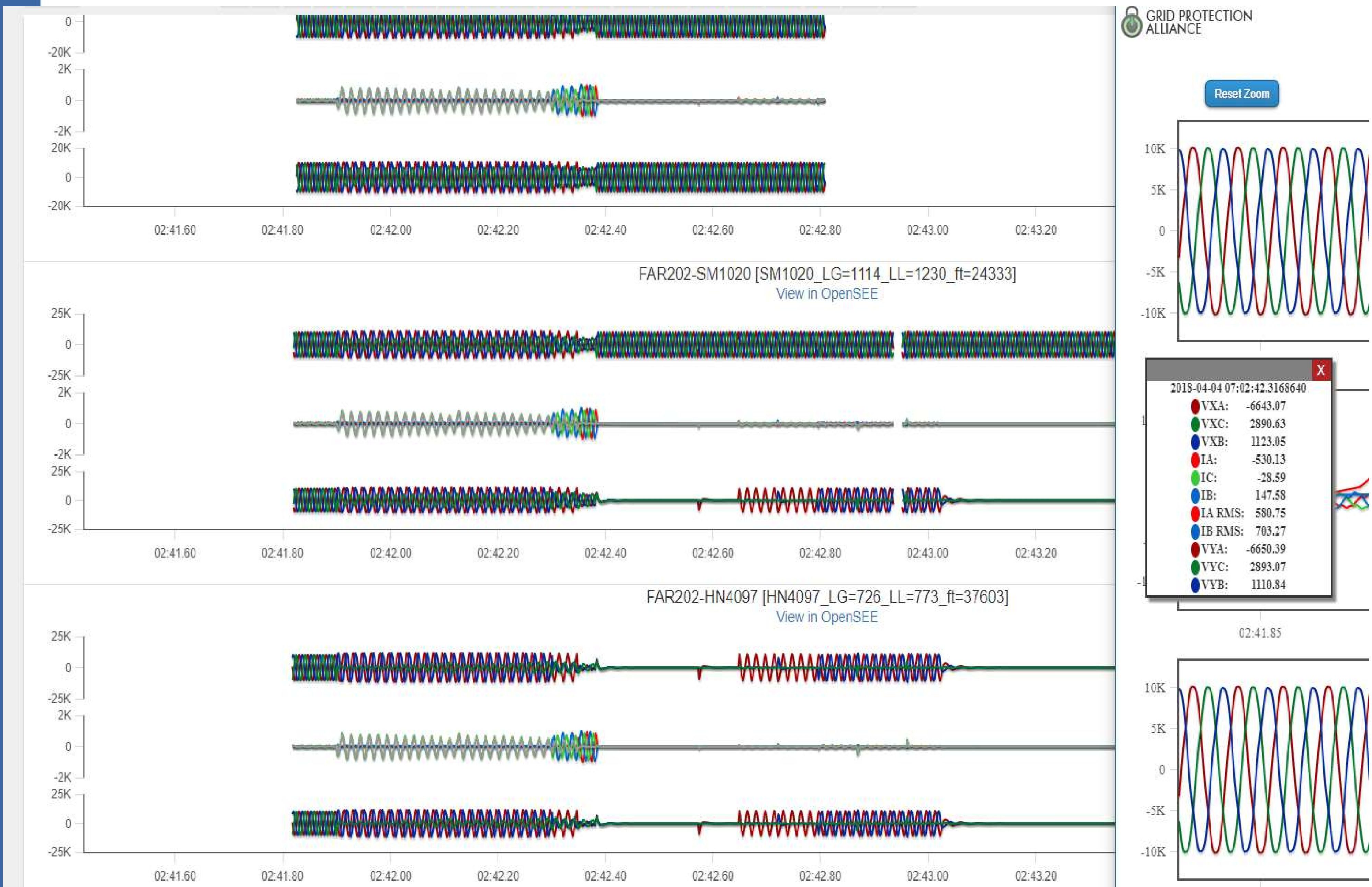
Volt Class	Circuit	Device	09/01/2024	09/02/2024	09/03/2024	09/04/2024	09/05/2024	09/06/2024	09/07/2024	09/08/2024	Total	LTE	PQS	CT Files	SOE
46	CNC-CNC	2	1		1		2				4	1263686	0.00	5	12
46	OGL-RID	2	1				2				3		0.00	3	5
12.470	AMZ201	1	1		2						3		0.00	4	8
12.470	AMZ202	1	1		2						3		0.00	4	8
12.470	API201	2		2							2		0.00	2	10
12.470	API207	4		4							4	10178	0.18	4	32
12.470	API211	1	1								1		0.00	2	18
12.470	BAK201	9		1	8						9	9711	0.01	9	27
12.470	BAK202	9		19							19	219155	0.04	20	64
12.470	BON201	2	4								4		0.05	4	14
12.470	BON202	2	4								4	662226	0.08	4	13
12.470	CHP201	8			11	1					12	1077715	0.20	12	40
12.470	CMG205	7	7								7	12250	0.01	7	19

Easier to visualize SOE

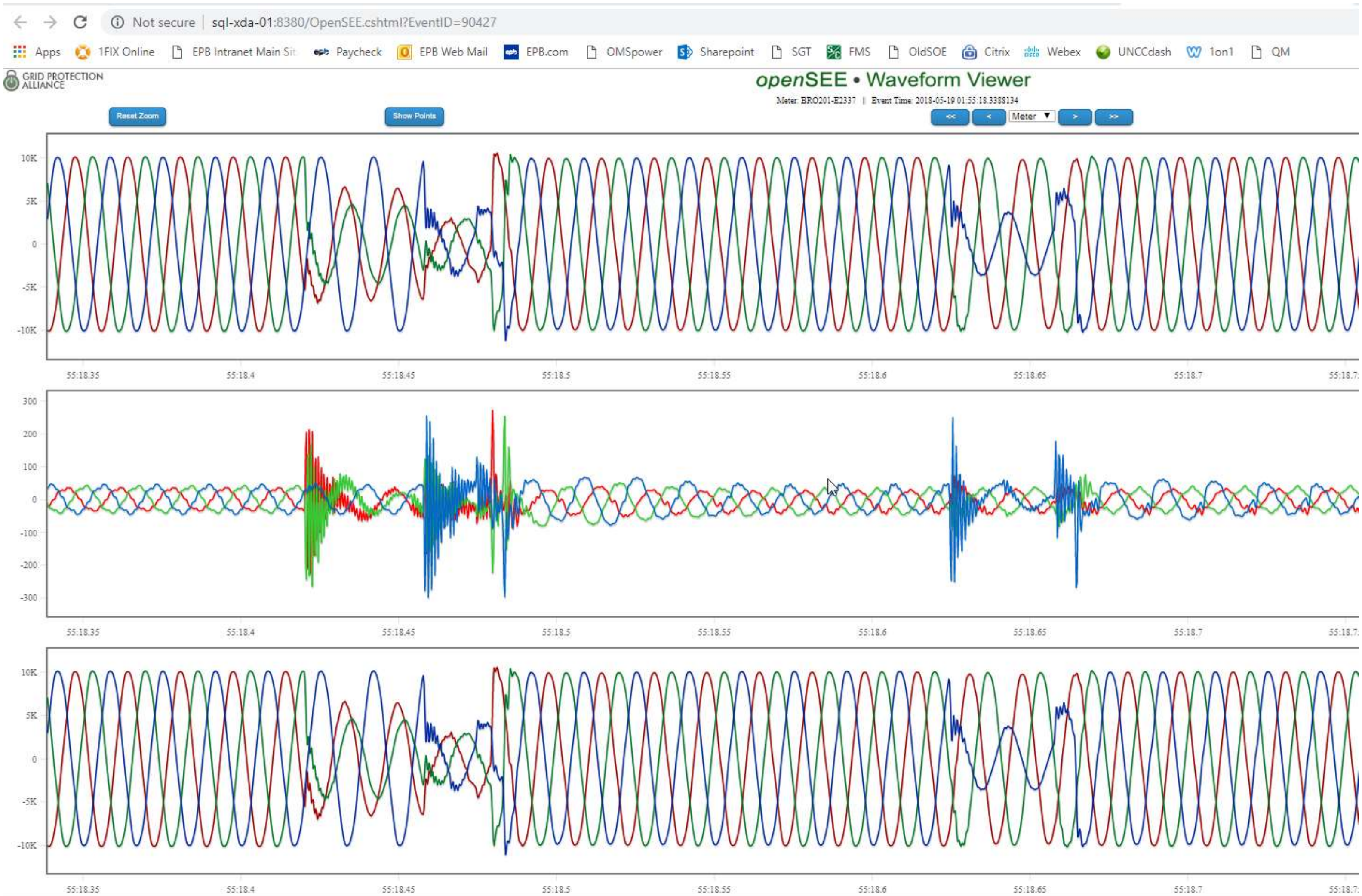
Looks Like Miscoordination



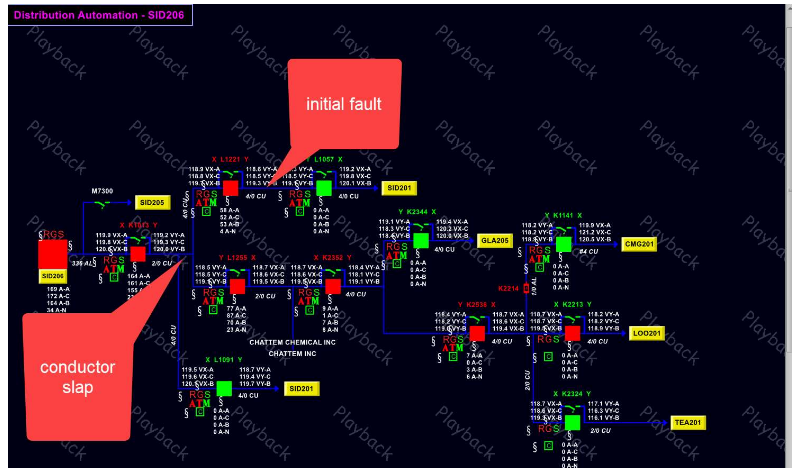
Confirmed: Miscoordination

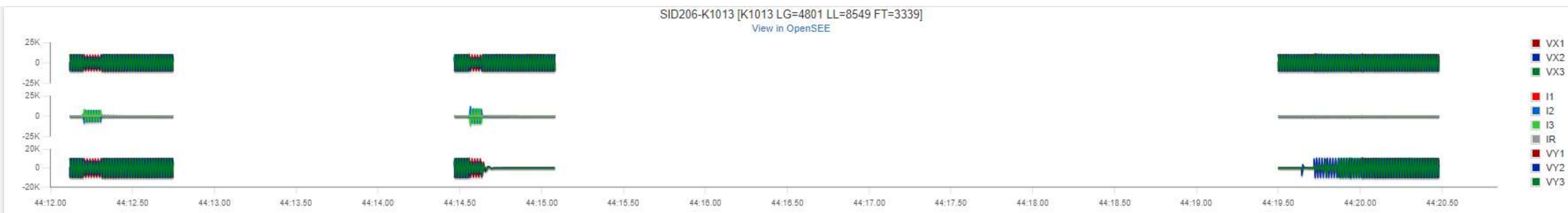


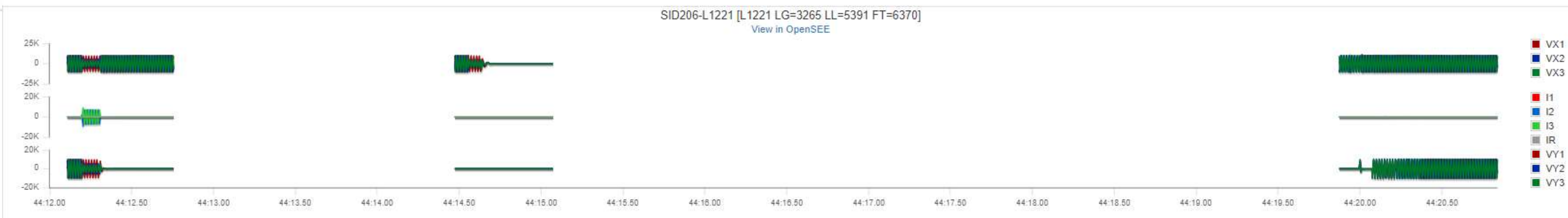
CAP Response



Conductor Slap







Conductor Slap

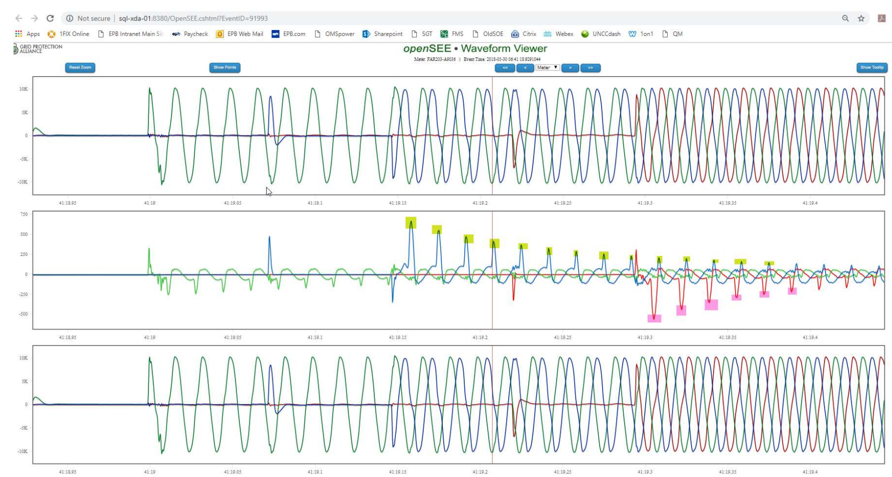
- Decreasing number of recloses
- Increasing open interval between recloses

Conductor Slap

- Negative sequence instantaneous
- Phase instantaneous not as easy to set due to differences in AFC for LL and 3Ø faults

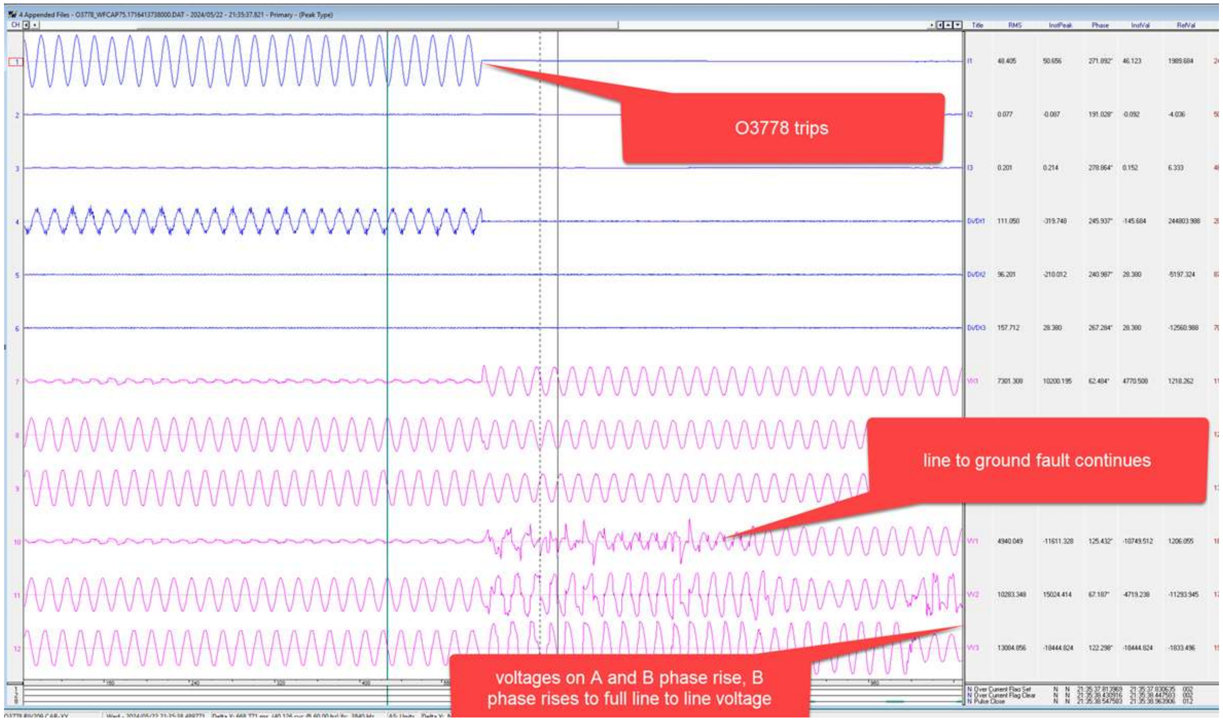
Transformer Magnetizing

- Historical waveforms provide an insight into past inrush for development of settings



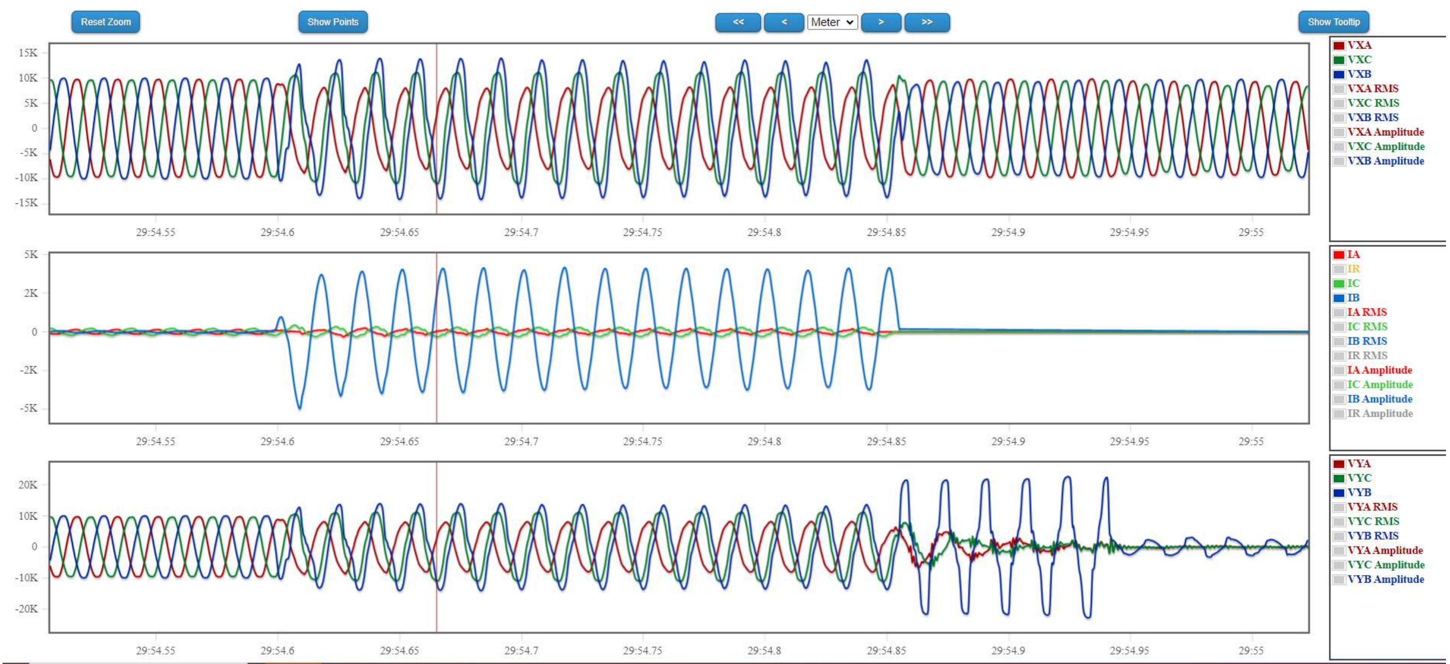
DER contribution to fault and islanding

- PV islanding and supplying fault current after loss of grid



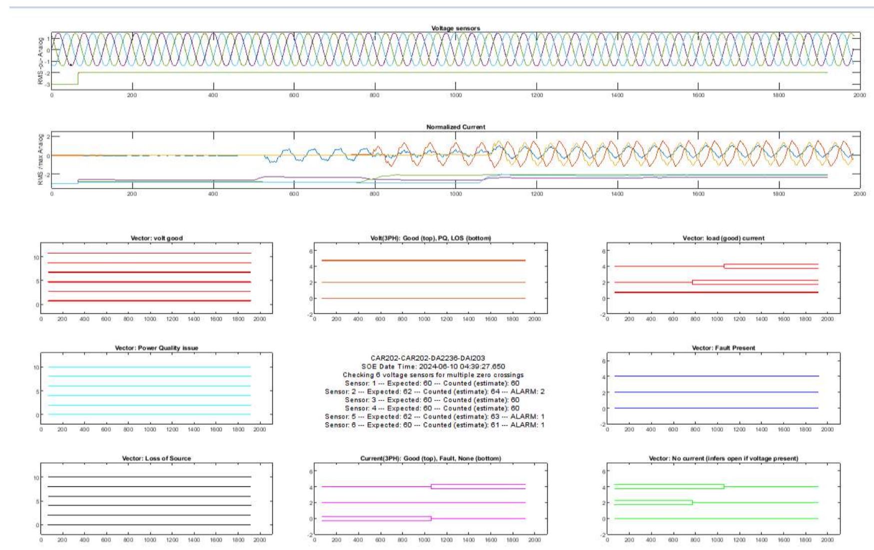
46 kV contact with 12 kV

- 46 kV contact with 12 kV through a tree branch



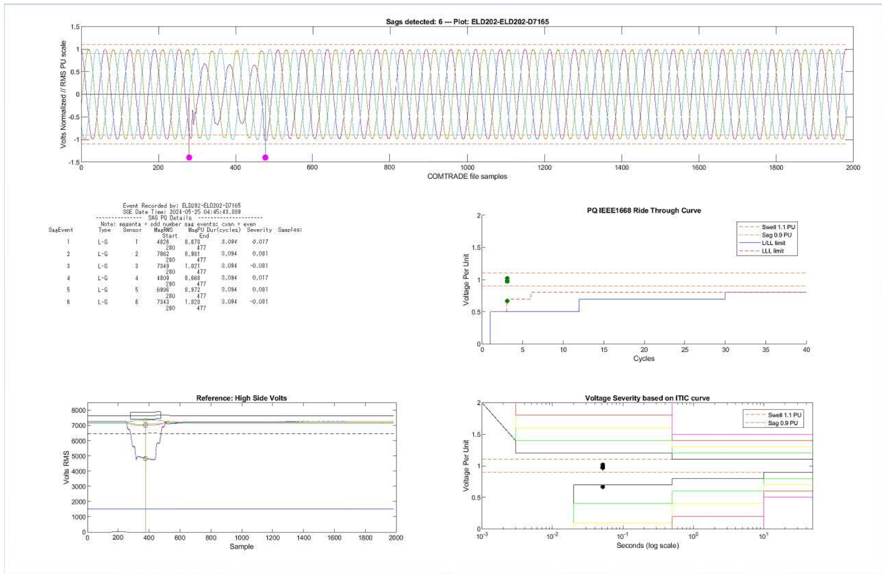
Waveform Summary Plot

- Quickly get an idea of what the recloser saw



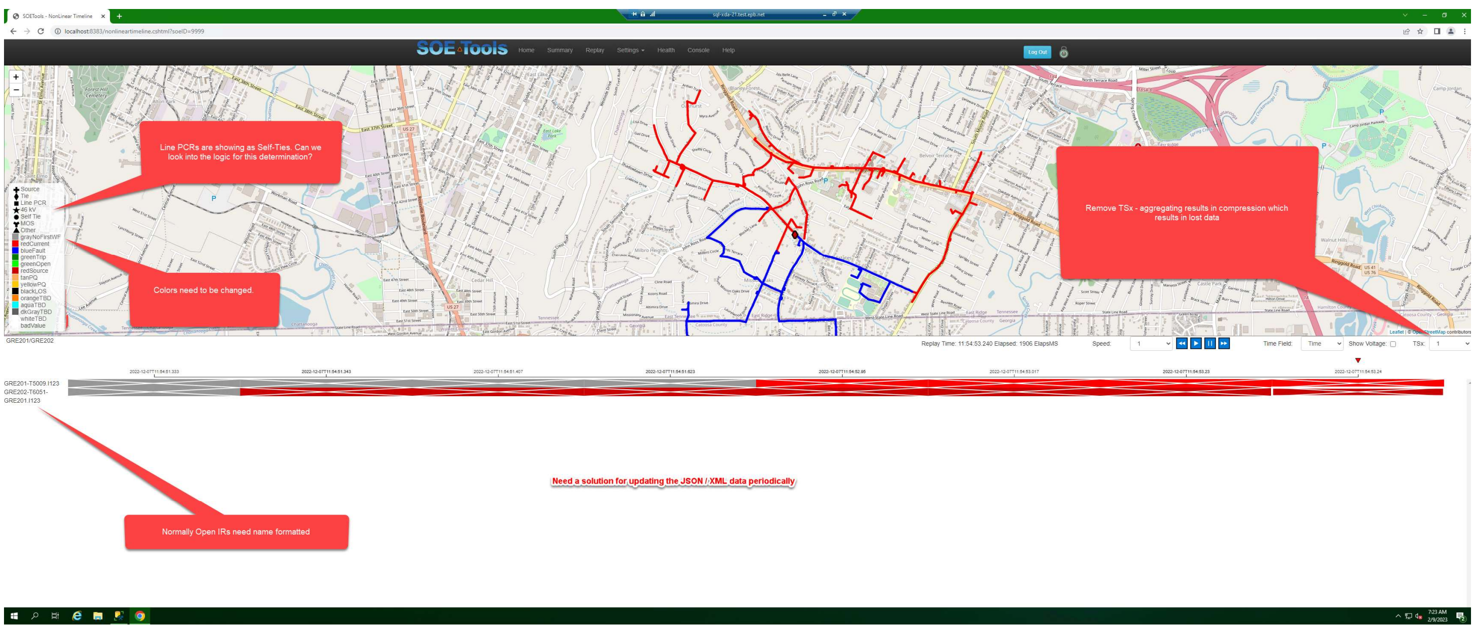
IEEE 1668 ride through plot

- Provide data to customers on IEEE 1668 compliance



Replay using waveforms

- Use waveforms to construct a replay of device operations



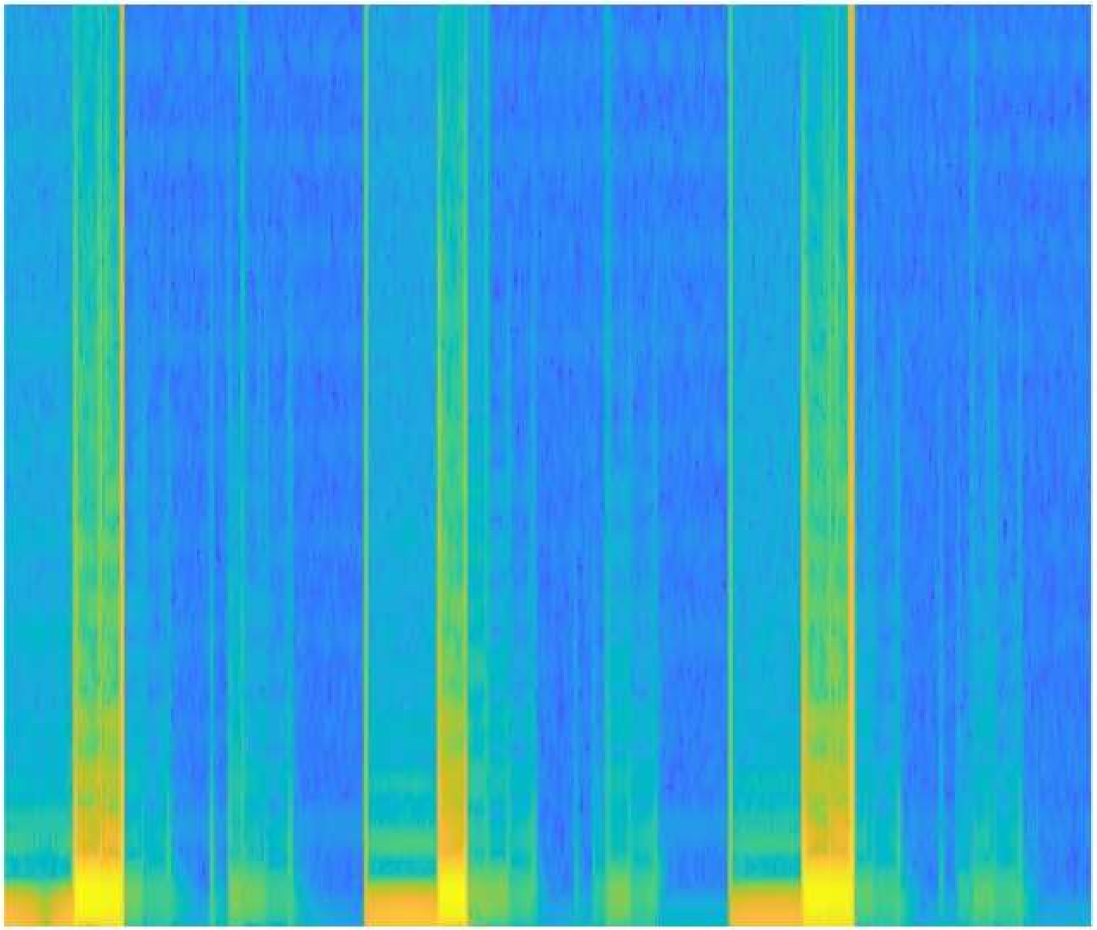
Additional uses of recloser data

- Power flow validation
- Capacitor bank placement
- Historical inrush
- Spectrograms from waveforms

Identifying miscoordination

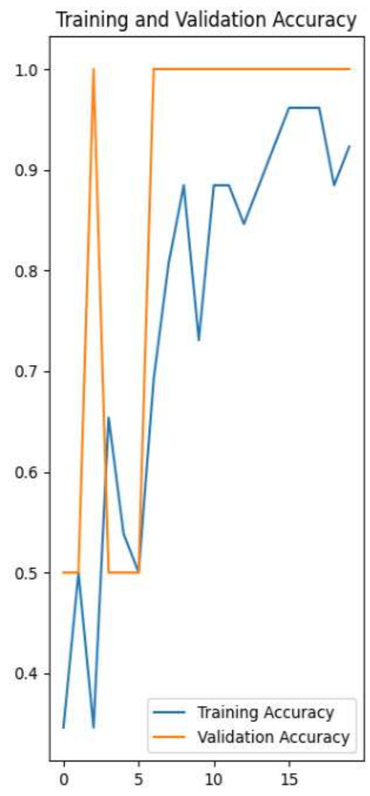
Spectrogram – A visual representation of the frequencies of a waveform over time.

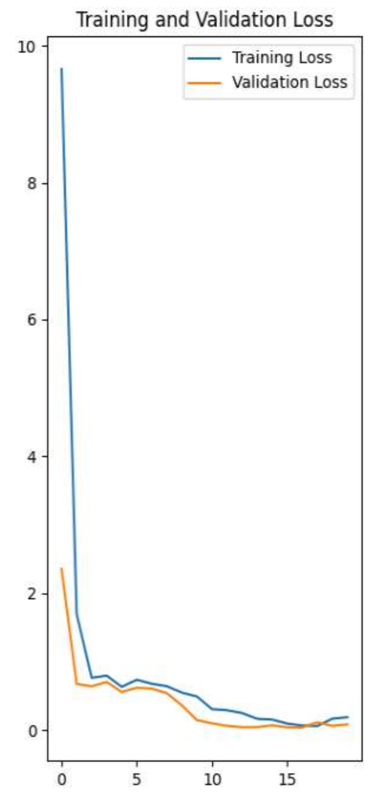
Use a CNN to classify images of spectrograms.

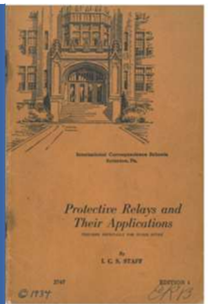


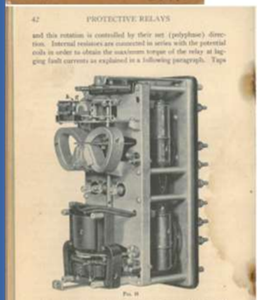
Identifying miscoordination

- Quickly determine miscoordination on a mass scale without in depth analysis






Protective Relays and
Their Applications


PROTECTIVE RELAYS


SEL
SEL-751A
SEL-751A
FEEDER RELAY
AUX 1
LOCK
CLOSE
TRIP


epb
Smart Grid
DISCOVER MORE NOW

End