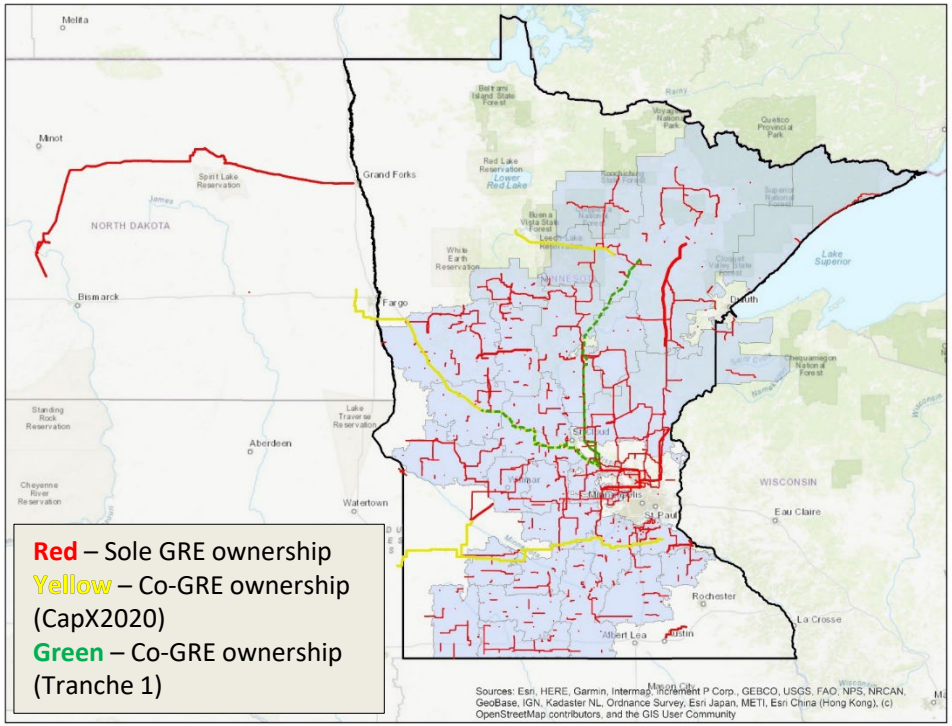
Two Broken Conductor Events

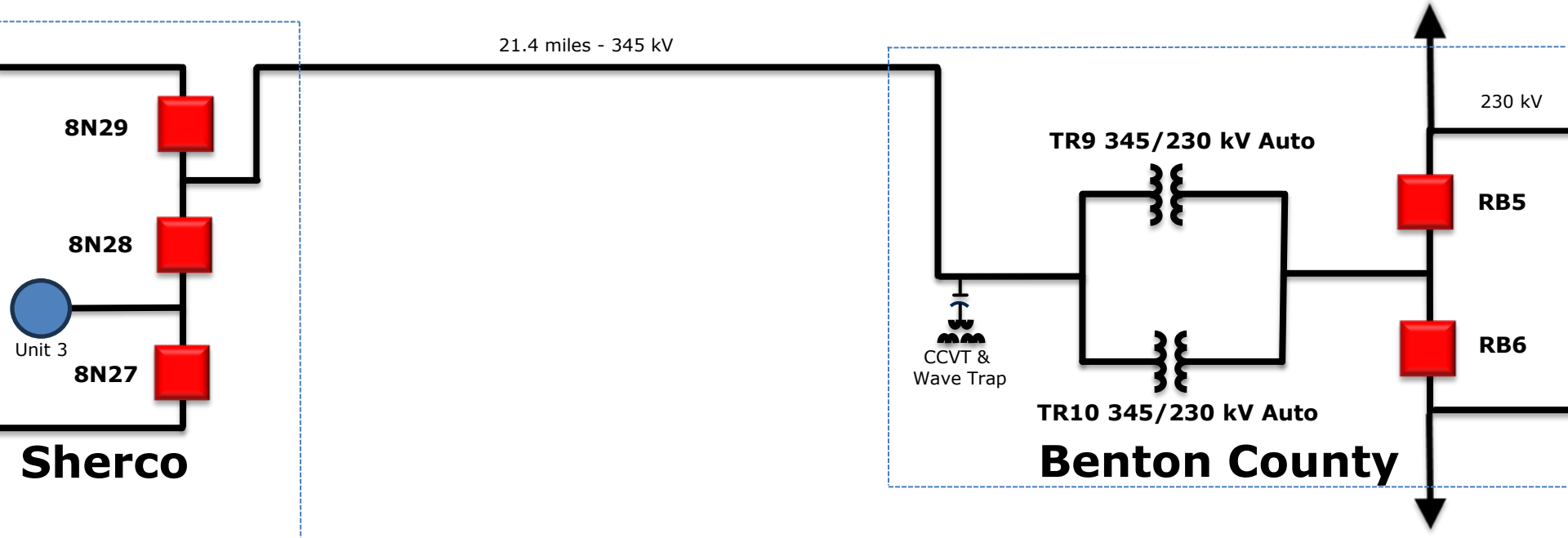
Presented by: Joe Livingston P.E.
Great River Energy

GRE transmission system

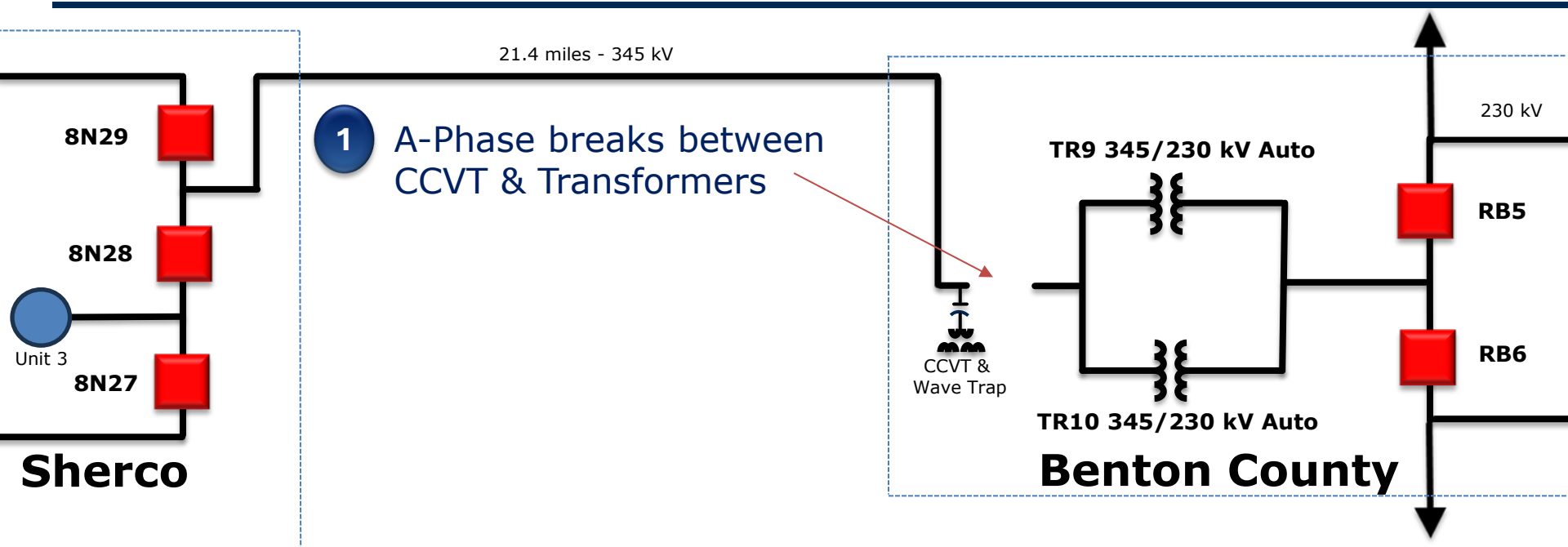


- 27 member-owner cooperatives
- 5,100 miles transmission
- 677 miles of transmission line maintained for others
- 109 transmission substations
- 1574 Relays

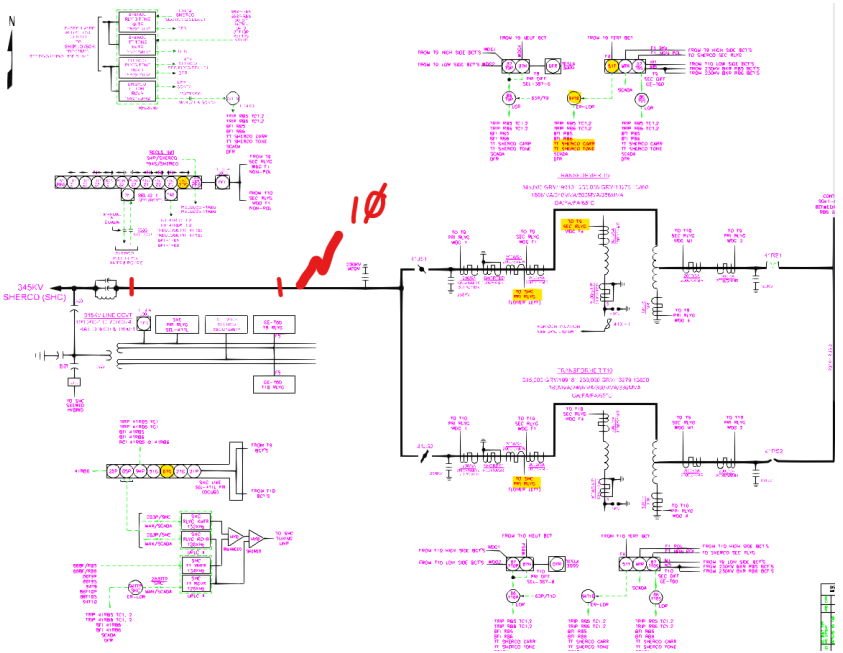
Event 1: SHERCO-Benton Co. 345 kV Line



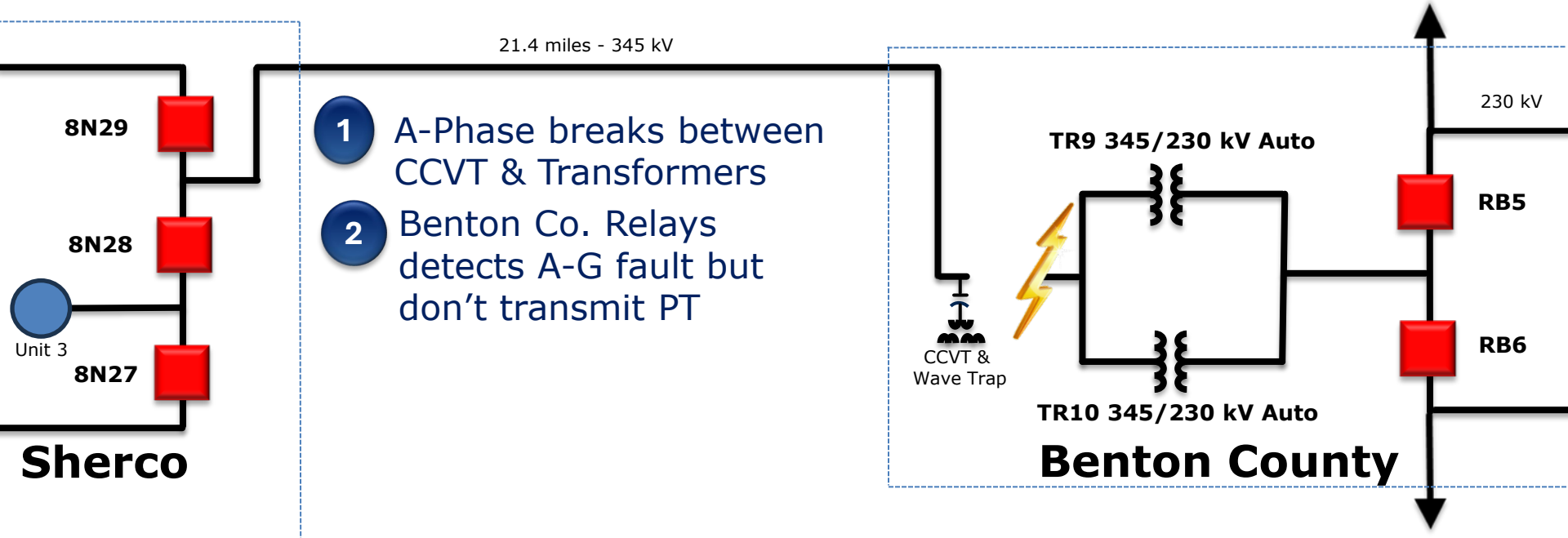
~22:31:54 A-Phase Bus work breaks open



Broken A-Phase buswork at Benton Co

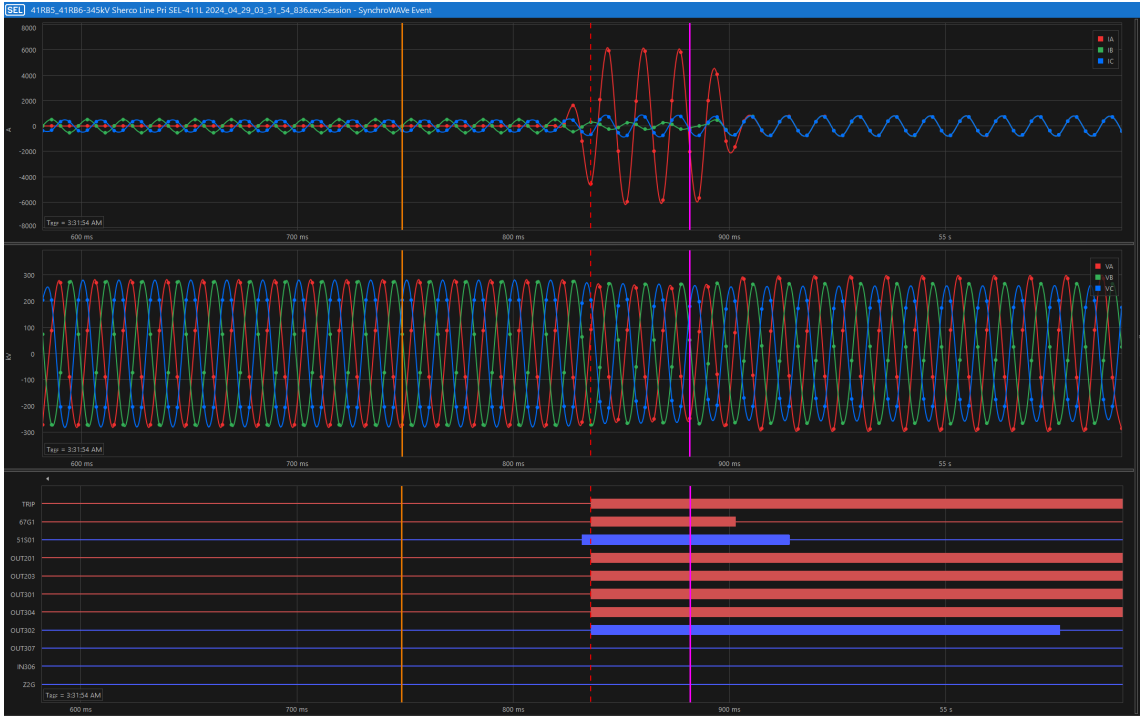


22:31:54.836 Bus work contacts ground

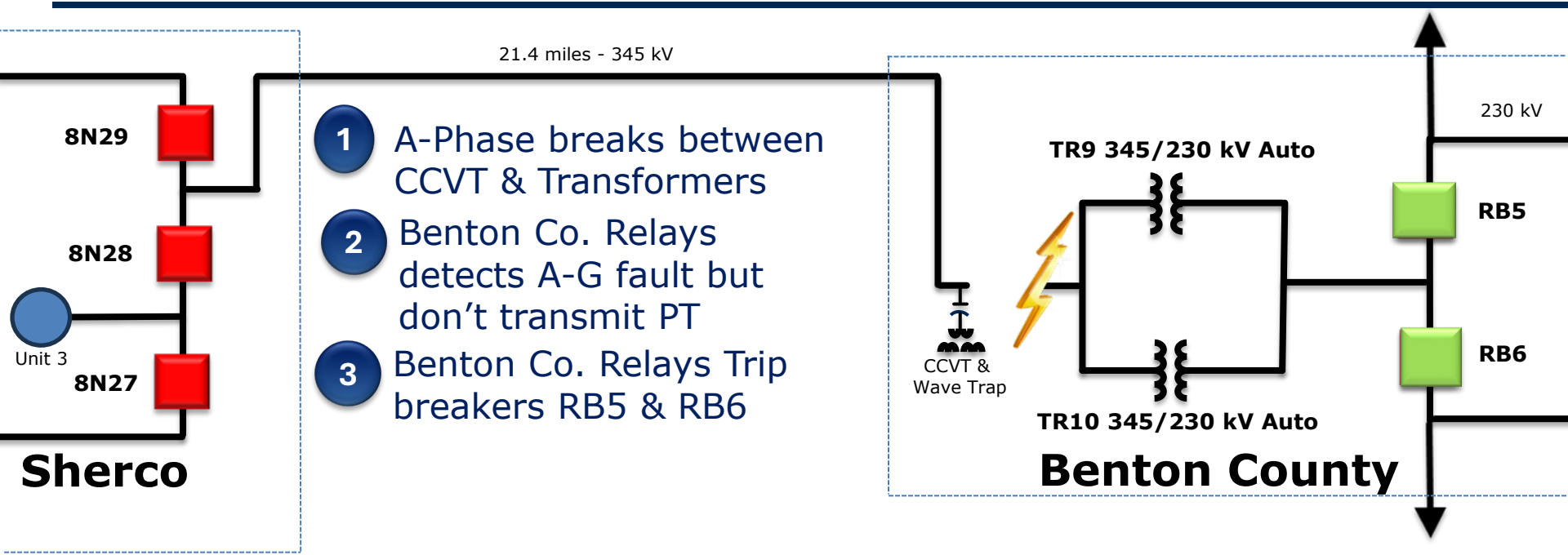


Benton Co Primary relay ER

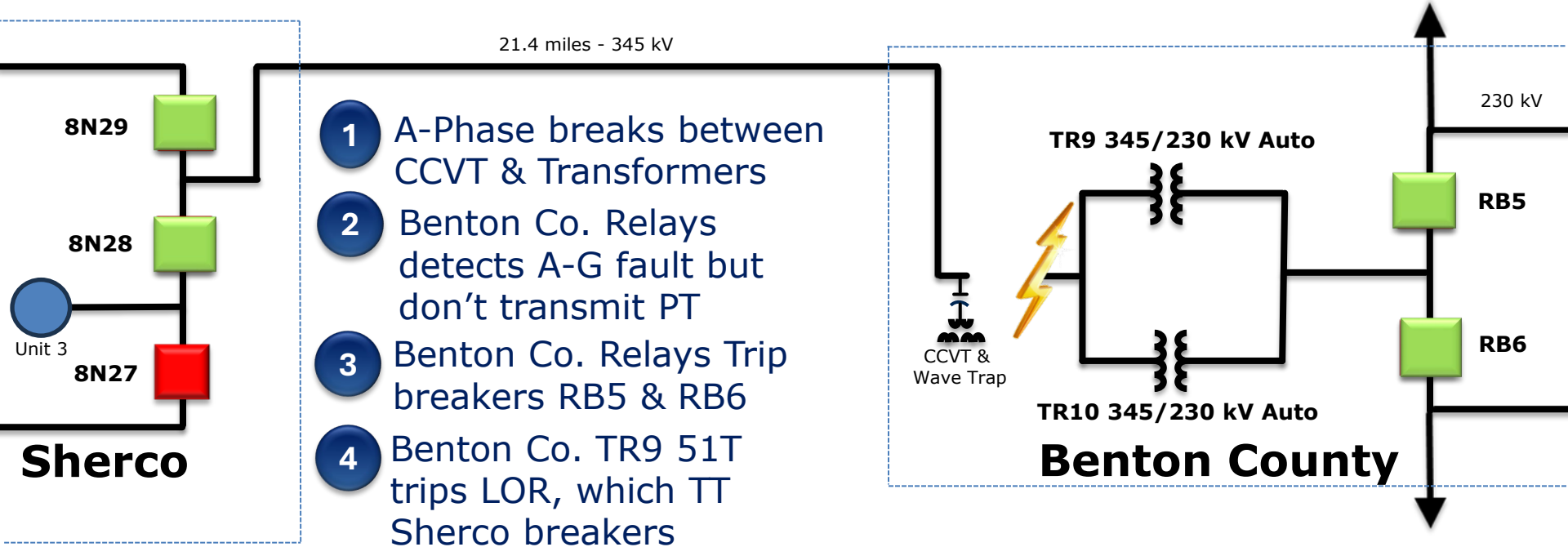
22:31:54.836 Benton County: Sherco primary 345kV Line relay (SEL-411L) & secondary relay (SEL-421) correctly detected an A-G fault (67G1, 51S01) and correctly tripped breakers RB5 and RB6 (OUT201, IN201-52a, OUT203, IN301-52a). Correctly initiated BFI for RB5 & 6 (OUT301, OUT304); and initiated RCI for RB5 & 6 (OUT302).



22:31:54.836 only Benton County trips

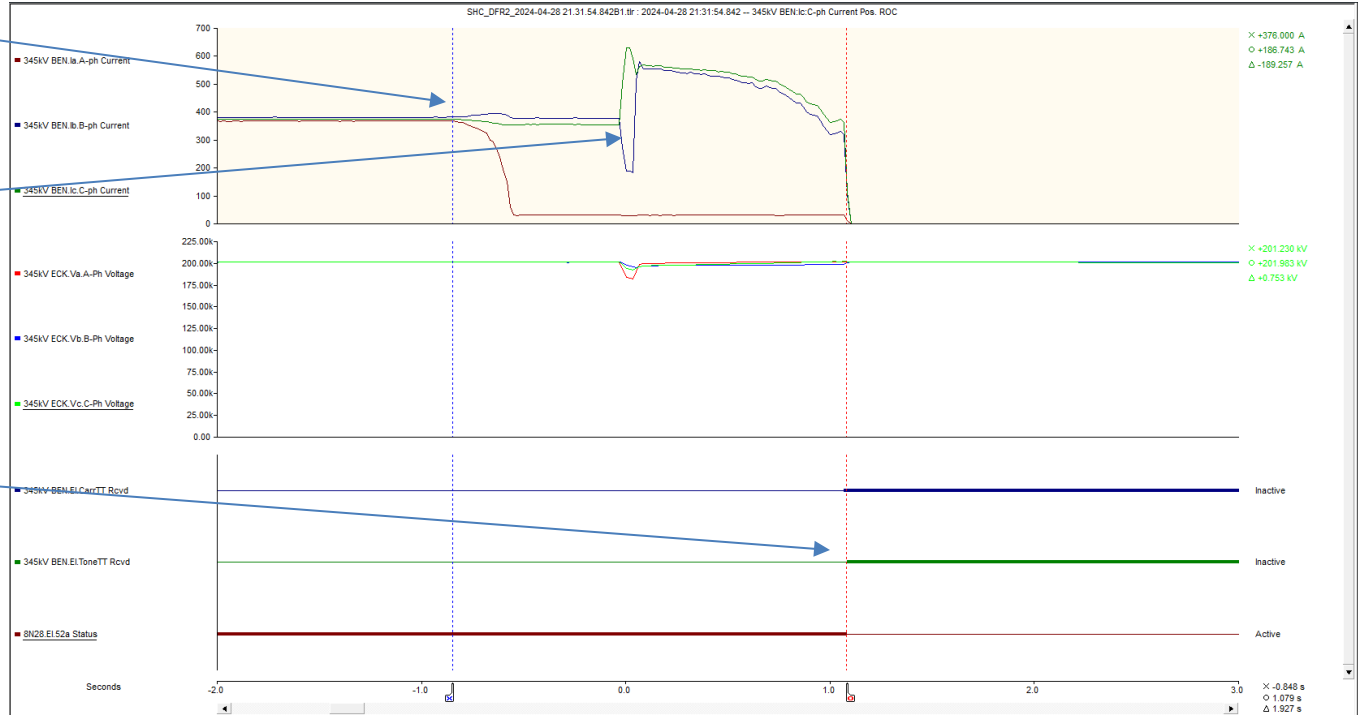


~22:31:56 TR9 tertiary over-current operates



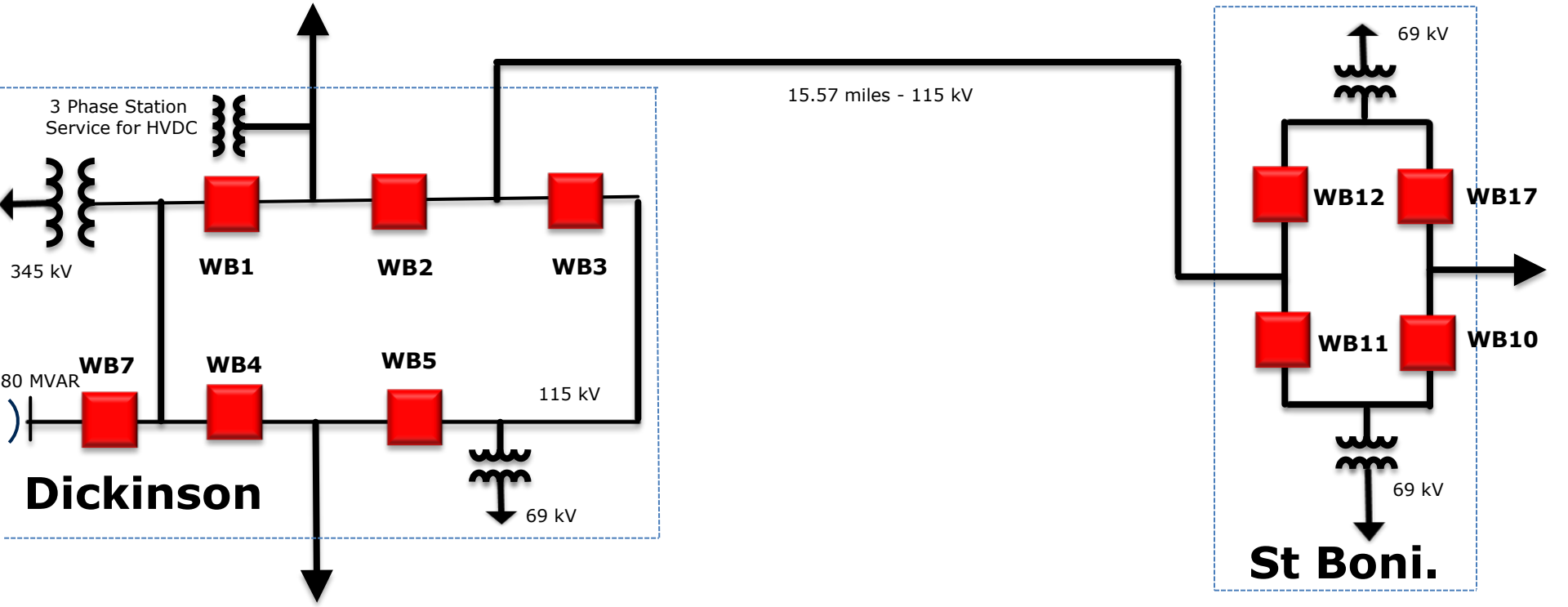
Sherco DFR

1. A-Phase breaks between CCVT & Transformers
2. Benton Co. Relays detects A-G fault but don't transmit PT
3. Benton Co. TR9 51T trips LOR, which TT Sherco breakers

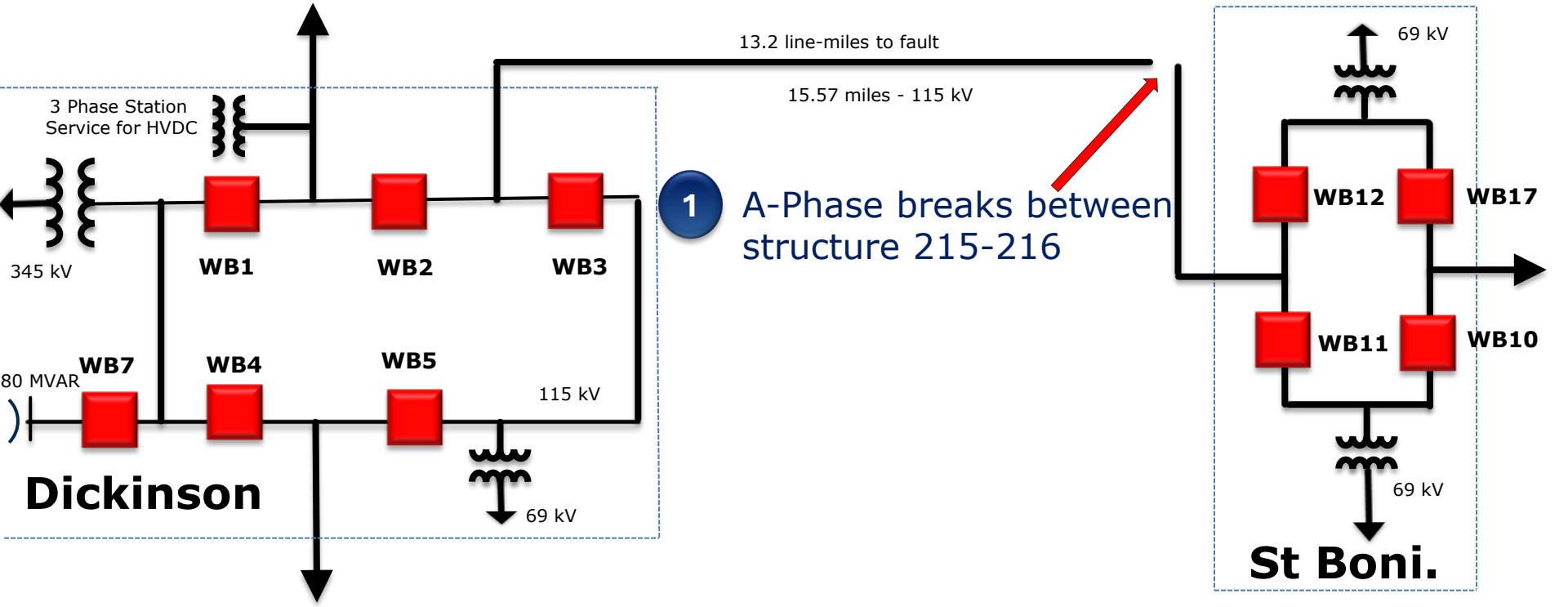


Event 2

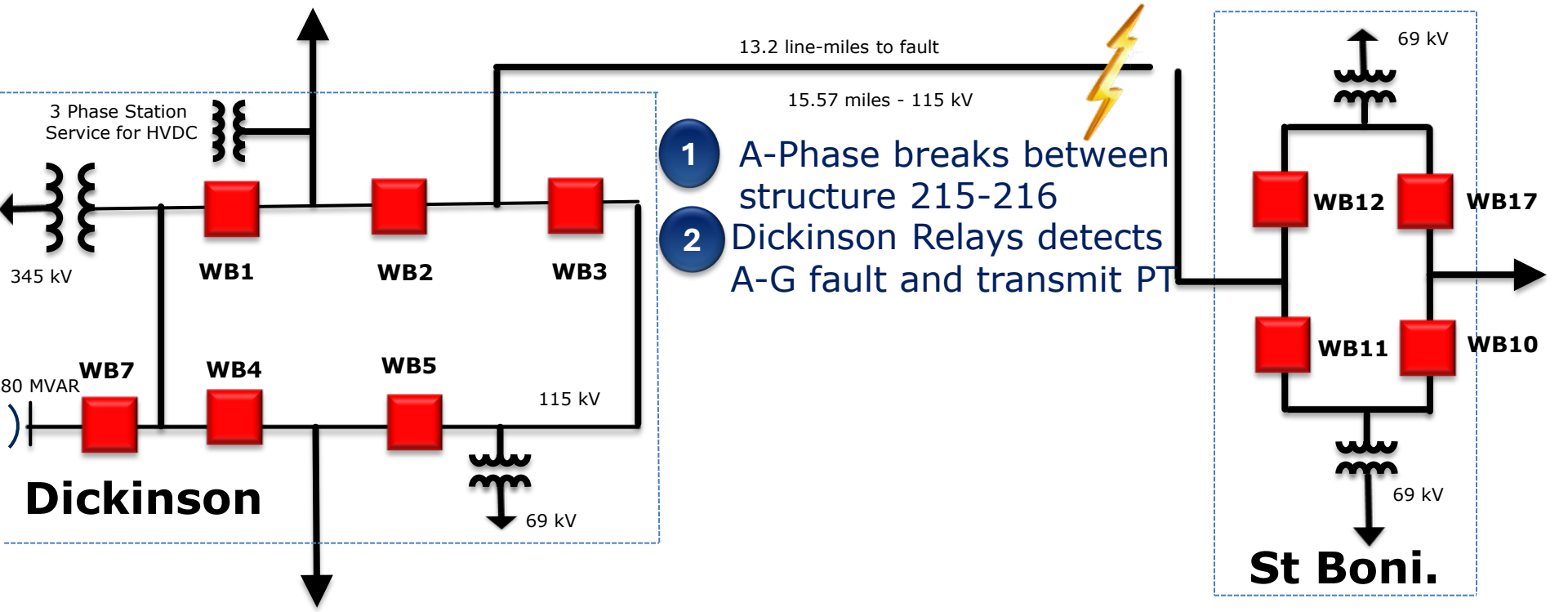
Event 2: Dickinson-St Boni. 115 kV Line



Approximately 23:57:33

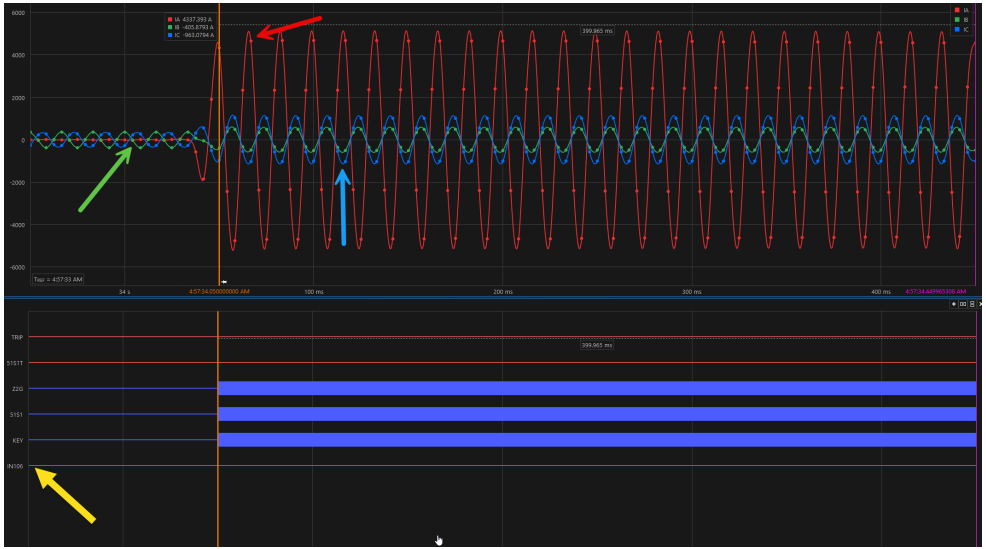


23:57:34.05 A-Phase contacts ground

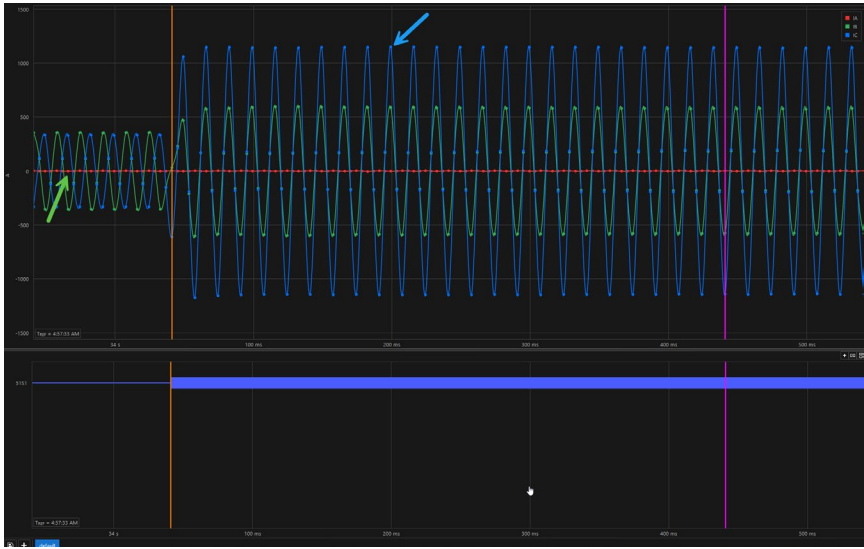


23:57:34.05 Relay Events

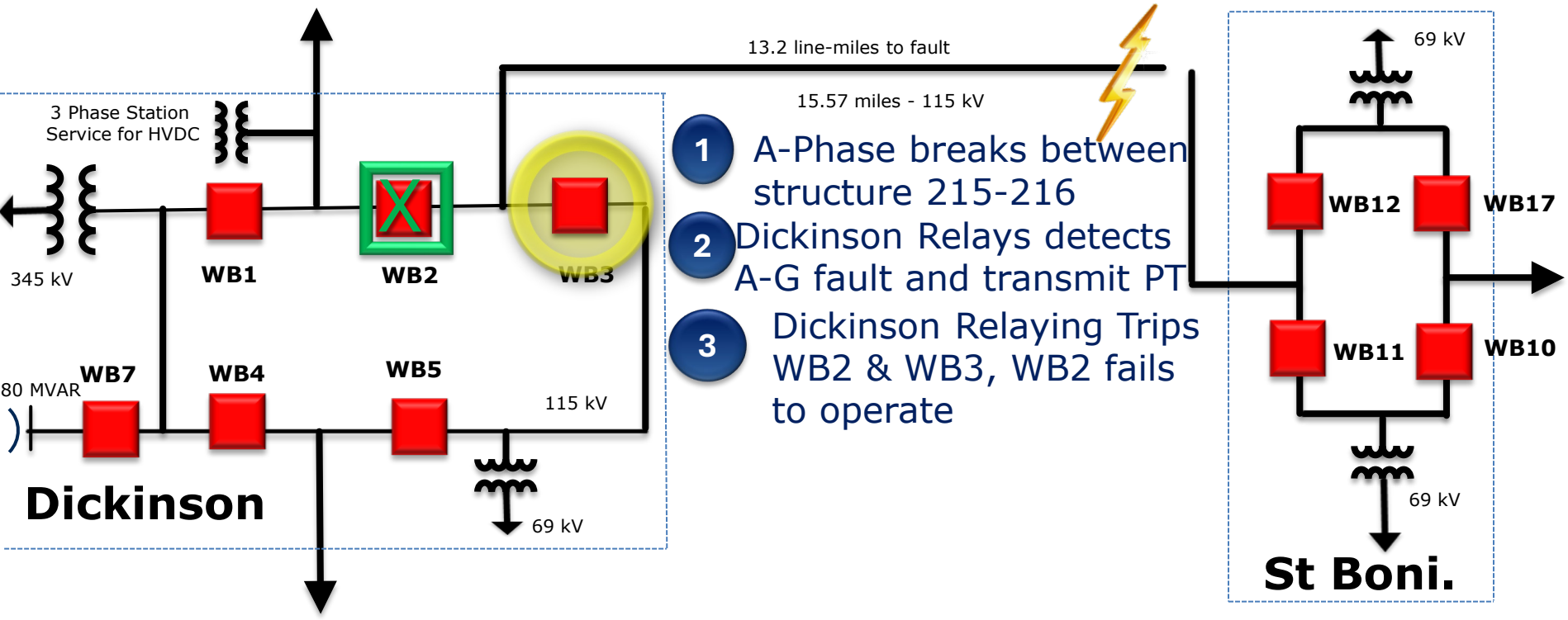
- Dickinson



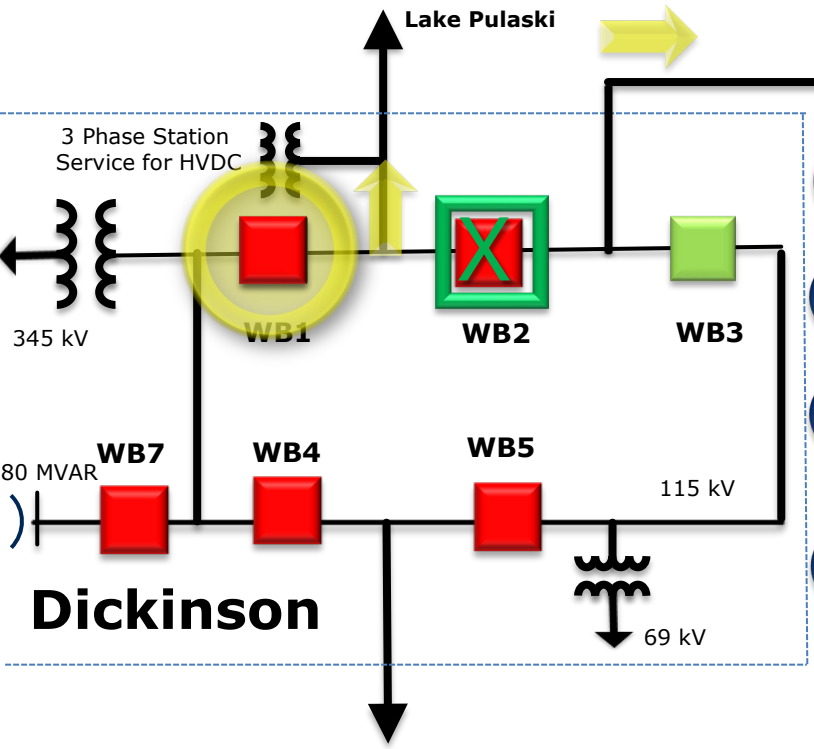
- St. Boni.



23:57:34.404 Dickinson relays trip

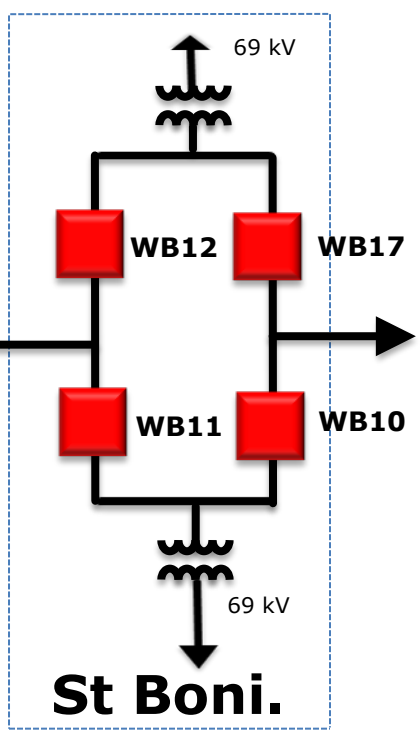


23:57:34.641 WB2/86BF trips (12 cycle)



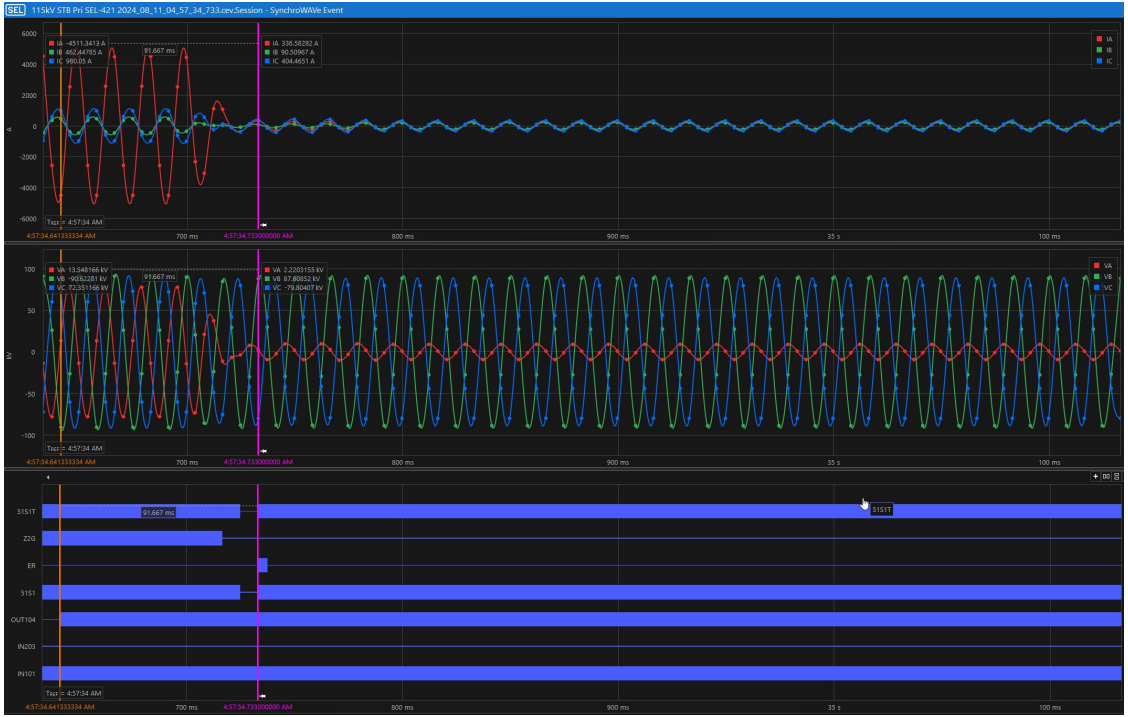
15.57 miles - 115 kV

1. A-Phase breaks between structure 215-216
2. Dickinson Relays detects A-G fault and transmit PT
3. Dickinson Relaying Trips WB2 & WB3, WB2 fails to operate
4. WB2/86BF trips WB1 and TT Lake Pulaski & St Boni.



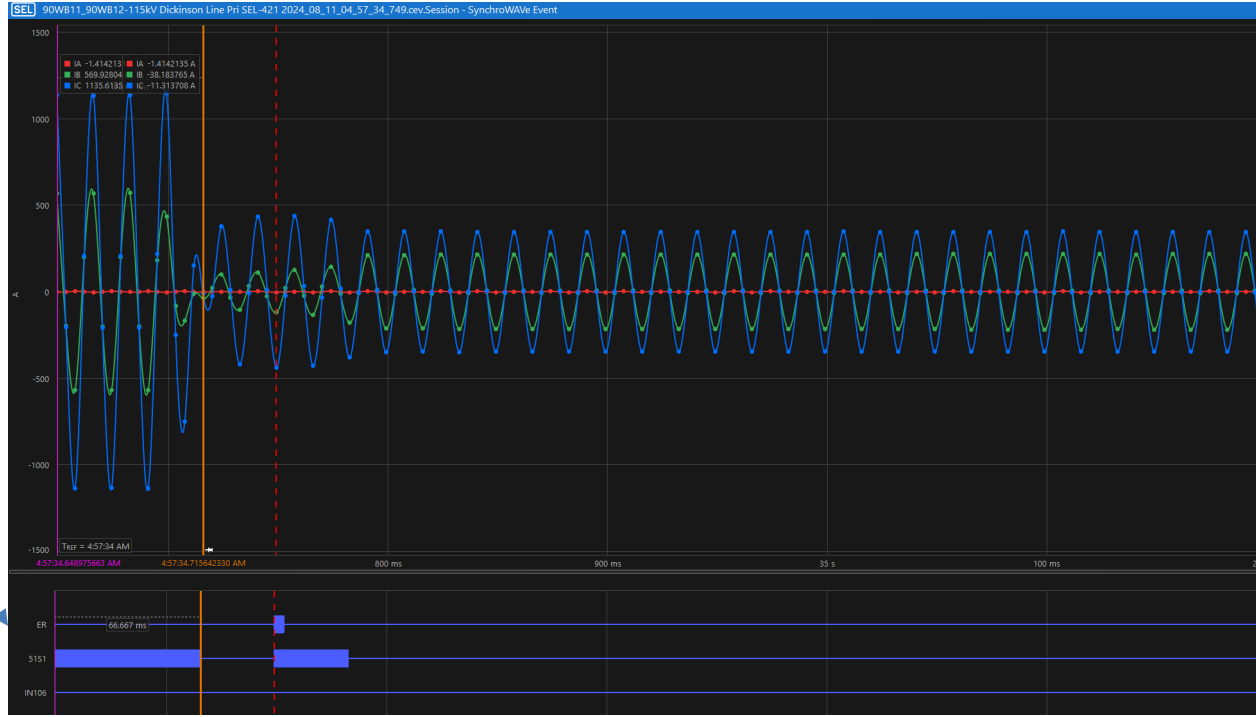
23:57:34.641 Dickinson BF Relay Event

- Current continues to flow on A-Phase after WB1 trips
- Voltage is still on A-Phase
- trips WB2/86BF (OUT104)
- WB2 remains closed (IN101)

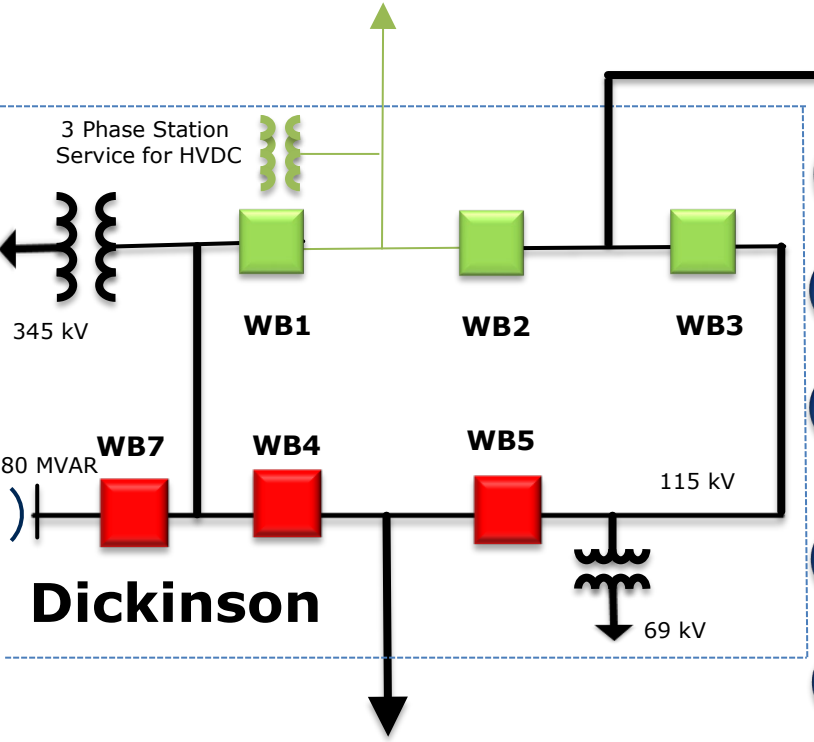


23:57:34.715 St Boni Relay Event

- After WB2/86BF trips WB1 and TT Lake Pulaski current reduces from St. Boni
- Ground over-current (51S1) drops out
- PT & TT never received at St Boni since A-Phase open



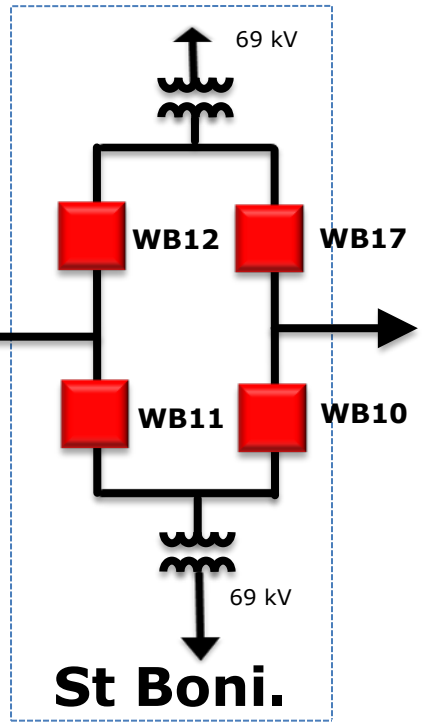
Approx. 23:57:35 WB2 finally trips (1 sec)



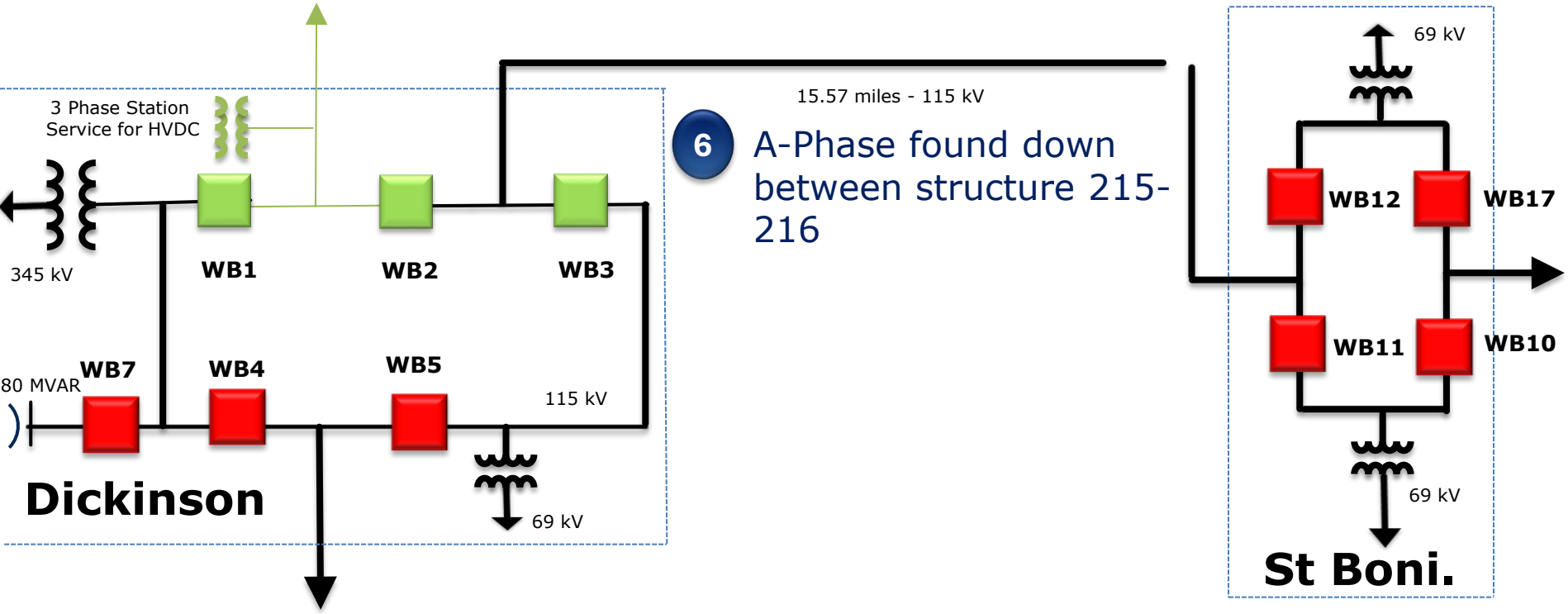
13.2 line-miles to fault

15.57 miles - 115 kV

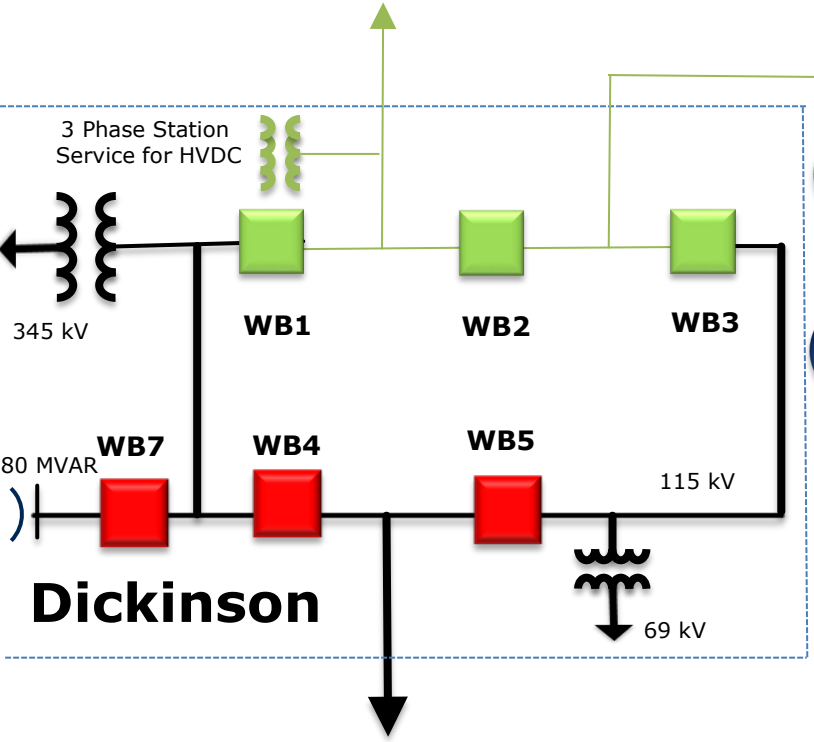
1. A-Phase breaks between structure 215-216
2. Dickinson Relays detects A-G fault and transmit PT
3. Dickinson Relaying Trips WB2 & WB3, WB2 fails to operate
4. WB2/86BF trips WB1 and TT Lake Pulaski & St Boni.
5. WB2 finally trips and isolates fault from system



1:54 A.M. ~2-Hours later Lineman arrive

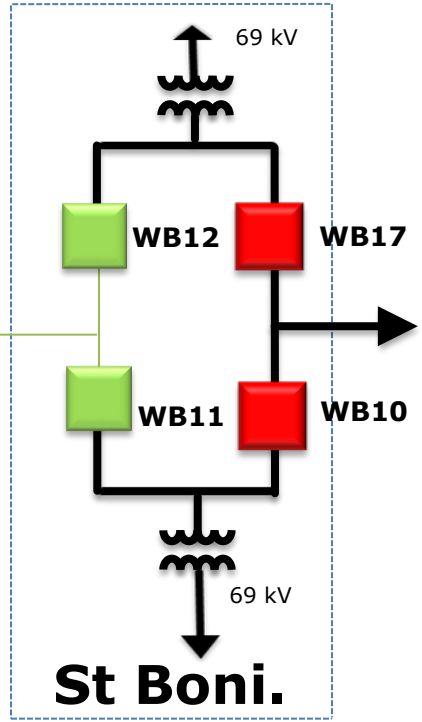


1:55 A.M. Line is de-energized

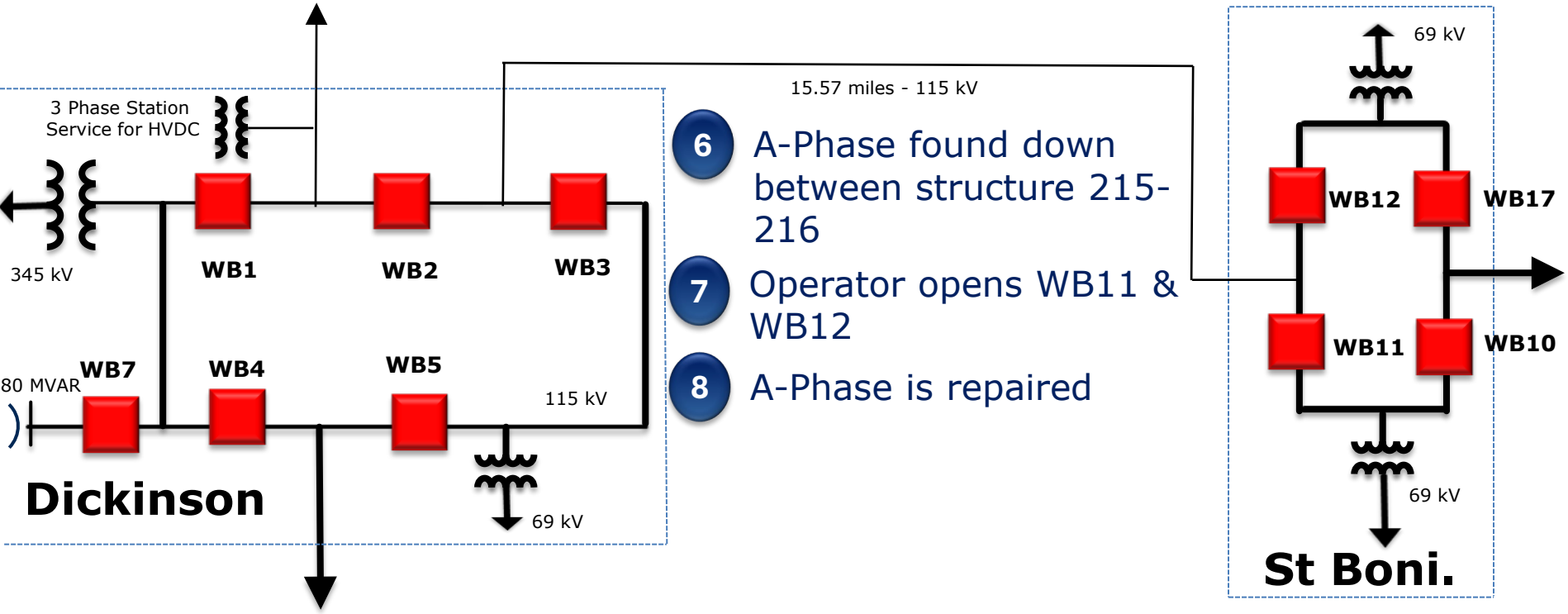


15.57 miles - 115 kV

6. A-Phase found down between structure 215-216
7. Operator opens WB11 & WB12



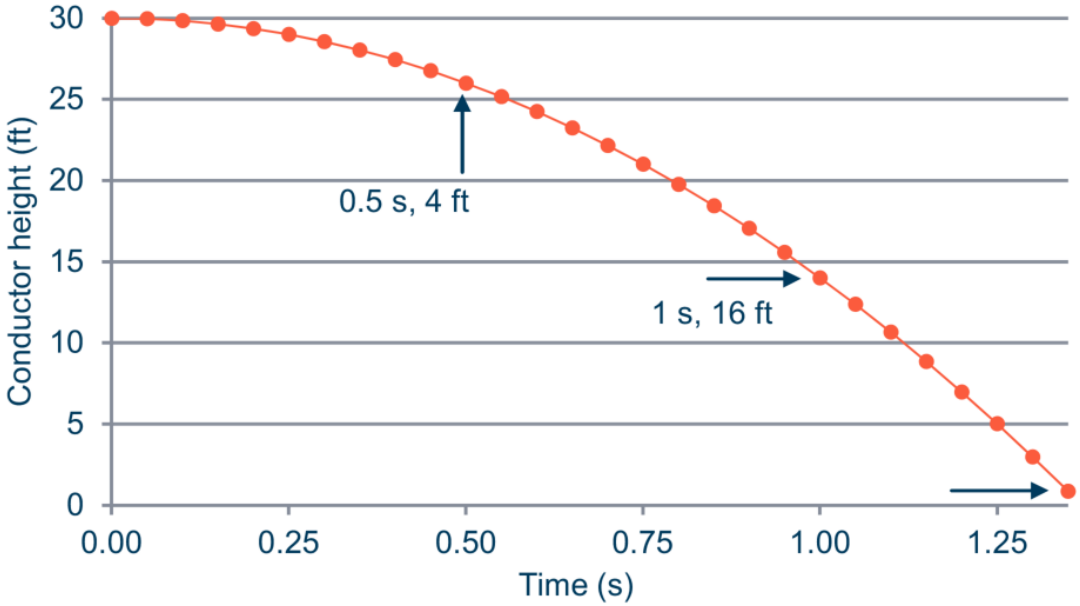
9:41 A.M. Line is repaired and put back in service



Corrective Action Plan

- Add broken conductor logic
- Add Directional Ground Over-current in permission trip to assist in detecting high-impedance fault

Falling conductor timeline



$$d = \frac{1}{2}gt^2 \rightarrow t = \sqrt{\frac{2d}{g}}$$

$$t = \sqrt{\frac{2(30)}{32.2}}$$

time ≈ 1.37s

Conductor hits ground at 1.37 s

Broken Conductor Logic

Quantities Data Table

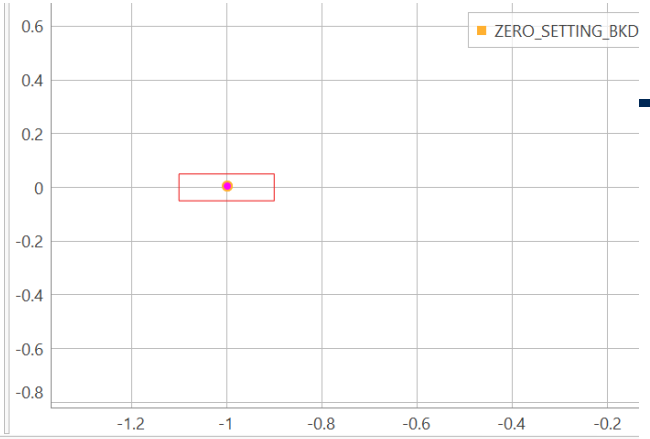
Cursor Color	Name	Real	Imag	Mag	Ang
	ZERO_SETTING_BKD	-0.9969952	0.0029073278	0.99699944	179.83293 Deg
	ZERO_SETTING_BKD	-0.99698704	0.0029151118	0.99699134	179.83247 Deg

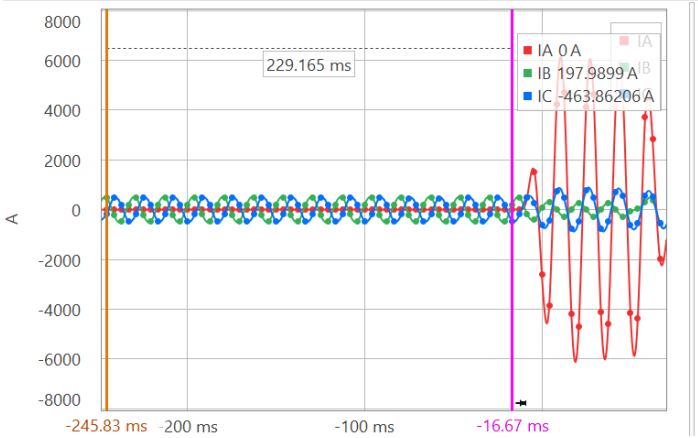
Filter Rows by Cursor

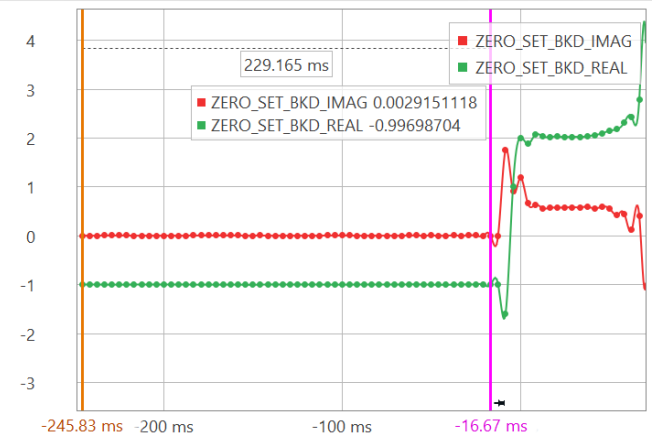
Orange Cursor Magenta Cursor Both Cursors

Chart Options

Advanced Options







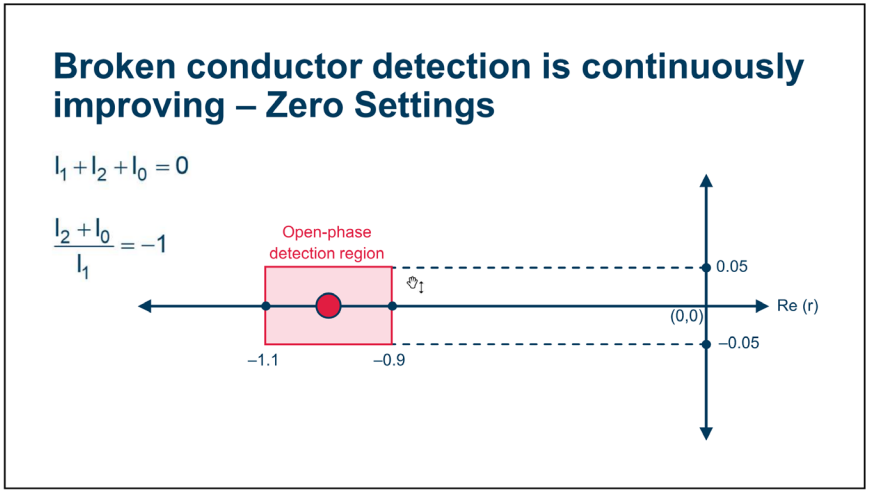
Broken Conductor Logic

Pros:

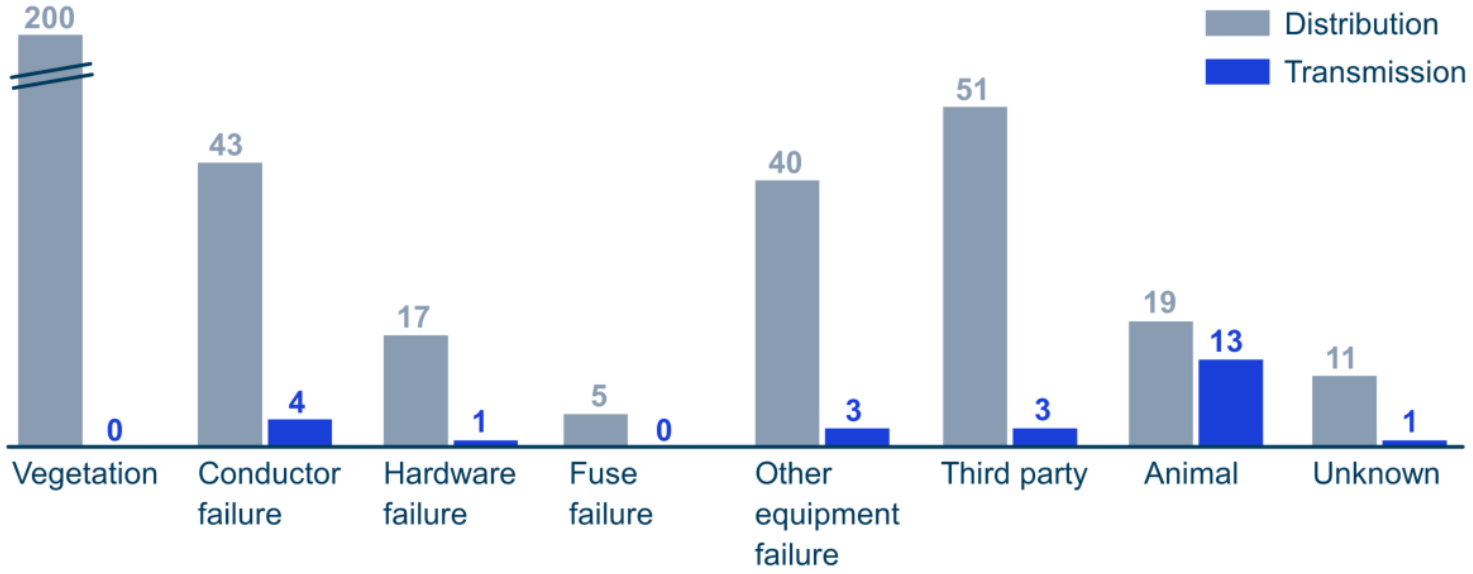
1. Both terminals would trip prior to fault occurring in both events 1 and 2
2. Auto-Reclosing would be canceled
3. Alarm System Operations

Cons:

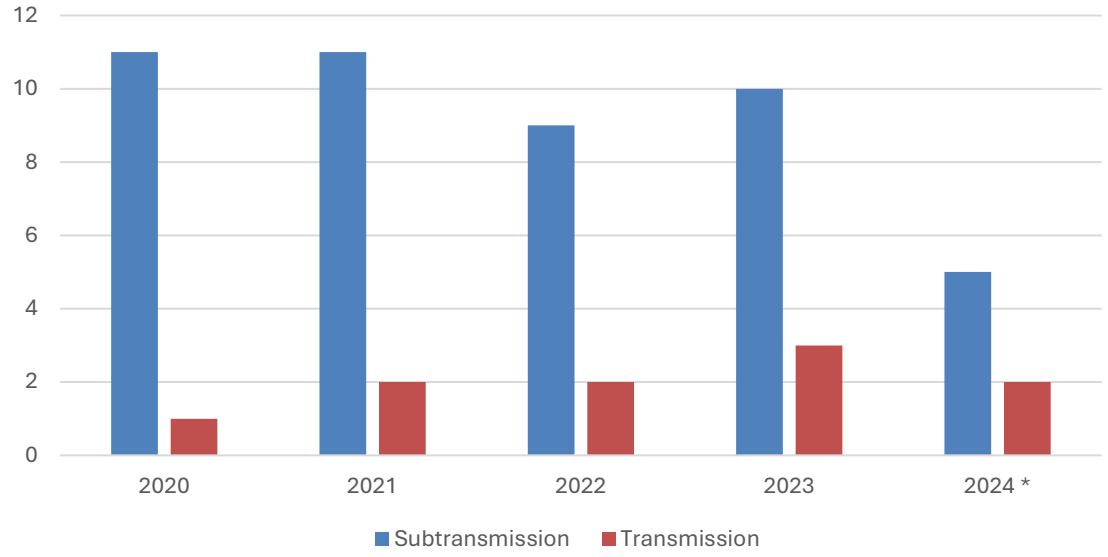
1. Fault distance would be unknown *



Causes of wildfire ignition related to the power system



GRE conductor down



*2024: January-August

Note: Some broken-conductor is operated by GRE but not owned and/or protected by GRE.

Transmission Line Relays

- 765 Line Relays
- 183 SEL-400 series
  - 44 SEL-411L
  - 138 SEL-421
  - 1 SEL-T401L
- 57 GE
  - 40 D60
  - 17 D90
- 45 ERLPhase
  - 45 L-PRO
- 480 SEL-300 series or older
  - 196 SEL-311B
  - 257 SEL-311C
  - 9 SEL-311L
  - 18 SEL-321

Broken Conductor Detection

Can be detected:

- Radial line
- 2-terminal lines
- 3-terminal lines with piloting
- Up to the point of the first tap

Cannot be detected:

- 3-terminal line without piloting (only terminal w/ broken conductor can be detected)
- Beyond the first tap point

Detectable Broken Conductor

BES	miles of line with detectable broken conductor	undetectable broken conductor	% of line length of detectable broken conductor logic
2-Terminal Lines protection wholy owned by GRE	469	25	95%
2-Terminal Lines protection not wholy owned by GRE	1342	96	93%
3-Terminal Lines protection not wholy owned by GRE	153	275	36%
BES Line totals	**1,964**	**396**	**83%**

Detectable Broken Conductor

Subtranmission (34.5, 41.6, 46, and 69 kV)	miles of line with detectable broken conductor	undetectable broken conductor	% of line length of detectable broken conductor logic
2-Terminal Lines protection wholy owned by GRE	830	644	56%
2-Terminal Lines protection not wholy owned by GRE	274	400	41%
3-Terminal Lines protection wholy owned by GRE	145	69	68%
3-Terminal Lines protection not wholy owned by GRE	42	178	19%
Radial lines	1134	0	100%
Subtransmission Line totals	**2,425**	**1,291**	**65%**

Detectable Broken Conductor

	miles of line with detectable broken conductor	undetectable broken conductor	% of line length of detectable broken conductor logic
Total System	4,389	1,687	72%

References

1. Zero-Setting Broken Conductor Detection Method Using Local Measurements Only

Yangfeng Gong, Gandhali Juvekar, and Kanchanrao Dase, Schweitzer Engineering Laboratories, Inc.

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Questions?