Protection System for a Wind Generation Plant in Panama: Challenges and Solutions

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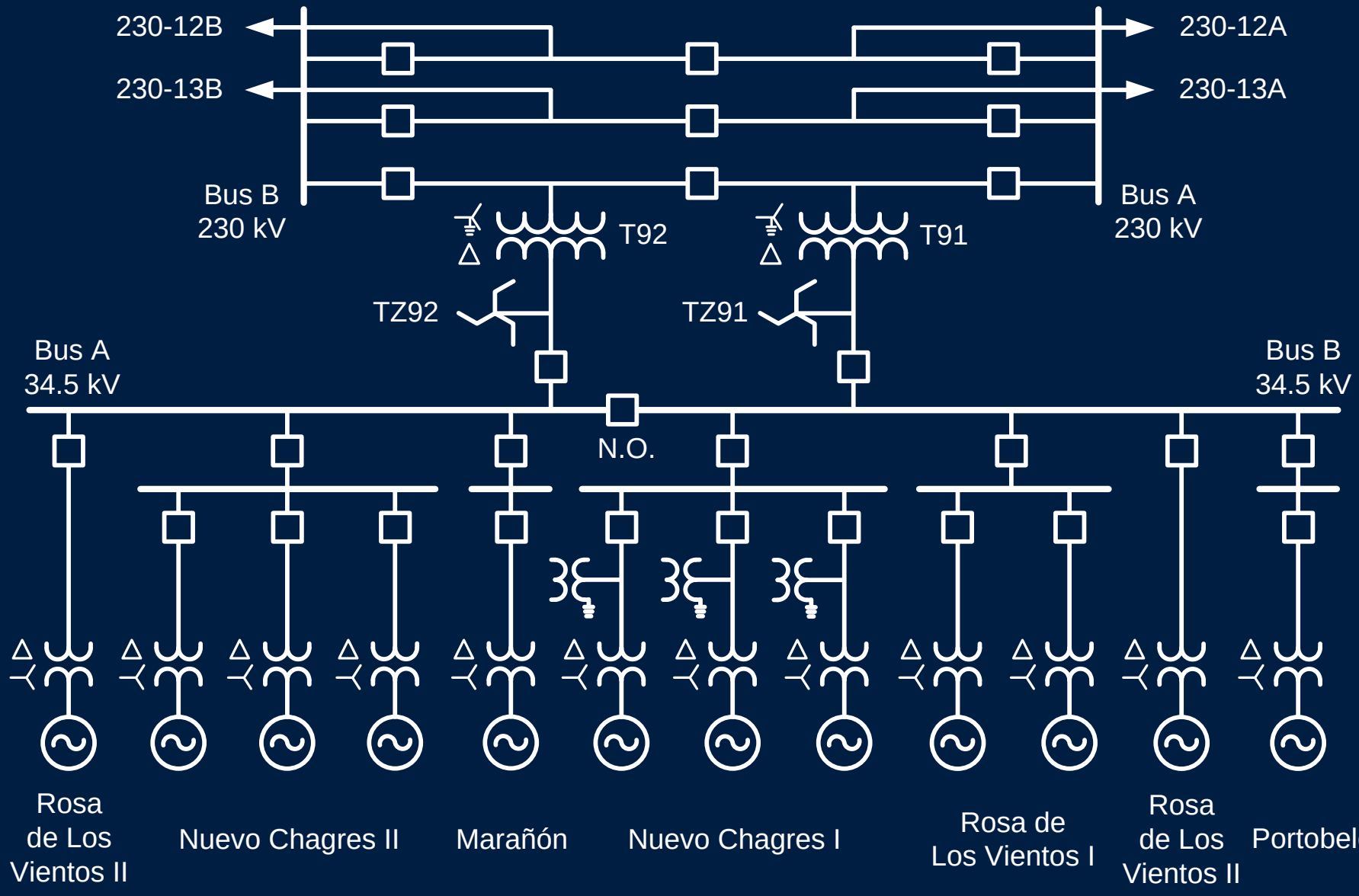
Outline

- Introduction
- Power system description
- P&C system
- Power system modeling
- Protection coordination
- Actual fault event
- Conclusion

Penonomé Wind Power Plant

- Location 70 miles southeast of Panama City
- Capacity
  - Total – 337.5 MW (135 WTGs)
  - In service – 270 MW (108 WTGs)
- Power system
  - Two step-up 120/140 MVA, 230/34.5 kV transformers
  - Twelve 34.5 kV collector circuits

Power System One-Line Diagram



Wind Power Plant Grounding

- Two 34.5 kV zig-zag transformers
  - Connection to low side of step-up transformers
  - 1,000 A ground fault contribution each
- Three 34.5/0.48 kV grounded-wye/delta banks
  - Connection to collector circuits
  - 1,100 A ground fault contribution each

230 kV Line P&C System

- Dual relays and fiber-optic channels
  - 87L
  - PUTT
  - 21/21N, 67N, and 79/25
- Bay controller
  - 50 BF
  - Switchgear control, interlocking, and circuit breaker supervision

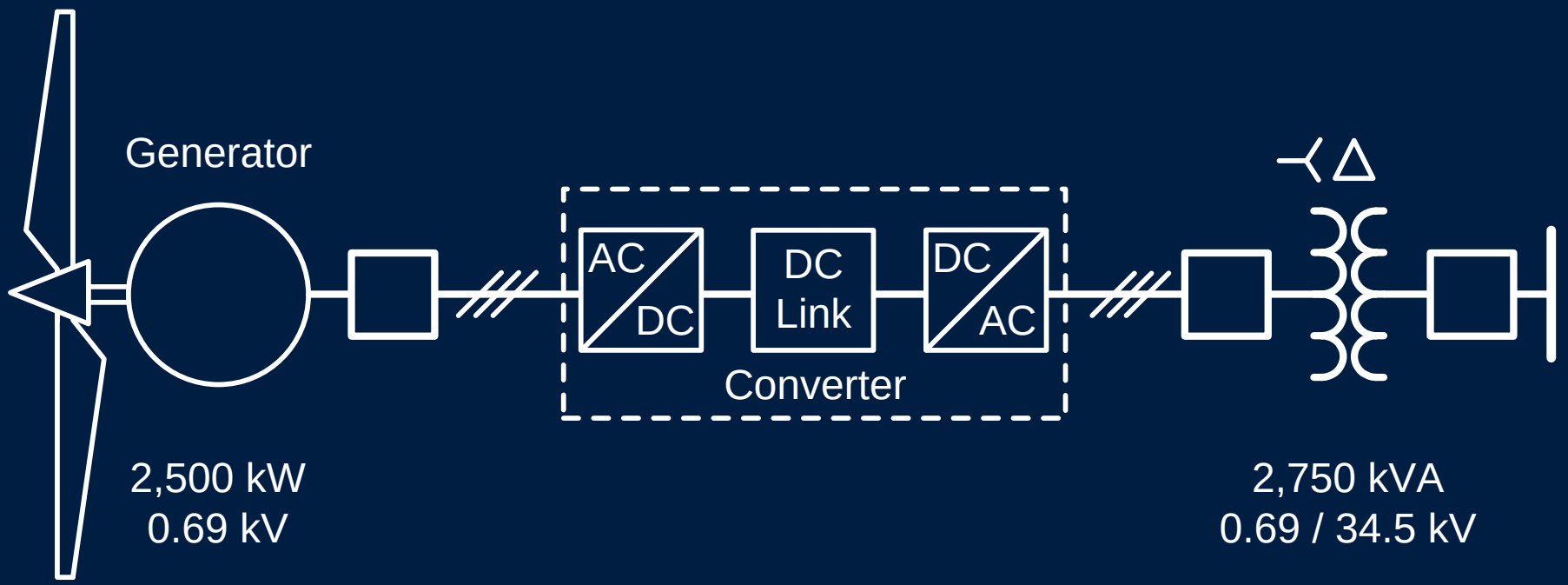
Transformer Protection

- Dual relays
  - 87
  - High side – 51/51N and REF
  - Low side – 51/51N/51G
- Bay controller
  - 50 BF
  - Control, interlocking, and supervision
  - Data collection for SCADA

Distribution System Protection

- Protection and monitoring functions
  - All collector circuits – 50/51 and 50N/51N
  - Grounded collector circuits – 67N
  - 81 alarming
  - 59/27 alarming
- Fast bus tripping will be added to 34.5 kV bus

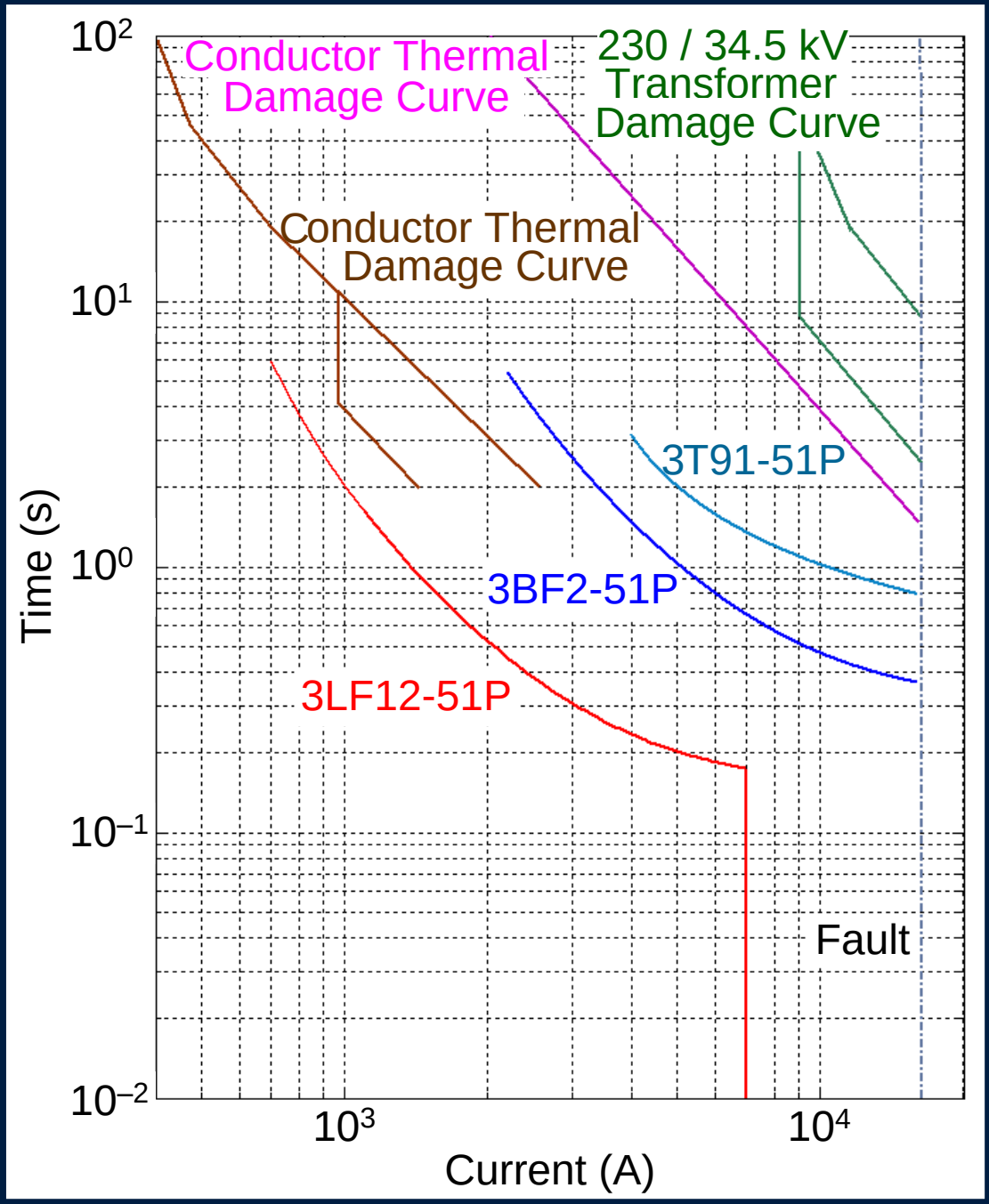
WTG Schematic Diagram



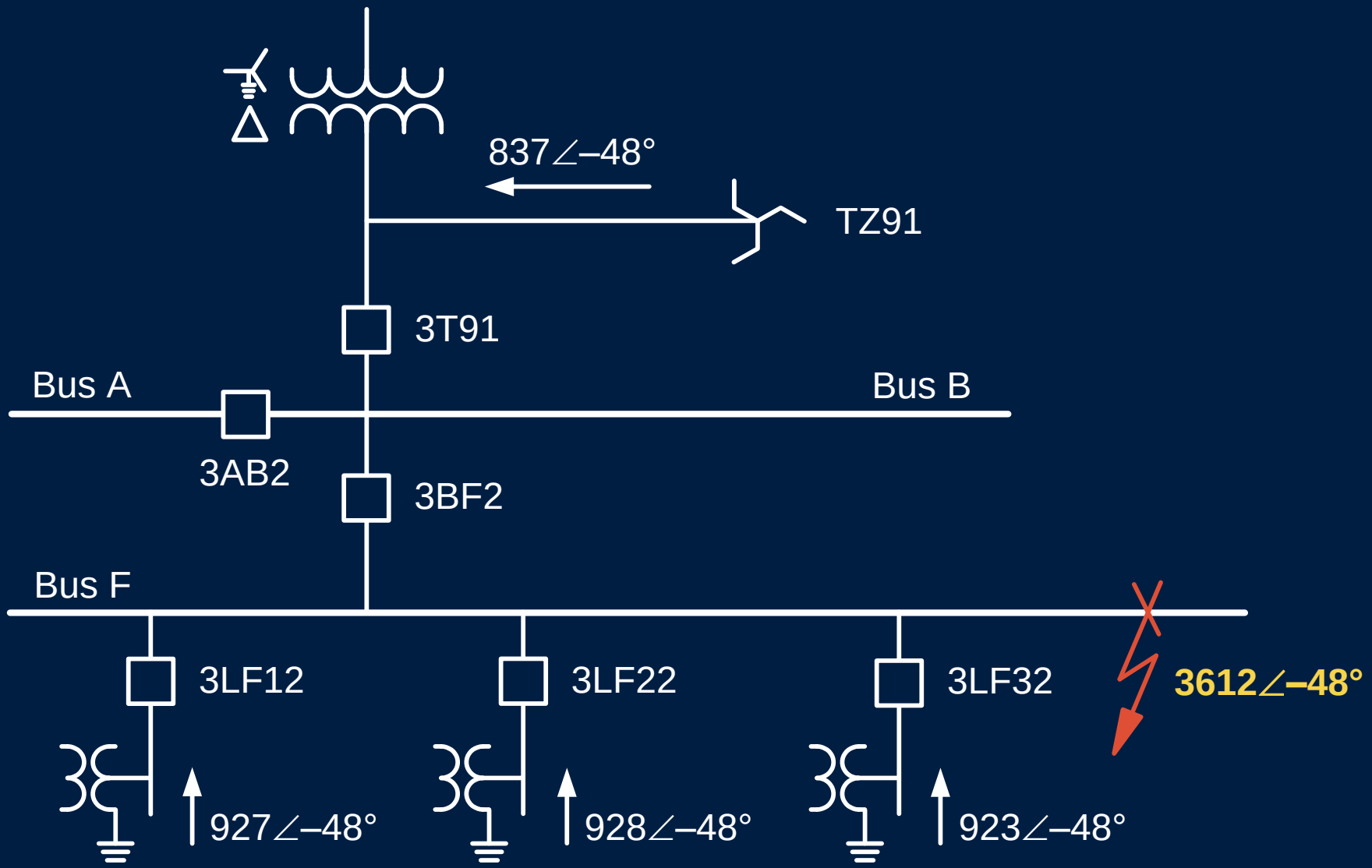
Type 4 WTG Response to Short Circuits

- WTG is ungrounded and contributes no zero-sequence current
- WTG current depends on control objective; not a natural generator response
- WTG control acts to balance currents and voltages during faults

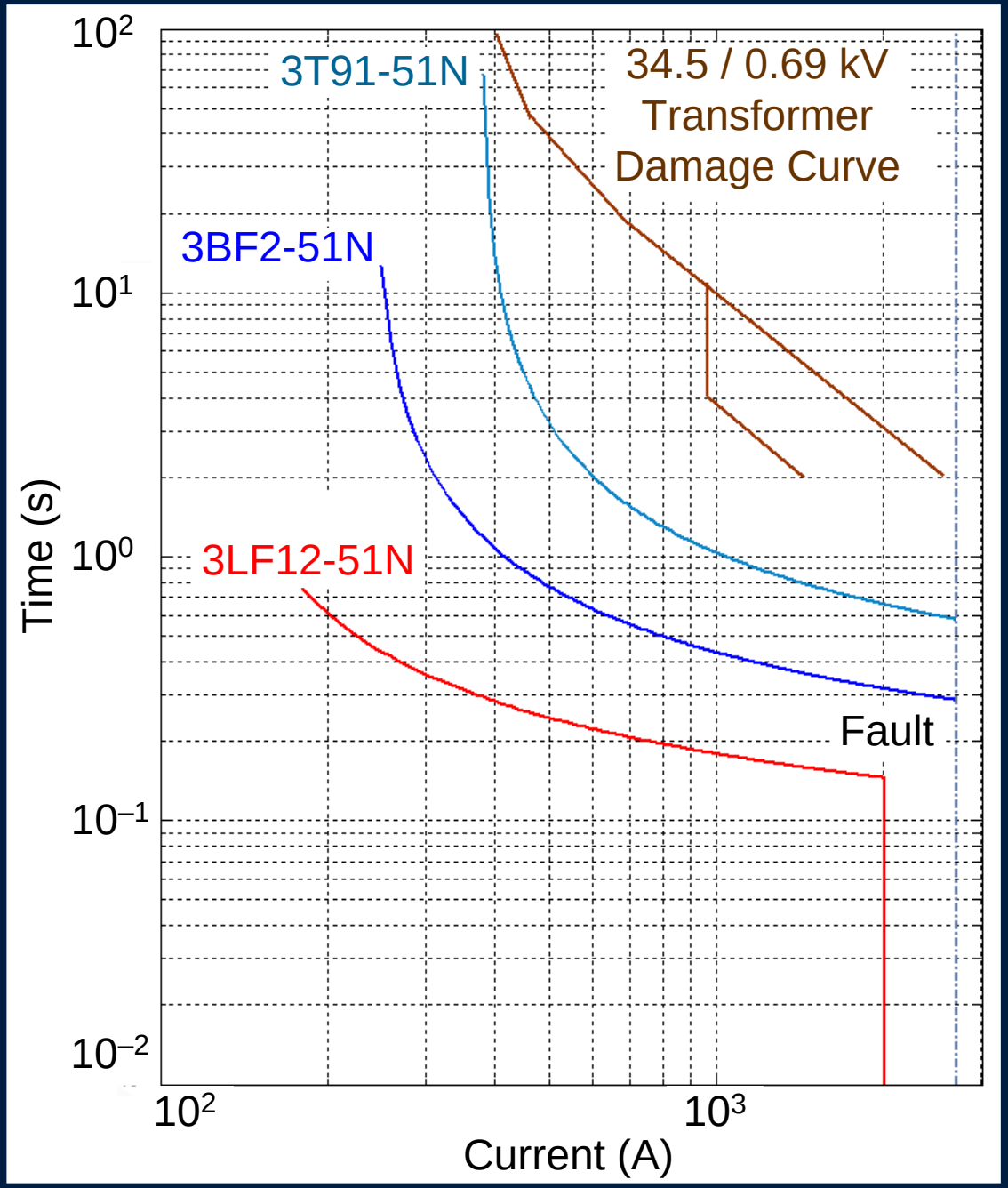
Phase Overcurrent Protection Coordination Example



Bus Ground Fault Currents



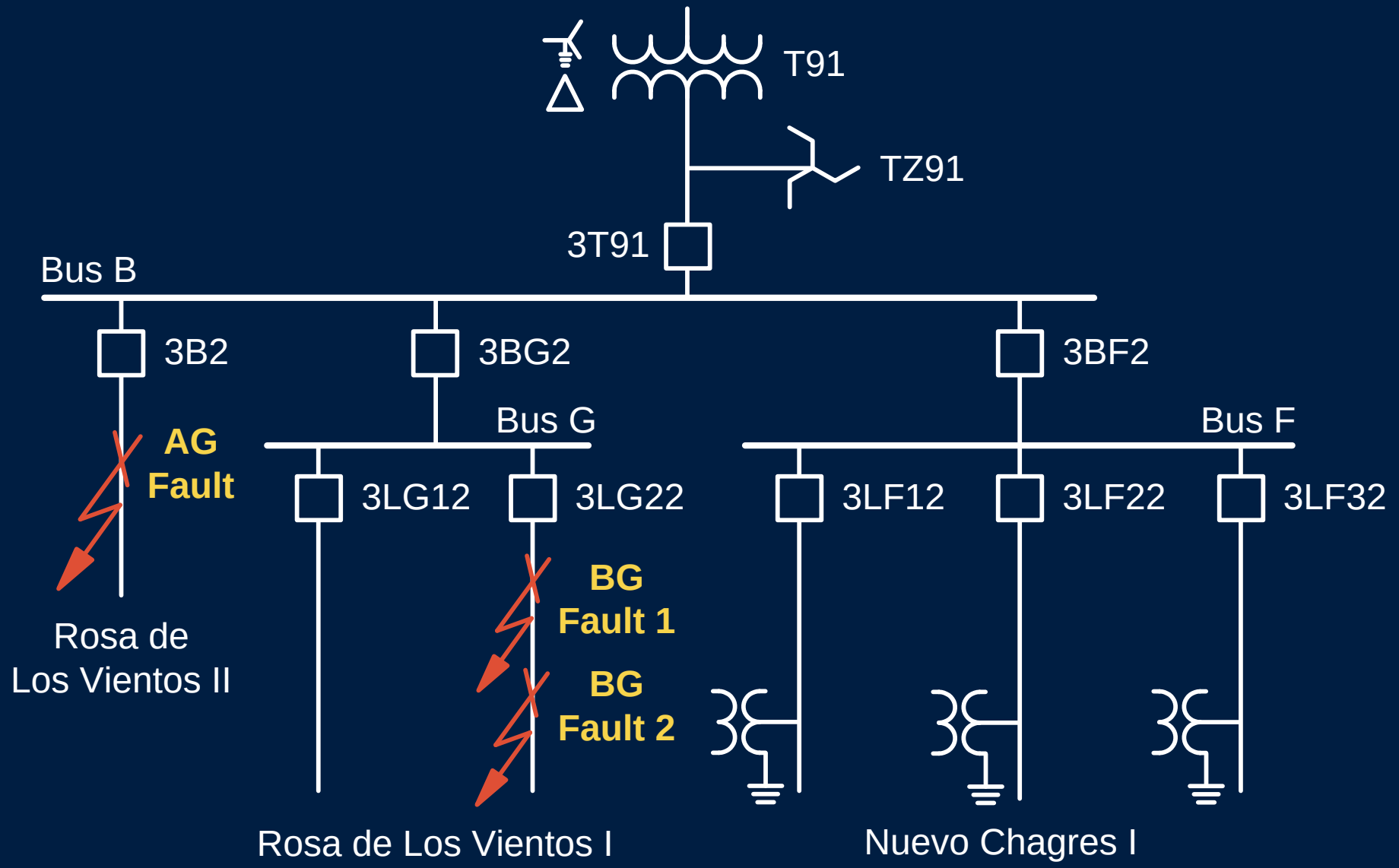
Ground Overcurrent Protection Coordination Example



Actual Fault Event: April 8, 2015

- Initial energization of collector circuit caused two cross-country faults
- Permanent AG fault occurred on cable
- Lightning arrester failed on another circuit
- Tripped breaker left system ungrounded
- New lightning arrester failed on another circuit

Faulted Power System Section



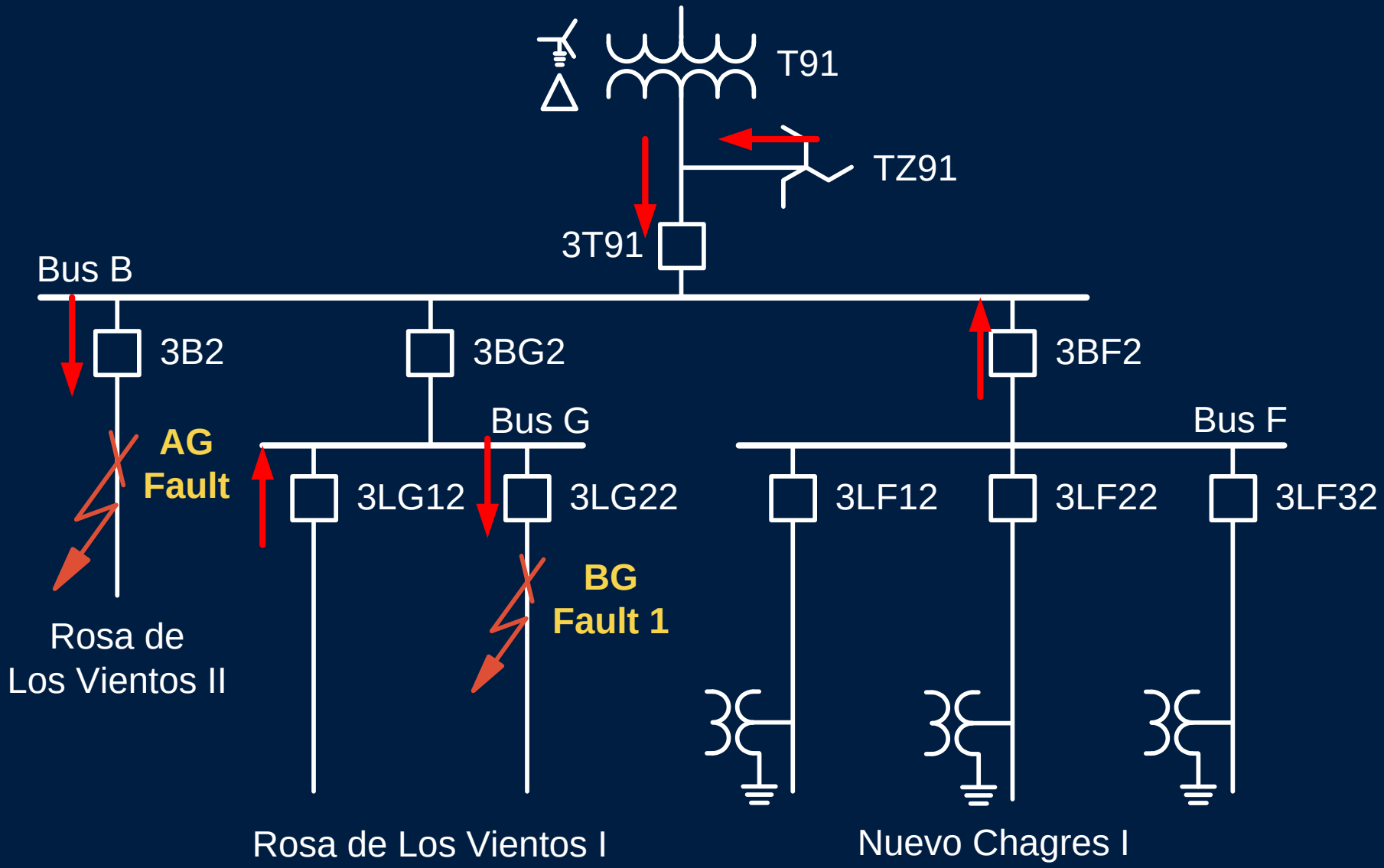
Sequence of Events

Event	Time	Relay		
		3T91	3BF2	3LG22
1	12:50:17:146	Pick up	Pick up	
2	12:50:17:359	–	51N Trip T_{OP} = 0.213 s	–
3	12:50:18:215	51N Trip T_{OP} = 1.069 s	–	Pick up
4	12:50:18:779	–	–	Trip T_{OP} = 0.564 s

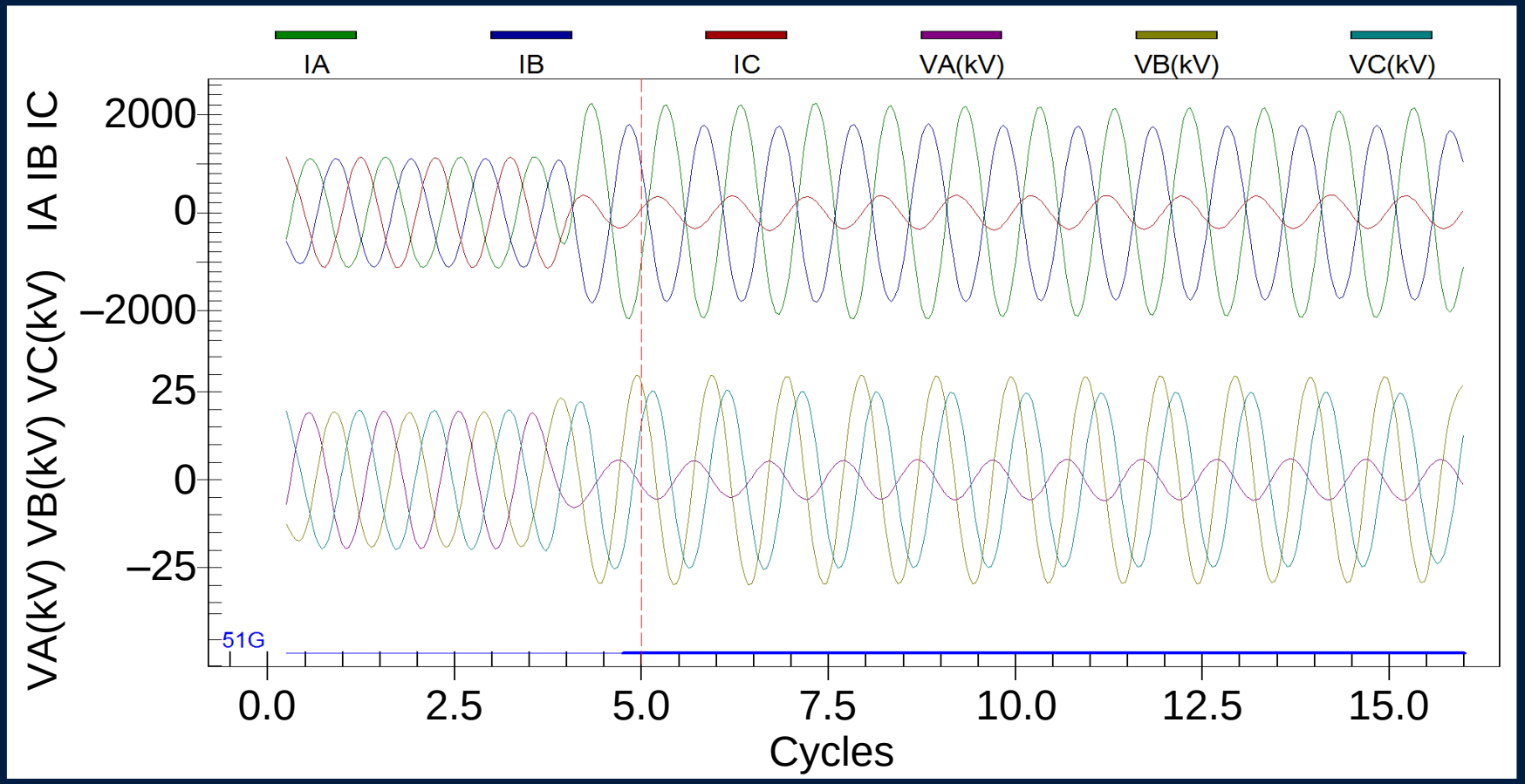
Relay Currents

Current	Relay			
	3T91	TZ91	3BF2	3LF12
I_A	2209.2∠0°	228.7∠0°	1482.4∠0°	540.4∠0°
I_B	1819.8∠175.3°	239.4∠1.1°	1513.7∠296.8°	545.8∠291.7°
I_C	326.3∠41.2°	247.4∠–2.9°	83.1∠275.6°	28.6∠206.3°
I_1	1209.5∠327.2°	9.8∠185.1°	862.1∠30.2°	330.6∠27.4°
I_2	1114.9∠28.6°	3.6∠88.8°	45.9∠73.7°	22.3∠69°
I_0	245.7∠29.6°	238.4∠–0.7°	867.9∠326.6°	295.2∠324.1°
I_G	736.8∠29.6°	715.1∠–0.7°	2603.7∠326.6°	885.5∠324.1°

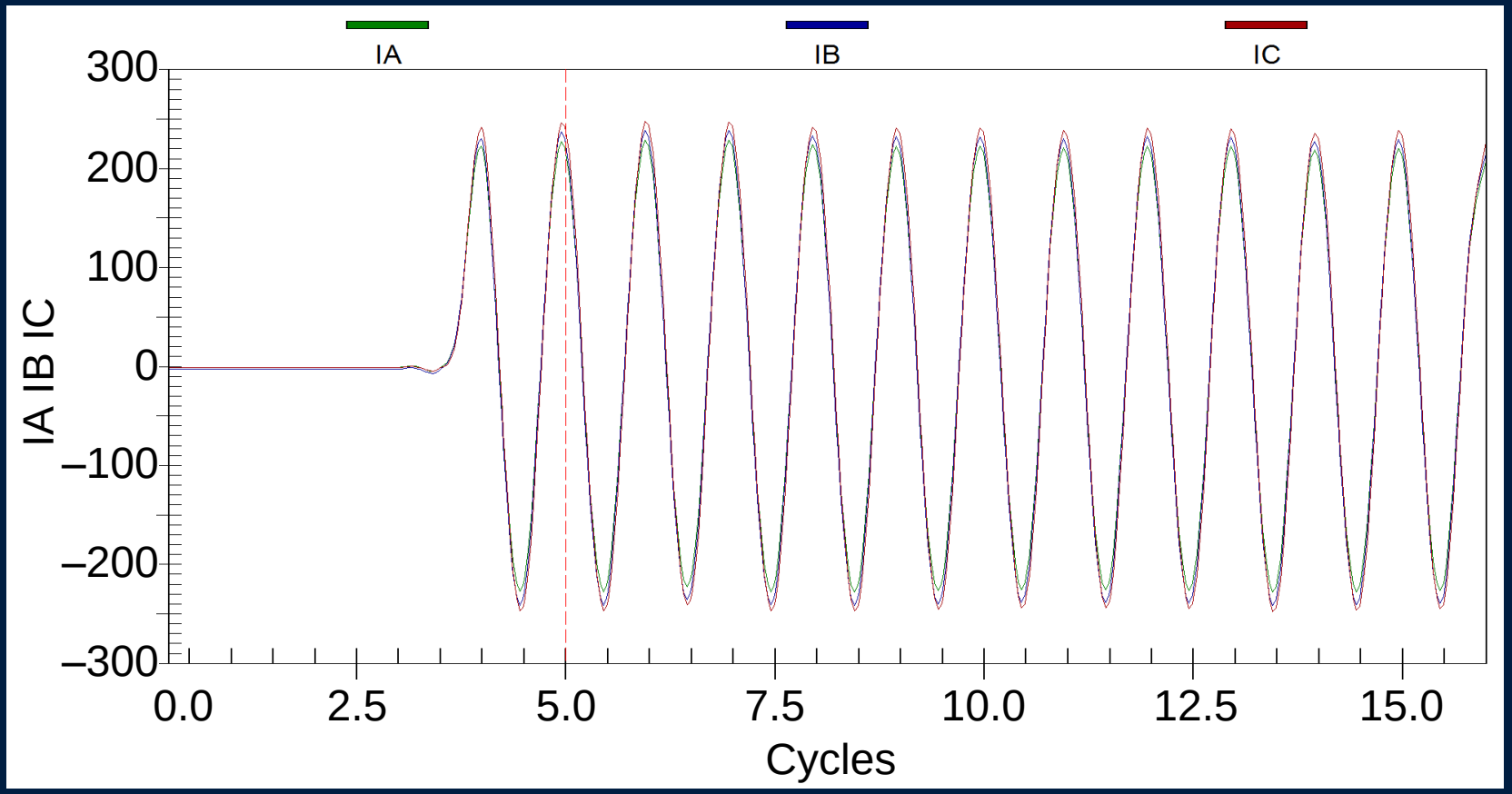
Faulted Power System Section



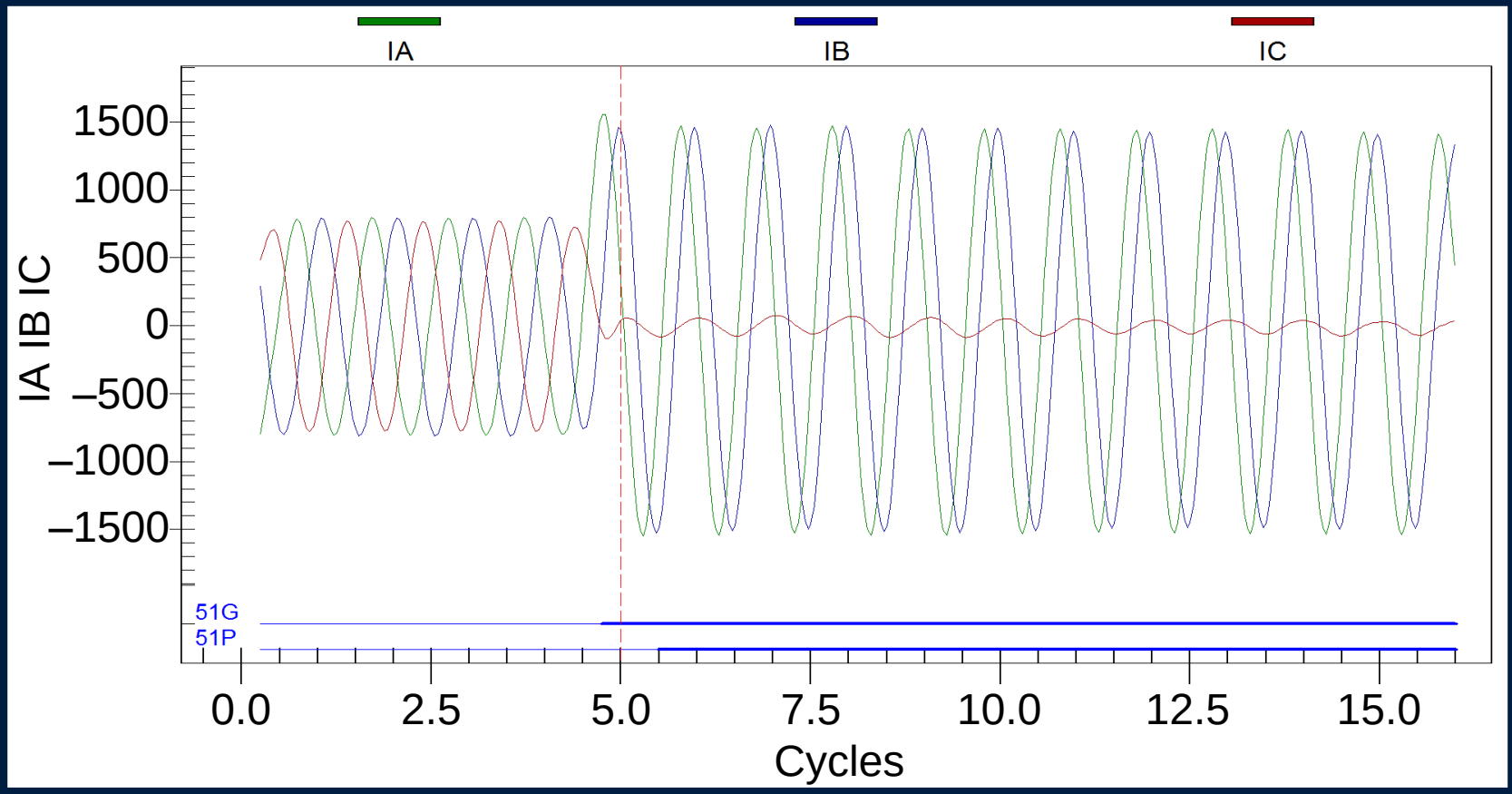
First Fault: Relay 3T91 Record



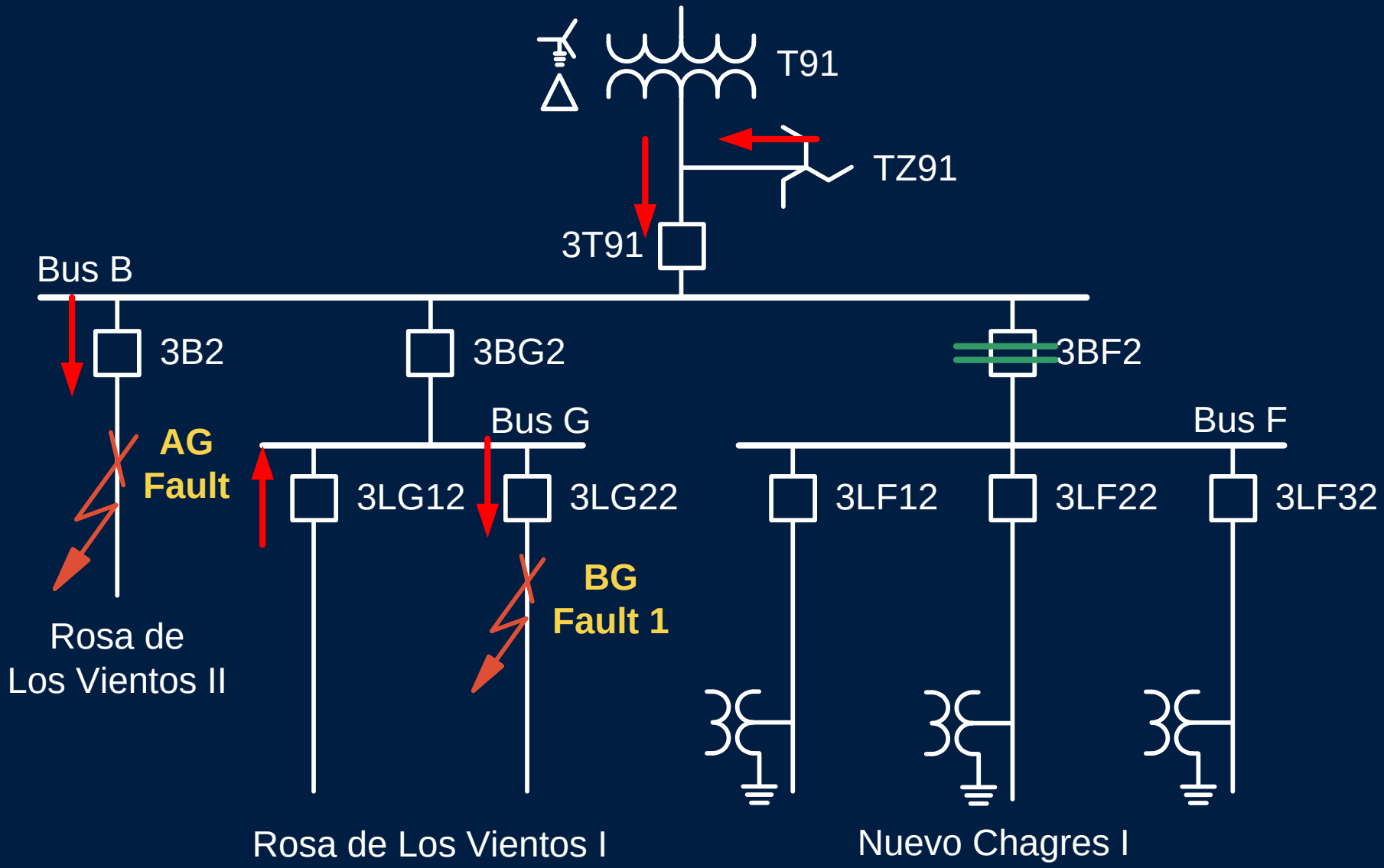
First Fault: Relay TZ91 Record



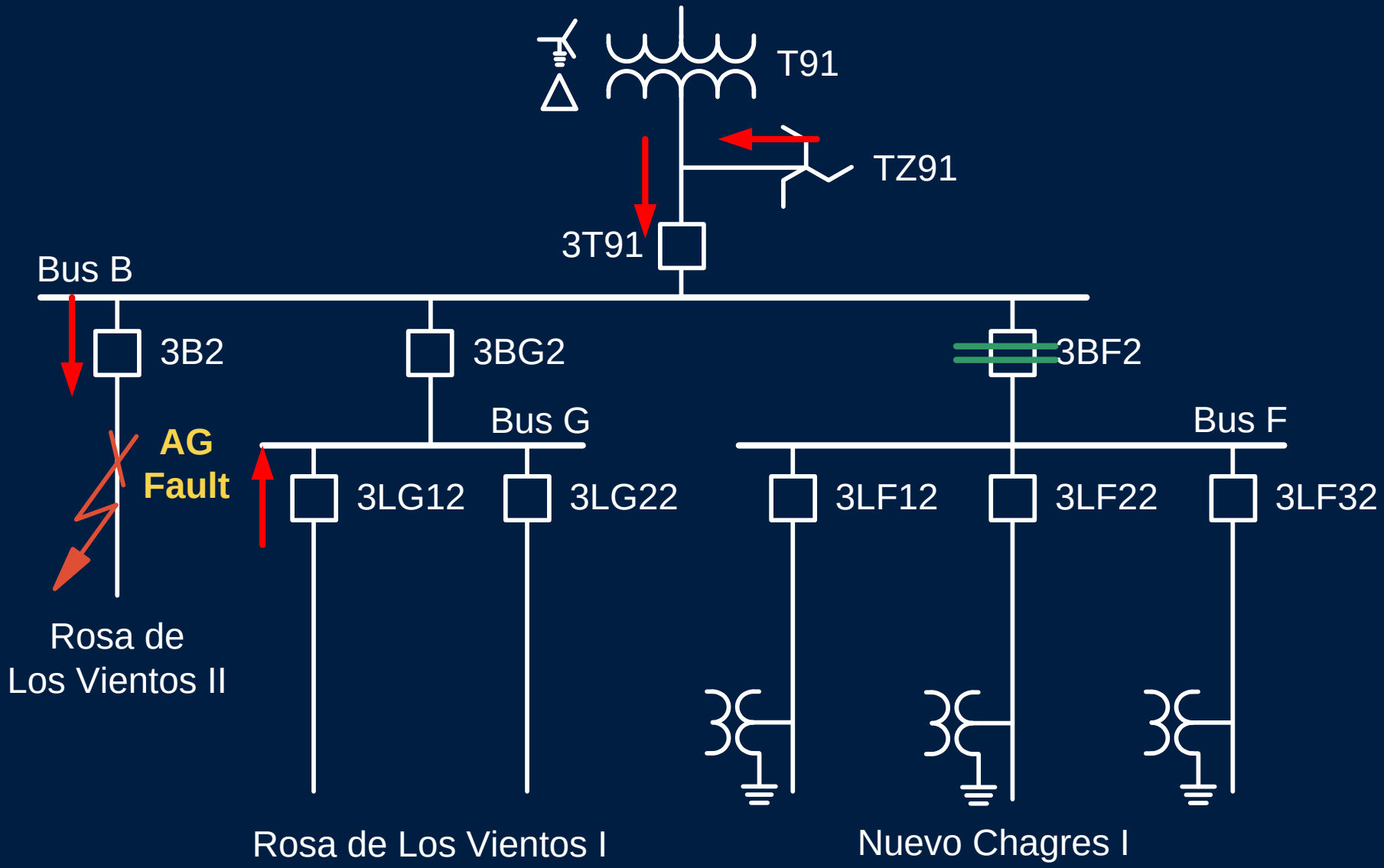
First Fault: Relay 3BF2 Record



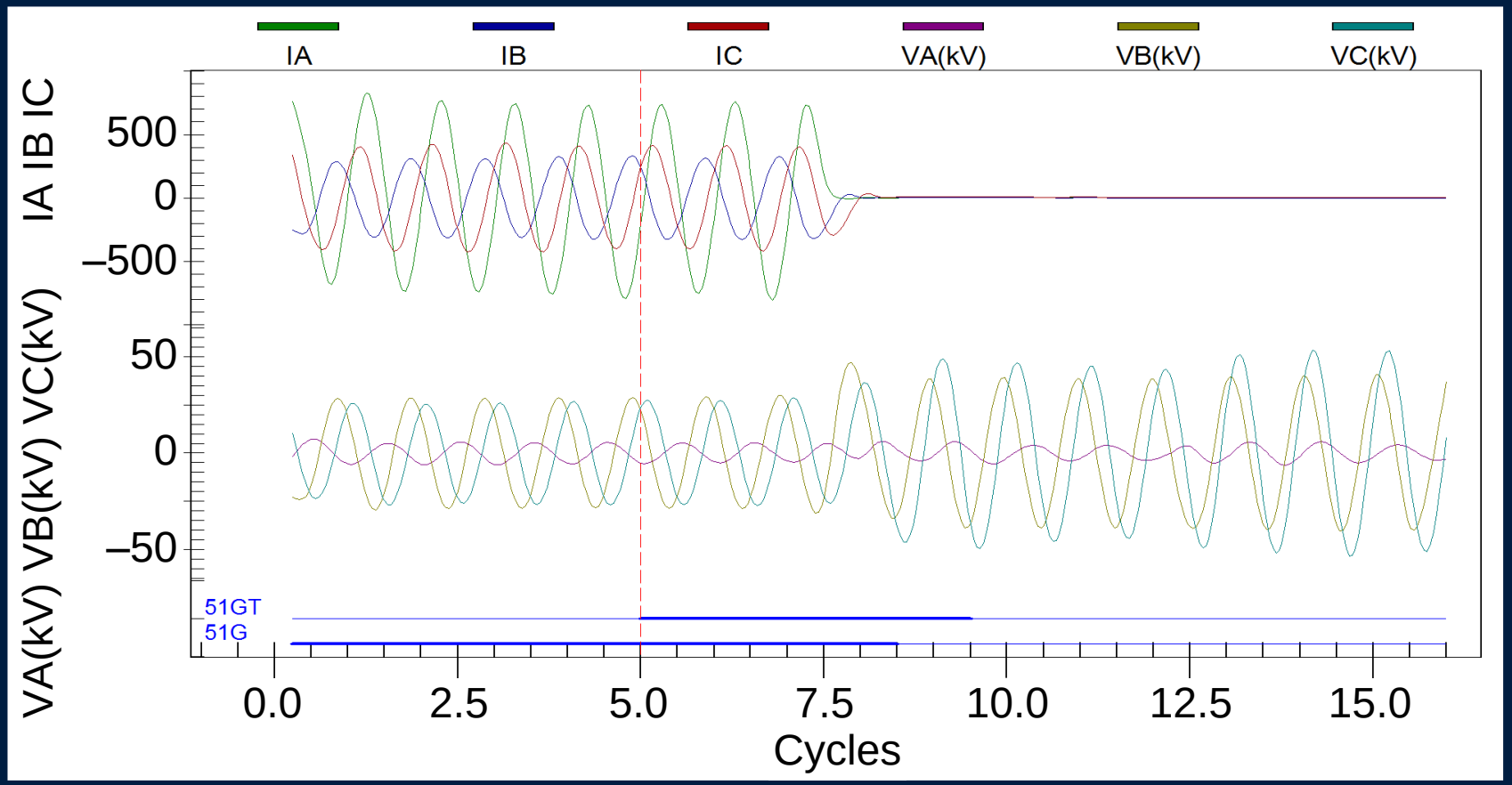
Faulted Power System Section



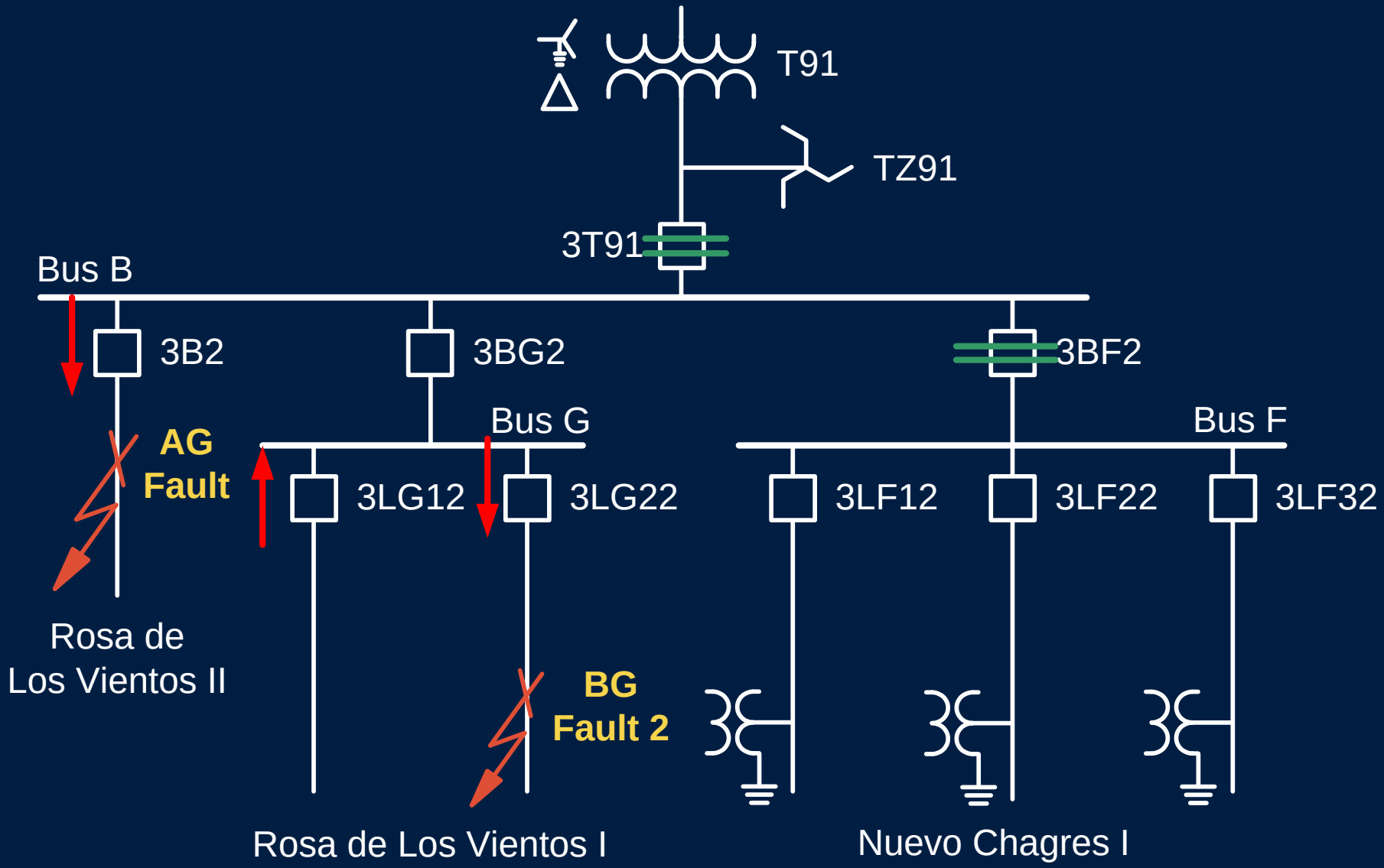
Faulted Power System Section



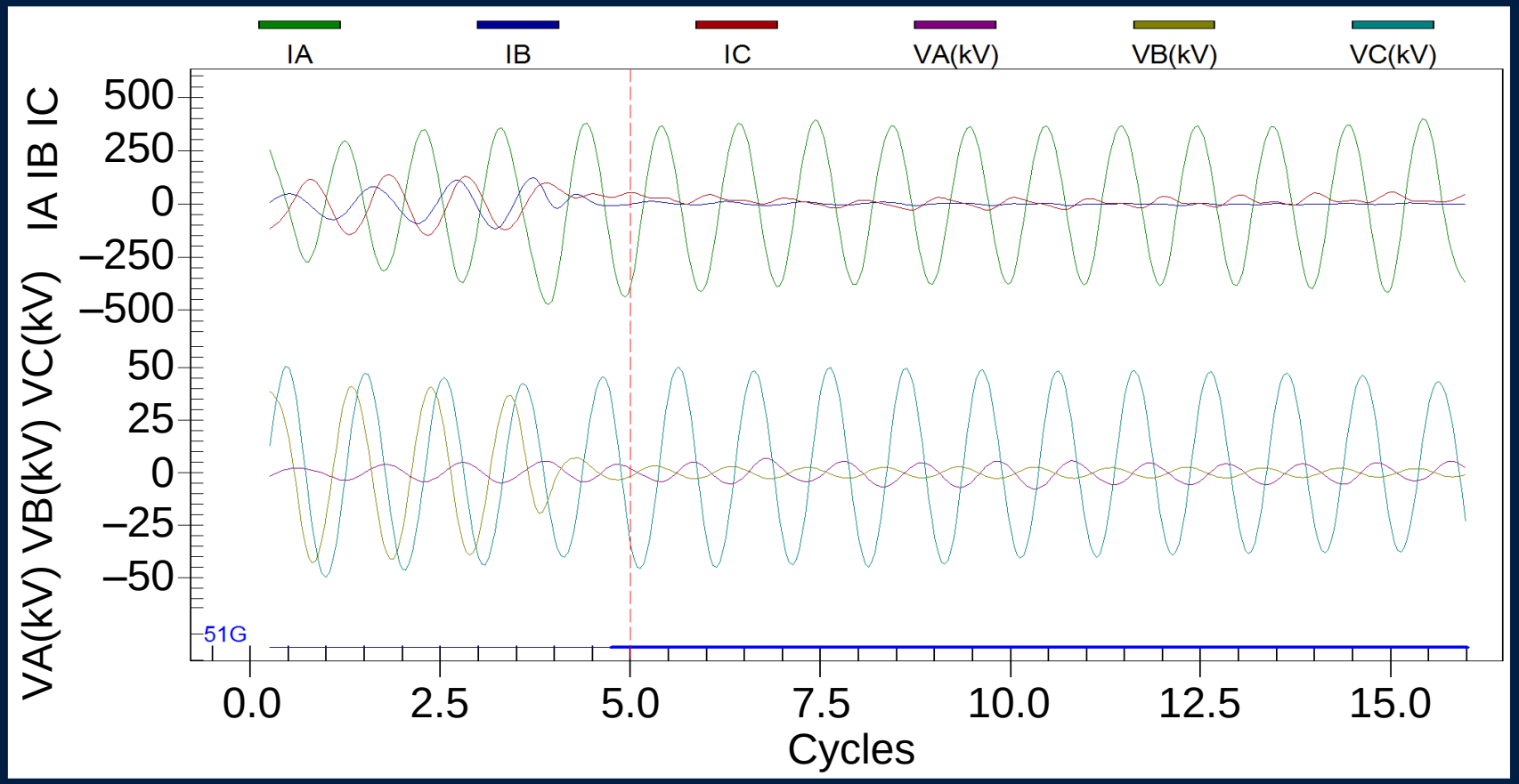
End of First Fault: Relay 3T91 Record



Faulted Power System Section



Second Fault: Relay 3BG2 Record



Conclusion

- Penonomé wind power plant: 270 MW, 108 WTGs
- Type 4 WTGs
  - Variable-speed wind turbine with synchronous generator and frequency converter
  - Power control and fault ride-through ability
  - Fault response determined by control system

Conclusion

- 230 kV P&C system includes
  - Dual 87L/PUTT 230 kV line protection
  - Dual step-up transformer protection
- 34.5 kV P&C system includes
  - Overcurrent protection for collector circuits
  - Additional 67N protection for grounded circuits
  - Fast-bus tripping (future)
- P&C system has performed well

Questions?