Out of Step Strikes Again

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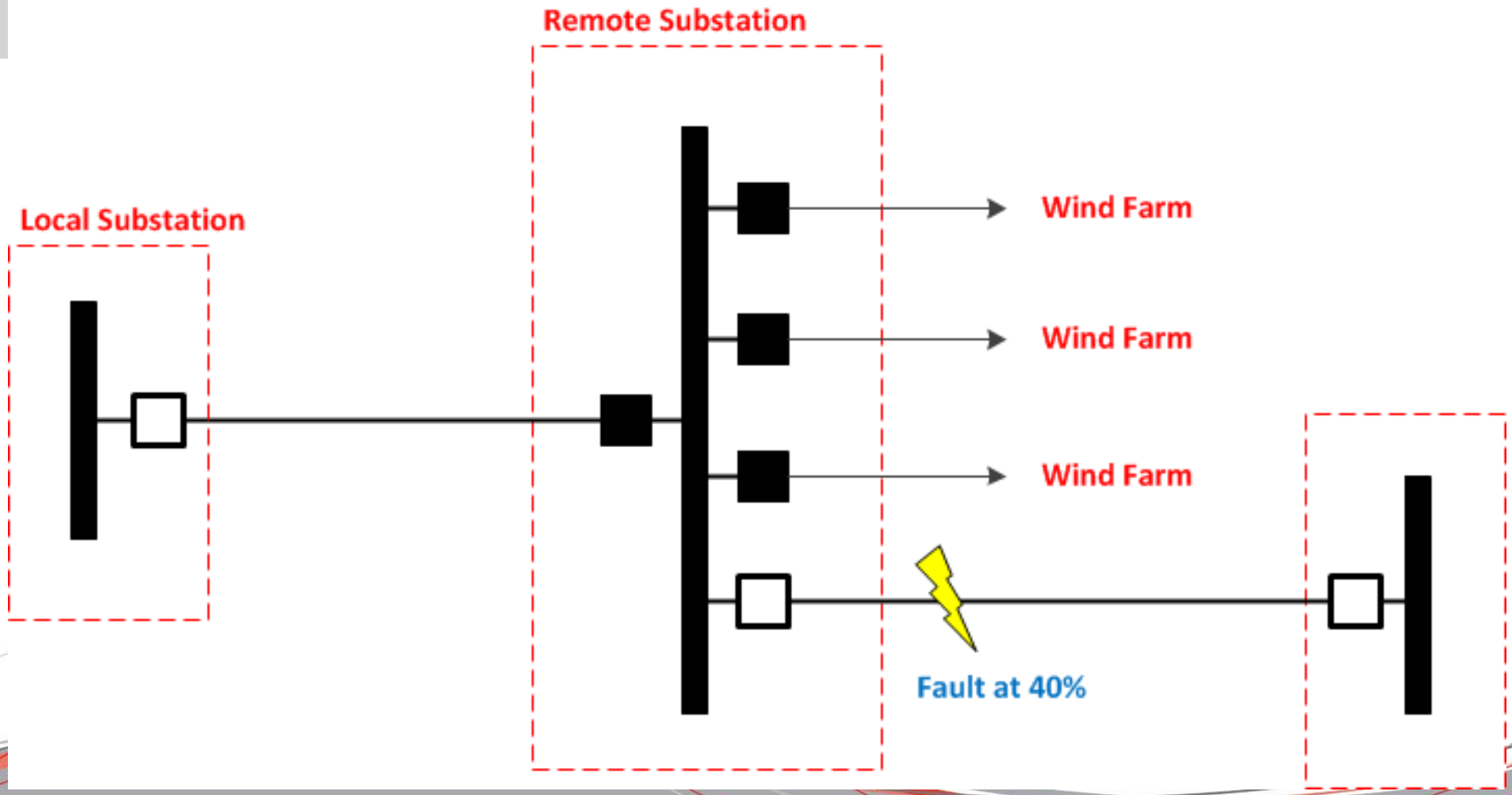
Outline

- Review misoperation
  - Why did the relay trip?
  - What was happening on the system at the time?
- Short review of Out-of-Step
- Corrective actions
  - Temporary plans
  - Long term plans

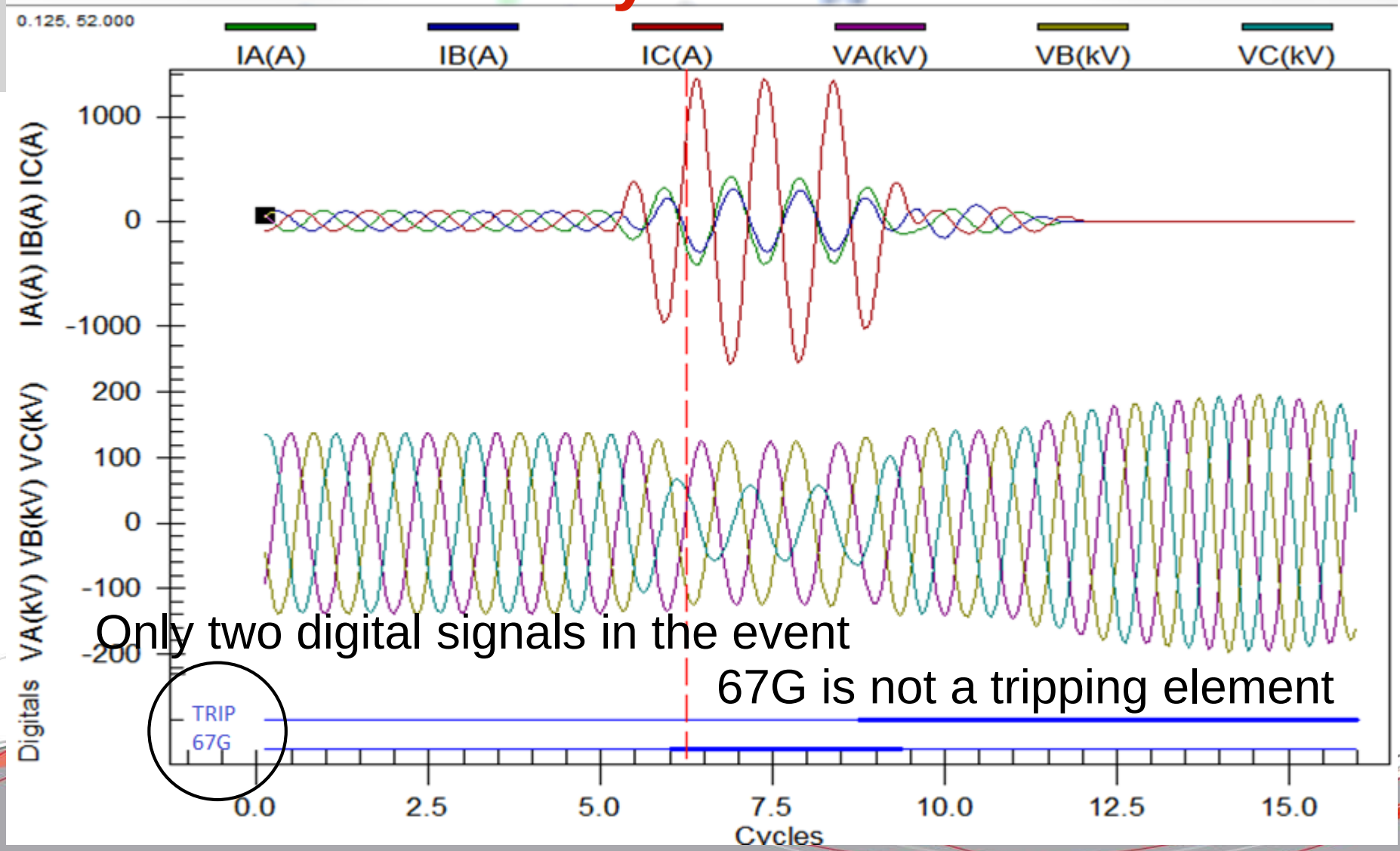
Background

- Breakers tripped on a tie line
- Remote end did not trip
- The fault was a SLG fault on another line
- The other line correctly operated for the fault
- The remote station has three wind farms connected to it

System Overview



What Our Relay Saw



Only two digital signals in the event

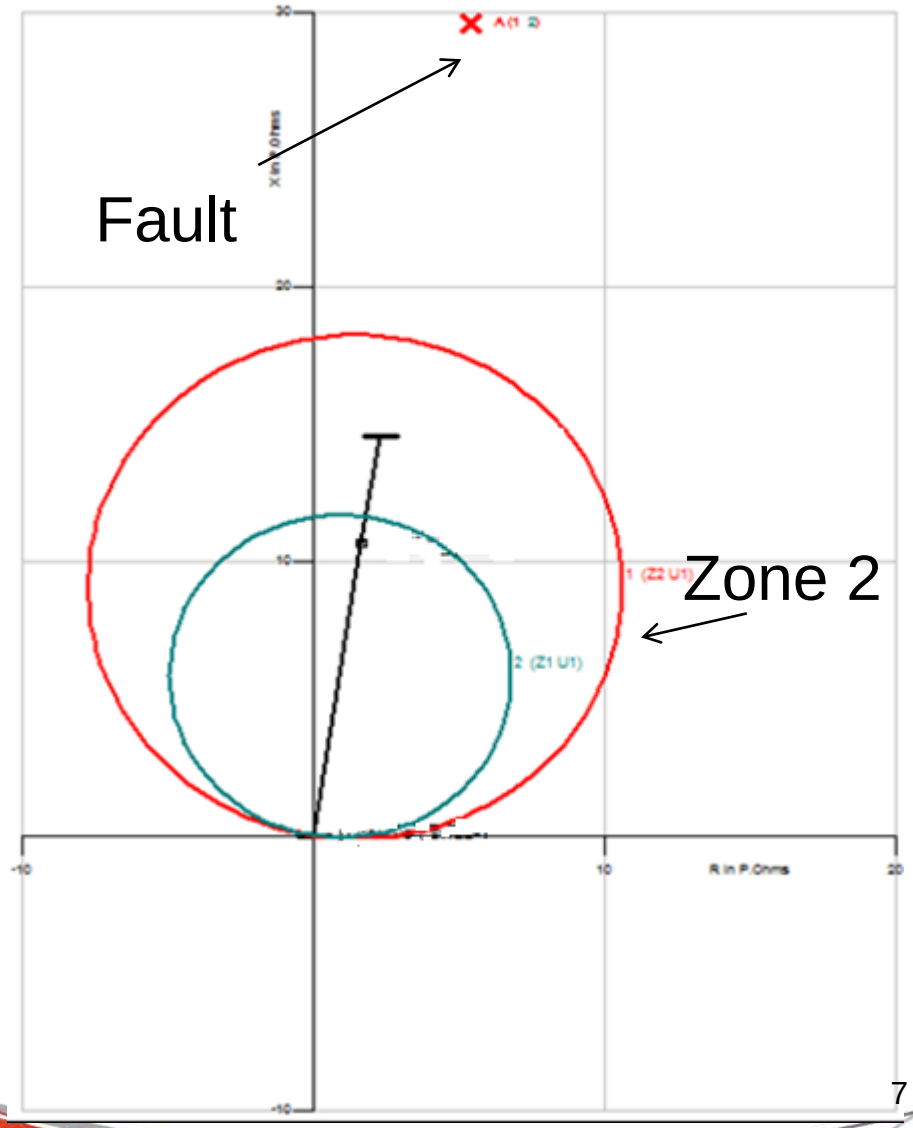
67G is not a tripping element

Possible Causes?

- Was this a Power Line Carrier failure?
  - Not a blocking scheme
  - Line has a DCUB scheme
  - Local digital fault recorders verified local carrier was not sending unblock
  - Remote relay records showed the carrier was not sending unblock

Possible Causes?

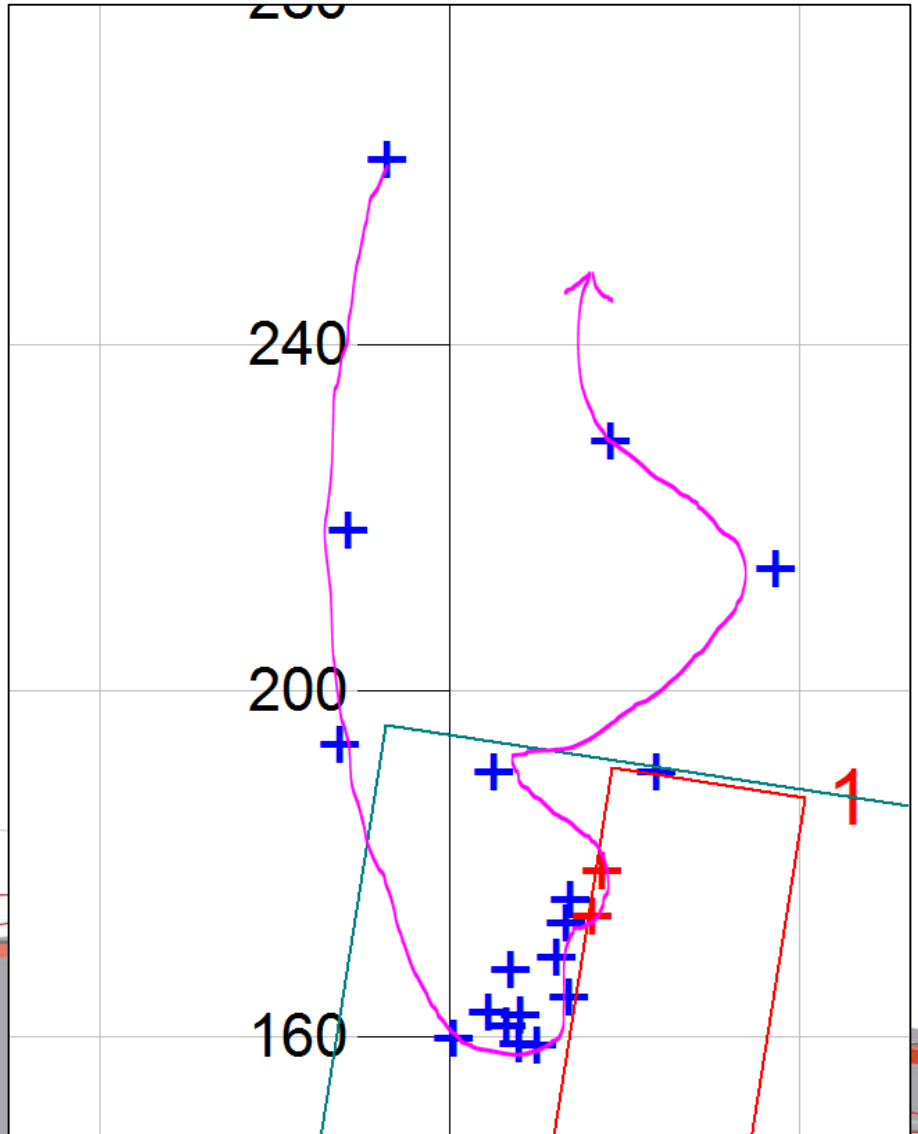
- Over Reaching Zone 2?
  - Fault duration was shorter than Zone 2 delay
  - Fault was outside Zone 2 reach
  - No distance elements were asserted in record



Possible Causes?

- No obvious cause for the trip was seen from event records
- Checked event in our Short Circuit Software
  - COMTRADE playback showed what happened
- Lab testing was used to confirm the simulation
  - Used a test set to play back the COMTRADE file
  - Added many more digital signals to event records
  - Duplicated the trip on the relay in the lab

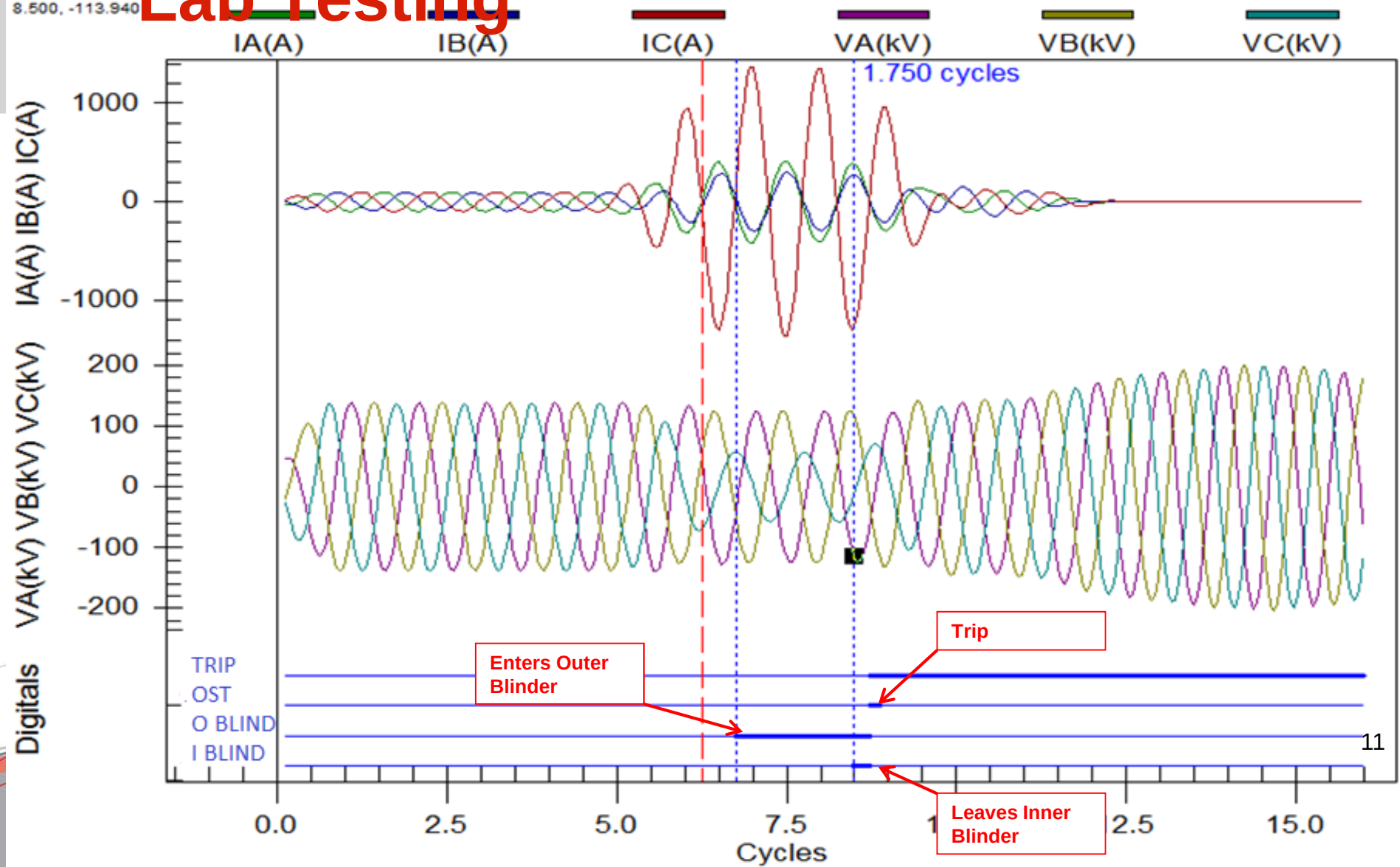
Short Circuit Software



Cause?

- The relay issued a trip for an Out-of-Step condition
- From the playback, the impedance trajectory
  - Entered the Outer Blinder
  - Out-of-step trip timer timed out and was armed to trip
  - Entered the Inner Blinder
  - Tripped when exiting Inner Blinder
- We classified the event as a misoperation

Lab Testing


8.500, -113.940
IA(A)
IB(A)
IC(A)
VA(kV)
VB(kV)
VC(kV)
1.750 cycles
IA(A) IB(A) IC(A)
1000
0
-1000
VA(kV) VB(kV) VC(kV)
200
100
0
-100
-200
Digitals
TRIP
OST
O BLIND
I BLIND
Enters Outer Blinder
Trip
Leaves Inner Blinder
0.0
2.5
5.0
7.5
12.5
15.0
Cycles

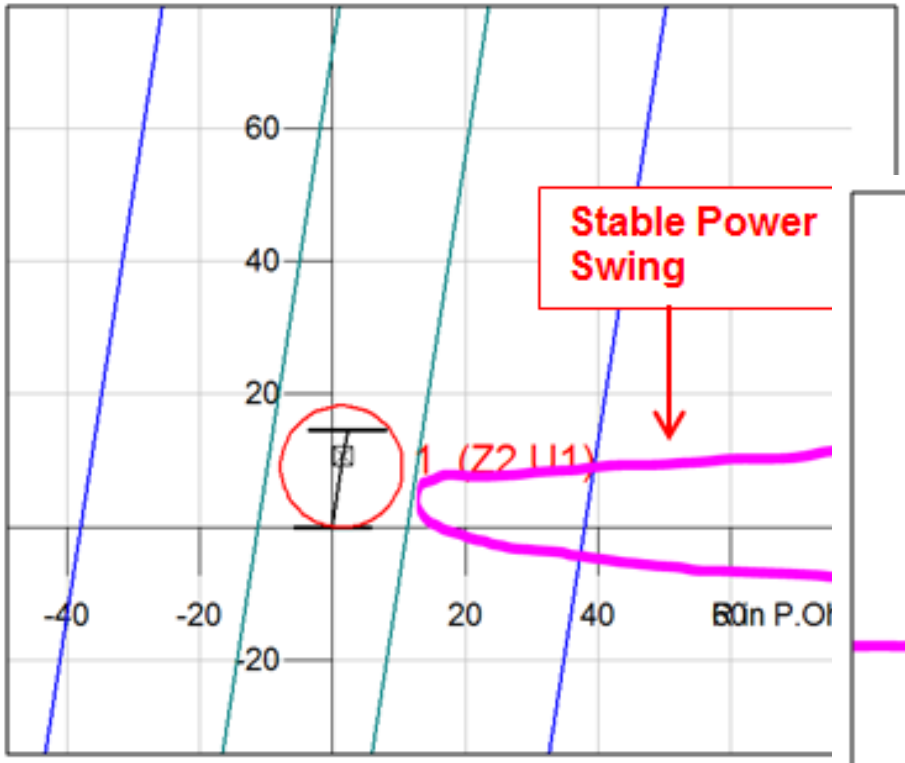
A Short Review

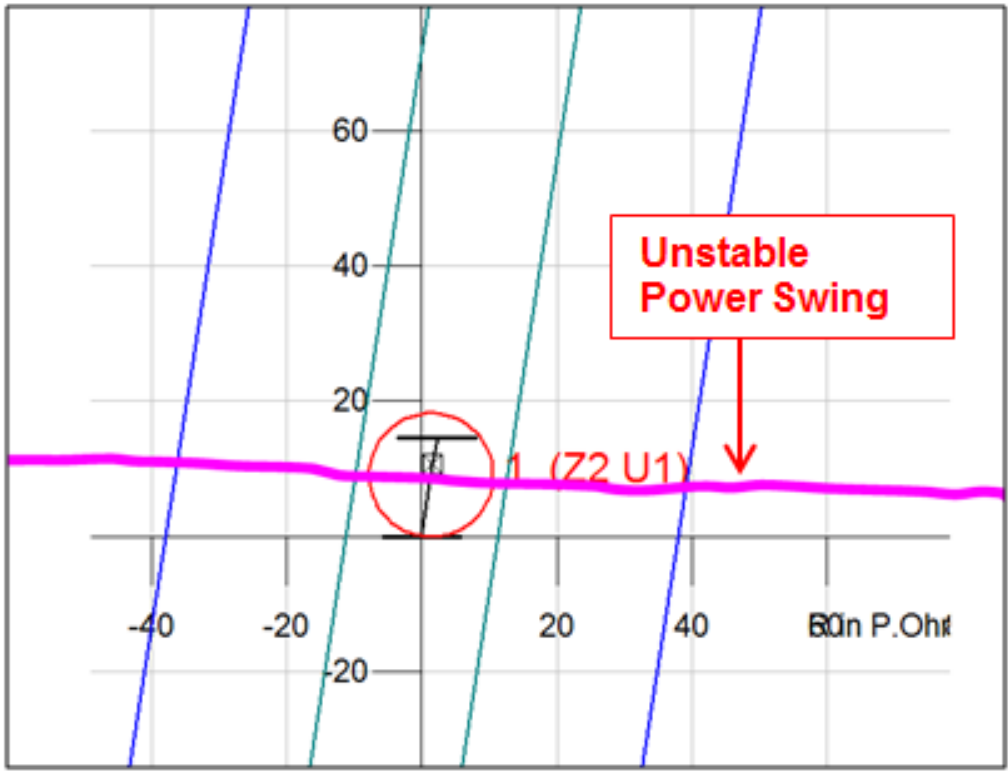
- **Why was this a misoperation?**
- **A power swing is a variation in the three phase power flow which occurs due to changing loads, faults, and changes to generation. It is caused by the generator rotor angles changing to balance the system**

A Short Review

- A power swing can have two results:
- Stable - where the generator(s) or systems do not slip poles and the system reaches a new state of equilibrium
- Unstable - where the generator(s) or systems experience pole slipping requiring action to keep the system stable

What a relay will see



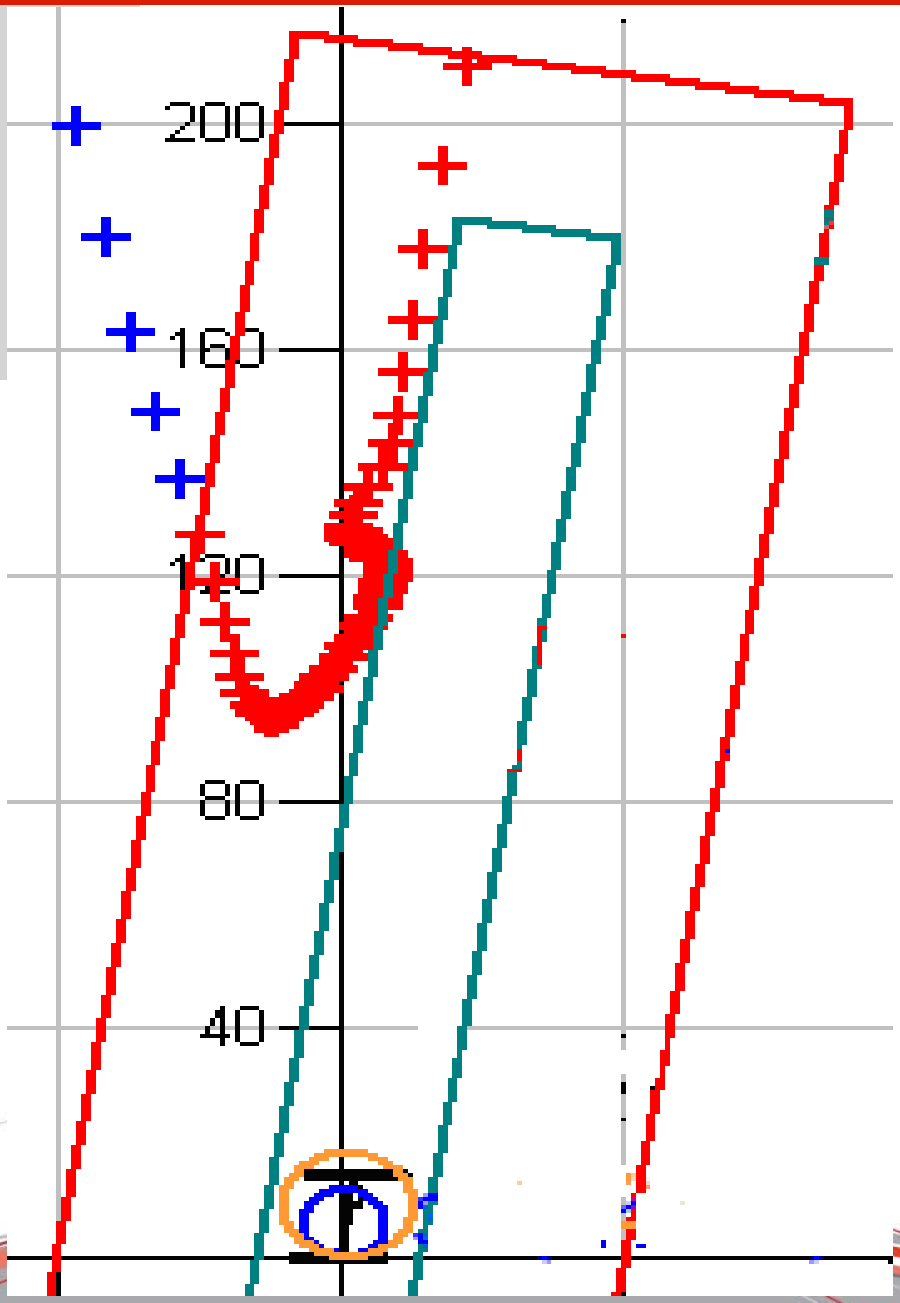


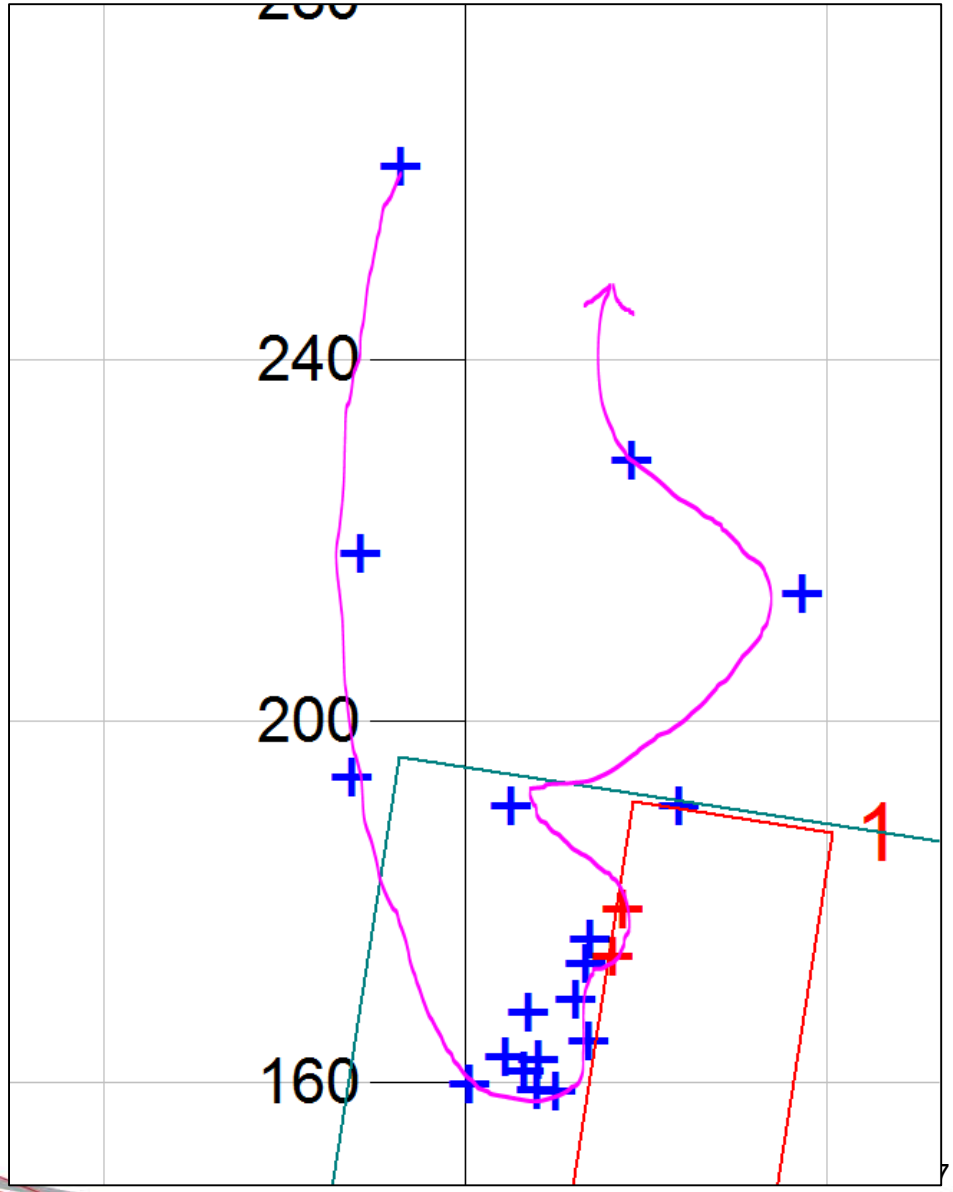
Not a Power Swing?

- The relay on this line incorrectly saw this disturbance as a power swing with none of the following being true:
  - The power swing was not a three phase event
  - No generators or systems slipped a pole during the event
  - The system returned to a stable equilibrium

Past History With This Line

- Line previously had an incorrect Out-of-Step trip a few years ago
  - Previous trip was for a Line to Line fault
  - This time the trip was for a Line to Ground fault
- We made changes before hoping to correct the issues
  - Increased out-of-step timers
  - Changed blinders by reducing the reaches
  - Changed trip logic to trip


200
160
120
80
40


240
200
160
1

2003 Blackout

- **“While zone 3/zone 2 relays operated during the August 2003 blackout according to their settings and specifications, the inability of these relays to distinguish between a dynamic, but stable power swing and an actual fault contributed to the cascade.”**
- **“If the power swing is stable, from which the system will recover, a line protection should not operate”**

Time to Stop and Re-evaluate

- **What is really wrong?**
  - **The root cause of this misoperation was that the relay incorrectly saw this fault as a power swing and tripped**
  - **Testing in the lab also revealed that zone one and zone two was not always being blocked during out-of-step events**

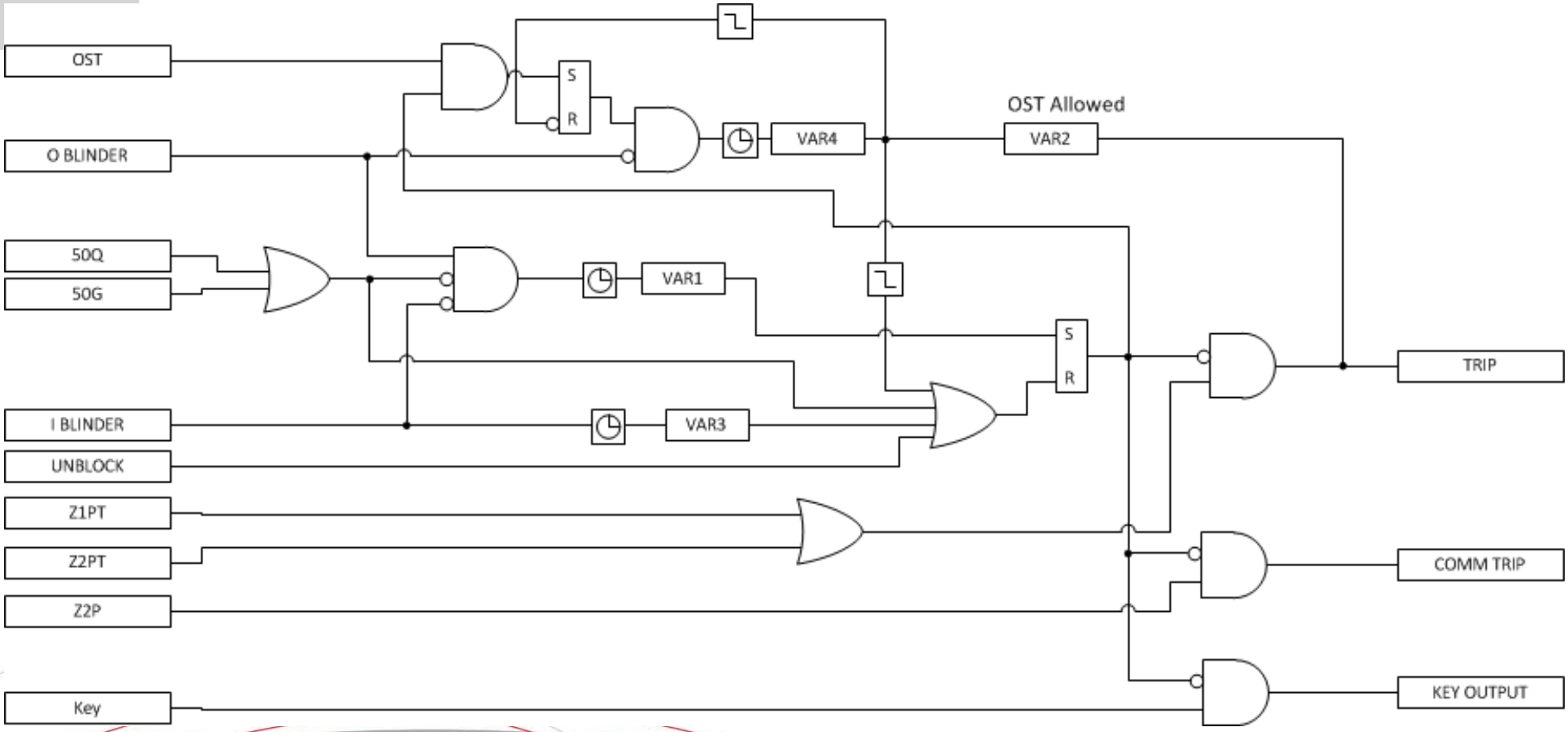
What do we want?

- We determined we want the relay to:
  - Only trip for unstable power swings
    - Three-Phase
    - Must cross 180 degree point
    - Not trip for stable power swings
  - Block Zone 1 and Zone 2 tripping
  - Trip for 3-Phase faults
  - Trip on the way out of outer blinders to minimize risk to breakers

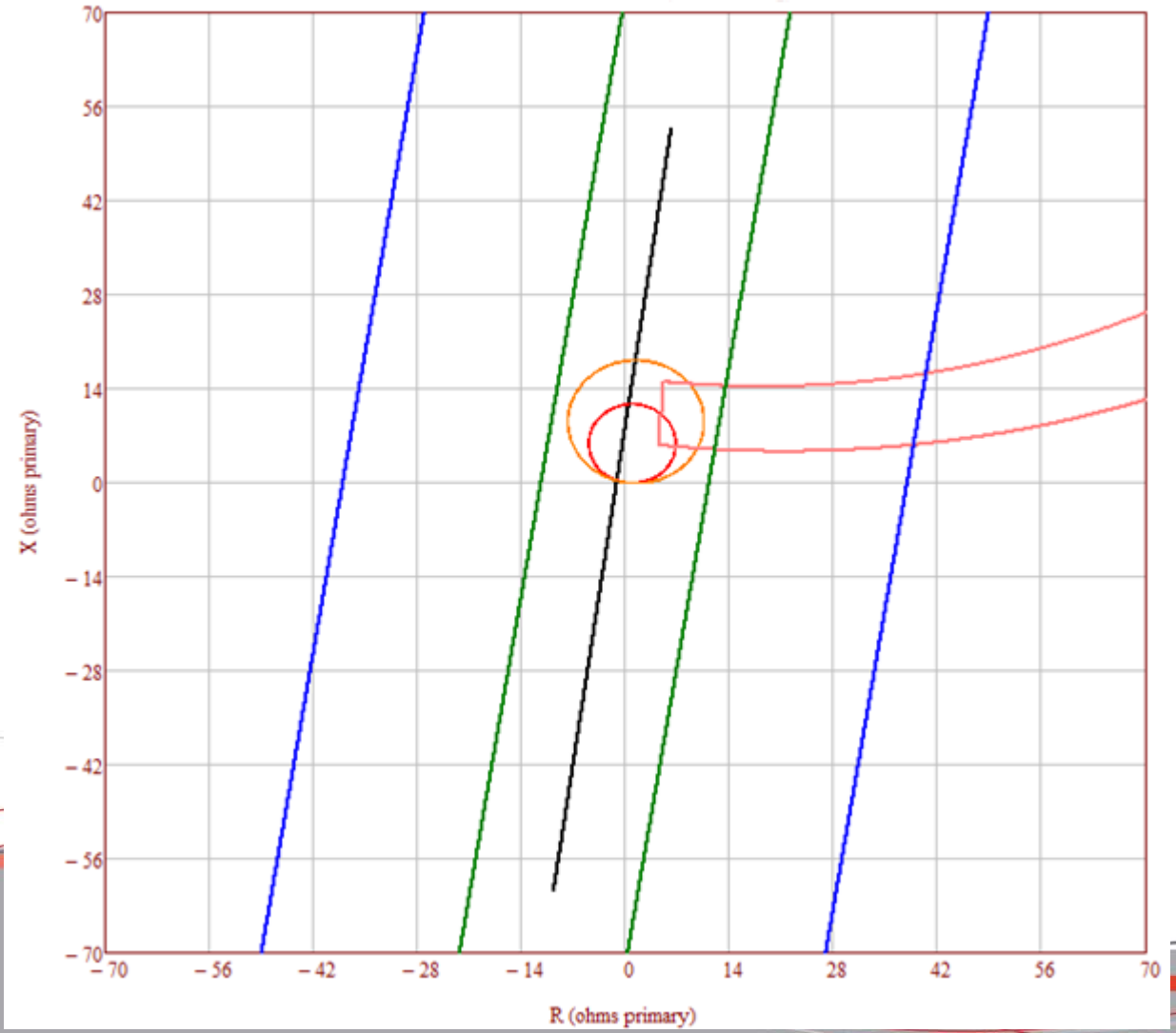
Back to the Drawing Board

- We were able to create logic to change a few items on our list
  - Blocked out-of-step tripping logic from tripping the breaker during faults
  - The relay issued a trip on the way out of outer blinder
- The existing relay we have installed is an older relay and can't accomplish all the items on the list.
  - Unable to tell the difference between stable and unstable
- We needed a better way of testing the settings

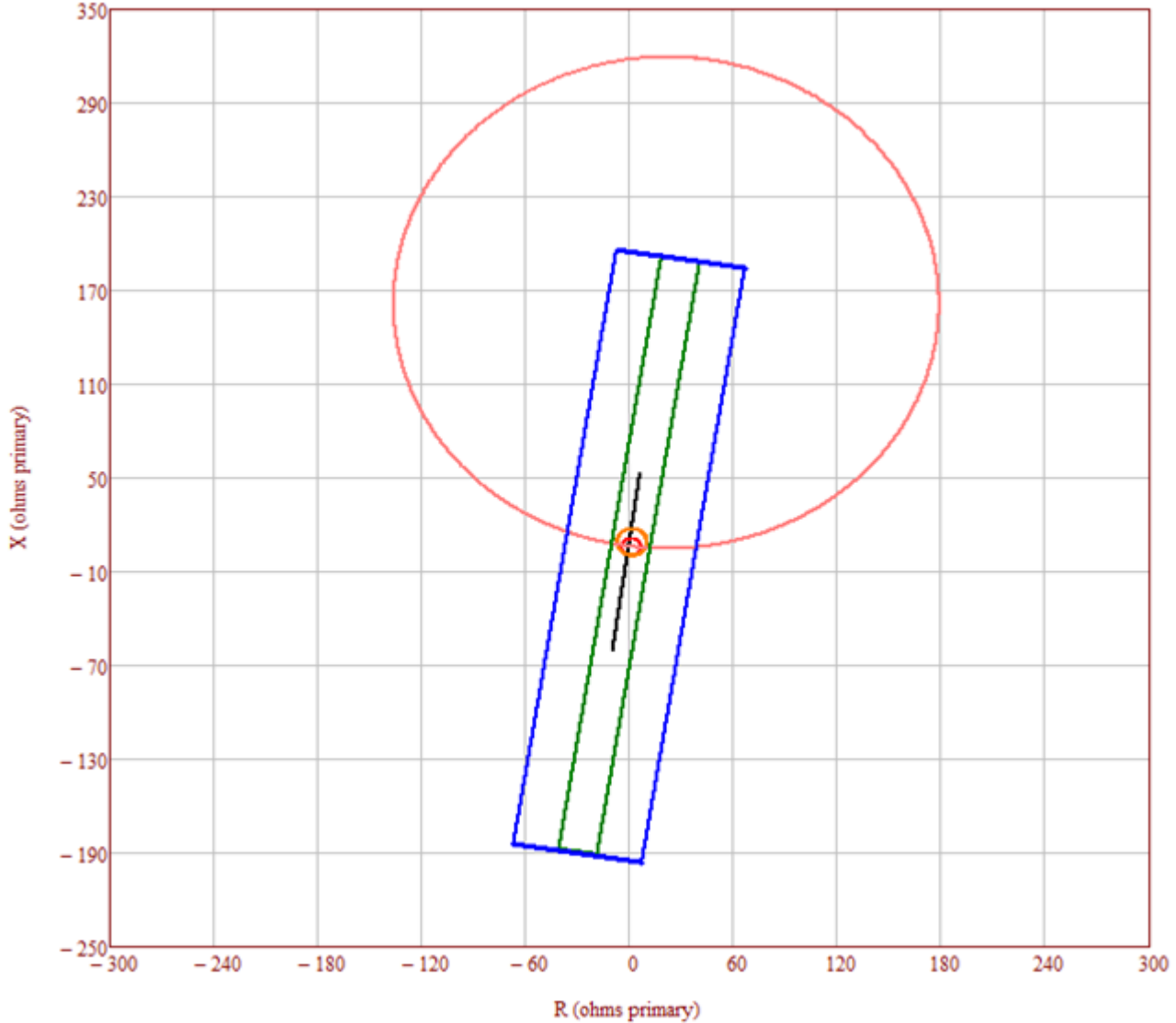
Temporary Solution



Stable Testing



Unstable Testing



Testing the Logic

	OST	Z1 BLK	Z2 BLK	TRIP OTWO			Trip
2.00 Hz Stable	N	**N**	**N**	N		Z1G	Y
0.20 Hz Unstable	**N**	Y	Y	**N**		Z2G	Y
0.50 Hz Unstable	**N**	Y	Y	**N**		Z1P	Y
1.00 Hz Unstable	Y	Y	Y	Y		Z2P	Y
2.00 Hz Unstable	Y	Y	Y	Y		Z3P	Y
3.00 Hz Unstable	**N**	Y	Y	**N**			
Orginal Event	N	N	N	NA			

Testing the Logic

	Original	Modified	Manufacture Recommended	Other #1	Other #2
Block Zone 1 during power swing	**No**	Yes	**No**		
Block Zone 2 during power swing	**No**	Yes	**No**		
Trip on the way out of Outer Blinder	**No**	Yes	Yes		
OST declared, then external fault, still get OST	Yes	Yes	Unknown		
No OST for stable power swings	**No**	**No**	Yes		
OST for all unstable power swings tested	Yes	Yes	**No**		
OST blocked for anything not 3PH	**No**	Yes	Yes		
All elements in TR setting still work	Yes	Yes	Yes		

Future Plans

- Evaluate out-of-step trip logic from several relay manufactures to determine which relay best fits our needs
- Work with the manufactures to resolve issues with the settings and tests
- Make recommendations to the company on where we should go from here to prevent future misoperations

Lessons Learned

- All relays do not respond the same to out-of-step conditions
- Testing will help gain an understanding of how the relays work
- Testing Out-of-Step settings can either confirm or bring to light issues with your settings/philosophy
- Testing showed there were holes in our philosophy relating to out-of-step tripping
- After a misoperation, stop and evaluate what is really happening

The End

Questions are welcome as time permits