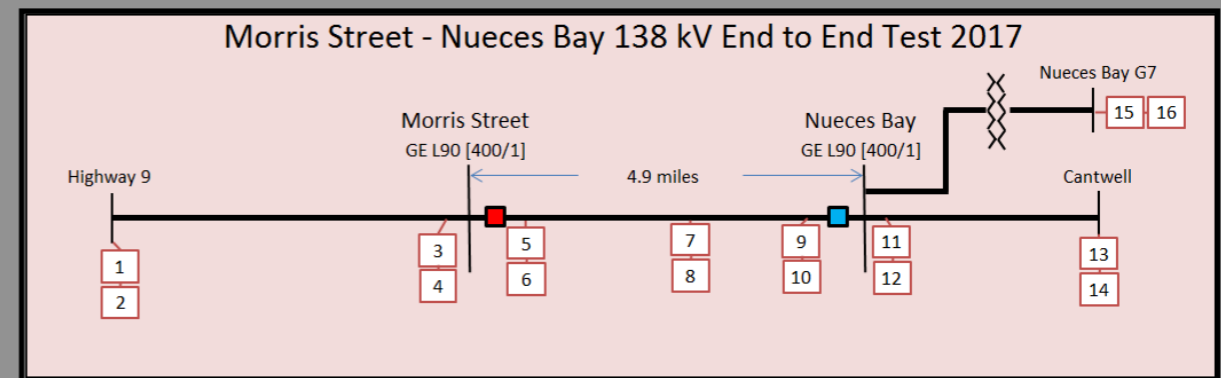


A Troubleshooting Methodology For Issues Discovered During End-to-End Testing

Jose R. Garza

End-to-End Testing

- Faults are simulated at various points on a protected line (ASPEN)
- Fault data exported for test set playback
- GPS synchronized test sets at each terminal playback faults and examine relay response for proper operation



Morris Street - Nueces Bay: Online and simulated fault locations

End-to-End Testing

- Three states of fault playback

- Pre-Fault

- “Normal” conditions

- Fault

- Secondary fault values

- Post-Fault

- Breaker open

	PREFault			FAULT			POSTFAULT	
	mag	ang		mag	ang		mag	ang
VA	66.4	0.0	VA	70.1	30.2	VA	66.4	0.0
VB	66.4	-120.0	VB	13.8	-120.8	VB	66.4	-120.0
VC	66.4	120.0	VC	15.5	177.5	VC	66.4	120.0
TA	1.00	0.0	TA	1.41	70.9	TA	0.00	0.0
TB	1.00	-120.0	TB	7.53	-160.5	TB	0.00	-120.0
TC	1.00	120.0	TC	8.02	80.3	TC	0.00	120.0

*End-to-End Test States:
Pre-fault, Fault, Post-fault*

End-to-End Testing

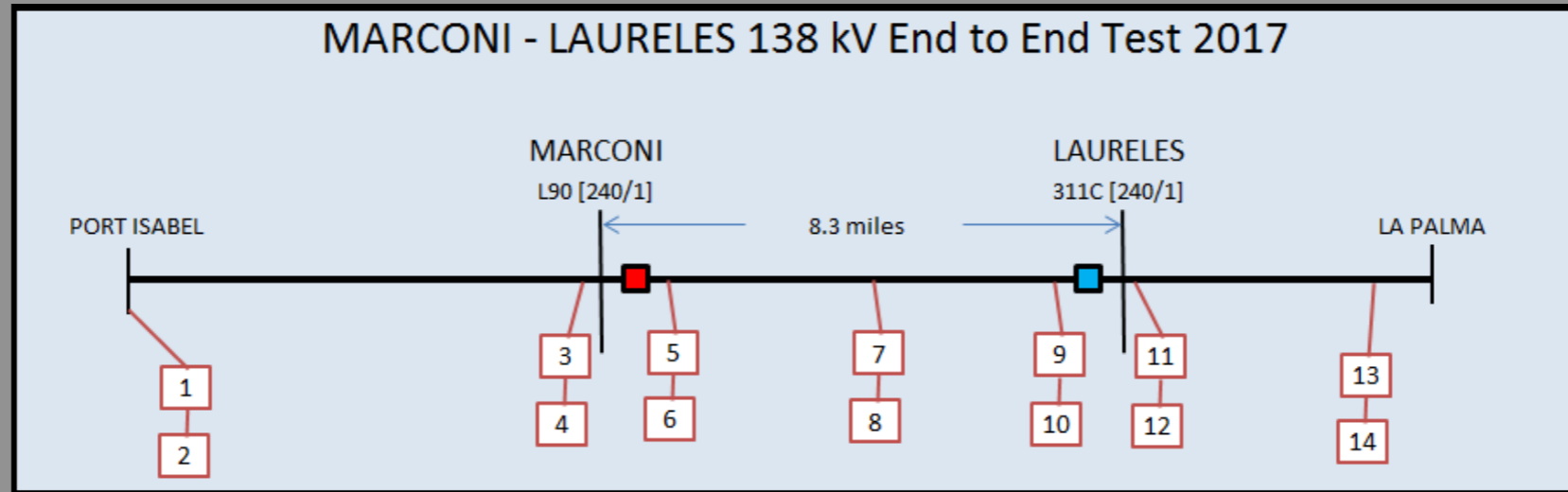
- Faults are simulated under two scenarios
 - No Comm
 - Hi speed protection disabled, fault duration 120 cycles
 - Tests backup distance/overcurrent elements
 - Comm
 - Hi-speed scheme in service, fault duration 10 cycles
 - Tests hi-speed scheme (87, POTT, DCB, etc.)

Troubleshooting Methodology

- 1st - Request relay events from field personnel
 - Buys time to examine rest of process
- 2nd - Assume test plan is wrong, work to prove/disprove first
 - Examine CT/PT ratios, one-line model, fault selection
- 3rd - Examine settings
 - Comm scheme settings, distance elements, logic, interconnect settings
- 4th - Examine application of test plan
 - Test set connections

Errors: Test Plan Creation

Scenario: @Laureles System 2 (311C) Z1 overreaching for tests 3-6 - no comm tests



Marconi - Laureles: Oneline and simulated fault locations

Test Name/Location	for Single-End
1. A-G PORT ISABEL 138kV Bus	trip, time,AG,51, 56.136 cy
2. B-C PORT ISABEL 138kV Bus	trip, BC,Z3, 61.71 cy
3. B-G 2% MARCONI - PORT ISABEL	trip, BG, Z1, 1.632 cy
4. A-C 2% MARCONI - PORT ISABEL	trip, AC, Z1, 1.758 cy
5. C-G 2% MARCONI - LAURELES	trip, CG,Z1, 1.644 cy
6. A-B 2% MARCONI - LAURELES	trip, AB,Z1,1.716 cy
7. A-B-C-G 50% MARCONI - LAURELES	trip, ABC, Z1, 1.566 cy
8. B-C-G 50% MARCONI - LAURELES	trip, BCG, Z1, 1.506 cy
9. A-G 98% MARCONI - LAURELES	trip, AG, Z1, 1.38 cy
10. B-C 98% MARCONI - LAURELES	trip, BC, Z1, 1.254 cy
11. B-G 2% LAURELES - LA PALMA	noop
12. A-C 2% LAURELES - LA PALMA	noop
13. C-G 80% LAURELES - LA PALMA	noop
14. A-B 80% LAURELES - LA PALMA	noop

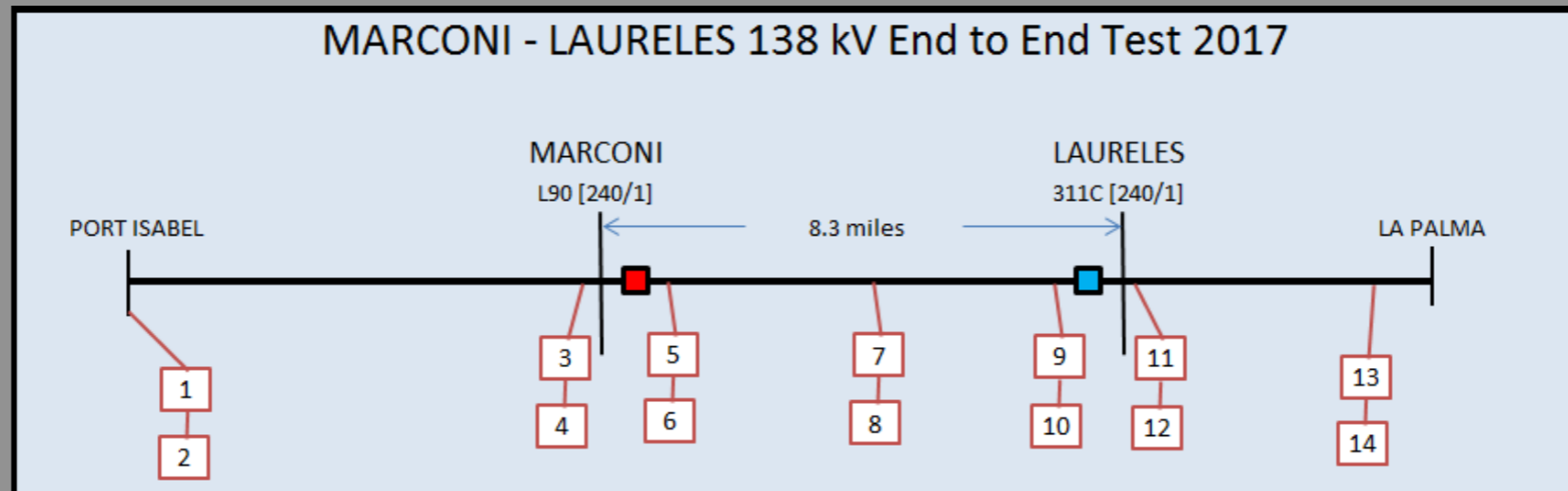
@Laureles System 2 311C - No Comm results
Z1 Overreach

Test Name/Location	for Single-End
1. A-G PORT ISABEL 138kV Bus	Trip,Neut TOC,AG 57.078 cyc
2. B-C PORT ISABEL 138kV Bus	Trip, PH Dist Z2, BC, 61.572 cyc
3. B-G 2% MARCONI - PORT ISABEL	Trip, Gnd Dist Z2, B G,31.566 cy
4. A-C 2% MARCONI - PORT ISABEL	Trip, PH Dist Z4, AC PH, 31.512 cy
5. C-G 2% MARCONI - LAURELES	Trip, Gnd Dist Z2, C G, 31.53 cy
6. A-B 2% MARCONI - LAURELES	Trip, PH Dist Z4, AB, 31.41 cy
7. A-B-C-G 50% MARCONI - LAURELES	Trip, PH DIST Z1,ABC PH, 1.176 cyc
8. B-C-G 50% MARCONI - LAURELES	Trip, PH Dist Z1, BCG,1.254 cy
9. A-G 98% MARCONI - LAURELES	Trip, Gnd Dist Z1, Neut IOC, AG, .99 cy
10. B-C 98% MARCONI - LAURELES	Trip, PH Dist Z1, BC, 1.092 cy
11. B-G 2% LAURELES - LA PALMA	noop
12. A-C 2% LAURELES - LA PALMA	noop
13. C-G 80% LAURELES - LA PALMA	noop
14. A-B 80% LAURELES - LA PALMA	noop

@Laureles System 1 421 - No Comm results
Proper distance element reach

Errors: Test Plan Creation

Scenario: @Laureles System 2 (311C) Z1 overreaching for tests 3-6 - no comm tests



Marconi - Laureles: Oneline and simulated fault locations

- Troubleshooting process
 - Field was asked for event files
 - Test plan was neither proven/disproven due to successful 421 results
 - Settings examined
 - PT Ratio discrepancy discovered

Errors: Test Plan Creation

Scenario: @Laureles System 2 (311C) Z1 overreaching for tests 3-6 - no comm tests

- @Laureles Sys 1 & Sys 2
 - Different PT Ratios
 - Intentional preference of @Laureles Utility
- Test plan was created at assumed PTR = 1200 for both
- Test plan PTR corrected
 - Results performed correctly

PTR Phase (VA,VB,VC) PT Ratio, PTR:1	
<input type="text" value="700.00"/>	Range = 1.00 to 10000.00

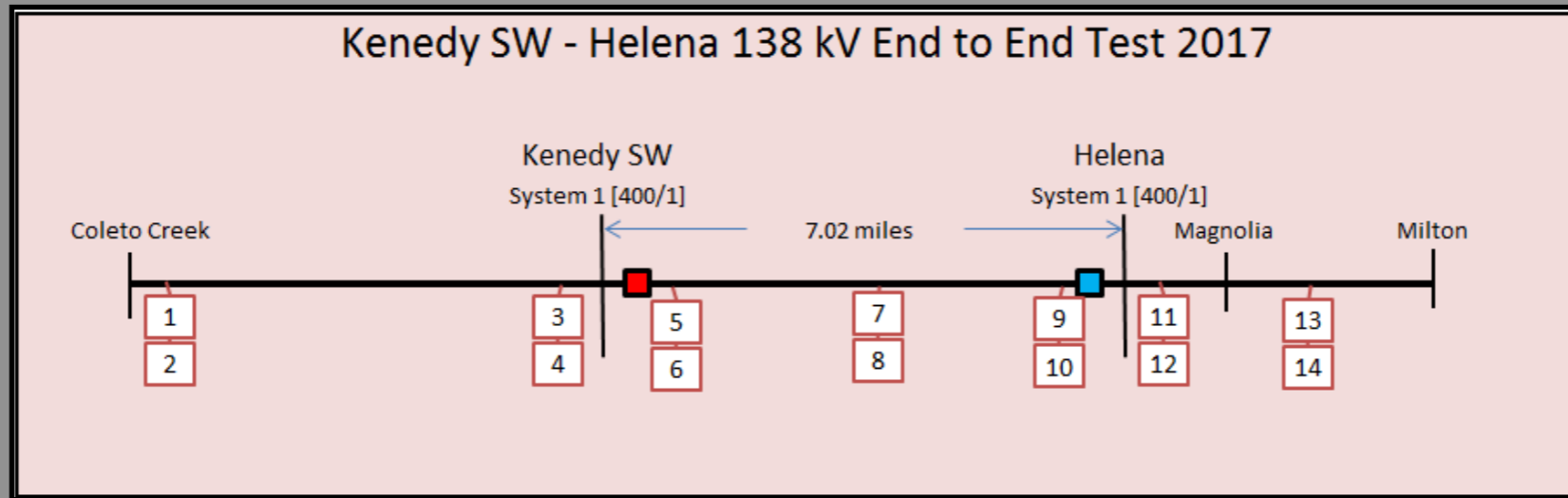
@Laureles 311C - PTR = 700

PTRY Potential Transformer Ratio - Input Y	
<input type="text" value="1200"/>	Range = 1 to 10000

@Laureles 421 - PTR = 1200

Errors: Relay Settings

Scenario: @Kenedy POTT scheme trips on 10, 12, 14, no-ops on 9, 11, 13



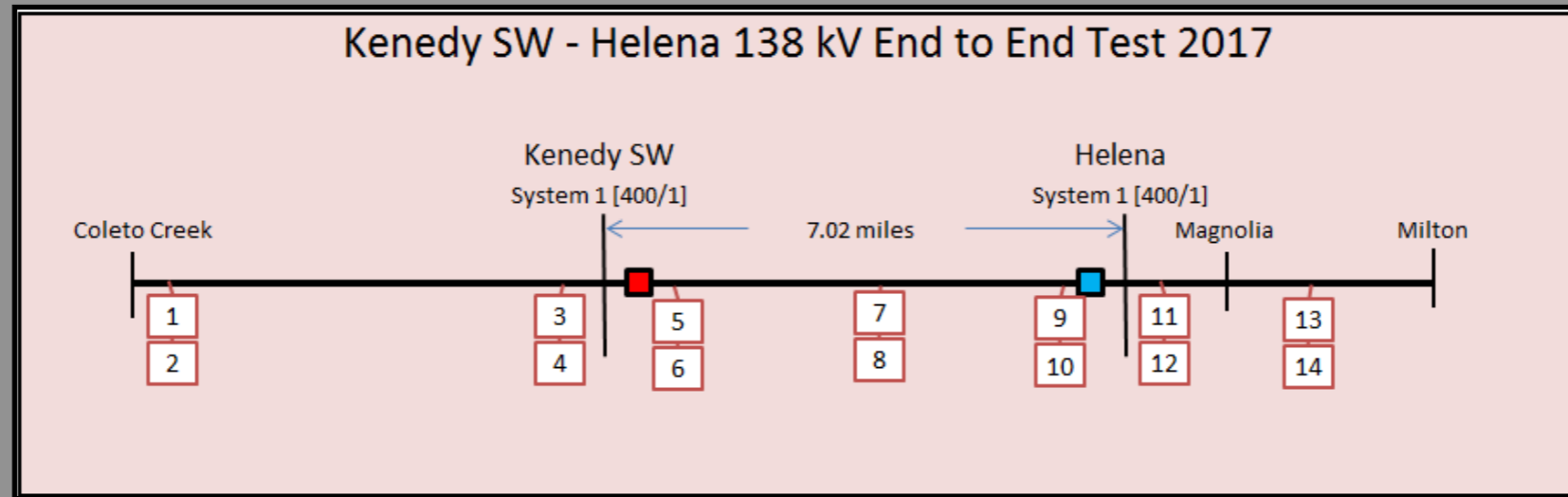
Kenedy SW - Helena: Online and simulated fault locations

Test Name/Location	for End-to-End
1. A-G 60% Kenedy SW - Coletto Creek	No-Op
2. B-C 60% Kenedy SW - Coletto Creek	No-Op
3. B-G 2% Kenedy SW - Coletto Creek	No-Op
4. A-C 2% Kenedy SW - Coletto Creek	No-Op
5. C-G 2% Kenedy SW - Helena	Trip,Gnd Dist Z1,Gnd Inst OC,C-G,0miles,0.96cyc
6. A-B 2% Kenedy SW - Helena	Trip,A-B-PH Dist Z1,PH Inst OC,POTT,0.75cyc
7. B-C-G 50% Kenedy SW - Helena	Trip,B-C-G,POTT,PH Dist Z1,0.936cyc
8. A-B-C-G 50% Kenedy SW - Helena	Trip,A-B-C,PH Dist Z1,POTT,5.62miles,0.348cyc
9. A-G 98% Helena - Kenedy SW	No-Op
10. B-C 98% Helena - Kenedy SW	Trip,B-C,POTT,0.888cyc
11. B-G 2% Helena - Milton	No-Op
12. A-C 2% Helena - Milton	Trip,A-C,POTT,0.996cyc
13. C-G 60% Helena - Milton	No-Op
14. A-B 60% Helena - Milton	Trip,A-B,1.00cyc

@Kenedy SW - Comm testing results

Errors: Relay Settings

Scenario: @Kenedy POTT scheme trips on 10, 12, 14, no-ops on 9, 11, 13



Kenedy SW - Helena: Online and simulated fault locations

- Relevant
 - Helena, Magnolia, and Milton are owned by different utility than Kenedy
 - Line was originally Kenedy SW - Milton
 - System 1 @Kenedy SW performed correctly on No Comms
 - System 1 @Helena performed correctly on Comms & No Comms
 - Validates test plan

Test Name/Location	for Single-End
1. A-G 60% Kenedy SW - Coletto Creek	No-Op
2. B-C 60% Kenedy SW - Coletto Creek	No-Op
3. B-G 2% Kenedy SW - Coletto Creek	No-Op
4. A-C 2% Kenedy SW - Coletto Creek	No-Op
5. C-G 2% Kenedy SW - Helena	Trip,C-G,Gnd Dist Z1,Gnd Inst OC,0.00miles,0.972cyc
6. A-B 2% Kenedy SW - Helena	Trip,A-B,Ph Dist Z1,Ph Inst OC,DTT2 Trip,NoMiles,0.93cyc
7. B-C-G 50% Kenedy SW - Helena	Trip,B-C-G,PH Dist Z1,DTT2 Trip,NoMiles,0.93cyc
8. A-B-C-G 50% Kenedy SW - Helena	Trip,A-B-C,PH Dist Z1, DTT2 Trip,3.51miles,0.84cyc
9. A-G 98% Helena - Kenedy SW	Trip,A-G,Gnd Dist Z2,7.02miles,31.482cyc
10. B-C 98% Helena - Kenedy SW	Trip,B-C,Ph Dist Z2,7.01miles,25.02cyc
11. B-G 2% Helena - Milton	Trip,B-G,Gnd Dist Z2,7.02miles,31.302cyc
12. A-C 2% Helena - Milton	Trip,A-C,Ph Dist Z2,7.01miles,25.392cyc
13. C-G 60% Helena - Milton	Trip,C-G,Gnd Time OC,14.96miles,65.22cyc
14. A-B 60% Helena - Milton	Trip,A-b,Ph Dist Z3,14.68miles,91.02cyc

@Kenedy SW - Proper No Comm results

Errors: Relay Settings

Scenario: @Kenedy POTT scheme trips on 10, 12, 14, no-ops on 9, 11, 13

- What we know so far
 - Test plan validated by Kenedy SW Comms & Helena Comms/No Comms
- Test Results
 - POTT overreaching for phase fault
 - Implies problem receiving remote signal
 - Not tripping POTT for ground faults
 - Implies problem with ground distance element

Errors: Relay Settings

Scenario: @Kenedy POTT scheme trips on 10, 12, 14, no-ops on 9, 11, 13

Trip Logic

TR Trip Equation (SELogic)
Z1P OR Z1G OR Z2PT OR Z2GT OR Z4PT OR 67P1 OR 67G1 OR 51S1T OR 67P3T OR 51S2T

TRCOMM Communications-Assisted Trip Equation (SELogic)
Z2P OR Z2G OR ((67Q2 OR 67G2) AND NOT LOP)

@Kendy SW - TRCOMM incorporates Z2G

Mho Ground Distance Element Reach

Z1MG Zone 1 (ohms,sec)
1.00 Range = 0.05 to 64.00, OFF

Z2MG Zone 2 (ohms,sec)
OFF Range = 0.05 to 64.00, OFF

Z3MG Zone 3 (ohms,sec)
OFF Range = 0.05 to 64.00, OFF

Z4MG Zone 4 (ohms,sec)
2.00 Range = 0.05 to 64.00, OFF

Z5MG Zone 5 (ohms,sec)
OFF Range = 0.05 to 64.00, OFF

@Kenedy SW - Z2MG = OFF

Errors: Relay Settings

Scenario: @Kenedy POTT scheme trips on 10, 12, 14, no-ops on 9, 11, 13

Mirrored Bits Transmit Equations

Mirrored Bits Channel A

TMB1A Channel A, Transmit Bit 1 Equation (SELogic)
KEY

TMB2A Channel A, Transmit Bit 2 Equation (SELogic)
0

TMB3A Channel A, Transmit Bit 3 Equation (SELogic)
IN101

*@Helena - Mirrored Bit Transmit Equations
Transmits Permissive on MB1
Transmits DTT on MB3*

PT1 General Permissive Trip Received Equation (SELogic)
(PT_RCV AND ROKA) AND NOT MBCS

OUT306 Interface Board 2 Output OUT306 (SELogic)
DTT_RCV AND ROKA AND NOT ALT08 # DTT TRIP

@Kenedy SW - Utilization of Mirrored Bits

AL46 Element Name	AR46 Alias Name
RMB3A	PT_RCV

@Kenedy SW - Receives Permissive on MB3

AL48 Element Name	AR48 Alias Name
RMB5A	DTT_RCV

@Kenedy SW - Receives DTT on MB5

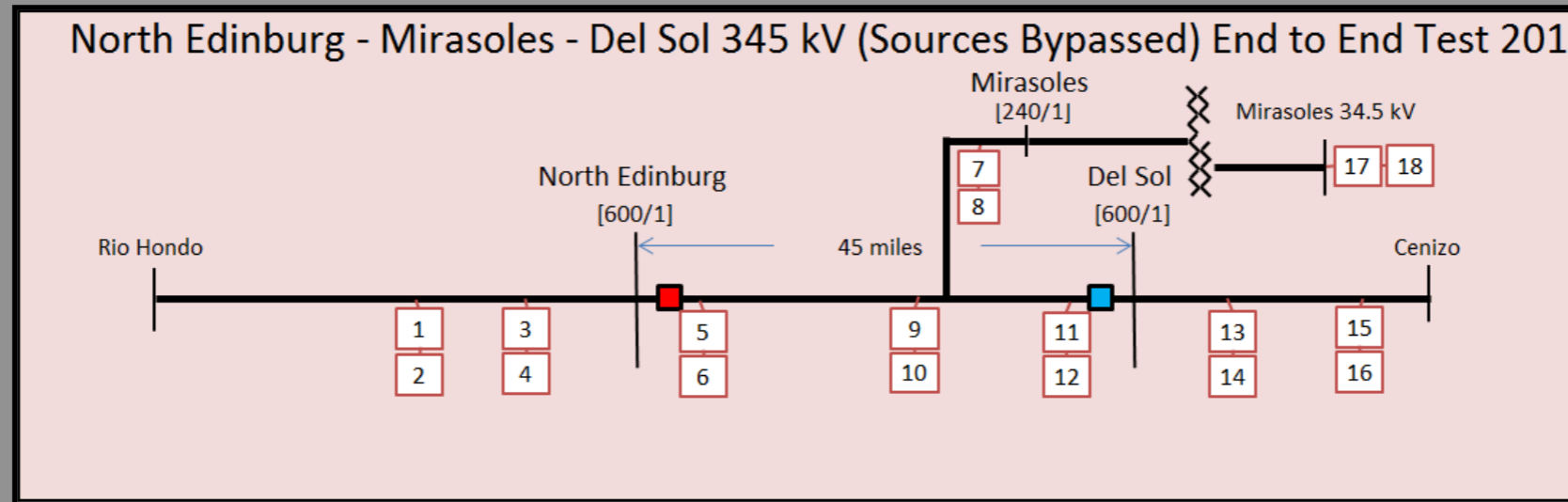
Errors: Relay Settings

Scenario: @Kenedy POTT scheme trips on 10, 12, 14, no-ops on 9, 11, 13

- Mirrored Bit issues reviewed with @Helena engineer
- @Kenedy SW settings errors corrected
- POTT scheme performed as expected
- Example of multi-fold problem

Errors: Test Plan Application

Scenario: All three terminals tripping on differential for tests 3, 14, & 17 - comm tests

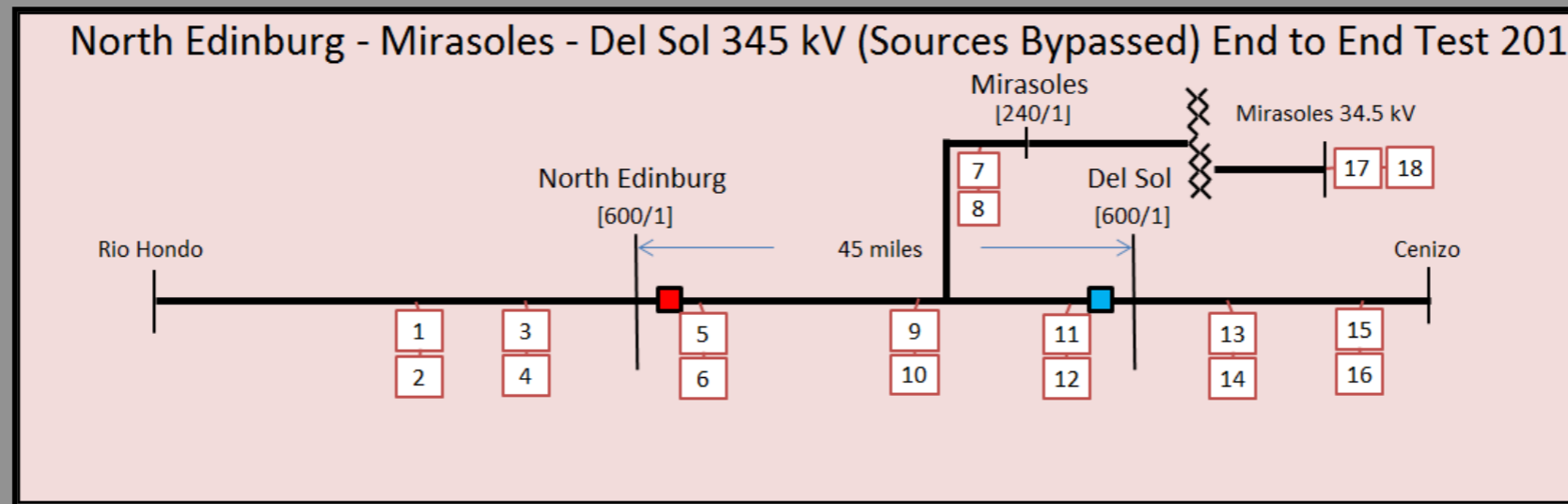


North Edinburg - Mirasoles - Del Sol: Online and simulated fault locations

- Field personnel started on comm testing
 - Chose reverse locations to start with (3, 14, 17)
 - All tripped on differential
- Field was asked for event files
 - Each terminal sent events at different times

Errors: Test Plan Application

Scenario: All three terminals tripping on differential for tests 3, 14, & 17 - comm tests



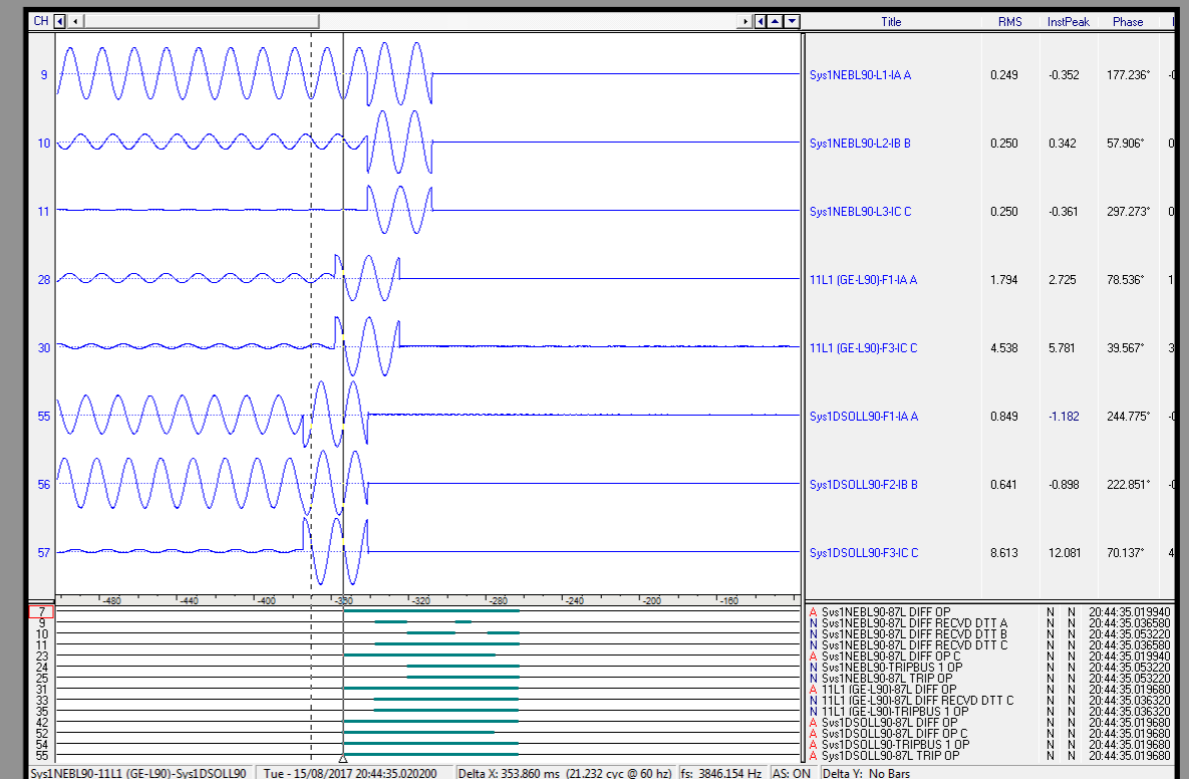
North Edinburg - Mirasoles - Del Sol: Oneline and simulated fault locations

- Test plan examined
 - CT/PT ratios, oneline model, verified correct
- Settings examined
 - Comm settings, remote CT tap, verified correct
- Test plan application examined
 - Received events compared to test plan currents/voltages = correct

Errors: Test Plan Application

Scenario: All three terminals tripping on differential for tests 3, 14, & 17 - comm tests

- Events received from all three ends
 - Sync-ed in WaveWin
- Each end transitions to fault state at different times
- Test set equipment examined and firmware discrepancy found
 - Firmware updated to match, tests performed correctly



*GPS synchronized events from all three terminals
Transition from pre-fault to fault state not synchronized*