

EPRI Protection Settings Evaluation Tool (PSET)



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Protection Settings Evaluation Tool (PSET)

Software

Intended use:

- Automatically assess the protection performance and identify misoperations, uncleared faults, and near-misses
- Use Web Browser/Excel/Access interface to report, track and trend over time

Requires network model with at least some protection relays in CAPE or ASPEN



Project Task Timeline

2015: Initial version of CAPE macro

2016: ASPEN macro, add near-miss to CAPE macro, basic database, case studies

➔ 2017: Optimize macros for speed, add new study scenarios, develop advanced trending database, case studies

2018: Further simulations, case studies

The Problem – Protection Misoperations

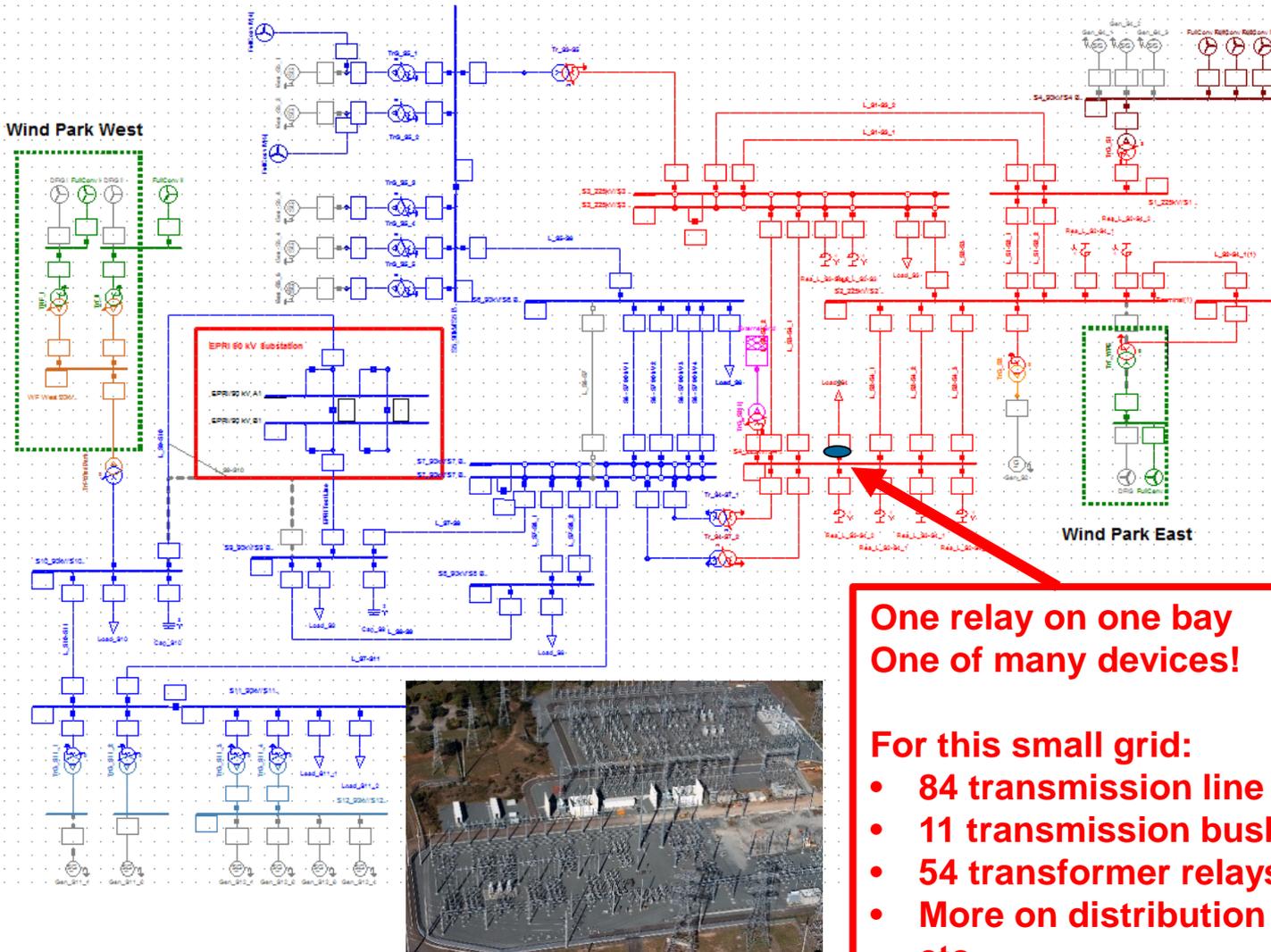
NERC Stats

- Misoperations occur in roughly 1 in 10 faults
- Approximately 29% of protection misoperations are due to settings, logic or design errors.
- NERC Events Analysis determined that incorrect ground instantaneous overcurrent settings on 115 kV and 230kV systems are a leading cause of relay misoperations.

Trends

- Misoperations tend to be more commonly associated with numerical relays. Number of numerical relays increasing.
- Significant changes to the system (generation retirements, etc.) are occurring quickly and can impact the performance of protection systems.
- Industry is losing P&C expertise at a rapid pace.

Grid Scenarios for Relay Settings



**One relay on one bay
One of many devices!**

For this small grid:

- 84 transmission line relays
- 11 transmission busbar protection
- 54 transformer relays
- More on distribution grid, generators etc

**Relays commissioned at different times
Settings based on different grid scenarios
Settings often not kept in a centralised DB**

Protection Settings Evaluation Tool (PSET)

Implemented using both CAPE and OneLiner

EPRI Protection Performance Review

1. Grid Region To Study
Grid Voltage (kV) 115
Grid Area 0
Grid Zone 0
Study depth around selected bus 0

2. Operating Scenarios to Study
 Normal Intact Network
 N-1 Minimum Infeed
 Inhibited Breaker/Circuit Breaker Fail

3. Fault Types to Study
 Single Line to Ground
 Line to Line
 Double Line to Ground
 Three Phase
 Single Line to Ground With Resistance
SLG Resistance 0 ohm

4. Fault Location
 Close-In Faults
 Remote-End Faults
 Remote End Breaker Open

Mid-line Fault #1 5 0.01-99.99 %
Mid-line Fault #2 70 0.01-99.99 %
Mid-line Fault #3 90 0.01-99.99 %

Protection Performance

5. Protection Simulation Depth 2
6. Coordination Time Between Prim/Bckp Relays 0.3 Seconds
7. Max Overall Fault Clearance Time 2.1 Seconds
8. Max Trip Time for Close-In Faults (<=50% line) 0.4 Seconds
9. Max Trip Time Remote-End Faults (>50% line) 0.8 Seconds
10. Max Line Reach For Instantaneous Tripping 90 % Line
11. Min Trip Time for Remote-End Faults (>Q10) 0.05 Seconds

File Home Create External Data Database Tools Tell me what you want to do

MainForm

Protection Setting Evaluation Tool

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View Station Report From Most Recent Results 1 GLEN LYN 132.0kV
View All Results For Grid Voltage 132
View Zone 1 and Inst Overcurrent Over-reaches
Trend Historical Protection Performance at Substation
View issues by Type Misoperation

Help: Select from any of the drop-down boxes above to view a report on the selected topic.

- Evaluate coordination of protection near a busbar, in a grid area or across whole grid
 - Applies multiple fault types across all lines in study area
- Flags relay misoperations, fast/slow trips, uncleared faults
- View results in web browser & store in database for simple reporting, trending over time
- Use database to track performance. Flag when grid changes cause relays to become miscoordinated.

Proactively identify & avert potential misoperations!

What does PSET Analyze?

Examines local protection relays after short circuit simulated and again after each circuit breaker trips open

Was the fault isolated?

- Did each relay trip correctly and quickly?
- Did any relay over-reach?
- Were any relays miscoordinated?
- Was any relay close to misoperation (near miss)?

Has Protection Performance Changed Since the Last Time the Tool was Run?

Define Fault Study and Protection Criteria - CAPE

Define protection performance requirements

Study all of a grid voltage level, area/zone, or all lines within X buses of the selected busbar

Study various fault scenario combinations:

- Grid scenarios
- Fault Types
- Fault Locations

Selecting all the options means 10,000s of fault simulations!

EPRI Protection Settings Evaluation Tool v2.01

1: Enter a voltage level for the study or leave at 0 for all voltage levels.
None

2: Enter an Area to study or leave at 0 for all areas. Can be combined with the grid voltage selected above.
None

3: Enter a Zone to study or leave at 0 for all zones. Can be combined with the grid voltage selected above.
None

4: Select a bus set to study. Leave blank to use Voltage/Area/Zone instead.

5: Select relay types/functions to include in the study
 Overcurrent relays only
 Impedance relays only
 All relays
 Debug Mode?

6: Select fault types to include in the study
 SLG (Single Line Ground AG)
 DLG (Double Line Ground BCG)
 TPH (Three Phase ABC)
 LTL (Line to Line BC)
 SLG_RF (SLG with resistance as entered below)
 DLG_RF (DLG with resistance as entered below)

7: Specify fault resistance for SLG_RF
Range: 0 - 5000
Value: 0 Units: Ohms (Primary)

8: Specify fault resistance for DLG_RF
Range: 0 - 5000
Value: 0 Units: Ohms (Primary)

9: Specify network configuration/Operating Scenario
 N Situation
 N-1 Situation (Largest Local Infeed Switched Out)
 N-1 Situation (2nd Largest Local Infeed Switched Out)
 N-1 Situation (Largest Regional Infeed Switched Out)
 N-1 Situation (Each Local Infeed Switched Out In Turn)
 N-2 Situation (Two largest local infeeds Switched Out)
 Inhibited Breaker/Circuit Breaker Fail

10: Select fault Locations
 Local close-in faults?
 Remote close-in faults?
 Open remote breakers?

11: 1st fault location for midline faults (0 for none)
Range: 0 - 0.999 step 0.001
Value: 0.05

12: 2nd fault location for midline faults (0 for none)
Range: 0 - 0.999 step 0.001
Value: 0.7

13: 3rd fault location for midline faults (0 for none)
Range: 0 - 0.999 step 0.001
Value: 0.9

14: Margin for identifying overcurrent near misses (Percent):
Range: 0 - 99.9 step 0.1
Value: 0

15: Protection Simulation Depth
Range: 0 - 10 step 1
Value: 2

16: Mutual Simulation Depth
Range: 0 - 10 step 1
Value: 1

17: Coordination Time Between Prim/Bckp Relays (SECONDS)
Range: 0.001 - 9999 step 0.001
Value: 0.3

18: Maximum fault duration (SECONDS)
Range: 0.001 - 9999 step 0.001
Value: 2

19: Maximum permissible fault clearance time for near-end (0-50%) faults (SECONDS)
Range: 0.001 - 9999 step 0.001
Value: 0.15

20: Maximum permissible fault clearance time for remote-end (51-100%) faults (SECONDS)
Range: 0.001 - 9999 step 0.001
Value: 0.7

21: Fastest permissible fault clearance time for remote-end faults (SECONDS)
Range: 0.001 - 9999 step 0.001
Value: 0.1

22: Maximum reach for instantaneous tripping (pu)
Range: 0.001 - 99.999 step 0.001
Value: 0.85

23: Select protection schemes and logic blocks to exclude from simulations
+ Select More - Remove Selected

24: Enter path to output file. Please name the file with a .xml extension.
[CapeHomeDir]EPRI_PROTECTION_REVIEW_RESULT

Save to File Load from File Ok Cancel

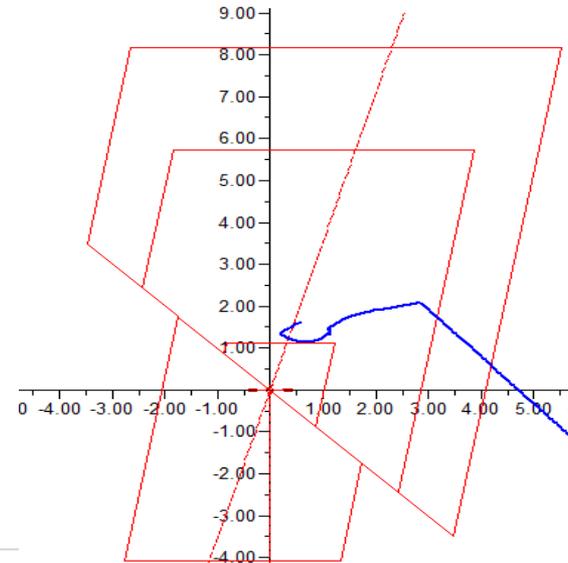
Identify Near-Misses

Identifying Protection Misoperation Near Misses

Simulations never 100% accurate

Fault current in practice is greater or less than simulation

- Trip setting=1000A, but what if fault current is 999A or 1001A?
- “Near-miss” feature identifies settings with small margin



CAPE/ASPEN Macros – Results – Web Browser

- Output file in XML file format
- Can open in a Web Browser, Excel, Access etc
- High-level results per fault; hover mouse over a fault and a box pops up with specific relay op details
- Just click CTRL-O from Internet Explorer, FireFox, or Excel and select the XML file

| EPRI Protection Settings Evaluation Tool 2017 (BETA) Results | |
|--|---|
| Results Created: | 29-Aug-17 11:02:31 |
| Database: | C:\Program Files (x86)\ASPEN\1LPFv14\SAMPLE30.OLR |
| Network Study Date: | 29-08-2017 |
| Studied Grid Voltage: | 132 |
| Studied Grid Area: | 0 |
| Studied Grid Zone: | 0 |
| Studied Busbar: | |

| Fault Number | From Station | To Station | Voltage (kV) | Circuit ID | Distance To Fault | Fault Type | Contingency | Outage(s) | Fault Clearance Time (Seconds) | Test Result | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|-------------------|---|--------------------|--------------|----------------|--------------------|-------------------------------|----------------------------------|-----------|--------------------------------|---|---------|-----------------|--------------|------------|----------------|------------------|---------------------|-------------|------------------|-------------------|-----|--|-----------|--------------------|-------|--------------|-------------------|------------------|-----|--|-----------|--------------------|-------|--------------|----------------|------------------|-----|--|-----------|-------------------|-------|--------------|----------------|------------------|-----|--|-----------|--------------------|-------|--------------|------------------|-----------------------|----|--|-------------|--------------------|-------|--------------|
| 1 | 2 CLAYTOR 132.0kV | 1 GLEN LYN 132.0kV | 132 | 1 | 5 | SINGLE_LINE_GROUND, R=0 (ohm) | Normal state with intact network | | 9999.000 | Inst Over-reach Misoperation, Fault Not Cleared | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2 | 1 GLEN LYN 132.0kV | 2 CLAYTOR 132.0kV | 132 | 1 | 5 | SINGLE_LINE_GROUND, R=0 (ohm) | Normal state with intact network | | 9999.000 | MISOPERATION, Fault Not Cleared | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | <table border="1"> <thead> <tr> <th>Station</th> <th>Circuit Breaker</th> <th>Voltage (kV)</th> <th>Circuit ID</th> <th>Tripping Relay</th> <th>Tripping Element</th> <th>Trip time (Seconds)</th> <th>Test Result</th> </tr> </thead> <tbody> <tr> <td>6 NEVADA 132.0kV</td> <td>2 CLAYTOR 132.0kV</td> <td>132</td> <td></td> <td>NV-G2 (B)</td> <td>Ground Overcurrent</td> <td>0.064</td> <td>MISOPERATION</td> </tr> <tr> <td>8 REUSENS 132.0kV</td> <td>6 NEVADA 132.0kV</td> <td>132</td> <td></td> <td>RE-G1 (B)</td> <td>Ground Overcurrent</td> <td>1.319</td> <td>MISOPERATION</td> </tr> <tr> <td>7 OHIO 132.0kV</td> <td>6 NEVADA 132.0kV</td> <td>132</td> <td></td> <td>OH-P1 (B)</td> <td>Phase Overcurrent</td> <td>0.756</td> <td>MISOPERATION</td> </tr> <tr> <td>6 OHIO 132.0kV</td> <td>6 NEVADA 132.0kV</td> <td>132</td> <td></td> <td>OH-G1 (B)</td> <td>Ground Overcurrent</td> <td>1.008</td> <td>MISOPERATION</td> </tr> <tr> <td>6 NEVADA 132.0kV</td> <td>10 NEW HAMPSHR 33.0kV</td> <td>33</td> <td></td> <td>NE-NH01 (B)</td> <td>Ground Overcurrent</td> <td>0.995</td> <td>MISOPERATION</td> </tr> </tbody> </table> | | | | | | | | | | Station | Circuit Breaker | Voltage (kV) | Circuit ID | Tripping Relay | Tripping Element | Trip time (Seconds) | Test Result | 6 NEVADA 132.0kV | 2 CLAYTOR 132.0kV | 132 | | NV-G2 (B) | Ground Overcurrent | 0.064 | MISOPERATION | 8 REUSENS 132.0kV | 6 NEVADA 132.0kV | 132 | | RE-G1 (B) | Ground Overcurrent | 1.319 | MISOPERATION | 7 OHIO 132.0kV | 6 NEVADA 132.0kV | 132 | | OH-P1 (B) | Phase Overcurrent | 0.756 | MISOPERATION | 6 OHIO 132.0kV | 6 NEVADA 132.0kV | 132 | | OH-G1 (B) | Ground Overcurrent | 1.008 | MISOPERATION | 6 NEVADA 132.0kV | 10 NEW HAMPSHR 33.0kV | 33 | | NE-NH01 (B) | Ground Overcurrent | 0.995 | MISOPERATION |
| Station | Circuit Breaker | Voltage (kV) | Circuit ID | Tripping Relay | Tripping Element | Trip time (Seconds) | Test Result | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 6 NEVADA 132.0kV | 2 CLAYTOR 132.0kV | 132 | | NV-G2 (B) | Ground Overcurrent | 0.064 | MISOPERATION | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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| 7 OHIO 132.0kV | 6 NEVADA 132.0kV | 132 | | OH-P1 (B) | Phase Overcurrent | 0.756 | MISOPERATION | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 6 OHIO 132.0kV | 6 NEVADA 132.0kV | 132 | | OH-G1 (B) | Ground Overcurrent | 1.008 | MISOPERATION | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 6 NEVADA 132.0kV | 10 NEW HAMPSHR 33.0kV | 33 | | NE-NH01 (B) | Ground Overcurrent | 0.995 | MISOPERATION | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 4 | 132.0kV | 132.0kV | --- | -- | -- | (ohm) | network | | | Cleared | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 8 | 1 GLEN LYN 132.0kV | 2 CLAYTOR 132.0kV | 132 | 2 | 5 | SINGLE_LINE_GROUND, R=0 (ohm) | Normal state with intact network | | 9999.000 | MISOPERATION, Fault Not Cleared | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 9 | 2 CLAYTOR 132.0kV | 1 GLEN LYN 132.0kV | 132 | 2 | 70 | SINGLE_LINE_GROUND, R=0 (ohm) | Normal state with intact network | | 9999.000 | MISOPERATION, Fault Not Cleared | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10 | 1 GLEN LYN 132.0kV | 2 CLAYTOR 132.0kV | 132 | 2 | 70 | SINGLE_LINE_GROUND, R=0 (ohm) | Normal state with intact network | | 9999.000 | Inst Over-reach Misoperation, Fault Not Cleared | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

CAPE/ASPEN Macros – Results – New Excel Interface

2017 - New Excel Sheet Interface

- Presents high level overview of latest or historical simulation run
- Compare sets of results; e.g. this week vs last month/last year
- Easy to filter results by station, fault clearance issue etc. Report instantly updates
- Identify changes since last run – flag new misoperations, miscoordinations, uncleared faults that weren't an issue the last time you ran the tool
- Track/trend fault clearance times
- Present high level statistics and graphs on fault clearance times and issue type

Clear Filters

[Return to Dashboard](#)

PSET Study ID

02/16/2017 #000

04/03/2017 #000

Differences Between Results

Not Unique Unique Tripping

Protection Issue

MISOPERATION

MISOPERATION, Fault Not Cleared

OK

SLOW TRIPPING FOR NEAR-END FAULT

SLOW TRIPPING FOR NEAR-END FAULT, F...

Station

0 Alaska 15.0kV

0 KNOXVILLE 15.0kV

1 GLEN LYN 132.0kV

12 VERMONT 33.0kV

14 MONTANA 33.0kV

15 MINNESOTA 33.0kV

2 CLAYTOR 132.0kV

28 ARIZONA 132.0kV

Fault Clearance Time

>20 0.1-0.2

0.3-0.4 0.5-0.6

0.9-1 0-0.1

Protection Performance Overview

MISOPERATION, 46, 4%

Inst TRIP OVER-REACH, Fault Not Cleared, 15, 2%

Inst Over-reach Misoperation, 146, 33%

Inst TRIP OVER-REACH, 61, 5%

OK, 115, 11%

NEAR-END FAULT, 10, 1%

SLOW TRIPPING FOR NEAR-END FAULT, Fault Not Cleared, 12, 1%

Histogram of Fault Clearance Times

Number of Occurrences

Study Case and Fault Clearance Time (seconds)

04/03/2017 #000 02/16/2017 #000

RELAY OPERATIONS

| PSET Study ID | Faulted Circuit | Clearance Time | Protection Performance Assessment | Tripped Element | Tripping Element | Trip Time |
|-----------------|---|----------------|-----------------------------------|--------------------------------------|--------------------|-----------|
| 04/03/2017 #000 | 2 CLAYTOR 132.0kV 1 GLEN LYN 132.0kV 113: | 0.05 | Inst Over-reach Misoperation | 1 GLEN LYN 132.0kV 2 CLAYTOR 132.0kV | Phase Overcurrent | 0.017 |
| | | | | 2 CLAYTOR 132.0kV 1 GLEN LYN 132.0kV | Phase Overcurrent | 0.017 |
| | | | | 6 NEVADA 132.0kV 2 CLAYTOR 132.0kV | Ground Overcurrent | 0.032 |
| | | | | | Ground Overcurrent | 0.050 |
| | | | | 1 GLEN LYN 132.0kV 2 CLAYTOR 132.0kV | Phase Overcurrent | 0.017 |
| | | | | 2 CLAYTOR 132.0kV 1 GLEN LYN 132.0kV | Phase Overcurrent | 0.017 |
| | | | | 1 GLEN LYN 132.0kV 2 CLAYTOR 132.0kV | Phase Overcurrent | 0.017 |
| | | | | 2 CLAYTOR 132.0kV 1 GLEN LYN 132.0kV | Phase Overcurrent | 0.017 |
| | | | | 6 NEVADA 132.0kV 2 CLAYTOR 132.0kV | Ground Overcurrent | 0.037 |
| | | | | | Ground Overcurrent | 0.033 |
| | | | | 1 GLEN LYN 132.0kV 2 CLAYTOR 132.0kV | Phase Overcurrent | 0.017 |
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| | | | | 6 NEVADA 132.0kV 2 CLAYTOR 132.0kV | Ground Overcurrent | 0.037 |
| | | | | | Ground Overcurrent | 0.033 |
| | | | | 1 GLEN LYN 132.0kV 2 CLAYTOR 132.0kV | Phase Overcurrent | 0.017 |
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| | | | | 6 NEVADA 132.0kV 2 CLAYTOR 132.0kV | Ground Overcurrent | 0.037 |
| | | | | | Ground Overcurrent | 0.033 |
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| | | | | 2 CLAYTOR 132.0kV 1 GLEN LYN 132.0kV | Phase Overcurrent | 0.017 |
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| | | | | 6 NEVADA 132.0kV 2 CLAYTOR 132.0kV | Ground Overcurrent | 0.037 |
| | | | | | Ground Overcurrent | 0.033 |

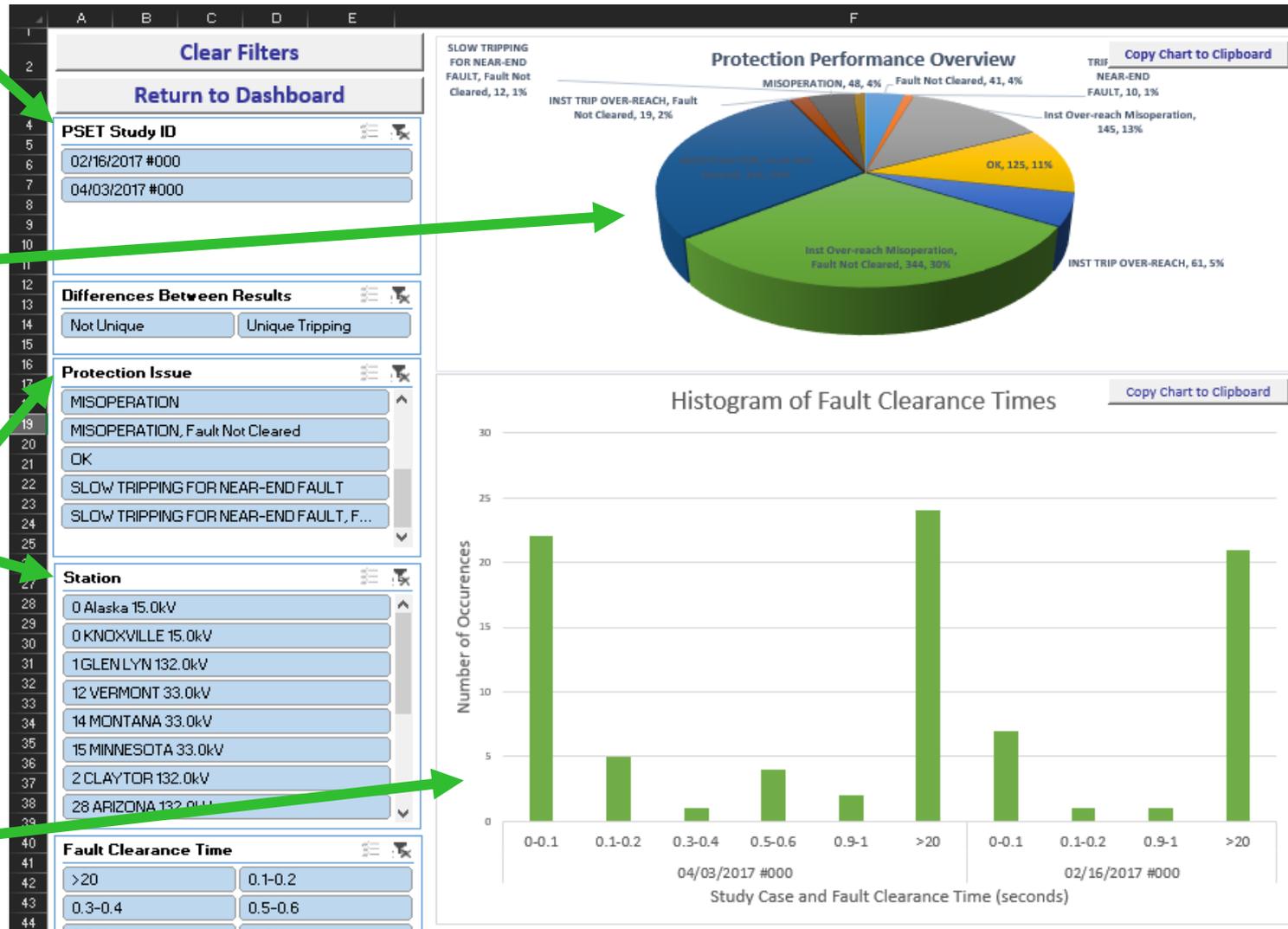
CAPE/ASPEN Macros – Results – New Excel Interface

User can view results from one or more past studies

Pie chart showing main protection issues

Easily filter results to look at particular stations or examine particular issues

Present spread of trip times for all faults



CAPE/ASPEN Macros – Results – New Excel Interface

By clicking on filters shown in previous slide, the main table automatically and instantaneously updates

Results shown here are just faults on lines connected to Glen Lyn 132 kV

| RELAY OPERATIONS | | | | | | |
|------------------|---|----------------|-----------------------------------|--------------------------------------|------------------|-----------|
| PSET Study ID | Faulted Circuit | Clearance Time | Protection Performance Assessment | Tripped Element | Tripping Element | Trip Time |
| 04/03/2017 #000 | 1 GLEN LYN 132.0kV 2 CLAYTOR 132.0kV 113: | 0.05 | Inst Over-reach Misoperation | 1 GLEN LYN 132.0kV 2 CLAYTOR 132.0k' | Phase Overcurr | 0.017 |
| | | | | | Ground Overcurr | 0.017 |
| | | | | 2 CLAYTOR 132.0kV 1 GLEN LYN 132.0k' | Phase Overcurr | 0.017 |
| | | | | | Ground Overcurr | 0.017 |
| | | | | 6 NEVADA 132.0kV 2 CLAYTOR 132.0kV | Ground Overcurr | 0.037 |
| | | | | | | 0.033 |
| | | | OK | 1 GLEN LYN 132.0kV 2 CLAYTOR 132.0k' | Phase Overcurr | 0.017 |
| | | | | | Ground Overcurr | 0.017 |
| | | | | 2 CLAYTOR 132.0kV 1 GLEN LYN 132.0k' | Phase Overcurr | 0.017 |
| | | | | | Ground Overcurr | 0.017 |
| | | | INST TRIP OVER-REACH | 1 GLEN LYN 132.0kV 2 CLAYTOR 132.0k' | Phase Overcurr | 0.017 |
| | | | | 2 CLAYTOR 132.0kV 1 GLEN LYN 132.0k' | Phase Overcurr | 0.017 |
| | | | | 6 NEVADA 132.0kV 2 CLAYTOR 132.0kV | Ground Overcurr | 0.037 |
| | | | | | | 0.033 |
| | | | | 1 GLEN LYN 132.0kV 2 CLAYTOR 132.0k' | Phase Overcurr | 0.017 |
| | | | | | Ground Overcurr | 0.017 |
| | | | | 2 CLAYTOR 132.0kV 1 GLEN LYN 132.0k' | Phase Overcurr | 0.017 |
| | | | | | Ground Overcurr | 0.017 |
| | | | OK | 1 GLEN LYN 132.0kV 2 CLAYTOR 132.0k' | Phase Overcurr | 0.017 |
| | | | | | Ground Overcurr | 0.017 |
| | | | | 2 CLAYTOR 132.0kV 1 GLEN LYN 132.0k' | Phase Overcurr | 0.017 |
| | | | | 2 CLAYTOR 132.0kV 1 GLEN LYN 132.0k' | Phase Overcurr | 0.017 |
| | | | | 6 NEVADA 132.0kV 2 CLAYTOR 132.0kV | Ground Overcurr | 0.080 |
| | | | | | | 0.557 |
| | | | | 2 CLAYTOR 132.0kV 1 GLEN LYN 132.0k' | Phase Overcurr | 0.017 |
| | | | | | Ground Overcurr | 0.017 |
| | | | | 5 FIELDALE 132.0kV 2 CLAYTOR 132.0k | Ground Overcurr | 6.786 |
| | | | | 8 REUSENS 132.0kV 6 NEVADA 132.0kV | Ground Overcurr | 1.361 |
| | | | | | | 1.142 |
| | | | | 7 OHIO 132.0kV 6 NEVADA 132.0kV | Phase Overcurr | 0.720 |
| | | | | | | 0.656 |
| | | | | | | 0.565 |
| | | | | | Ground Overcurr | 0.909 |
| | | | | | | 0.541 |
| | | | MISOPERATION, Fault Not Cleared | 6 NEVADA 132.0kV 2 CLAYTOR 132.0kV | Ground Overcurr | 0.462 |
| | | | | 5 FIELDALE 132.0kV 2 CLAYTOR 132.0k | Ground Overcurr | 6.786 |
| | | | | 8 REUSENS 132.0kV 6 NEVADA 132.0kV | Ground Overcurr | 1.239 |
| | | | | 7 OHIO 132.0kV 6 NEVADA 132.0kV | Phase Overcurr | 0.611 |
| | | | | | | 0.596 |
| | | | | | | 0.550 |

CAPE/ASPEN Macros – Results – Access Database

Output file in XML file format; Can also import into an Access Database

Store protection assessment results

Easily create custom reports for trending over time, audit reports etc

Basic version complete in 2016, advanced version with tracking/trending/auditing in 2017

File Home Create External Data Database Tools Tell me what you want to do

MainForm

Protection Setting Evaluation Tool

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View Station Report From Most Recent Results

View All Results For Grid Voltage

View Zone 1 and Inst Overcurrent Over-reaches

Trend Historical Protection Performance at Substation

View issues by Type

Help: Select from any of the drop-down boxes above to view a report on the selected topic.

CAPE/ASPEN Macros – Results – Access Database

Quickly Generate Reports such as:

- View all Zone 1/Overcurrent over-reaches
- View protection performance near a line or a station
- Trend over time, find where protection performance across the grid has improved or new issues have arisen e.g.
 - New issues flagged this month that weren't there last month or 2017 vs 2016
- Study future grids and see if new issues arise in coming year with the commissioning of new lines, commissioning/de-commissioning of generators

Faults By Station 1 GLEN LYN 132.0kV

| | FaultType | Fault Clearance Time | Protection Performance Assessment |
|-------------------|--|----------------------|-----------------------------------|
| ToStation | 2 CLAYTOR 132.0kV | | |
| Voltage | 132 | | |
| Ckt ID | 1 | | |
| Contingency | Normal state with intact network | | |
| OutagedElement | | | |
| Distance To Fault | 5 | | |
| | SINGLE_LINE_GROUND, R=0 (ohm) | 0.05 | Misoperation |
| | THREE-PHASE, R=0 (ohm) | 0.05 | Misoperation |
| Distance To Fault | 70 | | |
| | SINGLE_LINE_GROUND, R=0 (ohm) | 0.05 | Misoperation |
| | THREE-PHASE, R=0 (ohm) | 0.05 | Misoperation |
| Distance To Fault | 90 | | |
| | SINGLE_LINE_GROUND, R=0 (ohm) | 0.05 | Misoperation |
| | THREE-PHASE, R=0 (ohm) | 0.05 | Misoperation |
| Contingency | N-1 state with largest in-feed outaged | | |
| OutagedElement | 1 GLEN LYN 132.0kVUnit #1 100 MVA | | |
| Distance To Fault | 5 | | |
| | SINGLE_LINE_GROUND, R=0 (ohm) | 0.05 | Misoperation |
| | THREE-PHASE, R=0 (ohm) | 0.05 | Misoperation |
| Distance To Fault | 70 | | |
| | SINGLE_LINE_GROUND, R=0 (ohm) | 0.05 | Misoperation |
| | THREE-PHASE, R=0 (ohm) | 0.05 | Misoperation |

Faults with Issue: Misoperation

| | Distance To Fault | FaultType | Fault Clearance Time | Relay_FromStation | Relay_ToStation | Voltage | Ckt ID | Tripped Element | Trip Time | Relay Performance Assessment |
|--------------|----------------------------------|-----------------------|----------------------|--------------------|---------------------|---------|--------|--------------------|-----------|------------------------------|
| From Station | 1 GLEN LYN 132.0kV | | | | | | | | | |
| To Station | 2 CLAYTOR 132.0kV | | | | | | | | | |
| Voltage | 132 | | | | | | | | | |
| Ckt ID | 1 | | | | | | | | | |
| Contingency | Normal state with intact network | | | | | | | | | |
| Outage | 5 | SINGLE_LINE_GROUND | 0.05 | 2 CLAYTOR 132.0kV | 1 GLEN LYN 132.0kV | 132 | 2 | Phase Overcurrent | 0.017 | Misoperation |
| | 5 | SINGLE_LINE_GROUND | 0.05 | 6 NEVADA 132.0kV | 4 TENNESSEE 132.0kV | 132 | 1 | Fuse | 0.014 | Misoperation |
| | 5 | SINGLE_LINE_GROUND | 0.05 | 2 CLAYTOR 132.0kV | 1 GLEN LYN 132.0kV | 132 | 1 | Phase Overcurrent | 0.017 | OK |
| | 5 | SINGLE_LINE_GROUND | 0.05 | 2 CLAYTOR 132.0kV | 1 GLEN LYN 132.0kV | 132 | 1 | Ground Overcurrent | 0.017 | OK |
| | 5 | SINGLE_LINE_GROUND | 0.05 | 1 GLEN LYN 132.0kV | 2 CLAYTOR 132.0kV | 132 | 2 | Phase Overcurrent | 0.017 | Misoperation |
| | 5 | SINGLE_LINE_GROUND | 0.05 | 1 GLEN LYN 132.0kV | 2 CLAYTOR 132.0kV | 132 | 1 | Phase Overcurrent | 0.017 | OK |
| | 5 | THREE-PHASE, R=0 (oh) | 0.05 | 2 CLAYTOR 132.0kV | 1 GLEN LYN 132.0kV | 132 | 2 | Phase Overcurrent | 0.017 | Misoperation |
| | 5 | THREE-PHASE, R=0 (oh) | 0.05 | 1 GLEN LYN 132.0kV | 2 CLAYTOR 132.0kV | 132 | 1 | Ground Overcurrent | 9999.00 | No Operation |
| | 5 | THREE-PHASE, R=0 (oh) | 0.05 | 2 CLAYTOR 132.0kV | 1 GLEN LYN 132.0kV | 132 | 2 | Phase Overcurrent | 0.017 | Misoperation |
| | 5 | THREE-PHASE, R=0 (oh) | 0.05 | 2 CLAYTOR 132.0kV | 1 GLEN LYN 132.0kV | 132 | 1 | Phase Overcurrent | 0.017 | OK |
| | 5 | THREE-PHASE, R=0 (oh) | 0.05 | 2 CLAYTOR 132.0kV | 1 GLEN LYN 132.0kV | 132 | 1 | Ground Overcurrent | 9999.00 | No Operation |
| | 5 | THREE-PHASE, R=0 (oh) | 0.05 | 6 NEVADA 132.0kV | 4 TENNESSEE 132.0kV | 132 | 1 | Fuse | 0.014 | Misoperation |
| | 5 | THREE-PHASE, R=0 (oh) | 0.05 | 1 GLEN LYN 132.0kV | 2 CLAYTOR 132.0kV | 132 | 1 | Phase Overcurrent | 0.017 | OK |
| | 70 | SINGLE_LINE_GROUND | 0.05 | 1 GLEN LYN 132.0kV | 2 CLAYTOR 132.0kV | 132 | 1 | Phase Overcurrent | 0.017 | OK |
| | 70 | SINGLE_LINE_GROUND | 0.05 | 1 GLEN LYN 132.0kV | 2 CLAYTOR 132.0kV | 132 | 1 | Ground Overcurrent | 0.017 | OK |
| | 70 | SINGLE_LINE_GROUND | 0.05 | 2 CLAYTOR 132.0kV | 1 GLEN LYN 132.0kV | 132 | 1 | Phase Overcurrent | 0.017 | OK |

Summary of Protection Settings Evaluation Tool (PSET)

Problem

Protection becoming more numerous and complex: 10s to 100+s of settings

Grid state (outages and generators) can have a massive impact on protection performance and coordination

Relay settings calculated for credible grid states (N-1 etc) at that time

Settings checked/revise at maintenance intervals like 3-7+ years

10% of faults in US have at least one relay misoperation; 29% of misoperations due to relay configuration/settings issues

Solution

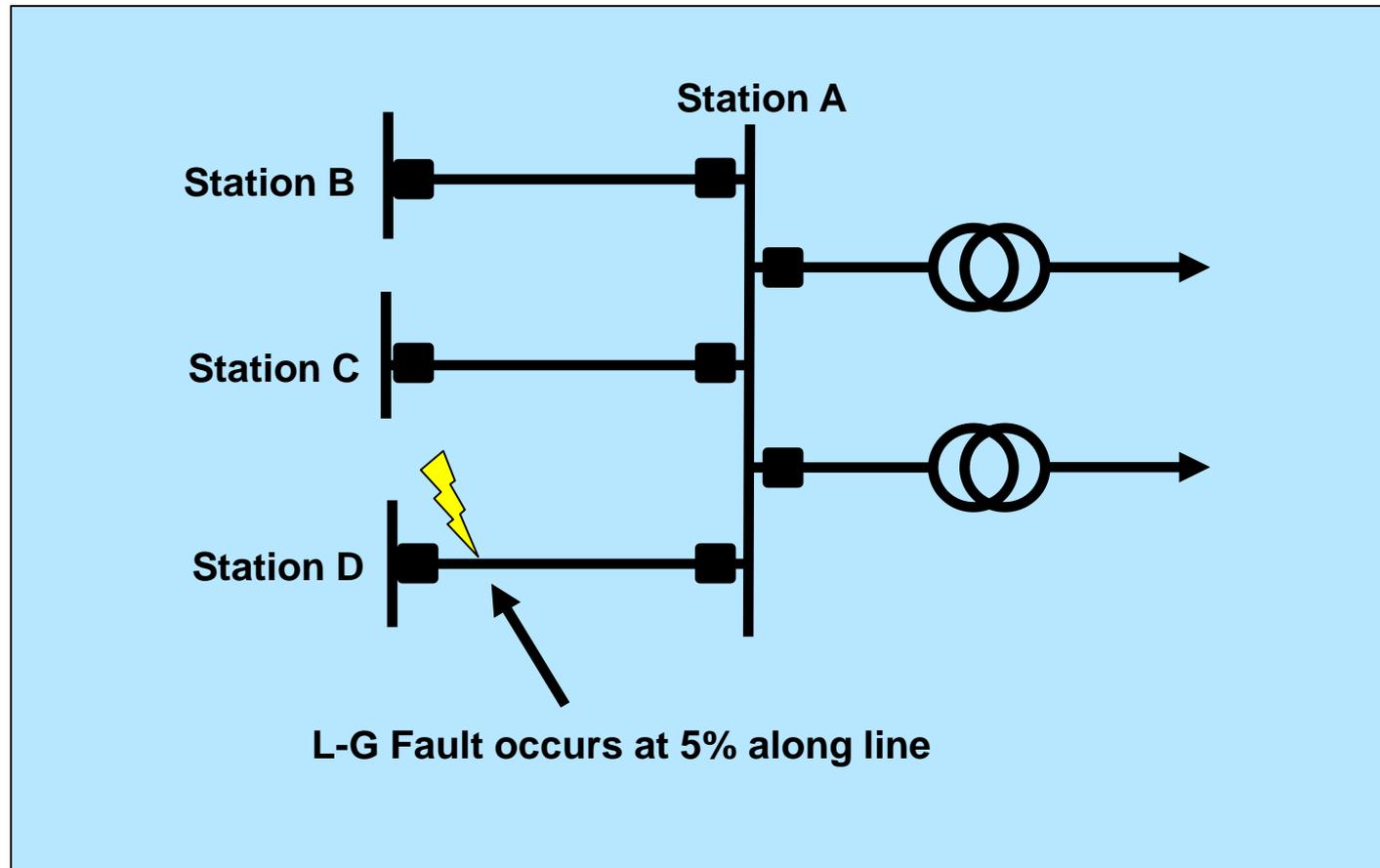
Automatically simulate multiple fault types at multiple locations along each transmission line across the grid and for each fault assess each relay tripping

For each fault, look at trip times of each relay and identify if all protection relays near the fault meet set criteria. Did any relays over-reach or misoperate, was the fault cleared quickly?

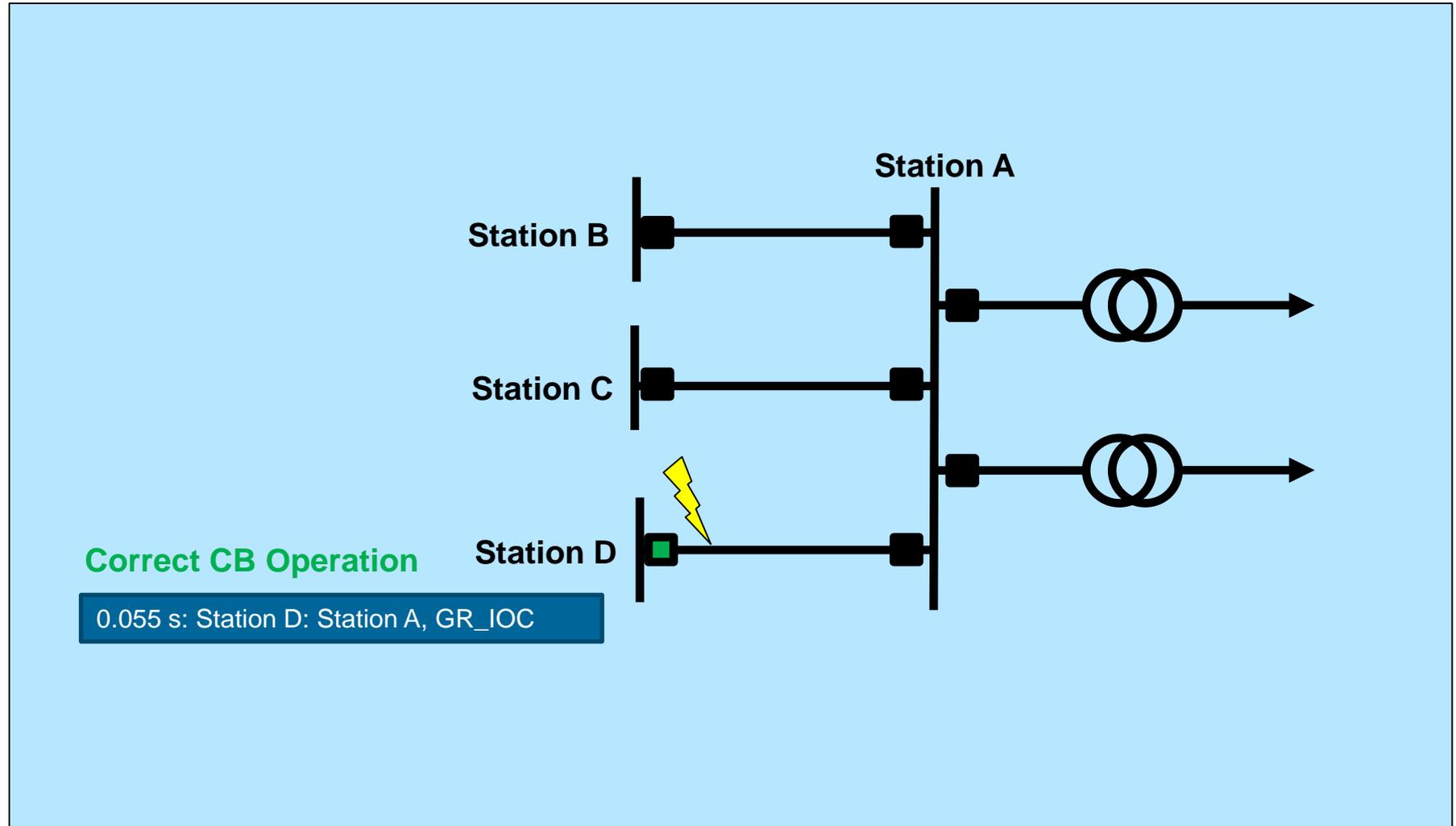
Engineers can't be expected to manually examine 1000s of results, so produce short, simple, easy to read report identifying issues - results file can be viewed in a webpage, Excel, or brought into an Access DB

Automatically compare latest results with last week/month/year etc. Flag new protection issues which didn't exist the last time you ran the tool

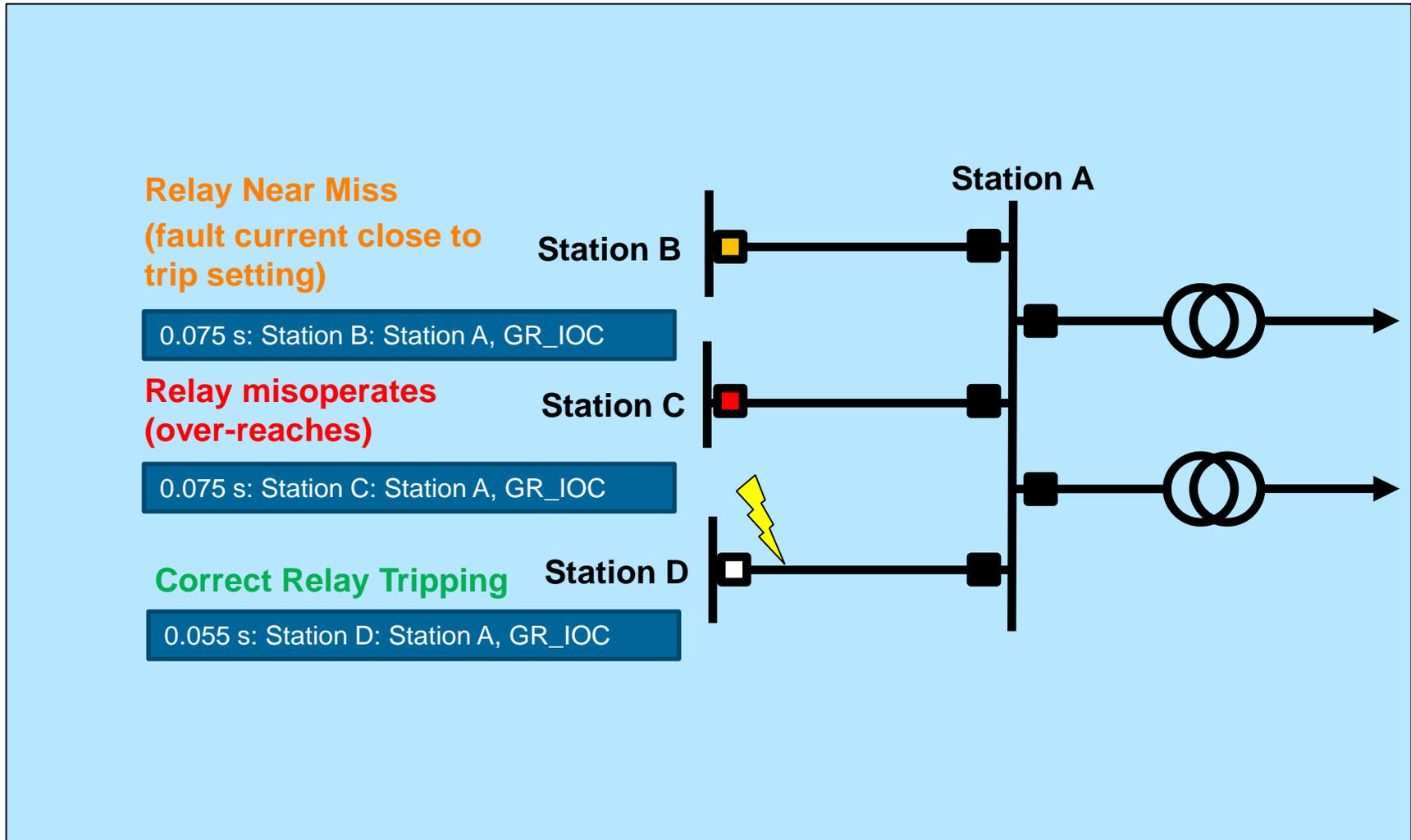
System Simulator Example: Fault Initiation (5% of Line)



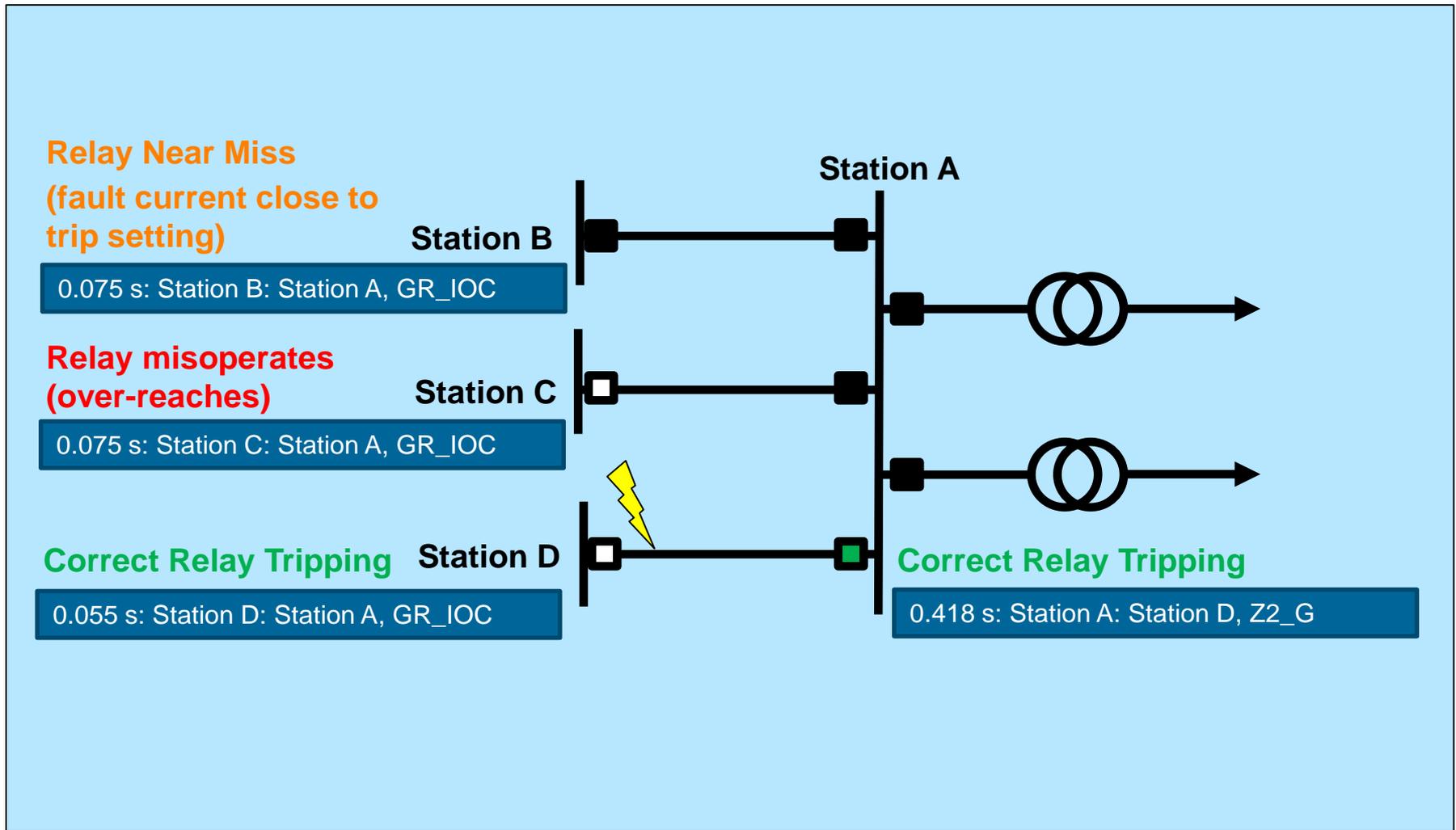
System Simulator Example: First PCB Opens



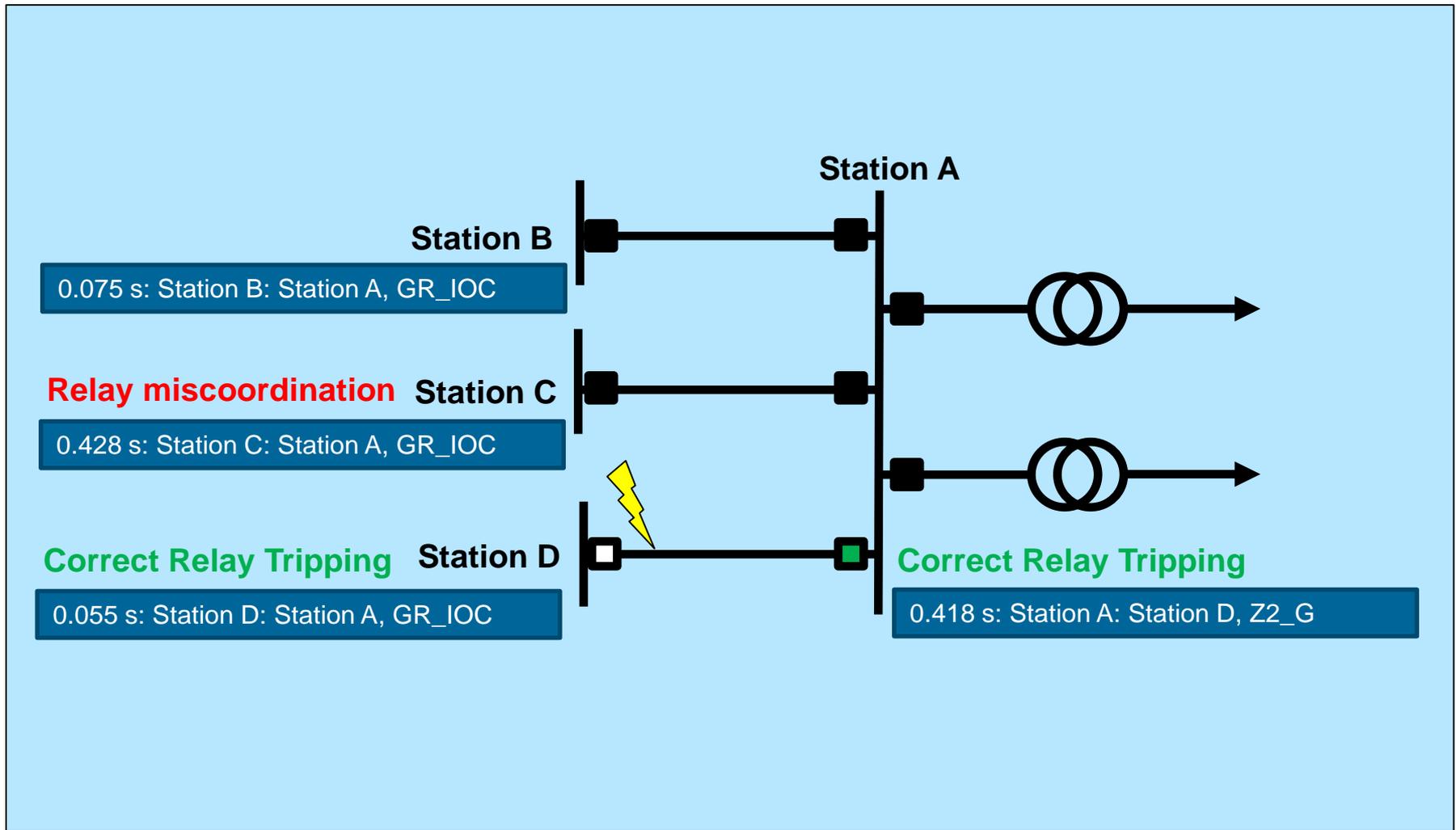
System Simulator Example: Second PCB Opens (Misoperation and Near Miss)



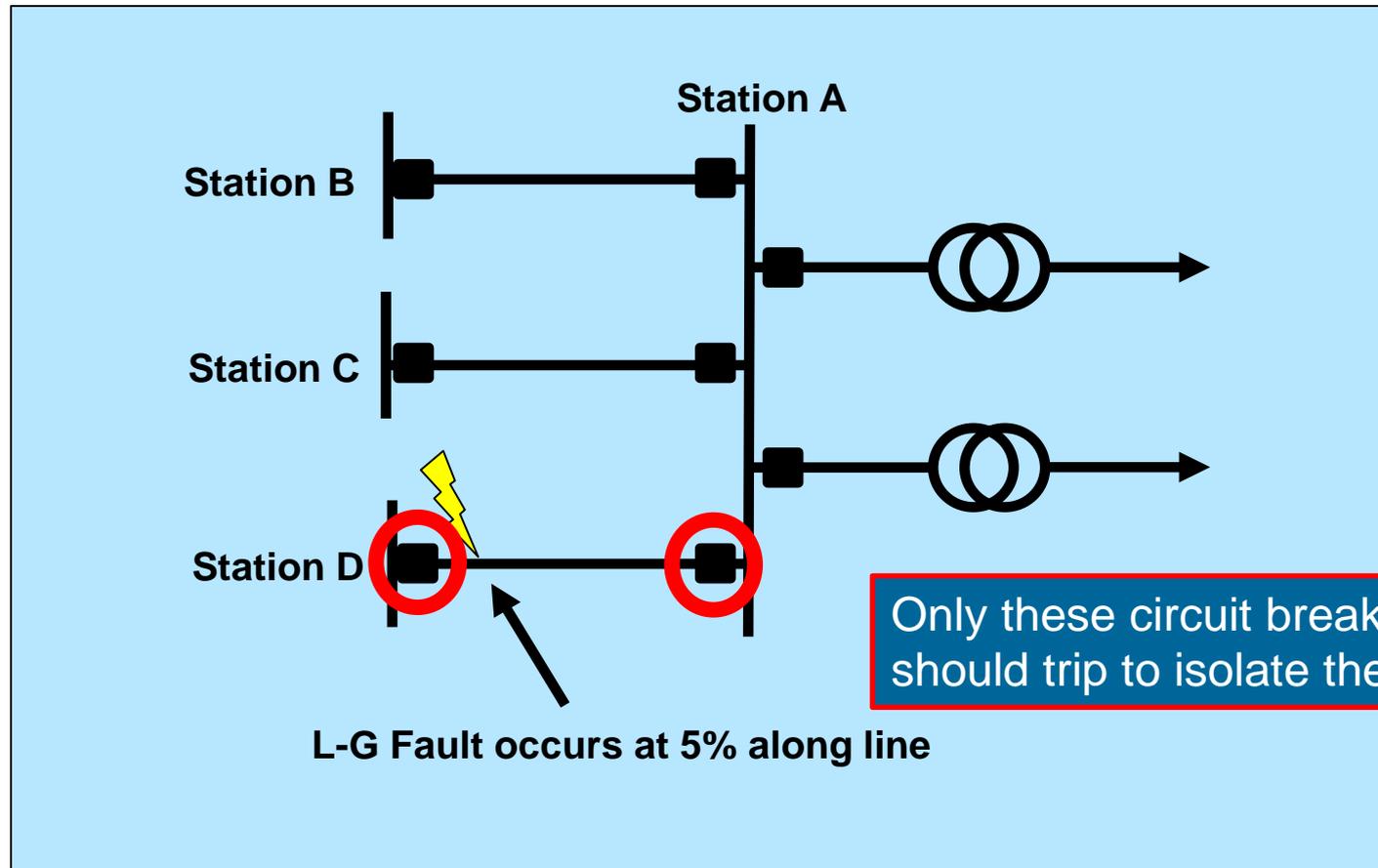
System Simulator Example: Third PCB Opens & Clears Fault



System Simulator Example: Miscoordination



System Simulator Example: Primary Protection



System Simulator Example: Backup Protection

