AUTOMATED APPROACH FOR COMPLIANCE WITH NERC PRC-027-1 REQUIREMENTS FOR PROTECTION SYSTEM COORDINATION OF BES ELEMENTS

March 28th 2019

Ishwarjot Anand, Tim Chang, and Saman Alaeddini
Quanta Technology, Markham, Canada

Background

- NERC standards are continually updated to help reduce misoperations and improve power system reliability
- New standards also put additional burden on engineers to study and demonstrate compliance
- Utilities are leaning towards compliance solutions that are comprehensive and provide long term efficiency
- NERC PRC-027-1 is an opportunity for utilities to adopt the industry leading protection analysis practices, and benefit from an automated solution

NERC PRC-027-1 Standard

What is PRC-027-1?

- NERC Reliability Standard with stated purpose: “To maintain the coordination of Protection Systems installed to detect and isolate Faults on the Bulk Electric System (BES) Elements, such that those Protection Systems operate in the intended sequence during Faults.”
- Comes into effect October 2020

PRC-027-1 Requirements – The standard has three main requirements:

- **R1. Establish a process** for developing new and revised protection system settings for BES elements such that the protection systems operate in the intended sequence during faults
- **R2. Perform protection system coordination studies** periodically, as per options described in the standard
- **R3. Develop new protection system settings by following the process** developed in requirement R1

Focus of the Paper

- The main focus of the paper is PRC-027-1 requirement R2
- PRC-027-1 requirements R1 and R3 are related to establishing and following a protection settings development process.
- Automation does have a role to play in R1 and R3 compliance; but it is not the focus of this paper.
- They are discussed as they relate to requirement R2, such as:
  - Primary Network and Protection System review and update

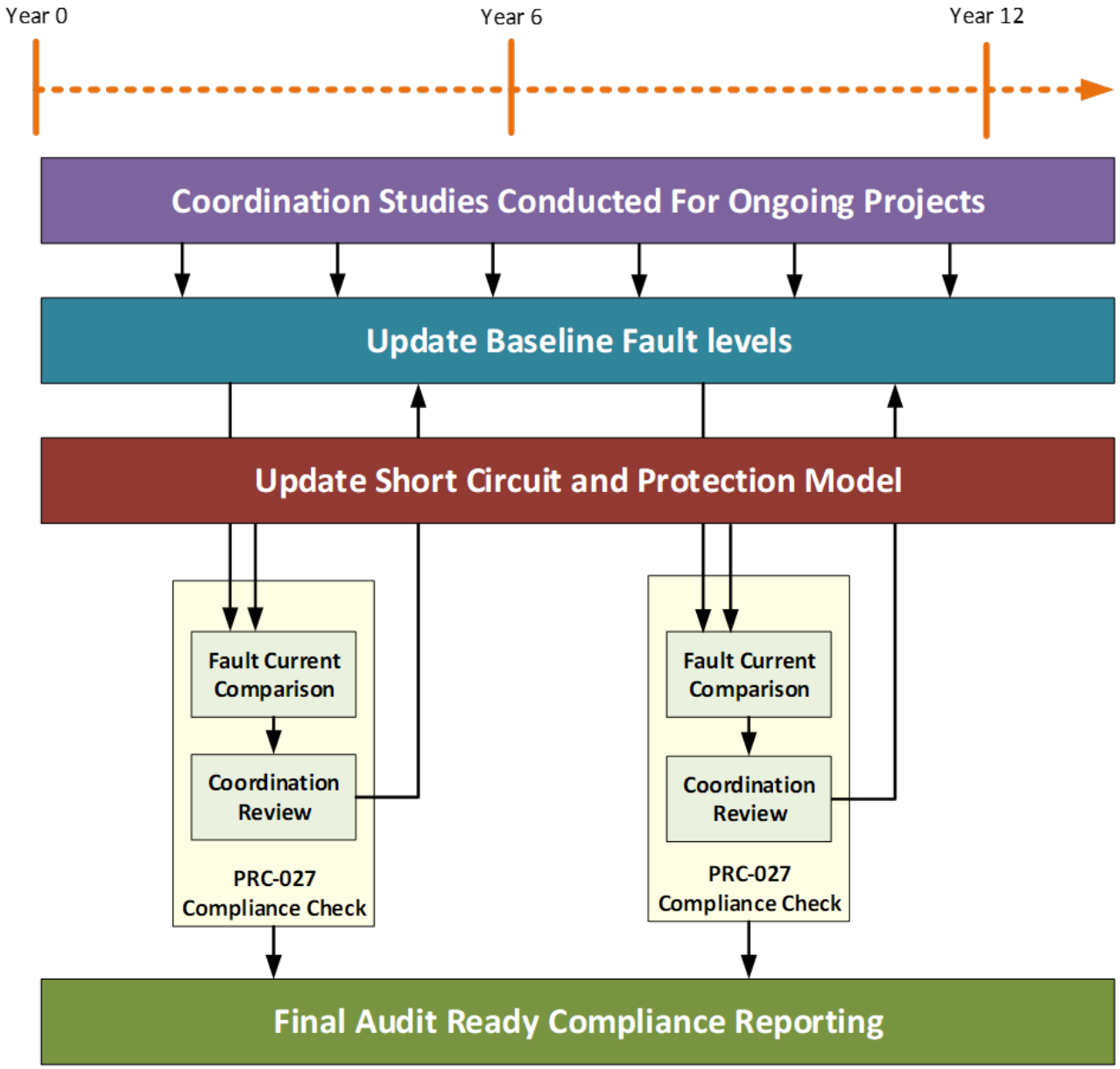
NERC PRC-027-1 Standard – R2 Compliance

R2 Compliance Options – For each BES element with protection system functions:

- **Option 1**. – Perform a protection System Coordination Study in a time interval not to exceed six-calendar years;
- **Option 2**. – Compare present Fault current values to an established Fault current baseline and perform a Protection System Coordination Study when the comparison identifies a 15 percent or greater deviation in Fault current values (either three phase or phase to ground) at a bus to which the BES Element is connected, all in a time interval not to exceed six-calendar years;
- **Option** 3. – Use a combination of Option 1 and 2

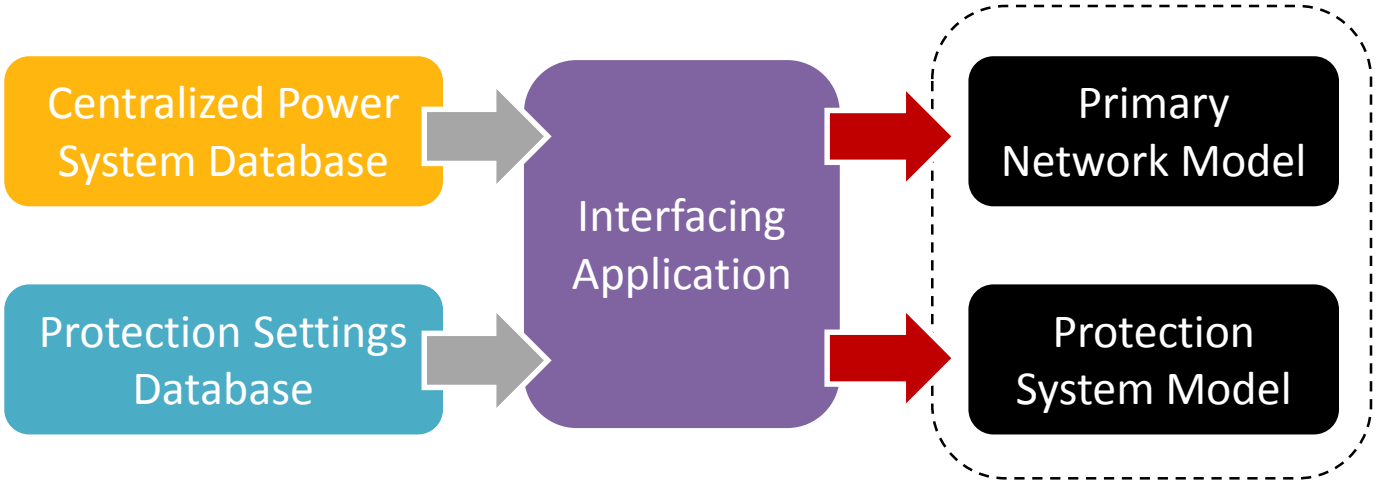
The standard provides the flexibility to use different options, therefore automation tools must be designed to be flexible as well.

PRC-027-1 R2 Compliance Process Overview



Primary Network and Protection System Modeling

- PRC-027-1 evaluations will require access to accurate and up-to-date primary network and protection system models
- Utilities are moving towards maintaining system parameters in centralized databases and protection data in asset management applications
- Protection simulation software platforms are capable of creating system model directly from centralized data sources
- Centralized databases must be setup to support automation-assisted model creation and verification



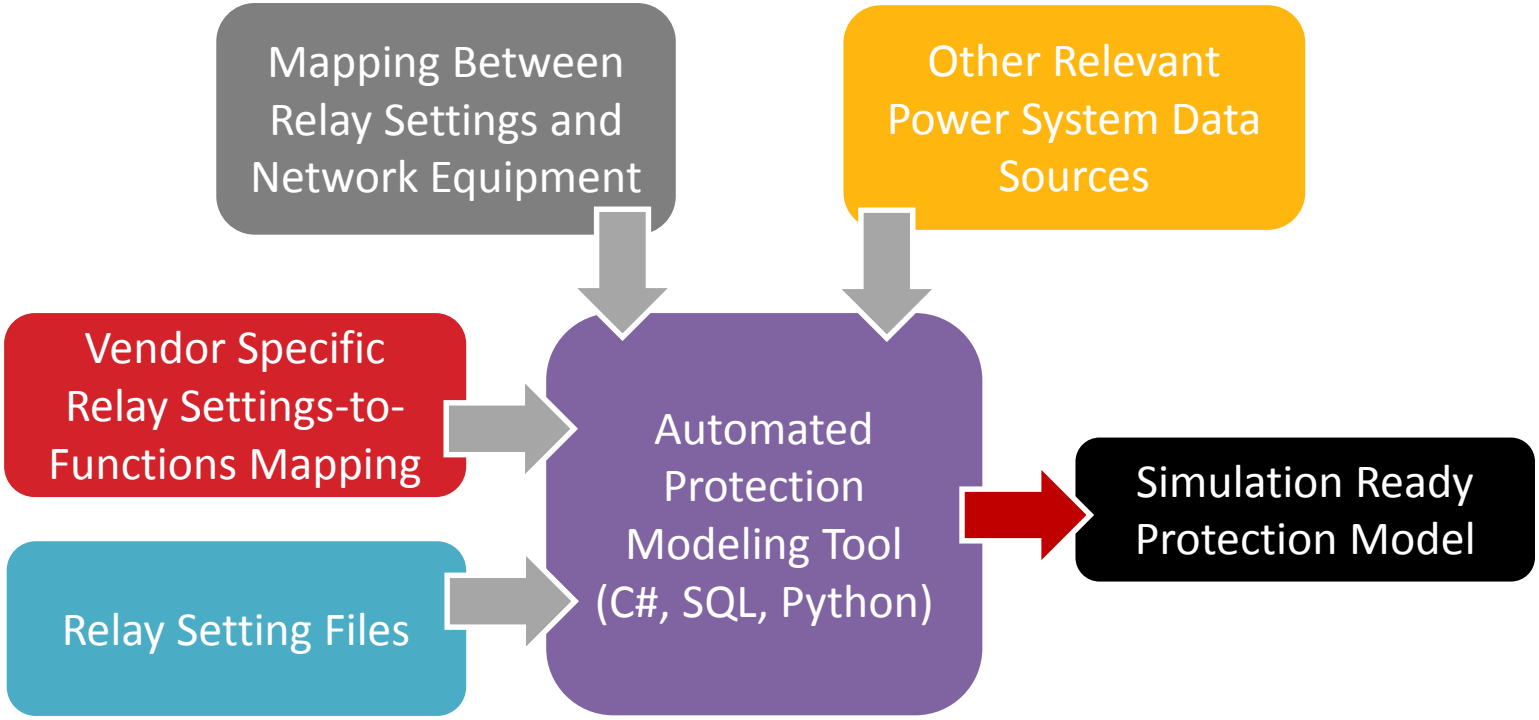
Primary Network and Protection System Modeling

- Access to the centralized data is only part of the puzzle…
- Interfacing application relies on:
  - Standardization of naming across data sources
  - Processes to maintain accuracy and the usefulness of the data
- Automated modeling tools are limited by the data available, therefore, some manual customizations may still be required

Even if manual customizations may be required, investment in centralized databases and interfacing applications that convert this data into simulation ready models is highly valuable

Primary Network and Protection System Modeling

Maintaining a detailed protection model can be especially challenging

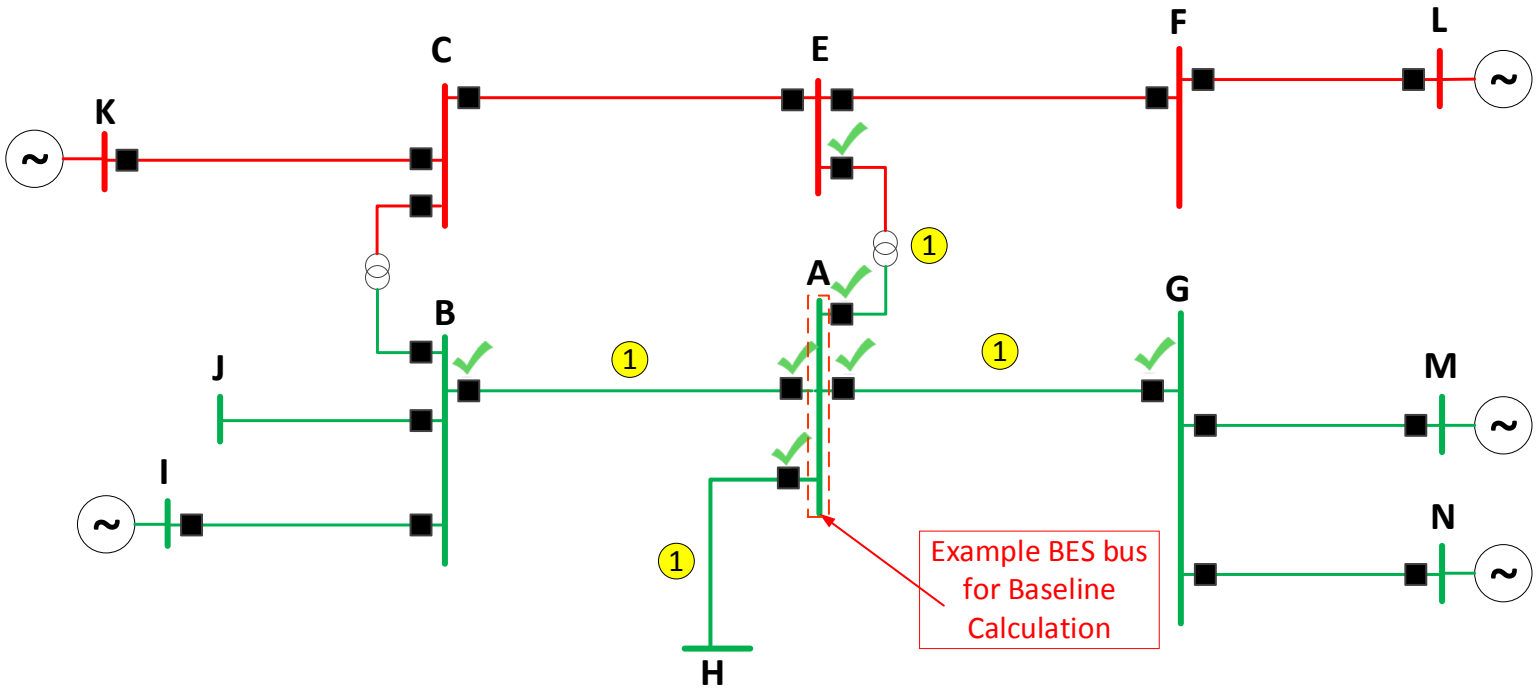


Utilities must invest in automated modeling tools that directly retrieve relay data (type, setting file, location) from Asset Management database, and prepare simulation ready protection model.

Determining and Tracking Bus Fault Baseline

- When should the baseline bus fault be updated?

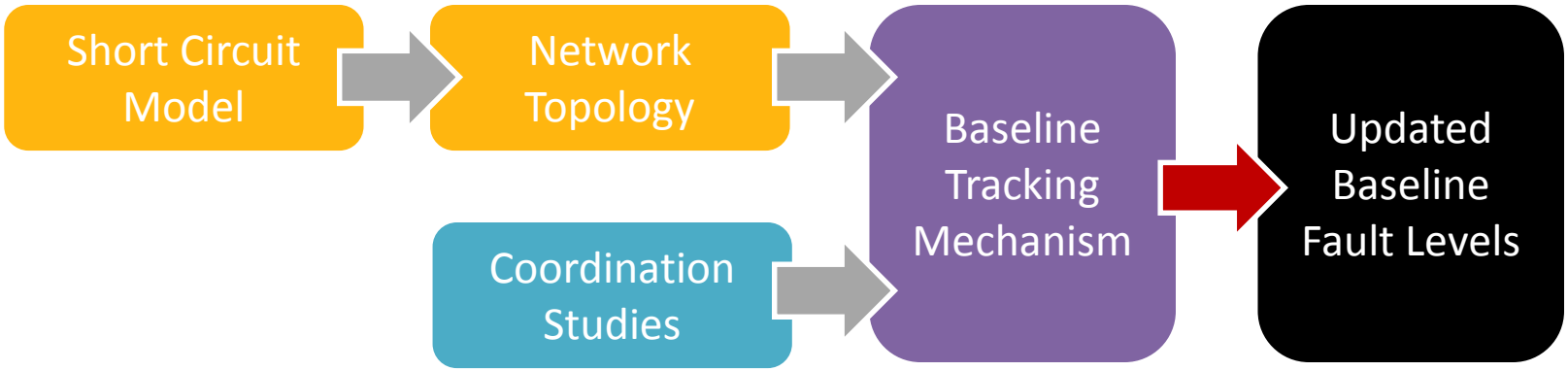
Protection Systems responsible for clearing faults on equipment connected to the BES buses shall operate in the intended sequence.



The bus fault current at which the protection systems are verified to operate as expected, should be set as the baseline.

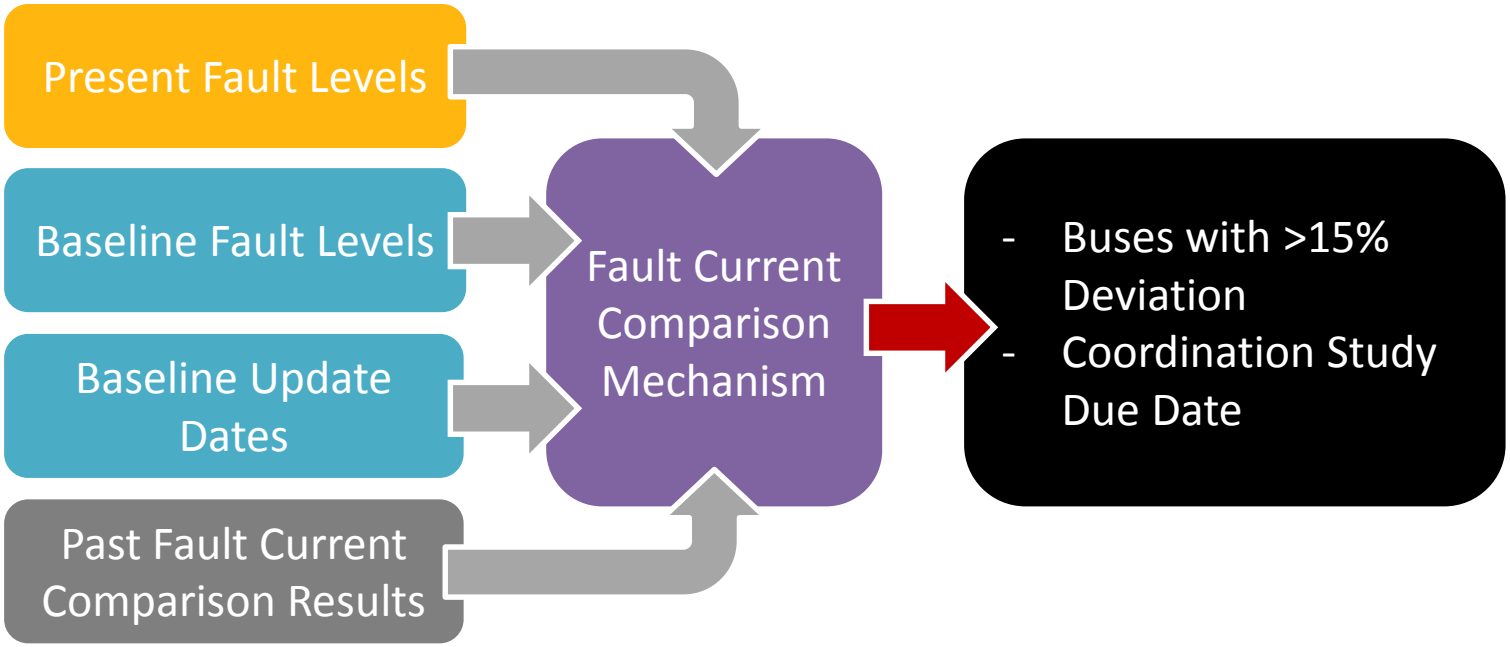
Determining and Tracking Bus Fault Baseline

- Initial baseline fault current levels can be determined based on:
  - Past records of coordination evaluation
  - Performing an initial system wide coordination study
- Continuously update baseline
  - Baseline fault current levels can be updated, as coordination studies are completed for network equipment connected to BES bus
  - The topological relationship between BES buses and connected equipment is determined from the short circuit program



Determining Buses with >15% Current Deviation and Study Due Dates

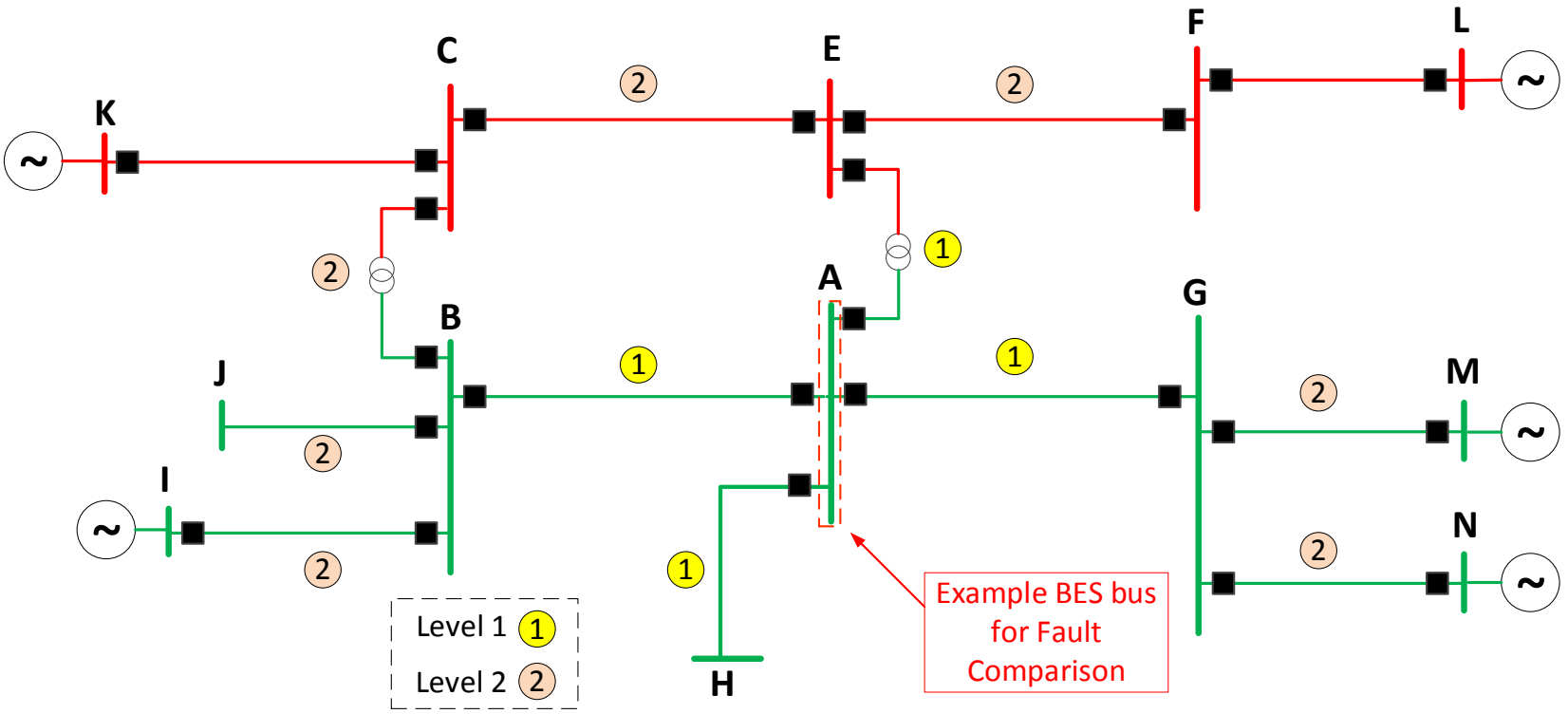
- Two Main Fault Current Comparison Outputs:
  - Buses with >15% deviation, and coordination study due date
- Key Inputs



Coordination study due date is not only a function of present fault comparison date, but also depends on results of previous fault comparisons, and when baselines were last updated.

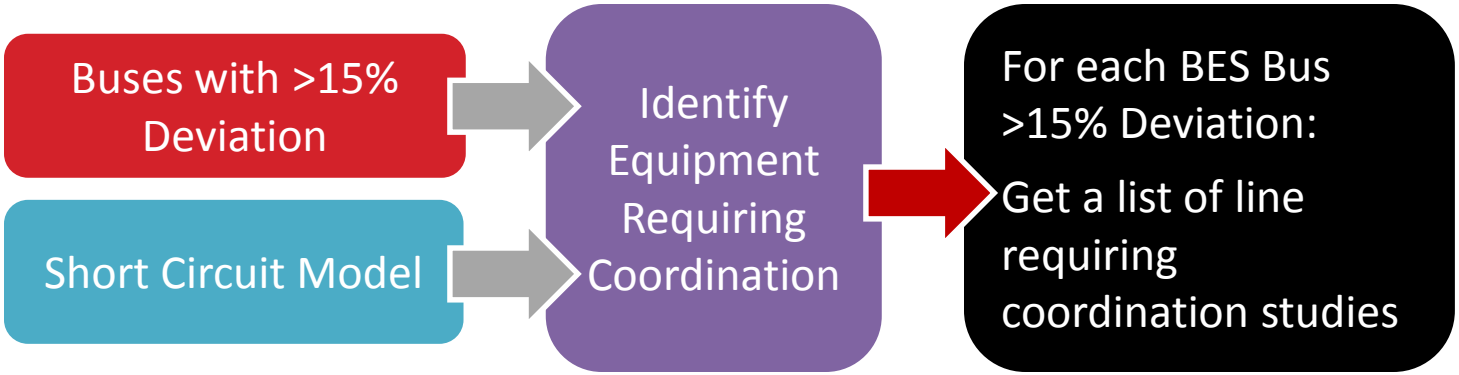
Determining Equipment Requiring Coordination Studies

- For BES buses with >15% deviation:
  - Equipment connected up to two levels away from a BES bus will need to be part of the coordination analysis

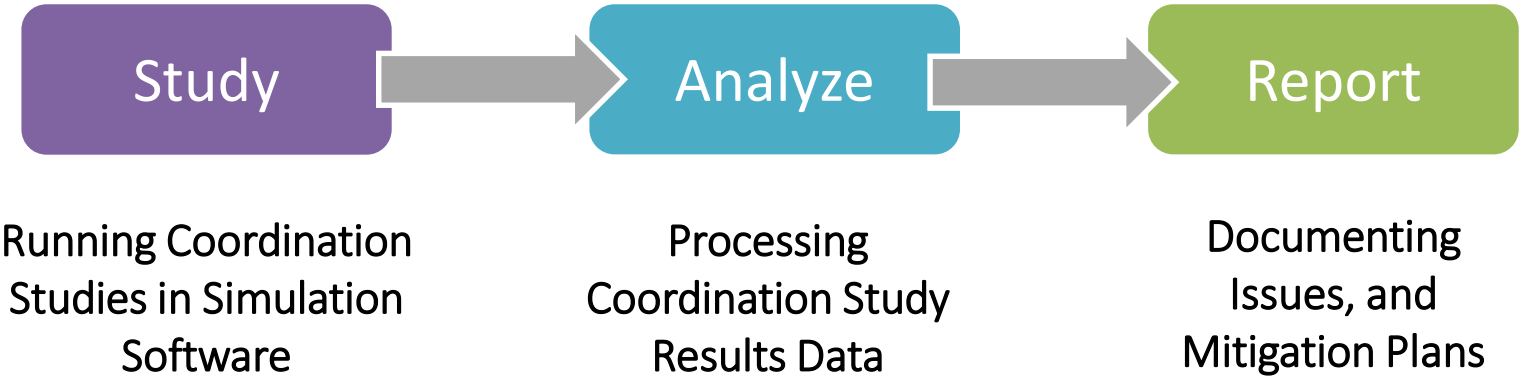


Determining Equipment Requiring Coordination Studies

- Modern protection simulation software applications allow topological searching to identify equipment requiring coordination studies
- The list of lines can also be used to start batch coordination studies



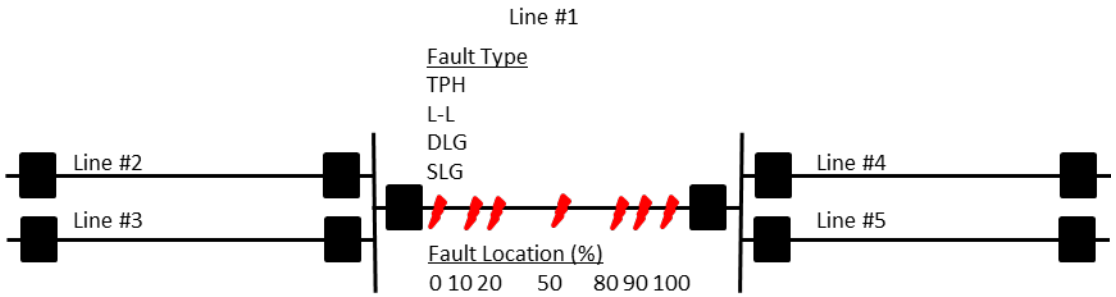
- Protection coordination studies can be performed in many different ways
- A systematic and comprehensive coordination review process should be adopted



Wide Area Coordination Macros/Scripts

- Wide area coordination study approach is designed for relay coordination across a large area within a transmission network
- Evaluate protection performance under numerous fault cases and contingencies including relay failure and/or breaker failure
- Highly automated to relieve the protection engineer from the tedium of running the studies
- Study generates sequence of events report showing primary and backup protection behavior and highlighting any misoperation or coordination time interval issues

Wide Area Coordination Macros/Scripts



CLASSIC

- TPH & LTL close-in fault at local bus for system normal (2)
- TPH close-in fault at local bus with strongest source out (1)
- Minimum LTL close-in fault at local bus (1)
- SLG remote bus fault at system normal (1)
- Minimum & maximum SLG remote bus fault at remote bus (2)
- LTL remote line-end fault for system normal (1)
- SLG line-end Fault (Strongest Source out) (1)
- No. of simulations per terminal = 9

AUTOMATED

- Four bolted faults SLG, LTL, DLG and TPH,
- Four resistive faults 1 & 5 ohms SLG & DLG
- Five fault locations
- Assume five local sources including mutual coupling
- Assume five remote sources
- Two protection packages, A and B
- No. of simulations per terminal =
- 8 x 5 x 11 x 2 = 880

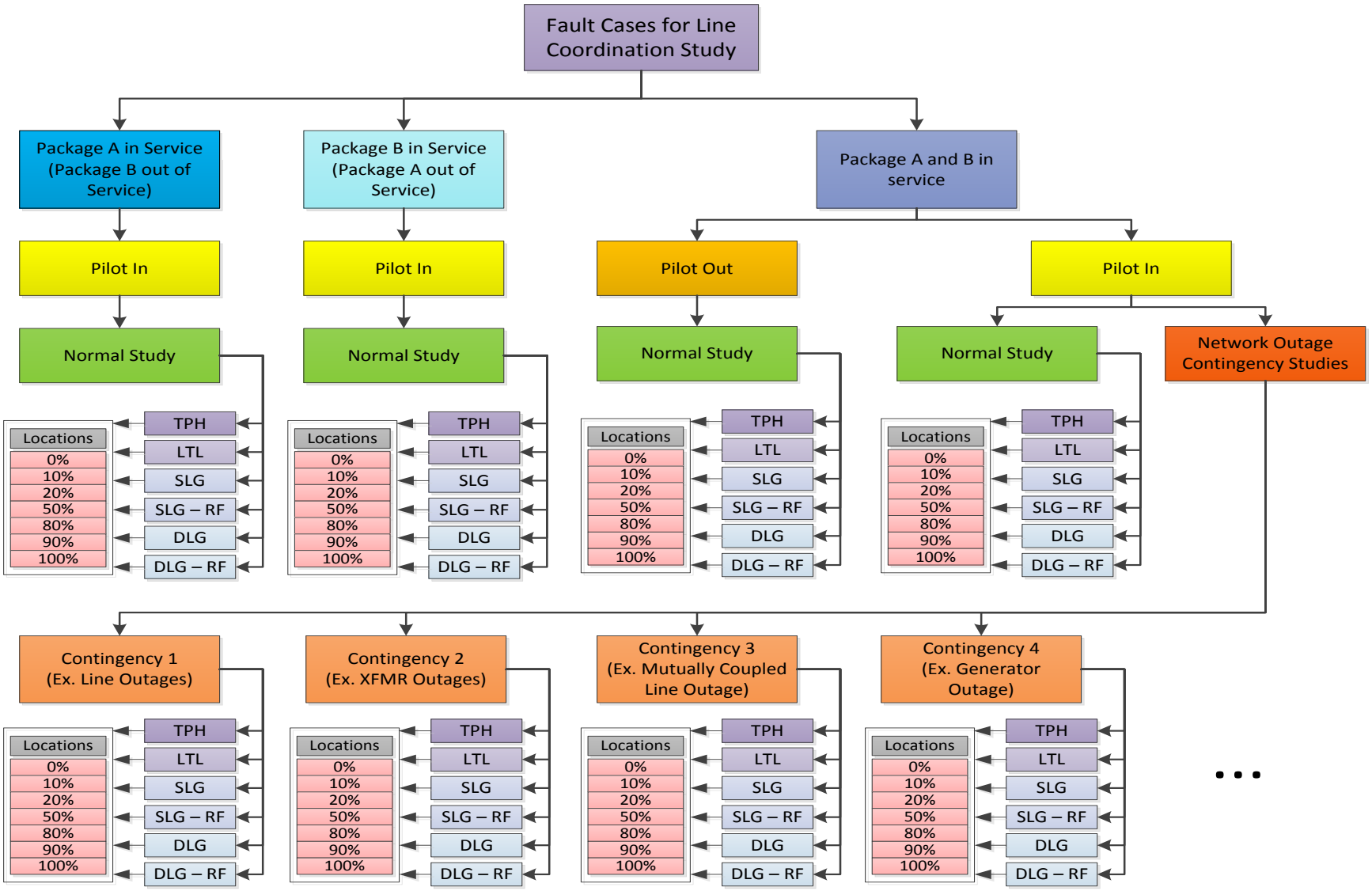
1 System Normal

10 Source outages

2 Packages

Performing Coordination Studies

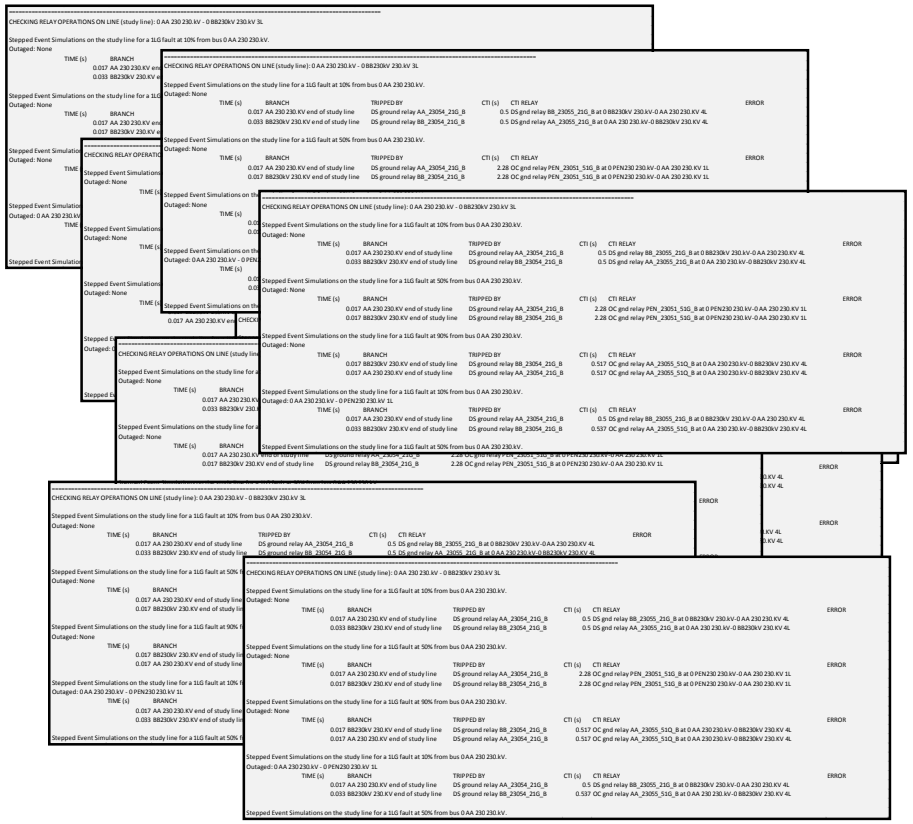
Be prepared for the high volume of test cases!



Performing Coordination Studies

Condensing Dilemma

- How can we focus an engineer's limited time on solving relay settings problems rather than reviewing thousands of pages of raw data?
- How do we keep track of all of the mitigation plans?
- How do we manage the studies being worked upon by a large team?



500 Transmission lines can produce about 4 million lines of raw data

Translate Fault Summary to Device Summary

- Example:

Substation	Device	Element	Contact Logic Code	LZOP	Risk	Pilot In: System Normal	Pilot In: N-1 Contingency	Pilot Out: System Normal	Pilot Out: N-1 Contingency	Action	Action Tag	Reason/Recommendation
Ontraio TS	D60	594 TIMER "T2_GND" "1"	21G2T_A	Ontario_Line1_1000	1		CTI		CTI			
AlbertaTS	D60	11261 TIMER "T2_PHS" "1"	21P2T_B	Alberta_Line2_2000	4		CTI		CTI			
Alberta TS	LFZP111	6173 TIMER "TZ2" "1"	21PG2T_B	Alberta_Line2_2000	2	CTI	CTI	CTI	CTI			
QuebecTS	SEL-311	11260 AUX "Z2D"	21PG2T_A	Quebec_Line3_3000	5	MISOP	MISOP	MISOP	MISOP			
Quebec TS	SEL-311	6172 AUX "Z2D"	21PG2T_A	Quebec_Line3_3000	4		MISOP		MISOP			
4.17 % of faults not cleared at 1 seconds												

Element: 594 TIMER "T2_GND" "1"
Substation: Ontario TS
LZOP: Ontario_Line1_1000
Type: D60
Tested Line: C21J
0% = Bus1 (220kV)
100% = Bus2 (220kV)

Ph-G Fault

Pilot	Package	Outages/Test	0.00%	15.00%	30.00%	50.00%	70.00%	85.00%	100.00%
Disabled	Package_A	Line : 7101-7259-1(C24Z)							C0.020 (77)
	Package_B	Line : 7101-7259-1(C24Z)							C0.017 (413)
	Both in service	Line : 7101-7259-1(C24Z)							C0.020 (749)

Mitigation Plan

Setting Change
Protection Upgrade
System Upgrade
No Change Required

Reducing 1000s pages of results into a list of miscoordinating devices requiring investigation and mitigation plan

Risk Assessment

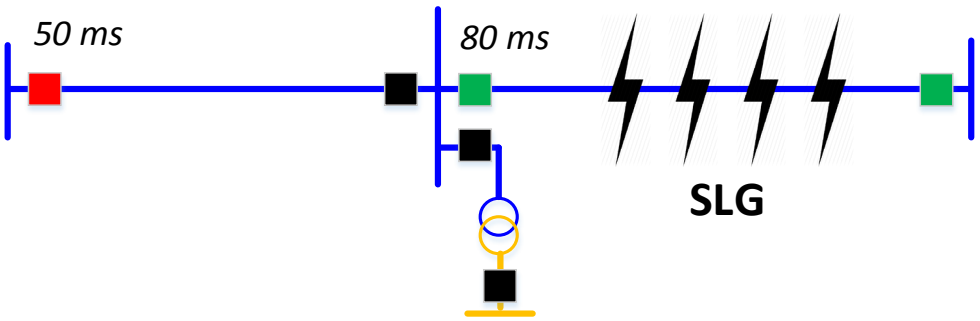
Risk
1
2
3
4
5

Function of Probability

Fault Probability
Contingency Probability
Time Margin

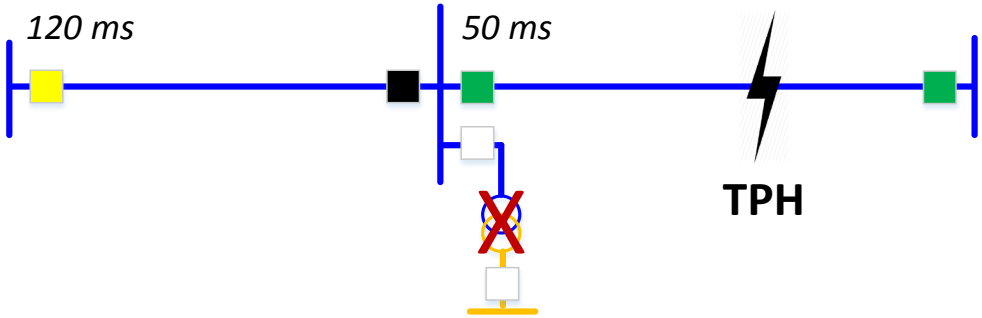
Function of Consequence

Impact to Bulk Electric System
Load Lost Through Outage Buses



Misoperation

High Risk
- *Misoperation*
- *Higher Probability Fault Type*
- *No Network Outage*
- *Multiple Fault Locations*

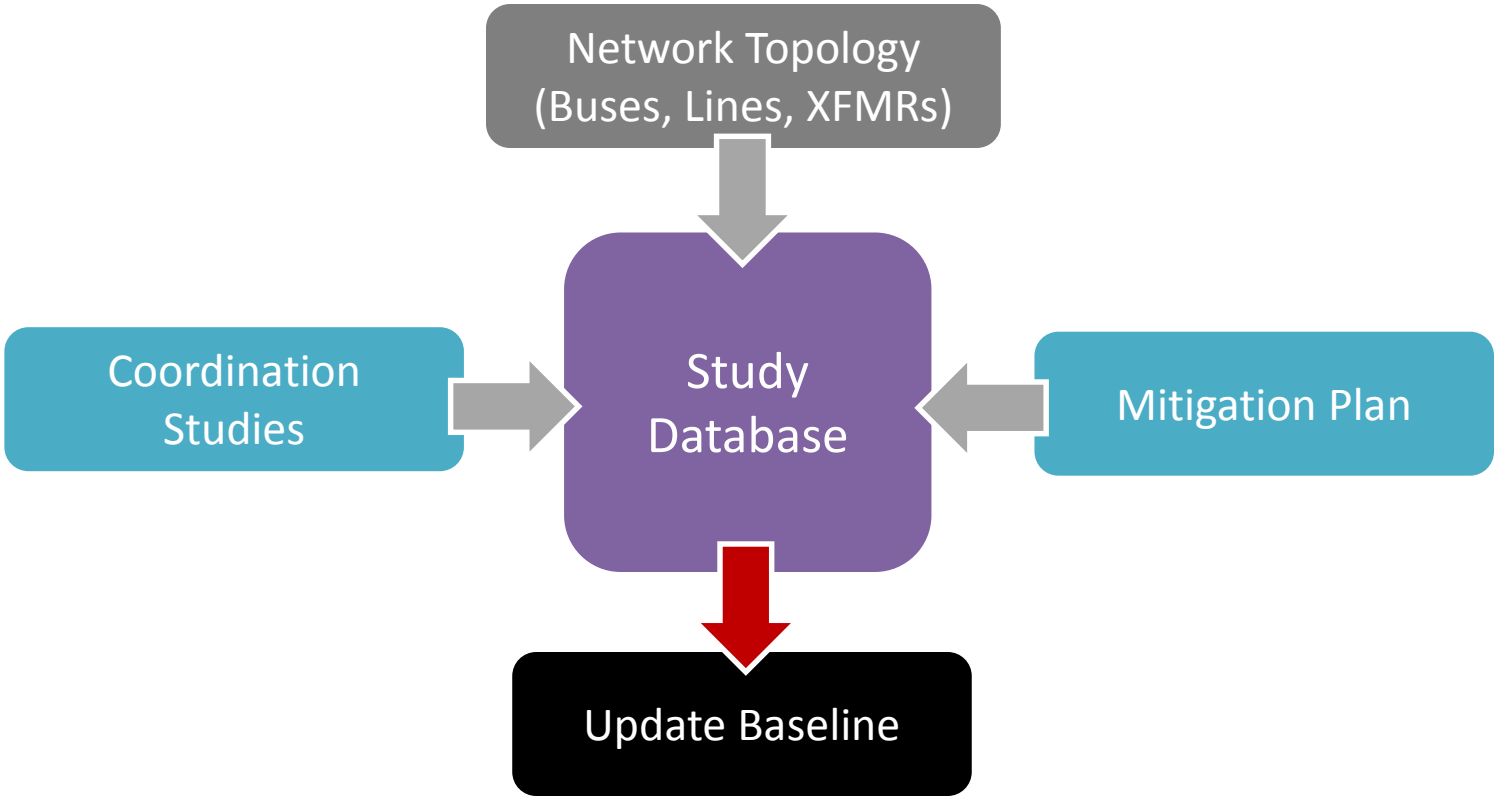


Low Coordination Margin (70 ms)

Low Risk
- *Coordination Margin Low*
- *Lower Probability Fault Type*
- *Network Outage*
- *Single Fault Location*

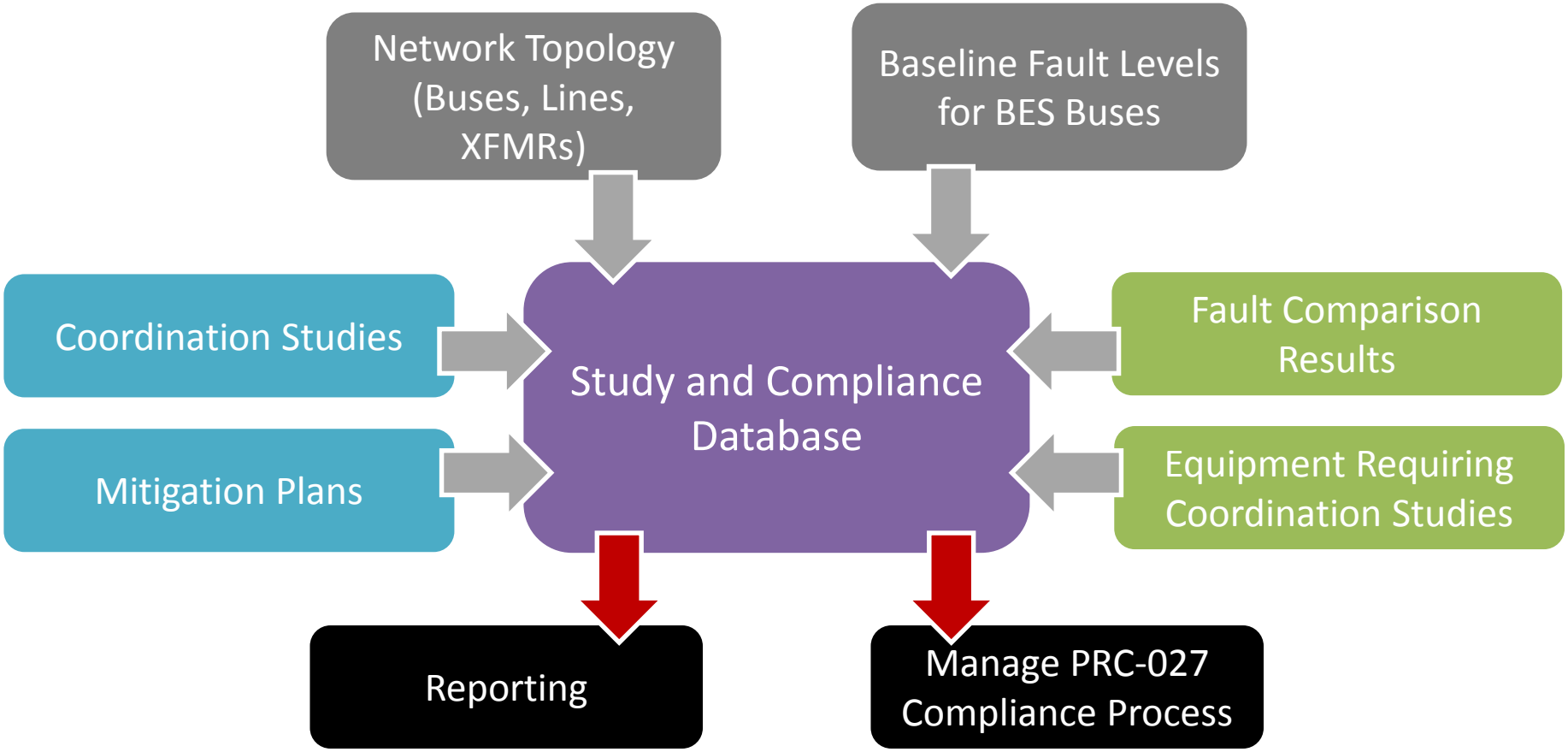
Document Mitigation Plan and Update Baseline

- A database can help manage the large number of coordination studies and the mitigation plans
- By having the network topology and coordination studies results, the Baseline Fault Levels can be automatically updated

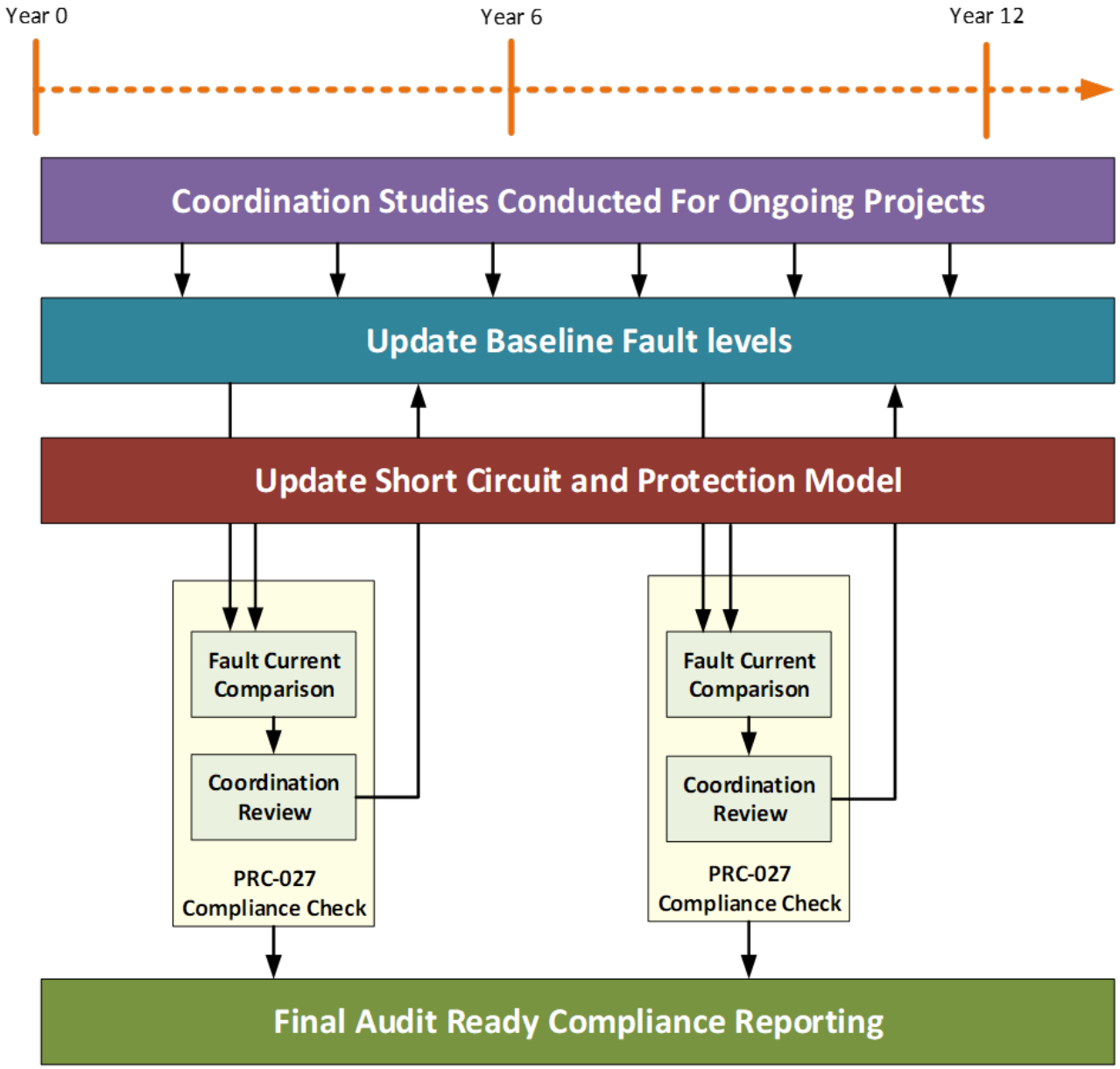


Final Audit Ready Compliance Summary Reports

- The database that can store all PRC-027 related fault comparison studies, network topology information, and coordination studies data will allow creation of audit ready documentation showing proof of compliance



Overall Process - Recap



Conclusion

- PRC-027 compliance has several aspects that require significant effort for preparation and execution
- The automated approach leverages advanced modeling and simulation capabilities of modern protection software
- Protection engineers' skills and time utilization is maximized by focusing their attention on investigation and mitigation of issues
- It is in harmony with other industry drivers of power system network and protection data consolidation efforts
- The time and effort for showing PRC-027 compliance is greatly reduced
- Gives confidence to utilities that they are meeting/exceeding PRC-027 Compliance Requirements

Thank you!

For more questions, please contact:
Ish Anand
9058184616
IAnand@Quanta-Technology.com