Automated Protection Engineering Process, from Standards and Simulation Studies to IED Configuration

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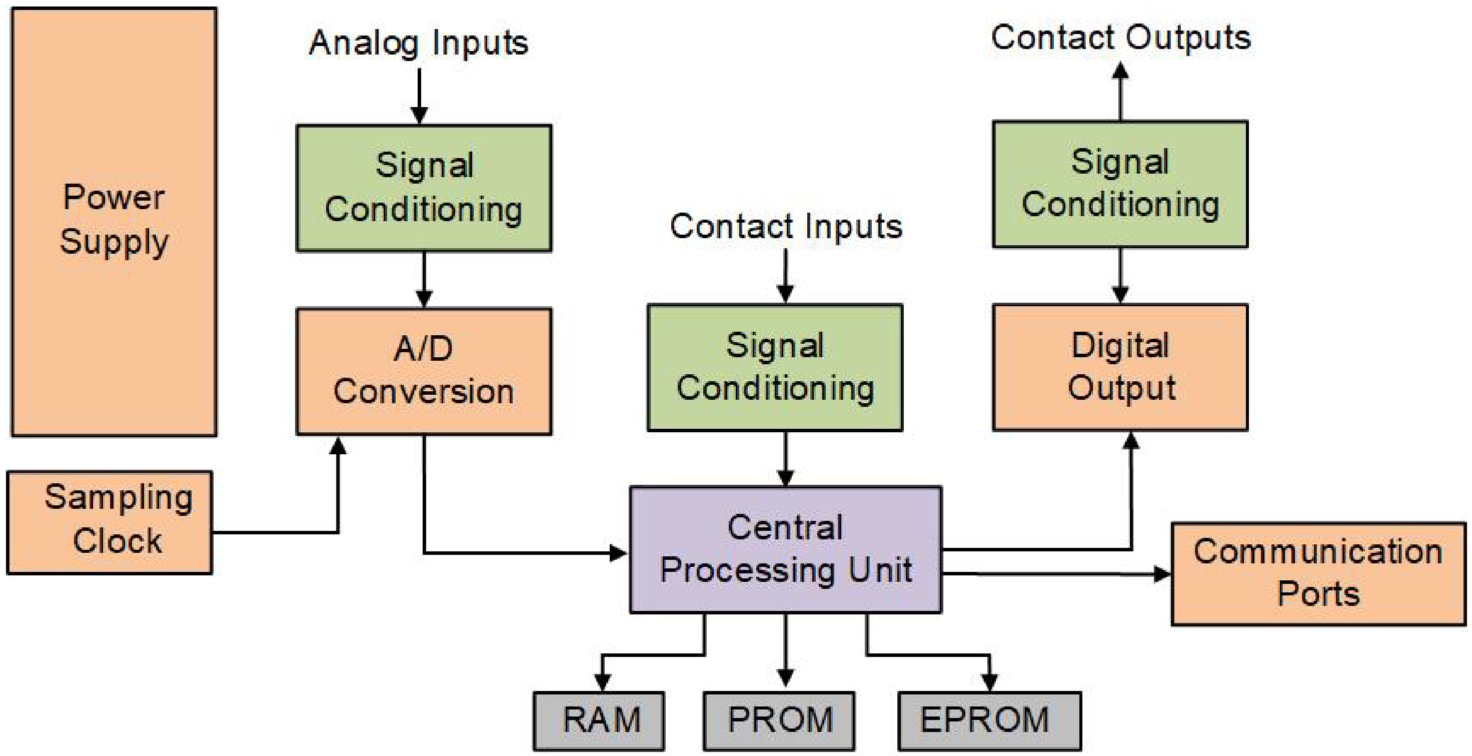
Introduction

- Characteristics of digital relays?
- Existing utility practices
- Why do we need automated engineering process?
- How to address the challenges?
- Automated engineering process
- The proposed solutions
- Conclusion

Characteristics of Digital Protection Relay

A complex device that consists of:

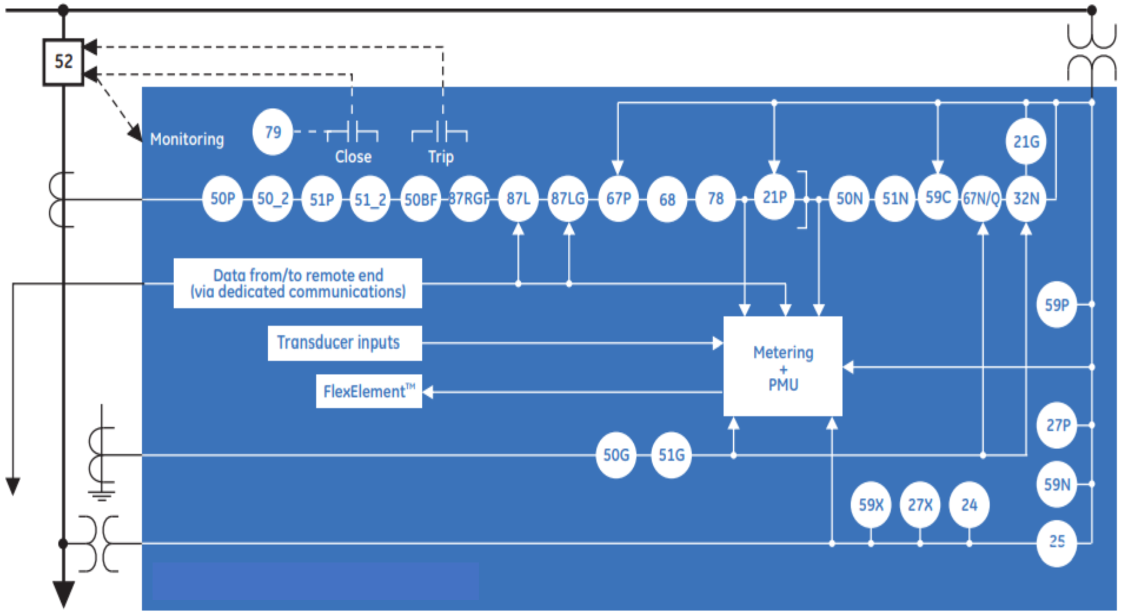
- Hardware
- Firmware
- Configuration
- Integration



Characteristics of Digital Protection Relay

A device that can replace at least dozens of ME relays for similar protection functions.

- Hundreds or even thousands of setpoints
- Complex internal logics
- Function dependency
- User logics
- User assigned I/Os
- User manual or instruction manual –thousands of pages



Characteristics of Digital Protection Relay

A device that supports advanced communication

- Digitalized data
- Variety of protocol support
- High-speed communication for real-time applications

A device that can do SOE and data archiving for post-event analysis

- Time synchronized event

Protection Relay Configuration

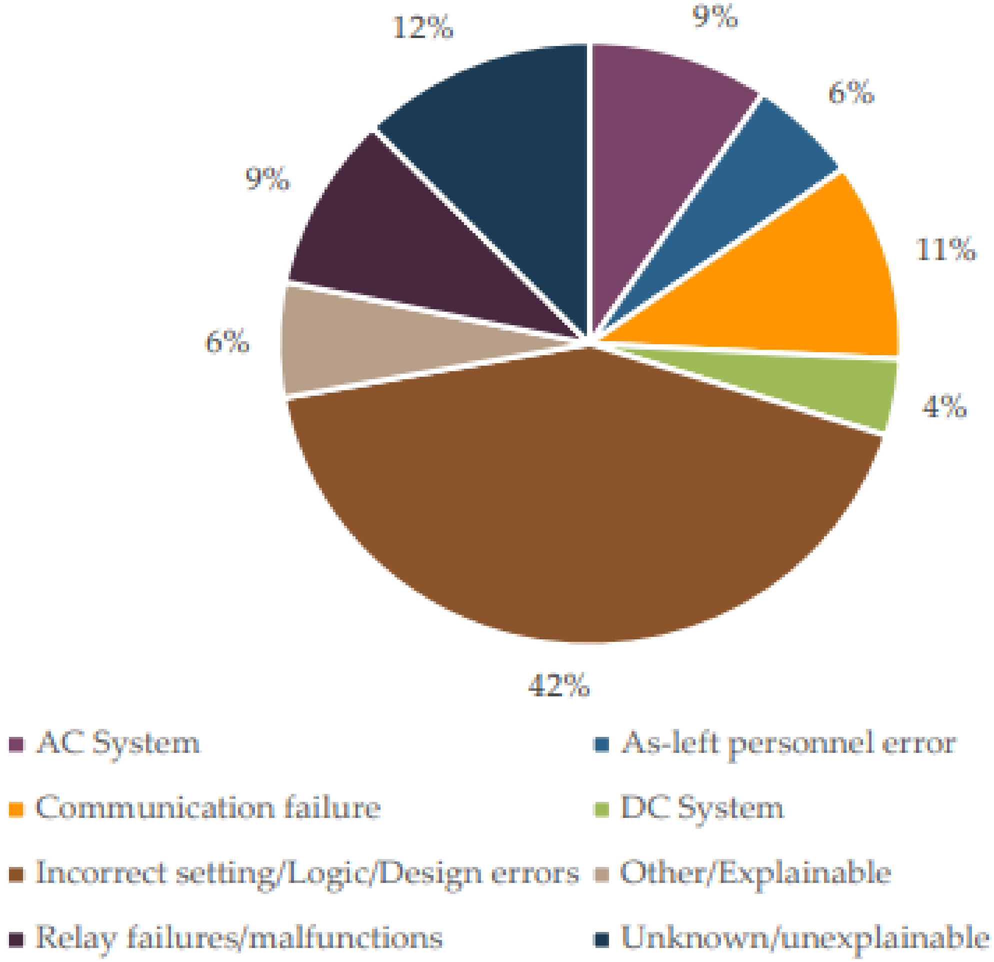
Tasks that are typically required to configure a protection relay:

a. Collection of system data, studies, and simulation
b. Comply with the utility or national standards, guides, common practices, and other standards
c. Engineered protection logics to work seamlessly with the device's internal logics implemented in firmware such as breaker failure, auto-reclose, single-pole tripping, and tele-protection schemes
d. Input and output configuration per DC schematic drawings
e. Communication message mappings according to the data mapping point lists
    - Modbus, DNP and IEC61850
f. Additional setpoints such as:
    - Device health monitoring
    - Data integrity
    - Cybersecurity
    - Event recording and archiving
    - Synchronized clock

Protection Relay Configuration

Cause of Protection Relay Mis-operations

- 48% related to human performance
- 33% to a Protection System component type category
- Unknown or unexplainable



Why do We Need Automated Engineering Process?

- Reduce or eliminate manual data transfer
- Optimization of setpoints
  - Reduce repeated inputs to simplify settings
- Directly interface the system study software and relay configuration software
- Increased productivity and accuracy without losing the understanding of protection philosophy
- Automatically tracking and handling the information required for setting calculation and verification

Why do We Need Automated Engineering Process?

Optimize Setpoints

- Reduce repeated inputs to simplify settings

Rated Voltage	230kV
CT Ratio	2000/5A
PT Ratio	3000/1
Line Positive Impedance (secondary)	4.54 Ohms , 85 deg
Line Zero Sequence Impedance (secondary)	15.32 Ohms, 72 deg
Line length	56.9 miles

A Relay		B Relay		C Relay	
Function	Enable/Disable	Mho Enable (E21MP)	N, 1-5	Setting Mode	Simple/Advanced
Z1 Direction	Forward/Reverse	Quad Enable (E21XG)	N, 1-5	Function	Enable/Disabled
Shape	Mho/Quad			Shape	Mho/Quad
Reach	3.62 ohms	Z1 Reach (Z1MP)	3.62 ohms	Z1 Reach (simple)	80%
RCA	85 deg			Z1 Reach (Advanced)	3.62 Ohms
				RCA (Advanced)	85 deg

Rated Voltage	230kV		
CT Ratio	2000/5A		
PT Ratio	3000/1		
Line Positive Impedance (Primary)	34.05 Ohms , 85 deg	Secondary	4.54 Ohms , 85 deg
Line Zero Sequence Impedance (Primary)	114.9 Ohms, 72 deg	Secondary	15.32 Ohms, 72 deg
Line length	56.9 miles		
C Relay			
Function	Enable/Disabled		
Shape	Mho/Quad		
Z1 Reach	80%	Secondary	3.62 Ohms
RCA	85 deg		

How To Address the Challenges

- Accumulate protection engineering experience and feedback
  - From other stakeholders: automation engineering groups and field-testing engineers
- Bidirectional interaction with the study software and relay configuration software
  - Generate customized study and testing report
- Automate:
  - Calculation of setpoints
  - Setpoints data entry
  - Test procedures
- Enforcement of standards and compliance
  - Automated compliance to relevant standards
- Integrate an IED Configuration Tool (ICT)
- Improve production of customized engineering documentation

Existing Utility Practices

Configuration of a protection delay to work as expected is not easy
Protection engineers are trying hard to catch the errors through:

- Peer Review
- FAT
- SAT
- Hardware-in-loop testing
- Periodically protection coordination review
- Use validated firmware only
- Use of logic and protection scheme templates that have been tested in the lab and field
- Use of setting calculation templates created in Mathcad or Microsoft Excel

Existing Utility Practices

- Use of logic and protection scheme templates that have been tested in the lab and field
- Use of setting calculation templates created in Mathcad or Microsoft Excel
- Automation of NERC compliance studies and test procedures using the setting calculation tool
- Define unified communication point mapping for each type of relay to reduce the work for typical settings

Existing Utility Practices

Relay setting calculation can be standardized per utility practice using tools such as MathCad or Excel

Zone 1 Reach, is set to trip with no intentional time delay.To avoid unnecessary operation for faults beyond the remote terminal, Zone 1 functions are usually set for approximately K1_P= 70–90% of the transmission line impedance.

$70\% \cdot Z1L_{mag} = 63.25\,\Omega$ $\quad 90\% \cdot Z1L_{mag} = 81.33\,\Omega$

$K1\_P := 85\%$

$Zone1P_{sec} := K1\_P \cdot Z1L_{mag} = 76.80894\,\Omega$

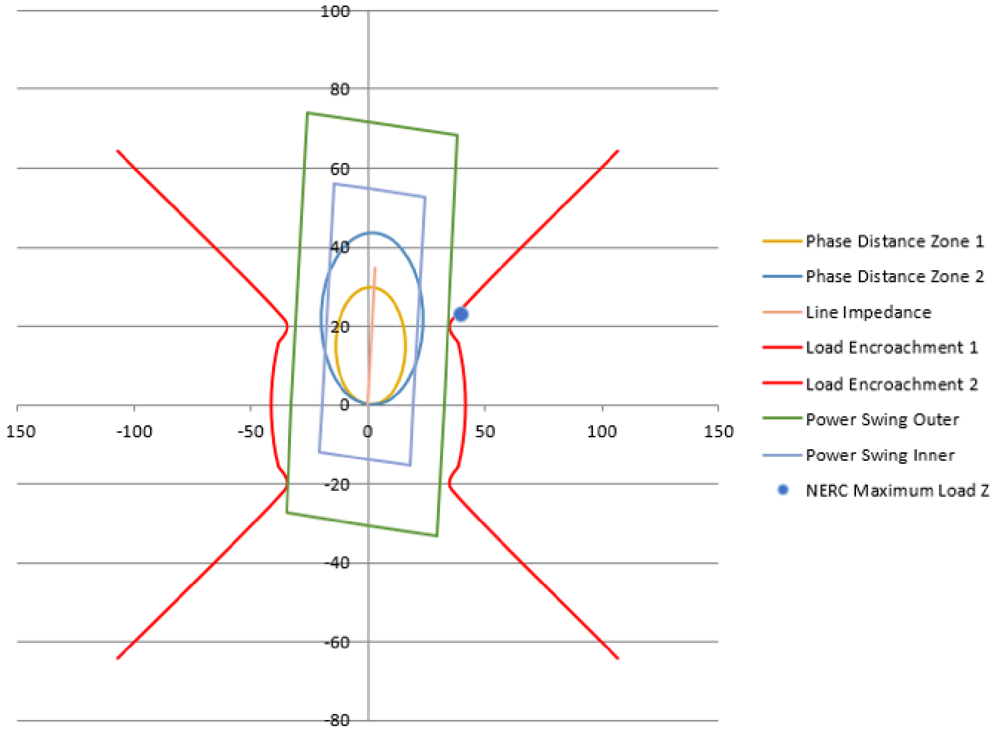
$Zone1P_{delay} := 0cycle$

Zone1P in primary ohms is: $\dfrac{Zone1P_{sec}}{Prim2Sec} = 79.88\,\Omega$

Existing Utility Practices

4. Phase Distance Z1 Settings Calculation:

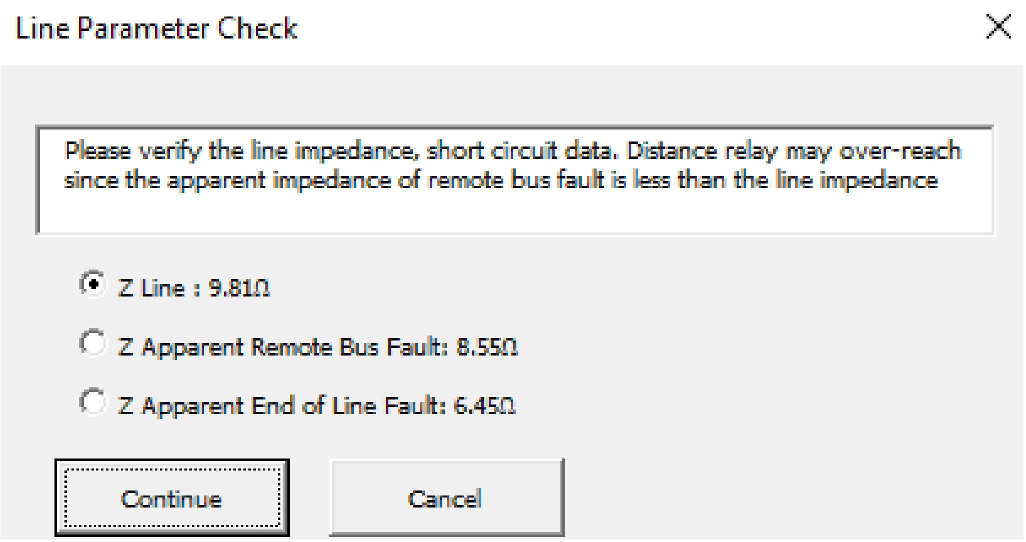
Function	Enabled	
Direction	Forward	
Shape	Mho	
Xfmr Vol Connection	None	Relay is not looking through a transformer.
Xfmr Curr Connection	None	Relay is not looking through a transformer.
Reach	3.57 ohms	-> 85% of Line Impedance without series capacitors -> 0.85 x 35.00 Ω = 29.75Ω pri -> 3.57 Ω sec -> 135% of Line Impedance with series capacitors -> 1.35 x (35.00 Ω - 1Ω - 12Ω) = 29.75Ω pri -> 3.57 Ω sec
RCA	85 deg	MTA Set Equal to line angle
Rev Reach	0.02 ohms	Minimum setting, element cannot be disabled
Rev Reach RCA	85 deg	MTA Set Equal to Line Angle
Comp Limit	90 deg	Set for Dir. Mho Distance Characteristics
DIR RCA	85 deg	Set equal to RCA
DIR Comp Limit	90 deg	Set for Dir. Mho Distance Characteristics
Quad Right Blinder	10.00 ohms	Quad shape is not being used.
Quad Right Blinder RCA	85 deg	Set equal to RCA, Quad shape is not being used
Quad Left Blinder	10.00 ohms	Quad shape is not being used.
Quad Left Blinder RCA	85 deg	Set equal to RCA, Quad shape is not being used
Supervision	1.20 pu	-> Set to 50.00% of 3 phase EOL Fault -> (0.50 x 2870.00 A pri) = 1435.00 A pri -> 5.98 A sec/5A = 1.20 pu -> For comparison: 100% of Capacitor Emergency Rating = 2.500pu -> For comparison: 100% of Ir_4h = 1.354pu Note: This is a Phase-to-Phase fault detector, the relay internally multiples the pickup value by sqrt(3), actual value = 2.07 pu or 10.36 A sec

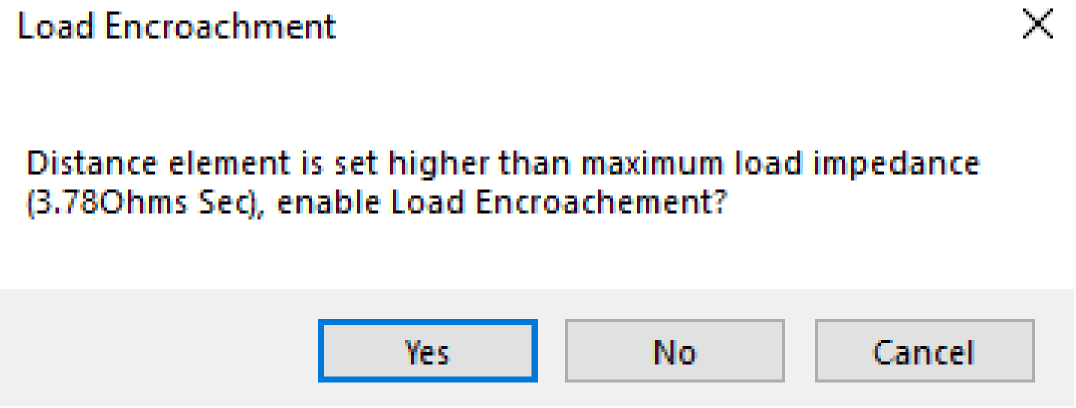


Automated Engineering Process

What if the setting configuration software giving you the information when you performing the distance relay configuration:

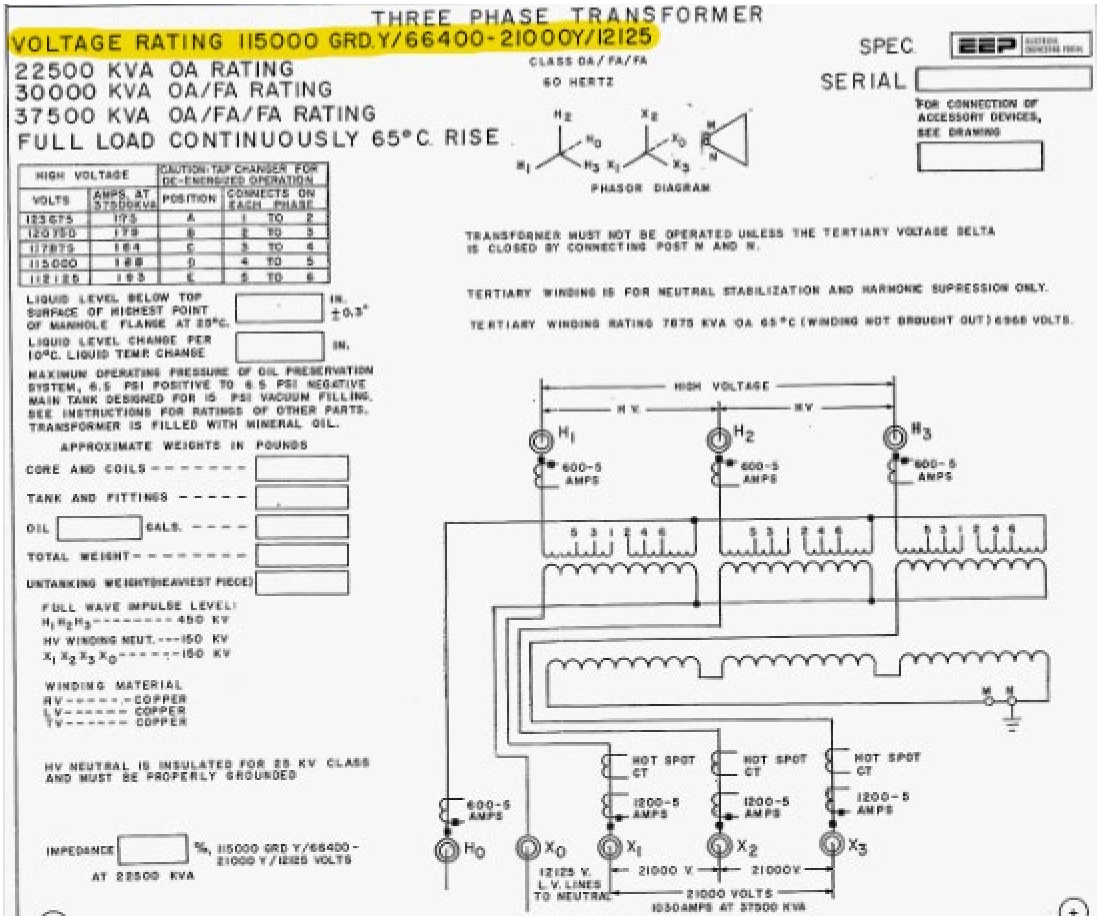
1. Your SIR ratio is too high, distance Z1 may overreach
2. The apparent impedance seen for line-end and remote bus fault
3. Or your distance element setting is lower than maximum load impedance and you may need to enable Load Encroahment





Automated Engineering Process

What if the configuration software set the transformer winding configuration (mag and ang compensation) using the vector group (such as Dyn11) and automatically generate the test procedures?

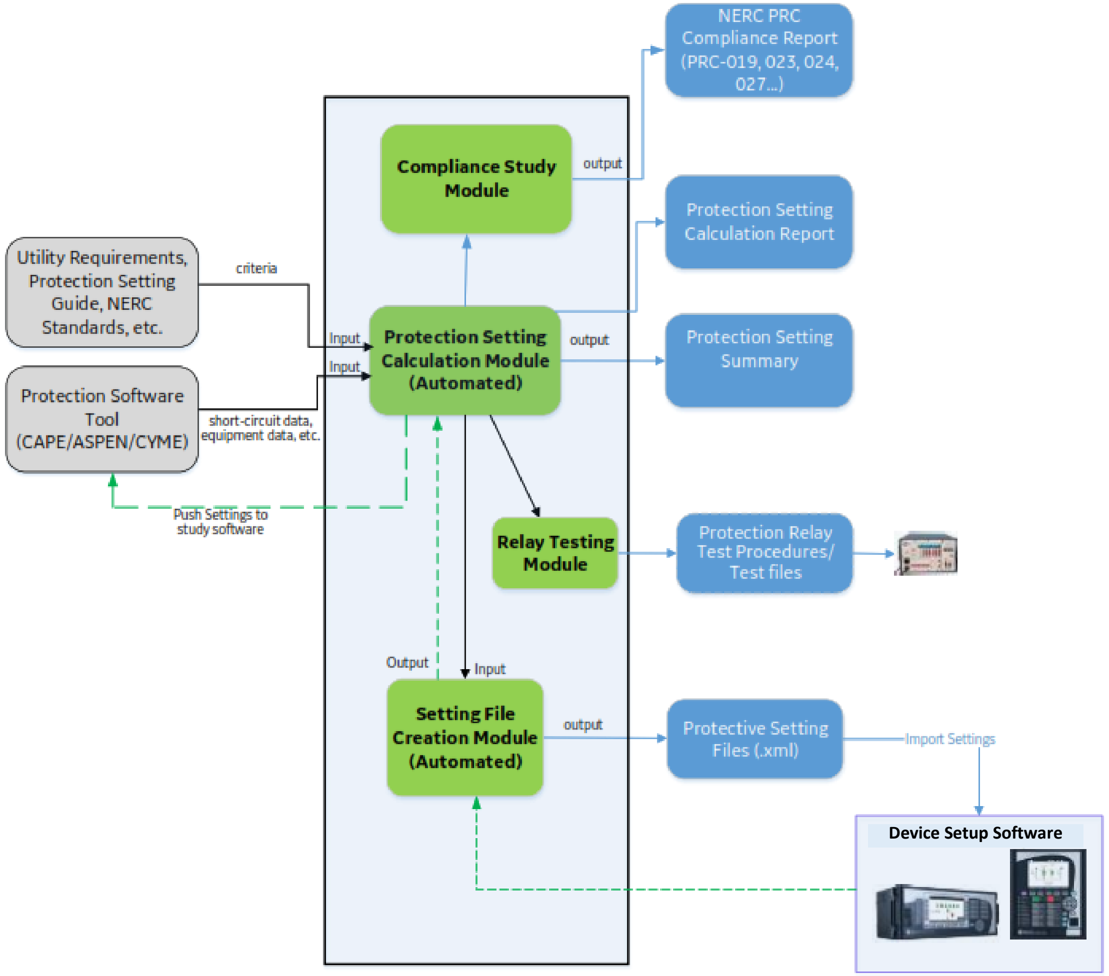


Automated Engineering Process

A window or web-based application or APP can be created to support the Automated Engineering Process

It provides:

- An interface to power system simulation software
- A customizable set calculation module to implement the protection philosophy
- A customizable compliance study module and RTM
- An interface to ICT tool



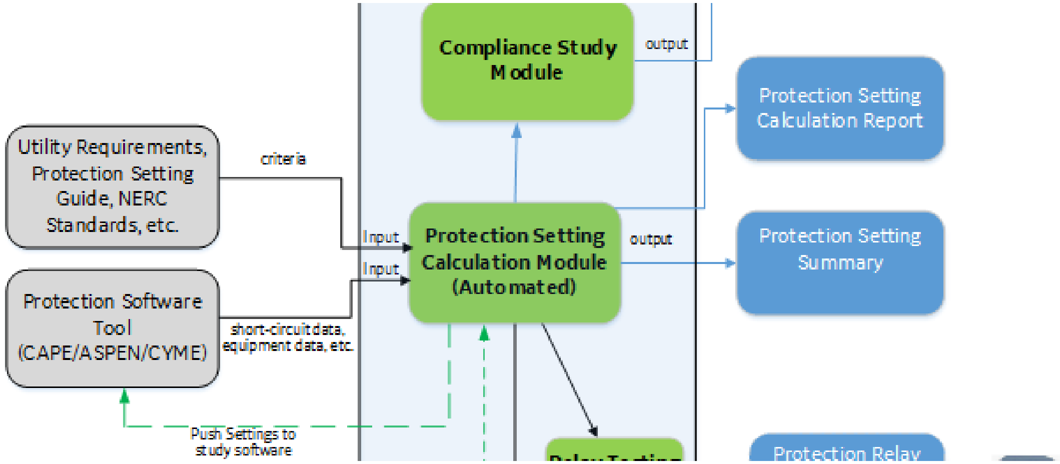
Automated Engineering Process

A. Setting Calculation

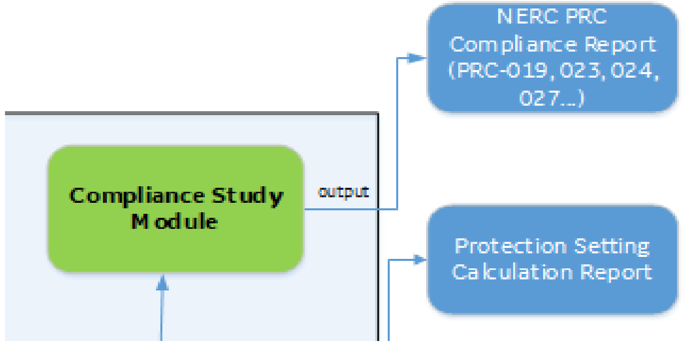
This section interfaces the study software that is commonly used by utilities to perform required short circuit studies under specified contingencies

For example, the following criteria may need to be considered when calculating the distance zones' reach:

- Source Impedance Ratio (SIR):
- Loadability
- Apparent impedance under different operation scenarios



Automated Engineering Process



B. Compliance Study

Utilities are mandated to adhere to approved internal standards or reliability standards developed by their regional regulatory entity. The proposed tool should be capable of automatically checking compliance to published standards.

- How to identify the generation and generation interconnection protection relays that are subject to the various NERC standards
- How to set and verify the distance/loss-of-field/out-of-step protection elements for stable power swing compliance
- How to set and verify the under- and over-frequency/voltage protection elements for generator protection and satisfying the NERC frequency and voltage ride through requirements
- How to set and verify the over-excitation and loss-of-field protection elements to coordinate with generator excitation limiters.
- A customized compliance report can be generated for utilities to provide evidence of compliance

Automated Engineering Process

C. Relay Testing

A Relay Testing Module (RTM) capable of automatically creating a test procedure based on the protection functions activated and using the settings already determined by the setting tool

Protection relays with a digital interface are to be tested, the setting tool can be directly used in the automated testing of such protection relays

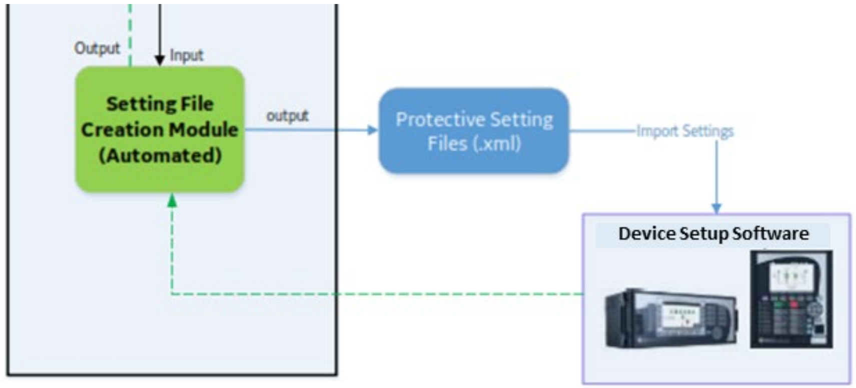
Automated Engineering Process

D. Relay Setting File Creation

a. The tool can generate an ICT readable file (text or XML)

b. The tool can generate setting file using the IED template file

c. The tool can be integrated to ICT tools



Conclusions

- The engineering tool eliminates manual copy/paste errors
  - Bidirectional interaction with the study software and relay configuration software
  - Generates a customized study and testing report
- The engineering tool can be integrated to the IED configuration tool (ICT) to provide a better user experience
- Increased productivity and accuracy without losing the understanding of the protection philosophy.

Thank You

Questions?