FirstEnergy®

Protection Settings Automation and Standardization

Transmission Protection

Josh Counihan

Energy Association of PA – Electrical Equipment and Protection Committee Meeting

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Overview

NERC Reliability Standard PRC-027

- **Title:** Coordination of Protection Systems for Performance During Faults
- **Purpose:** To maintain the coordination of Protection Systems installed to detect and isolate Faults on Bulk Electric System (BES) Elements, such that those Protection Systems operate in the intended sequence during Faults.
- **Effective Date:** April 1, 2021
- **Replaces:** Requirements in PRC-001 (coordination with others)
- **Requires us to establish and follow a procedure for developing relay settings for BES elements.**

Overview

FirstEnergy Transmission Protection "Tools and Templates" Team Formed

- **Purpose:** To assist with adherence to the relay setting guidelines and philosophy in the "FirstEnergy Transmission Protection Settings Criteria" document, and to ensure that Protection Systems operate in the intended sequence during Faults in support of PRC-027, develop a collection of Relay Setting Calculation Tools and Standard RDB Templates, referred to as "tools" and "templates." The tools and templates are intended for use by protection engineers when developing new or revised Protection System settings for relays.

Relay Setting Calculation Tools & Standard RDB Templates

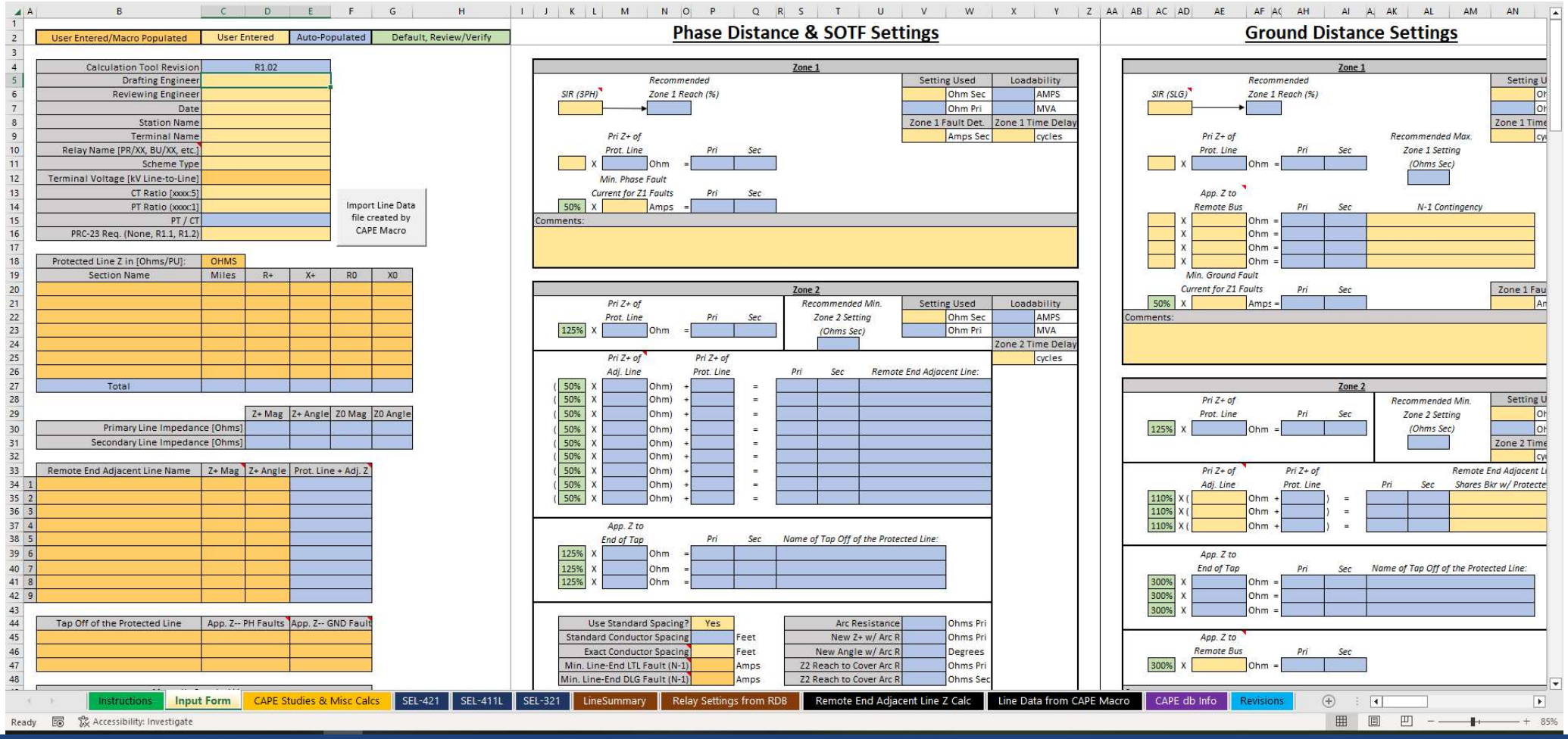
- **Calculation tools are a collection of Excel workbooks**
  - One calculation tool workbook per scheme and relay type (i.e. 2 Terminal Line-Micro, Low Impedance Diff-Bus-Micro, Primary & OA Diff Scheme-Transformer-Micro, etc.)
  - Designed for most common relay schemes and the SEL relays found in FirstEnergy's Transmission Protection Standard Panel Specifications
  - Some tools created for schemes that are still in-service using legacy electro-mechanical line, bus, and transformer relays
- **Standard RDB templates are a collection of RDB files**
  - RDB templates are the receptacle for the protection settings exported from the completed relay setting calculation tools
  - Created using FirstEnergy's standard protection specification SEL part numbers and approved firmware
  - Contain standard, scheme specific settings (outputs, logic, event reporting, front panel settings)

Relay Setting Calculation Tools & Standard RDB Templates

- 2 Terminal Line-Micro-R1.02.xlsm
- 3 Terminal Line-Micro-R1.02.xlsm
- DCB Scheme-2 Terminal Line-EM-R0.3.xlsm
- Grounded Voltage Differential Scheme-Shunt Capacitor-Micro-R0.2.xlsm
- High Impedance Diff-Bus-Micro-R0.1.xlsm
- HS-LS Lead Backup-Transformer-Micro-R0.2.xlsm
- Linear Coupler Bus Protection LC2 R0.1.xlsm
- Low Impedance Diff-Bus-Micro-R0.1.xlsm
- Primary & OA Diff Scheme-Transformer-Micro-R0.1.xlsm
- Standard Breaker Failure-Breaker-Micro Lev Sens Inputs-R1.0.xlsm
- System Backup-Transformer-Micro-R0.2.xlsm
- Transformer_Differential_EM-R0.3.xlsx
- Unbalance Scheme-Shunt Capacitor-Micro-R0.2.xlsm
- Zero Sequence OC Backup- Tranformer-Micro-R0.3.xlsm

- Breaker Failure SEL-501-0 R902-V65.rdb
- Breaker Failure-SEL-451-5 R323-V4-Z026.rdb
- DCB Fiber 2 Terminal Line-SEL-411L-0 R123-V1-Z014.rdb
- DCB Fiber 2 Terminal Line-SEL-411L-1 R123-V1-Z014.rdb
- DCB Fiber-2 Terminal Line-SEL-421-4 R326-V0-Z027.rdb
- DCB Fiber-2 Terminal Line-SEL-421-5 R323-V0-Z027.rdb
- DCB PLC-2 or 3 Terminal Line-SEL-411L-0 R123-V1-Z014.rdb
- DCB PLC-2 or 3 Terminal Line-SEL-411L-1 R123-V1-Z014.rdb
- DCB PLC-2 or 3 Terminal Line-SEL-421-4 R326-V0-Z027.rdb
- DCB PLC-2 or 3 Terminal Line-SEL-421-5 R326-V0-Z027.rdb
- Hi Imp Bus Diff-SEL-587Z R200-V0-Z001.rdb
- Line Curr Diff-2 Terminal Line-SEL-411L-0 R123-V1-Z014.rdb
- Line Curr Diff-2 Terminal Line-SEL-411L-1 R123-V1-Z014.rdb
- Low Impedance Bus Diff SEL-487B R314-V0-Z014.rdb
- Transformer Diff-SEL-487E-3 R317-V1-Z110.rdb
- Transformer HS-LS LEAD SEL-421-4 R326-V0-Z027.rdb
- Transformer PR Diff-SEL-587-1 R704-V5b-Z001.rdb
- Transformer PR Diff-SEL-587-1 R800-Vxb-Z002.rdb
- Transformer Zero Seq OC-SEL-351A R514-Vf-Z105.RDB
- Transformer Zero Seq OC-SEL-551 R514-Vf-Z002.RDB
- Transformer Zero Seq OC-SEL-551 R600-Vf-Z003.rdb
- Wye-Gnded Capacitor Bus-MidPoint Voltage Diff-SEL-487V-1 R107-V1-Z004.rdb
- Wye-Gnded Capacitor Bus-Neutral Voltage Diff-SEL-487V-1 R107-V1-Z004.rdb
- Wye-Gnded Capacitor MidPoint-MidPoint Voltage Diff-SEL-487V-1 R107-V1-Z004.rdb

2-Terminal Line Micro Relay Setting Calculation Tool



Relay Setting Calculation Tools

- **“Input Form” worksheet**
  - Numeric and/or text type input fields for entering record-keeping, scheme-specific, impedance, short circuit, and relay settings data.
  - Built-in formulas to auto-calculate settings based on guidance in criteria document and past practice, with final settings selected by the engineer
  - Free form comment fields for the engineer to optionally add clarifying comments for selected settings, especially where the settings may reflect a deviation from typical settings
  - Option to manually enter data, or where available, use built-in Excel macro button for importing CAPE data
- **“CAPE Studies & Misc Calcs” worksheet**
  - Free form worksheet to copy/paste notes, your own calculations, or supporting documentation

Relay Setting Calculation Tools

- **"CAPE db Info" worksheet**
  - Documentation of the CAPE database used to calculate the settings
  - Auto-populates using Get_Line_Data macro
  - Manually populate by copy/pasting screenshots of CAPE Include/Exclude categories
- **Individual SEL relay worksheets**
  - Settings from the Input Form will auto populate into the relay setting list
  - Engineer is expected to review and confirm settings in the list and where needed, manually enter remaining settings that are not automatically populated
  - Excel macro button exports settings to a text file that can be imported into the standard RDB using AcSELerator
  - Setting list formatted to enable future use of SEL Grid Configurator software that will allow for simple copy/paste of settings into RDB file

Relay Setting Calculation Tools

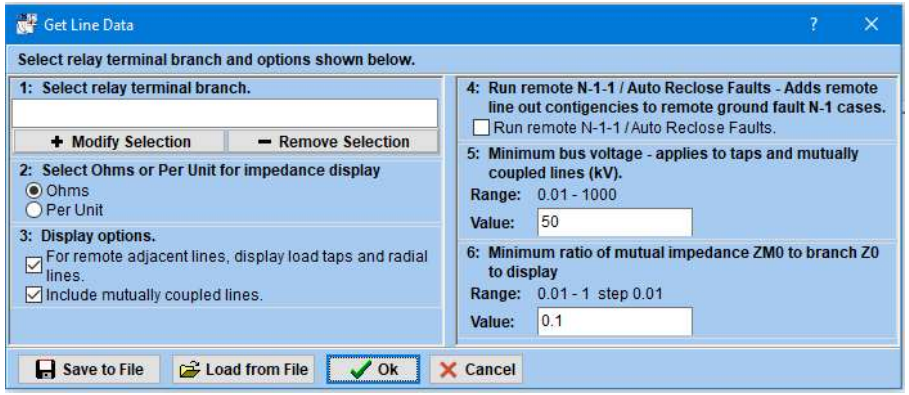
- **Summary worksheet**
  - Imports settings from RDB file using macros
  - Auto-Generates summary of the basic relay functions
  - Provides a comparison of the RDB settings vs. the calculation tool settings

Fairview East SS Gore Jct 115kV Line (PR/GJ)			
SUBSTATION:	Fairview East	DATE:	3/23/2023
TERMINAL:	Gore Jct	APPLICATION:	DCB
VOLTAGE:	115kV	RELAY:	SEL-421
BREAKER 1:	B30	POWERBASE RLID:	
BREAKER 2:		PREPARED BY:	Josh Counihan
OPCO/REGION/AREA:	Penelec - North	APPROVED BY:	Reviewer
GENERAL COMMENTS:			
New installation			
RELAY SETTINGS & DATA			
CT & PT RATIO	**COMMENTS**	**LINE IMPEDANCE & LENGTH**	
CT Ratio = 1200/5		Z1 = 4.42Ω Pri at 82.01°, Z1 = 1.06Ω Sec at 82.01°	
PTY Ratio = 1000:1		Z0 = 15.33Ω Pri at 74.18°, Z0 = 3.68Ω Sec at 74.18°	
PTZ Ratio = 1000:1		Line Length = 6.1 miles	
MHO PHASE DISTANCE ELEMENTS		**MHO GROUND DISTANCE ELEMENTS**	
Z1MP = 3.33Ω Pri, 0.8Ω Sec, (FWD); Z1PD = 0 Cycles		Z1MG = 2.92Ω Pri, 0.7Ω Sec, (FWD); Z1GD = 0 Cycles	
Z2MP = 5.83Ω Pri, 1.4Ω Sec, (FWD); Z2PD = 30 Cycles		Zone 2 Disabled	
Z3MP = 16.67Ω Pri, 4Ω Sec, (REV); Z3PD = OFF		Zone 3 Disabled	
Z4MP = 10.42Ω Pri, 2.5Ω Sec, (FWD); Z4PD = 60 Cycles		Zone 4 Disabled	
RESIDUAL GROUND INSTANTANEOUS OVERCURRENT		**RESIDUAL GROUND INVERSE TIME OVERCURRENT**	
50G1P = 2736A Pri, 11.4A Sec; 67G1TC = 1		51S1O = 3I0L; 51S1P = 240A Pri, 1A Sec	
50G2P = 240A Pri, 1A Sec; 67G2TC = 1		51S1C = U2; 51S1TD = 1.5 (0.64 seconds @ 5X pickup)	
50G3P = 120A Pri, 0.5A Sec; 67G3TC = 1		51S1RS = N; 51S1TC = 32GF OR LOP	
TRIP SCHEME LOGIC			
TR = Z1P OR Z2PT OR Z4PT OR Z1G OR 67G1 OR 51S1T			
TRCOMM = IN202 AND (Z2PGS OR 67QG2S)			
TRSOTF = 50P1			
SWITCH ONTO FAULT			
SOTF/50P1 Disabled			

SEL-421				
	.rdb Setting	Calc Tool Setting	Match?	Comments
SID	Fairview East SS	Fairview East SS	Yes	
RID	Gore Jct 115kV Line (PR/GJ)	Gore Jct 115kV Line (PR/GJ)	Yes	
CONAM	PNS	PNS	Yes	
NUMBK	1	1	Yes	
BID1	B30	B30	Yes	
BID2	0	0	Yes	
PHROT	ABC	ABC	Yes	
ESS	N	N	Yes	
LINEI	IW	IW	Yes	
BK1I	IW	IW	Yes	
BK2I	NA	NA	Yes	
IRIGC	NONE	None	Yes	
CTRW	240	240	Yes	
CTRX	240	240	Yes	
PTRY	1000	1000	Yes	
VNOMY	115	115.0	Yes	
PTRZ	1000	1000	Yes	
VNOMZ	115	115.0	Yes	
Z1MAG	1.06	1.06	Yes	
Z1ANG	82.01	82.01	Yes	
Z0MAG	3.68	3.68	Yes	
Z0ANG	74.18	74.18	Yes	
LL	6.1	6.1	Yes	

Get Line Data Macro

PSS-CAPE Macro using CUPL code



- **Pulls information from CAPE**
  - Line Impedances/Lengths
  - Fault Currents for Relevant Faults
  - Apparent Impedances for Faults on Taps
  - Mutually Coupled Lines
- **Produces output .txt files**
  - “Line Data” file that can be imported into Calculation Tools
  - “Additional Data” file containing full listing of data compiled by the macro that may be truncated in the “Line Data” file for use in the Tools

Thank You