



**PPL Electric Utilities**

We Deliver.

# Protection Settings Automation and Standardizing

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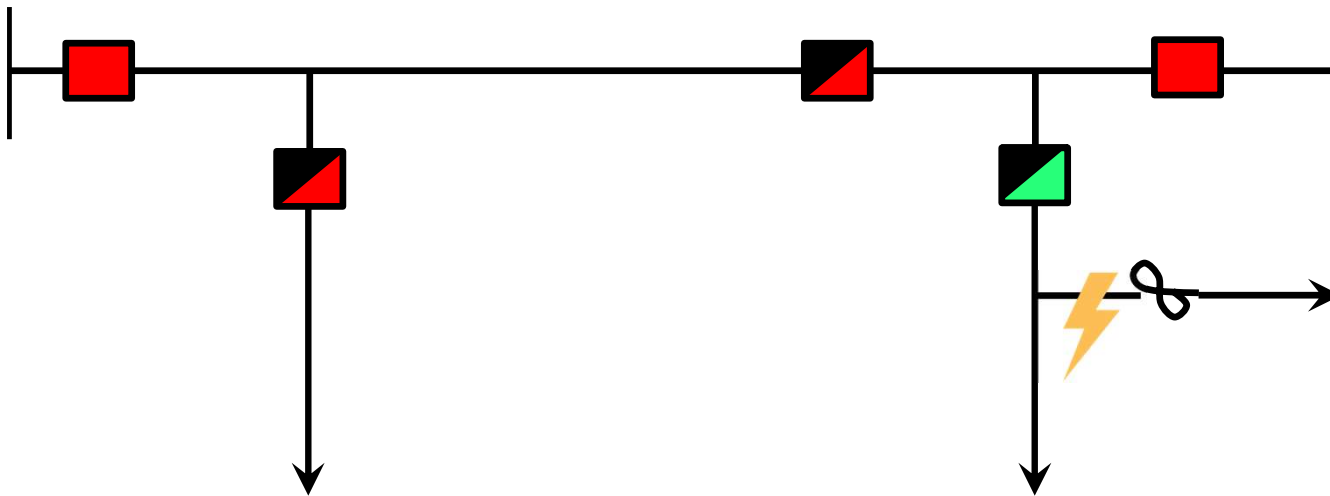
# Agenda

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- Protection Settings
- Settings Workflow
- Standard Files
- Automation
- Q&A

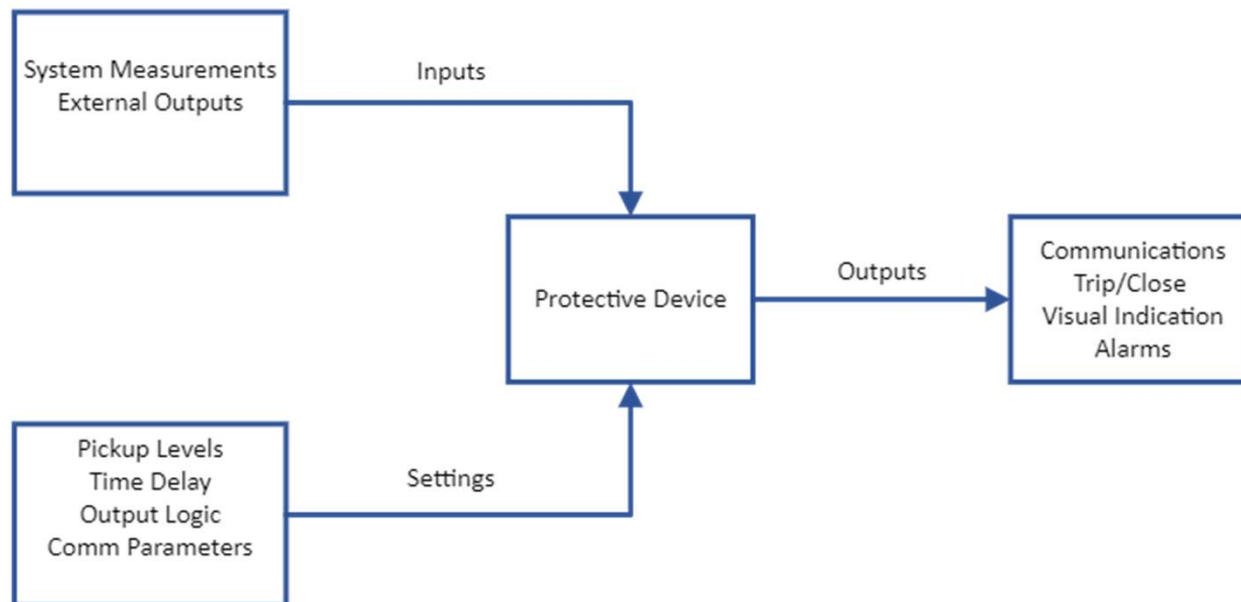
# Protection Settings

A protection scheme is intended to keep the power system stable by isolating only the faulted elements, maintaining as much facilities as possible in operation as well as preventing assets from damage.

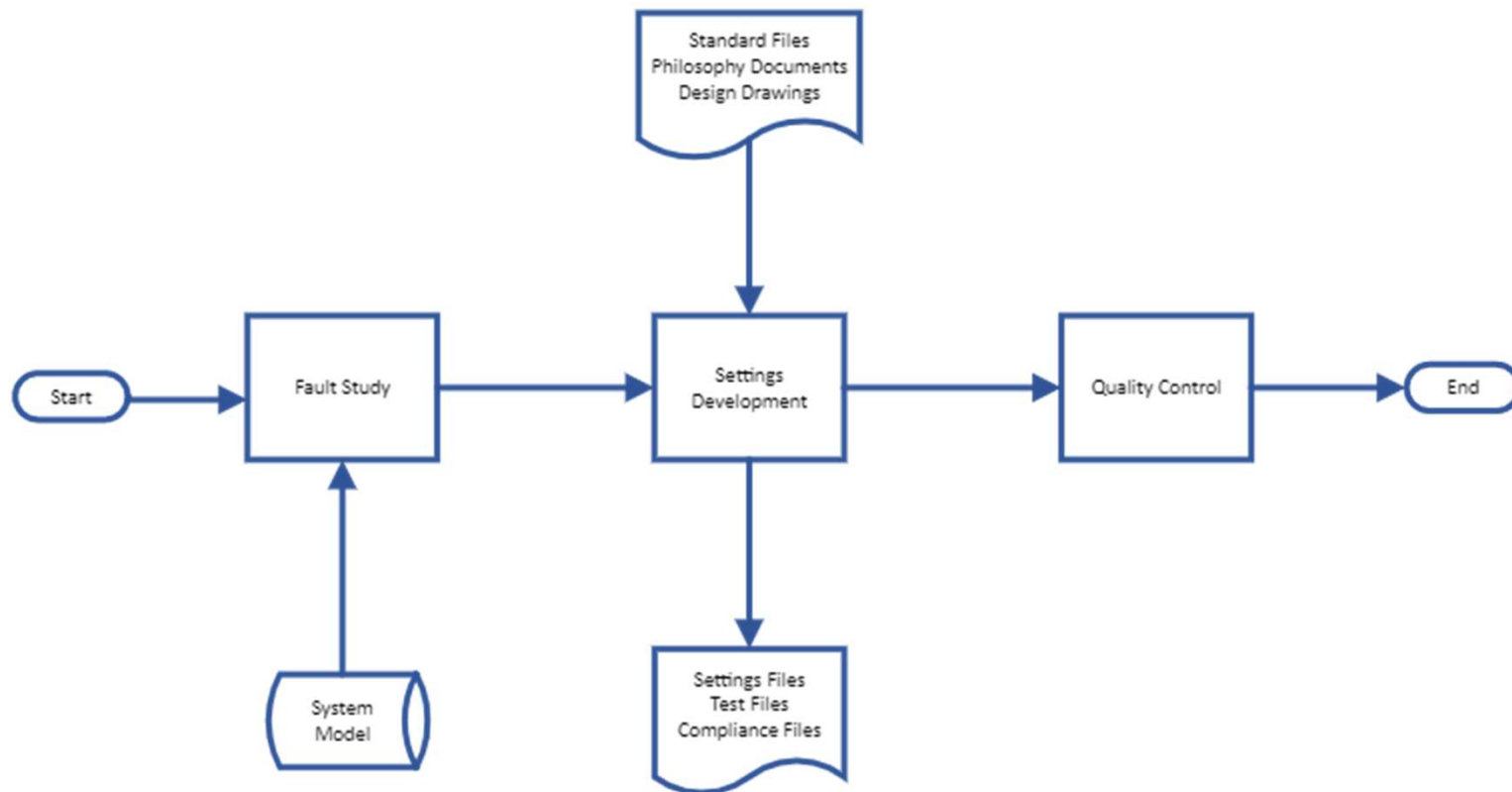


# Protection Settings

The microprocessors devices used to protect the power systems from faults are normally programmed via settings files. These files are loaded to the device for any given configuration change.



# Settings Workflow



# Standard Files

## Standard Settings Files

General Global Settings

SID Station Identifier

STATION-NAME 500/230 kV

RID Relay Identifier

hln# XXXkV LINE BU 411L

CONAM Company Name

abc

NUMBK Number of Breakers in Scheme

2

Select: 1, 2

BID1 Breaker 1 Identifier

CBx1

BID2 Breaker 2 Identifier

CBx2

NFREQ Nominal System Frequency (Hz)

60

Select: 50, 60

PHROT System Phase Rotation

ABC

Select: ABC, ACB

FAULT Fault Condition Equation (SELogic)

Z2P OR Z2G OR 51S01 OR 51S02 OR 51S03 OR 87OP

EGADVS Advanced Global Settings

N

Select: Y, N

EINVPOL Enable Polarity Inversion

OFF

Combination of: W, X, Y, Z, WA-WC, XA-XC, YA-YC, ZA-ZC or OFF

General Global Settings

SID Station Identifier

SUBN-LINE# 69 kV VCR

RID Relay Identifier

DSUB TP# 421 PRI GRID NUMBER

NUMBK Number of Breakers in Scheme

1

Select: 1, 2

BID1 Breaker 1 Identifier

VCR

BID2 Breaker 2 Identifier

NFREQ Nominal System Frequency (Hz)

60

Select: 50, 60

PHROT System Phase Rotation

ACB

Select: ABC, ACB

FAULT Fault Condition Equation (SELogic)

Z2P OR 67G2 OR Z3P OR Z5P

EGADVS Advanced Global Settings

N

Select: Y, N

Figure 1: SEL-411L Standard Global Settings

General Global Settings

SID Station Identifier

STATION-NAME 530/230 kV

RID Relay Identifier

500/230kV TRANS r% BU 487E

CURSTU Current Channels: S = 5A, T = 5A, U = 5A

1

Select: 1-4

CURWXY Current Channels: W = 5A, X = 5A, Y = 5A, 5A, 5A

1

Select: 1-8

CONAM Company Name

abc

NFREQ Nominal System Frequency (Hz)

60

Select: 50, 60

PHROT System Phase Rotation

ABC

Select: ABC, ACB

Figure 2: SEL-421 (VCR) Standard Global Settings

General Global Settings

SID Station Identifier

STATION-NAME 530/230 kV

RID Relay Identifier

500/230kV TRANS r% BU 487E

CURSTU Current Channels: S = 5A, T = 5A, U = 5A

1

Select: 1-4

CURWXY Current Channels: W = 5A, X = 5A, Y = 5A, 5A, 5A

1

Select: 1-8

CONAM Company Name

abc

NFREQ Nominal System Frequency (Hz)

60

Select: 50, 60

PHROT System Phase Rotation

ABC

Select: ABC, ACB

Figure 3: SEL-487E Standard Global Settings

# Standard Files

## Protection Philosophy Documents

- Transmission Line Protection Philosophy
- Transformer Protection Philosophy
- Bus Protection Philosophy
- Capacitor Protection Philosophy
- Circuit Breaker Philosophy

1	Introduction and Protection Overview.....	9
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Figure 1: Table of Contents from Line Protection Philosophy

# Standard Files

## Calculation Sheets

- Line SEL-421, 411L
  - TP&C Calc Sht Line SEL-421&411L\_PR&BU\_20220906.xlsm
- Bus Section CB SEL-451
  - TP&C Calc Sht Bus Section CB SEL-451\_CN\_20201202.xlsm
- Bus SEL-487B
  - TP&C Calc Sht Bus SEL-487B\_PR&BU\_20190909.xlsm
- Cap Bank SEL-487E
  - TP&C Calc Sht Cap Bank 5-String SEL-487E\_PR\_20201102.xlsm
  - TP&C Calc Sht Cap Bank 9-String SEL-487E\_PR1&2\_20161207.xlsm
  - TP&C Calc Sht Cap Bank Double Wye SEL-487E\_PR\_20201218.xlsm
  - TP&C Calc Sht Cap Bank Neutral CT Only SEL-487E\_PR\_20201218.xlsm
- Transformer SEL-487E
  - TP&C Calc Sht Transformer SEL-487E\_PR&BU\_20200922.xlsm
- Cap Bank SEL-487V
  - TP&C Calc Sht Cap Bank 5&9-String SEL-487V\_BU\_20201112.xlsm
  - TP&C Calc Sht Cap Bank Double Wye & Neutral CT Only SEL-487V\_BU\_20201214.xlsm
- Line SEL-T401L
  - TP&C Calc Sht Line SEL-T401L\_PR&MON\_20221031.xlsm

Figure 1: List of Calculation Sheets

**Transmission Line Protection and Monitoring**

Project: SUBSTATION XXX/XXXkV ER code: XXXXXX

Line: XXXXXXXXXXX XXXkV LINE Relay: SEL-T401L

Part #: XXXXXXXXXXX Serial #: XXXXXXXXXXX SVN #: XXX FID #: XXX

Setting Application: PRIMARY Nominal Line kV: 69 RLID: 1

Settings File Name: Substation XXX-XXXkV - SUBS XXXkV LINE - T401L\_XXX RLID\_NID.rdb NID:

**Project Description, Purpose and Schemes**

**Additional Comments**

**Instructions to use the spreadsheet**

1) Enter data only in blue fields.  
2) Look for the down arrow (▼) to select from a drop down menu.  
3) Read instructions and comments in each sheet.  
4) Settings calculated in each tab are summarized at the end of the tab.

Option:  
Hide Disabled Settings [TRUE,FALSE] TRUE

**Legend**

SAMPLE	User Input
Meets Requirements	
Outside Requirements or Entered/Recommended Differs	
INPUT	User Input Necessary elsewhere prior to Solving

Figure 2: T401L Calculation Sheet Cover Page



# Standard Files

## Quality Assurance/Control Checklist

Relay Settings QA/QC Checklist

Substation Name:

Primary kV:

Protected Equipment:

Equipment Type:


PRI/BU:

Relay Type:

Settings File Name:

RLID:

NID:



Reason for Settings Change

New Relay:

Reset Checklist

Protection Settings:

Programmable Logic:

Relay Firmware:

Front Panel Display Point Changes:

Circuit Breaker Control:

Ports/DNP Maps/IP Addresses:

Front Panel LED Changes:

Traveling Wave/Time Domain Elements:

Project Personnel

Settings Author:

Initials:

Peer Reviewer:

Initials:

Alternate Logic Reviewer

Review Completion

Self Check Completed

Workbook Completed

Toggle Self Check Status Indicators

Toggle Complete Checks Indicators

Figure 1: QA/QC Checklist Cover Page

PRC-023: Transmission Relay Loadability

Identification

The relay you are setting is subject to PRC-023. Please verify the following:

Criteria	Response	Self Check	Peer Check
Who is the manufacturer of the relay you are setting?			

PRC-025: Generator Relay Loadability

Identification

The relay you are setting is subject to PRC-025. Please verify the following:

Criteria	Response	Self Check	Peer Check
Is the relay located on a line serving as a primary outlet of a generating facility with aggregate capacity greater than 75MVA and will the relay operate on phase current leaving the generator?			

PRC-026: Relay Performance During Stable Power Swings

Identification

The relay you are setting is subject to PRC-026. Please verify the following:

Criteria	Response	Self Check	Peer Check
Does the relay protect a line on the PRC-026 BES Element List?			

PRC-027: Coordination of Protection Systems for Performance During Faults

Identification

The relay you are setting is subject to PRC-027. Please verify the following:

Criteria	Response	Self Check	Peer Check
----------	----------	------------	------------

Figure 2: QA/QC Checklist Compliance Section



# Automation

## Settings Calculations

**Zone 2 Phase Distance**

Zone 2 Phase Distance Time Delay (ZP2D) [OFF, 0.000-10.000]:  (sec) or  (cyc)

Zone 2 Desired Phase Coverage:  % Forward Reach @ 84 Degrees

	Recommended	Entered	(ohms,sec)
Zone 2 Phase Distance Reach (ZP2) [0.05-84.00]:	9.75	9.75	
	48.75	48.75	(ohms,pr)

Zone 2 Phase Distance Phase-Phase Overcurrent Pickup (ZP2\_50PP) [0.50-150.00]:  (A,sec)

Actual Coverage with the Applied Setting: ZZ: 125.00 (%)

**Condition Check 1: Check arc resistance coverage of Time delayed Zone 2**  [HELP](#)

$R_{line}$ : Resistive component of the line  
 $R_{reach}$ : Resistive reach at Line end @ Line angle  
 $R_{MAX,ARC}$ : Maximum allowable arc resistance at Line end @ Line angle

$$\left( R_{reach} - \left( \frac{ZP2}{2} \cos(\text{Line Angle}) \right) + \left( X_{line} - \frac{ZP2}{2} \sin(\text{Line Angle}) \right)^2 = \left( \frac{ZP2}{2} \right)^2 \quad R_{MAX,ARC} = R_{reach} - R_{line}$$

Resistive reach at Line end @ Line angle ( $R_{reach}$ ) =  (ohms,pr)

Maximum allowable arc resistance at Line end @ Line Angle ( $R_{MAX,ARC}$ ) =  (ohms,pr)

ARC Resistance  $R_{arc}$ :  (ohms,pr)

	Recommended	Entered	(%)
% $R_{arc}$ to cover:	125.00		
% $R_{arc}$ value:	INPUT	INPUT	(ohms,pr)

$R_{reach} > \% R_{arc}$  seen by Relay  
18.03

Figure 1: Arc Resistance Check

**Condition Check 4: Check Zone 2 reach margin for tapped transformer**  [HELP](#)

Line 1 ZL1

TX-1 TX-2 TX-3

Maximum Reactive reach of Mho Circle:  $X_{max}(ZP2, \alpha) = \frac{ZP2}{2} \sin \alpha + \frac{ZP2}{2}$

Safety Margin Test:  $X(Z_{line} + TAP) + X_{trans} > 1.1 \times X_{max}(ZP2, \alpha)$

Maximum reactive reach of Zone 2 Mho circle  $X_{max}(ZP2, \alpha)$ :  (ohms,pr)

Select number of Tapped Transformers (TX-n):

- Cape Low Side Bus Name and Number:

Total Impedance of Line + Transformer to 12kV Bus:  (ohms,pr) @  (degrees)

Coordination needed for this bus?  Customer Sub?
- Cape Low Side Bus Name and Number:

Total Impedance of Line + Transformer to 12kV Bus:  (ohms,pr) @  degrees

Coordination needed for this bus?  Customer Sub?
- Cape Low Side Bus Name and Number:

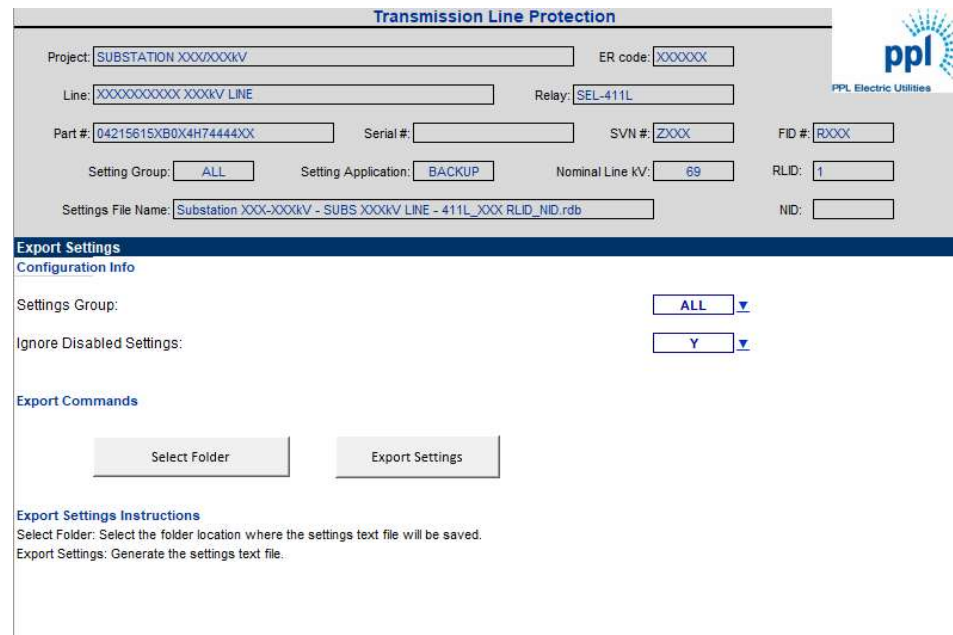
Total Impedance of Line + Transformer to 12kV Bus:  (ohms,pr) @  degrees

Coordination needed for this bus?  Customer Sub?

Figure 2: Tapped Transformer Coordination Check

# Automation

## Settings File Update



The screenshot displays a web-based interface for 'Transmission Line Protection' settings. The top section contains various input fields for project and line information, including Project, Line, Part #, Serial #, SVN #, FID #, Setting Group, Setting Application, Nominal Line kV, RLID, and Settings File Name. Below this is a section titled 'Export Settings' with a 'Configuration Info' subsection containing dropdown menus for 'Settings Group' and 'Ignore Disabled Settings'. The 'Export Commands' section features two buttons: 'Select Folder' and 'Export Settings'. At the bottom, 'Export Settings Instructions' provide guidance on folder selection and the export process. The PPL Electric Utilities logo is visible in the top right corner.

**Transmission Line Protection**

Project: SUBSTATION XXX/XXXkV ER code: XXXXXX

Line: XXXXXXXXXXX/XXXkV LINE Relay: SEL-411L

Part #: 04215615XB0X4H7444XX Serial #: SVN #: ZXXX FID #: RXXX

Setting Group: ALL Setting Application: BACKUP Nominal Line kV: 69 RLID: 1

Settings File Name: Substation XXX-XXXkV - SUBS XXXkV LINE - 411L\_XXX RLID\_NID.rdb NID:

**Export Settings**

**Configuration Info**

Settings Group: ALL

Ignore Disabled Settings: Y

**Export Commands**

Select Folder Export Settings

**Export Settings Instructions**

Select Folder: Select the folder location where the settings text file will be saved.

Export Settings: Generate the settings text file.

Figure 1: Calc Sheet Settings Export Feature

# Automation

## Fault Study Macro

Figure 1: Custom Macro Guide User Interface

Fault Typ	Faulted B	Faulted B	Local Bus	310 (A)	/ 310	Iph_fault / Iph_fau	System Condition	Tested Line
SLG	208040	MONT	GLBR	1591.57	-77.205	31661.2	-86.53	MONT TR 230/24kV MONT-GLBR
SLG	208040	MONT	GLBR	1583.8	-77.2	31506.6	-86.525	MONT TR 230/24kV MONT-GLBR
SLG	208040	MONT	GLBR	1478.9	-76.685	40771	-87.164	MONT-MONTSCR1 MONT-GLBR
SLG	208040	MONT	GLBR	1478.75	-76.683	40772.3	-87.164	MONT-MONTSCR2 MONT-GLBR
SLG	208040	MONT	GLBR	1445.96	-76.752	39427.1	-87.173	MONT-GLBR 230kV MONT-MILT ;
SLG	208040	MONT	GLBR	1445.96	-76.752	39427.1	-87.173	MONT-MILT 230kV MONT-GLBR
SLG	208040	MONT	GLBR	1445.87	-76.753	39427.9	-87.172	MONT-GLBR 230kV MONT-MILT ;
SLG	208040	MONT	GLBR	1445.87	-76.753	39427.9	-87.172	MONT-MILT 230kV MONT-GLBR
SLG	208040	MONT	GLBR	1428.99	-76.721	41219.4	-87.156	MONT-GLBR 230kV None
SLG	208040	MONT	GLBR	1413.99	-76.58	40139.9	-87.142	MONT-GLBR 230kV MONT-SAEG
SLG	208040	MONT	GLBR	1413.99	-76.58	40139.9	-87.142	MONT-SAEG 230kV MONT-GLBR
SLG	208040	MONT	GLBR	1413.99	-76.58	40139.9	-87.142	MONT-SAEG 230kV MONT-GLBR
SLG	208040	MONT	GLBR	1407.94	-76.341	38921.1	-87.243	MONT-GLBR 230kV MONT-COLU
SLG	208040	MONT	GLBR	1407.94	-76.341	38921.1	-87.243	MONT-COLU TR2 2: MONT-GLBR
SLG	208040	MONT	GLBR	1053.55	-75.175	32010.9	-86.369	MONT TR 230/24kV MONT-MILT ;
SLG	208040	MONT	GLBR	1053.46	-75.176	32012.1	-86.368	MONT TR 230/24kV MONT-MILT ;
SLG	208040	MONT	GLBR	1048.76	-75.171	31865.3	-86.365	MONT TR 230/24kV MONT-MILT ;
SLG	208040	MONT	GLBR	1048.67	-75.172	31866.5	-86.364	MONT TR 230/24kV MONT-MILT ;
SLG	208040	MONT	GLBR	1026.73	-75.078	33818.9	-86.418	MONT TR 230/24kV None
SLG	208040	MONT	GLBR	1024.01	-74.64	31597.4	-86.506	MONT TR 230/24kV MONT-COLU
SLG	208040	MONT	GLBR	1022.23	-75.074	33670.6	-86.413	MONT TR 230/24kV None
SLG	208040	MONT	GLBR	1019.22	-74.634	31449.4	-86.501	MONT TR 230/24kV MONT-COLU
SLG	208040	MONT	GLBR	1018.72	-74.908	32790.3	-86.4	MONT TR 230/24kV MONT-SAEG
SLG	208040	MONT	GLBR	1014.09	-74.903	32641.1	-86.395	MONT TR 230/24kV MONT-SAEG
SLG	208040	MONT	GLBR	961.273	-74.547	41267.8	-87.069	MONT-MONTSCR1 MONT-MILT ;
SLG	208040	MONT	GLBR	961.212	-74.548	41268.8	-87.069	MONT-MONTSCR1 MONT-MILT ;
SLG	208040	MONT	GLBR	961.178	-74.545	41269.3	-87.07	MONT-MONTSCR2 MONT-MILT ;
SLG	208040	MONT	GLBR	961.117	-74.546	41270.3	-87.07	MONT-MONTSCR2 MONT-MILT ;
SLG	208040	MONT	GLBR	945.517	-74.519	43031.3	-87.066	MONT-MONTSCR1 None
SLG	208040	MONT	GLBR	945.428	-74.517	43032.7	-87.067	MONT-MONTSCR2 None
SLG	208040	MONT	GLBR	938.197	-74.137	40811.2	-87.153	MONT-MONTSCR1 MONT-COLU

Figure 2: Custom Macro Output

# Future Enhancements

- Relay Settings Maintained in CAPE
- Automated Settings Adequacy Check
- Automated Compliance Checks



# Questions?