# SEL Relay Settings Calculation for 1 MW Generator GEN 1 PRI

SEL-700GT+ **Primary**, Part No: SEL- 0700GT1A2X0X75850330

The following procedures guide the reader through the process of setting the SEL-700G based upon industry standards and the SEL instruction manual.

## Configuration Summary

| | | |
|---|---|---|
| **Part Number** | 0700GT1A2X0X75850330 | Map |
| **Key Code** | 1938 | |

### Selected Options

| | |
|---|---|
| **Model** | 700GT+ Model, Intertie and Generator Protection, Auto Synchronizer |
| **SELECT Power Supply with I/O Option Slot A** | Power Supply 110–250 Vdc, 110–240 Vac, 50/60 Hz (SELECT PSIO / 2 DI / 3 DO); 125 Vdc/Vac Digital Input |
| **SELECT Processor Board Option Slot B** | Processor Board (SELECT CPU/COM); All Slot B options include EIA-232 Front, IRIG-B, Fiber Optic Serial Multimode ST, SEL ASCII, Compressed ASCII, Fast Meter, Fast Operate, Fast Message, MIRRORED BITS, and Modbus RTU |
| **SELECT Ethernet/Rear Serial Options Slot B** | Ethernet/Rear Serial Options; Single 10/100Base-T Ethernet, EIA-485 Rear |
| **SELECT Protocols Slot B** | Protocols; Standard plus DNP3 plus IEC 61850 (requires Ethernet) |
| **SELECT I/O Card Option Slot C** | 8 Digital Output (SELECT 8 DO); Electromechanical DO |
| **SELECT I/O Card Option Slot D** | No Card; Empty |
| **SELECT I/O Card Option Slot E** | 3-Phase AC Current Input / 3-Phase AC Voltage (300 Vac) Input and Vsync Input (SELECT 3 ACI / 4 AVI); 5 Amp Phase |
| **SELECT I/O Card Option Slot Z** | 3-Phase AC Current Input / Neutral AC Current Input / 3-Phase AC Voltage (300 Vac) (SELECT 4 ACI / 3 AVI); 5 Amp Phase, 5 Amp Neutral |
| **Conformal Coat** | None |

# Calculation of the Protection Settings for G1 - SEL-700G

## 1. General Data

Generator X side Current Transformer Ratio Calculations

$CTRX := \frac{200}{5}$ $CTRX = 40$

Generator Potential Transformer Ratio Calculations

$PTRX := \frac{4200}{120}$ $PTRX = 35$

Generator Nominal Secondary Voltage Calculations DELTAY_X = DELTA

Bus Y side Current Transformer Ratio Calculations

$CTRY := \frac{300}{5}$ $CTRY = 60$

Bus Potential Transformer Ratio Calculations

$PTRY := \frac{4200}{120}$ $PTRY = 35$

Generator and Bus Nominal Secondary Voltage Calculations

$VNOM := \frac{4160}{PTRX}$ $VNOM = 118.9$

$VNOM := \frac{4160}{PTRY}$ $VNOM = 118.9$

Relay setting is primary L-L voltage [kV] $VNOM\_X := 4.16$

Relay setting is primary L-L voltage [kV] $VNOM\_Y := 4.16$

Generator Name Plate Ratings

Nominal Frequency = 60Hz $FNOM := 60$

Generator Capacity $Gen\_VA := 1176000$

Generator Voltage $Gen\_V := 4160$

Generator Power Factor $Gen\_pf := 0.85$

Generator Synchronous Reactance Xd [p.u.] $X_d := 1.75$ [p.u.]

Generator Transient Reactance Xd' [p.u.] $X_{d\ trans} := 0.33$ [p.u.]

Generator Subtransient Reactance Xd" [p.u.] $X_{d\_subtrans} := 0.198$ [p.u.]

Conversion of Generator Nameplate Reactance to secondary value calculations

*Primary*

$V_{base} := 4160$ $MVA_{base} := 1176000$ $I_{base} := \frac{MVA_{base}}{\left(\sqrt{3} \cdot V_{base}\right)}$ $Z_{base} := \frac{V_{base}^{2}}{MVA_{base}}$

$I_{base} = 163.212$ $Z_{base} = 14.716$

$Xd_{sec} := X_d \cdot Z_{base} \cdot \frac{CTRX}{PTRX}$ $Xd'_{sec} := X_{d\_trans} \cdot Z_{base} \cdot \frac{CTRX}{PTRX}$ $Xd''_{sec} := X_{d\_subtrans} \cdot Z_{base} \cdot \frac{CTRX}{PTRX}$

$Xd_{sec} = 29.431$ Ohms $Xd'_{sec} = 5.55$ Ohms $Xd''_{sec} = 3.33$ Ohms

## 2. Calculate Generator secondary nominal current

$$I_{NOM} := \frac{\left(\frac{Gen\_VA}{\sqrt{3} \cdot Gen\_V}\right)}{CTRX}$$

$I_{NOM} = 4.08$

## 2. Calculate Bus secondary nominal current

$$I_{NOMY} := \frac{\left(\frac{Gen\_VA}{\sqrt{3} \cdot Gen\_V}\right)}{CTRY}$$

$I_{NOMY} = 2.72$

## 3. Calculate generator fault current

$$Gen\_Fault := \frac{Gen\_VA}{\sqrt{3} \cdot Gen\_V \cdot X_{d\_subtrans}}$$

$Gen\_Fault = 824.305$

$$Gen\_Fault\_sec := \frac{Gen\_Fault}{CTRX}$$

$Gen\_Fault\_sec = 20.608$

## 4. Set Undervoltage 27 Element

The generator is designed to operate at minimum 95% of rated voltage.

$_27PPX1P := 0.88 \cdot VNOM$ $_27PPX1P = 104.6$ V

$_27PPX1D := 2$ $_27PPX1D = 2$ sec

$_27PPX2P := 0.50 \cdot VNOM$ $_27PPX2P = 59.4$ V

$_27PPX2D := 0.16$ $_27PPX2D = 0.16$ sec

## 5. Set Overvoltage Protection 59 Element

The generator is designed to operate continuously at 105% of rated voltage

$_{59PP1P} := 1.1 \cdot VNOM$ $\quad _{59PP1P} = 130.7$ V

$_{59PPX1D} := 1.0$ $\quad _{59PPX1D} = 1$ sec

$_{59PP2P} := 1.2 \cdot VNOM$ $\quad _{59PP2P} = 142.6$ V

$_{59PPX2D} := .16$ $\quad _{59PPX2D} = 0.16$ sec

## 6. Set Reverse Power Protection 32 Element

Set to existing ICW relay setting of 3.5%.

$_{32P1P} := 0.02 \quad [p.u.]$ $\quad _{32P1P} = 0.02$

$_{3PWRX1P_{PRI}} := _{32P1P} \cdot Gen\_VA$ $\quad _{3PWRX1P_{PRI}} = 2.352 \cdot 10^4$

$_{3PWRX1P} := \frac{_{3PWRX1P_{PRI}}}{(PTRX \cdot CTRX)}$ $\quad _{3PWRX1P} = 16.8$

$PWRX1D := 2 \quad [sec]$ $\quad PWRX1D = 2$

The element is internally blocked if voltages VAB or VBC are lower than 20V

**Table 12-2—Maximum motoring power for prime movers**

| | |
|---|---|
| Steam turbine | 3.0% |
| Water wheel turbine | 0.2% |
| Gas turbine | 50.0% |
| Diesel engine | 25.0% |

## 7. Set Loss-of-Field Protection 40 Element

Set according to IEEE C37.102, Appendix A and SEL guidance. Per SEL, "Typically, Zone 1 and Zone 2 are offset from the impedance plane origin by a value equal to one-half the machine transient reactance. Zone 1 is intended to operate with little time delay in the event of a loss-of-field under full load conditions. Zone 2 reaches further and operates with a longer time delay. Zone 2 is intended to trip for loss-of-field conditions that occur under light load conditions."

Zone 1 Setting Calculations  Method 1: Negative Offset

$$\_40Z1P := \frac{VNOM}{\left(\sqrt{3} \cdot I_{NOM}\right)}$$

$\_40Z1P = 16.8$

$$\_40XD1 := \frac{-Xd'_{sec}}{2}$$

$\_40XD1 = -2.8$

$\_40Z1D := 0.1$

$\_40Z1D = 0.1$

Zone 2 Settings Calculations

$\_40Z2P := Xd_{sec}$

$\_40Z2P = 29.4$

$$\_40XD2 := \frac{-Xd'_{sec}}{2}$$

$\_40XD2 = -2.8$

$\_40Z2D := 0.5$

$\_40Z2D = 0.5$

40ZTC=NOT LOPX

## 8. 51C Phase Element Settings

Set to PG&E Distribution and Planning requested values.

51CP = 0.5
51CC = U5
51CTD = 2
51CRS = N
51VTC = 27PPX1
SV03 = 51C
SV03PU = 1.5 S
SV03DO = 0 S

## 9. Ground Element Settings

Set to existing BE1-59N relay settings.

EXT3EV0_X:=VS

$_{59GX1P} := 9.0$ V
$_{59GX1D} :=$ "0.04" Sec

## 10. Set Frequency Protection 81 O/U Element

Set to existing relay settings.

81XTC=52A

$_{81X1P} := 59.3$ $_{81X1D} := 0.16$
$_{81X2P} := 60.5$ $_{81X2D} := 0.16$

# 11. Set Negative Sequence Overcurent Protection 46 Element

Level 1, set to trip

Set according to IEEE C50.12 (Section 4.2.4) and SEL guidance.

$_{46Q1P} := 8$ [%]

$_{46Q1D} := 30$ [sec]

Level 2, set to trip

Set according to SEL recommendations and IEEE C50.12 Table 2 below.
(Generator MVA=1 MVA)

**Table 2—Short-time negative-sequence current capability**

| Type of generator rotor cooling | Minimum generator short-time capability expressed in terms of $I_2^2t$ |
|---|---|
| Indirectly cooled | 30 |
| Directly cooled up to 800 MVA | 10 |
| 800 MVA to 1600 MVA | 10 – (0.00625)(MVA – 800) |
| Above 1600 MVA | By agreement |

$_{46Q2P} := 8$ [%]

$_{46Q2K} := 10$ $\quad$ $_{46Q2K} = 10$

$$t_{op2} := \frac{_{46Q2K}}{\left(\frac{_{46Q2P}}{100}\right)^2}$$

Expected operating time at 8% unbalanced current $\quad t_{op2} = 1562.5$ [sec]

$$t_{op2} := \frac{_{46Q2K}}{\left(\frac{_{46Q2P} \cdot 3}{100}\right)^2}$$

Expected operating time at 24% unbalanced current $\quad t_{op2} = 173.611$ [sec]

$$t_{op2} := \frac{_{46Q2K}}{\left(\frac{_{46Q2P} \cdot 6}{100}\right)^2}$$

Expected operating time at 48% unbalanced current $\quad t_{op2} = 43.403$ [sec]

## 12. Input / Output Assignment

INPUTS

IN101 = 52a
IN102 =
IN301 =

OUTPUTS

OUT101 = TRIP1 (5E1A) = SV03T OR SV06T OR 59GX1T OR 40Z1T OR 40Z2T OR 46Q2T
OUT102 = TRIP2 (5ES) = 27PPY1T OR 27PPY2T OR 59PPY1T OR 59PPY2T OR 81Y1T OR 81Y2T
OUT103 = ***Test Output***
OUT301 =
OUT302 =
OUT303 =
OUT304 =
OUT305 =
OUT306 =
OUT307 =
OUT308 =

SELogic Variables and Timers

| | |
|---|---|
| SV01T = PB01 | LOCK BUTTON |
| SV02T = PB01 OR PB02 OR PB03 OR PB04 | BUTTON DEBOUNCE TIME |
| SV03T = 51C | CLOSE SIGNAL |
| SV04T = LT04 | TRIP SIGNAL |
| SV05T = (PB01 OR PB02 OR LT03 OR LT04) AND NOT SV05T | INITIATE FLASHING LED |
| SV06T = IN101 AND (27PPX1T OR 27PPX1T OR 59PPX1T OR 59PPX2T OR 81X1T OR 81X2T OR 3PWRX1T) | ENABLE TRIP WITH 52A |