

SEL Relay Settings Calculation for 1 MW Generator GEN 1 BU

SEL-700GT+ **Backup**, Part No: SEL- 0700GT1A2X9X75850330

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	0700GT1A2X9X75850330	Map
Key Code	2037	

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, MIRRORRED 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	10 RTD Input (SELECT 10 RTD)
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

$$CTR_X := \frac{200}{5}$$

$$CTR_X = 40$$

Generator Potential Transformer Ratio Calculations

$$PTR_X := \frac{4200}{120}$$

$$PTR_X = 35$$

Generator Nominal Secondary Voltage Calculations

$$DELTA_X = DELTA$$

Bus Y side Current Transformer Ratio Calculations

$$CTR_Y := \frac{300}{5}$$

$$CTR_Y = 60$$

Bus Potential Transformer Ratio Calculations

$$PTR_Y := \frac{4200}{120}$$

$$PTR_Y = 35$$

Generator and Bus Nominal Secondary Voltage Calculations

$$VNOM := \frac{4160}{PTR_X}$$

$$VNOM = 118.9$$

$$VNOM := \frac{4160}{PTR_Y}$$

$$VNOM = 118.9$$

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 X_d [p.u.]

$$X_d := 1.75 \text{ [p.u.]}$$

Generator Transient Reactance X_d' [p.u.]

$$X_{d_trans} := 0.33 \text{ [p.u.]}$$

Generator Subtransient Reactance X_d'' [p.u.]

$$X_{d_subtrans} := 0.198 \text{ [p.u.]}$$

Conversion of Generator Nameplate Reactance to secondary value calculations

Primary

$$V_{base} := 4160$$

$$MVA_{base} := 1176000$$

$$I_{base} := \frac{MVA_{base}}{(\sqrt{3} \cdot V_{base})}$$

$$Z_{base} := \frac{V_{base}^2}{MVA_{base}}$$

$$I_{base} = 163.212$$

$$Z_{base} = 14.716$$

$$X_{d_{sec}} := X_d \cdot Z_{base} \cdot \frac{CTR_X}{PTR_X}$$

$$X_{d'_{sec}} := X_{d_{trans}} \cdot Z_{base} \cdot \frac{CTR_X}{PTR_X}$$

$$X_{d''_{sec}} := X_{d_{subtrans}} \cdot Z_{base} \cdot \frac{CTR_X}{PTR_X}$$

$$X_{d_{sec}} = 29.431 \text{ Ohms}$$

$$X_{d'_{sec}} = 5.55 \text{ Ohms}$$

$$X_{d''_{sec}} = 3.33 \text{ Ohms}$$

2. Calculate Generator secondary nominal current

$$I_{NOM} := \frac{\left(\frac{Gen_VA}{\sqrt{3} \cdot Gen_V} \right)}{CTR_X}$$

$$I_{NOM} = 4.08$$

2. Calculate Bus secondary nominal current

$$I_{NOMY} := \frac{\left(\frac{Gen_VA}{\sqrt{3} \cdot Gen_V} \right)}{CTR_Y}$$

$$I_{NOMY} = 2.72$$

3. Calculate generator fault current

$$Gen_Fault := \frac{Gen_VA}{\sqrt{3} \cdot Gen_V \cdot X_{d_{subtrans}}}$$

$$Gen_Fault = 824.305$$

$$Gen_Fault_{sec} := \frac{Gen_Fault}{CTR_X}$$

$$Gen_Fault_{sec} = 20.608$$

4. Set Undervoltage 27 Element

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

$$_27PPX1P := 0.88 \cdot VNOM$$

$$_27PPX1P = 104.6 \text{ V}$$

$$_27PPX1D := 2$$

$$_27PPX1D = 2 \text{ sec}$$

$$_27PPX2P := 0.50 \cdot VNOM$$

$$_27PPX2P = 59.4 \text{ V}$$

$$_27PPX2D := 0.16$$

$$_27PPX2D = 0.16 \text{ sec}$$

5. Set Overvoltage Protection 59 Element

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

$$\begin{aligned} _59PP1P &:= 1.1 \cdot VNOM \\ _59PPX1D &:= 1.0 \end{aligned}$$

$$_59PP1P = 130.7 \quad \text{V}$$

$$_59PPX1D = 1 \quad \text{sec}$$

$$\begin{aligned} _59PP1P &:= 1.2 \cdot VNOM \\ _59PPX1D &:= .16 \end{aligned}$$

$$_59PP1P = 142.6 \quad \text{V}$$

$$_59PPX1D = 0.16 \quad \text{sec}$$

6. Set Reverse Power Protection 32 Element

Set to existing ICW relay setting of 3.5%.

$$\begin{aligned} _32P1P &:= 0.02 \quad [p.u.] \\ _3PWRX1P_{PRI} &:= _32P1P \cdot Gen_VA \end{aligned}$$

$$_32P1P = 0.02$$

$$_3PWRX1P_{PRI} = 2.352 \cdot 10^4$$

$$_3PWRX1P := \frac{_3PWRX1P_{PRI}}{(PTRX \cdot CTRX)}$$

$$_3PWRX1P = 16.8$$

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

$$PWRX1D = 2$$

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

$$_{40Z1P} := \frac{VNOM}{(\sqrt{3} \cdot I_{NOM})}$$

$$_{40Z1P} = 16.8$$

$$_{40XD1} := \frac{-Xd'_{sec}}{2}$$

$$_{40XD1} = -2.8$$

$$_{40Z1D} := 0.1$$

$$_{40Z1D} = 0.1$$

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 Overcurrent Protection 46 Element

Level 1, set to trip

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

$$_46Q1P := 8 \quad [\%]$$

$$_46Q1D := 30 \quad [\text{sec}]$$

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^2t
Indirectly cooled	30
Directly cooled up to 800 MVA	10
800 MVA to 1600 MVA	$10 - (0.00625)(\text{MVA} - 800)$
Above 1600 MVA	By agreement

$$_46Q2P := 8 \quad [\%]$$

$$_46Q2K := 10$$

$$_46Q2K = 10$$

$$t_{op2} := \frac{_46Q2K}{\left(\frac{_46Q2P}{100}\right)^2}$$

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

$$t_{op2} := \frac{_46Q2K}{\left(\frac{_46Q2P \cdot 3}{100}\right)^2}$$

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

$$t_{op2} := \frac{_46Q2K}{\left(\frac{_46Q2P \cdot 6}{100}\right)^2}$$

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

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 = 0
OUT103 = **Test Output**
OUT301 = 51VT
OUT302 = 3PWRX1T
OUT303 = 59GX1T
OUT304 = 40Z1T OR 40Z2T
OUT305 = 27PPY1T
OUT306 = 46Q1T OR 46Q2T
OUT307 =
OUT308 =

SELogic Variables and Timers

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