
SIEMENS
Examples
Distance Protection
Gustav Steynberg
© Siemens AG 2008
Energy Sector

SIEMENS

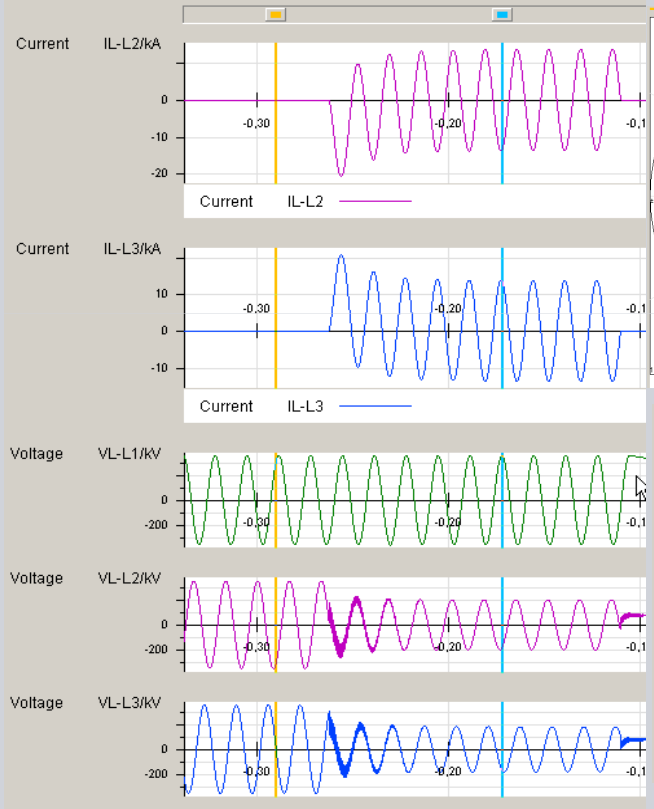
Calculation examples of distance protection

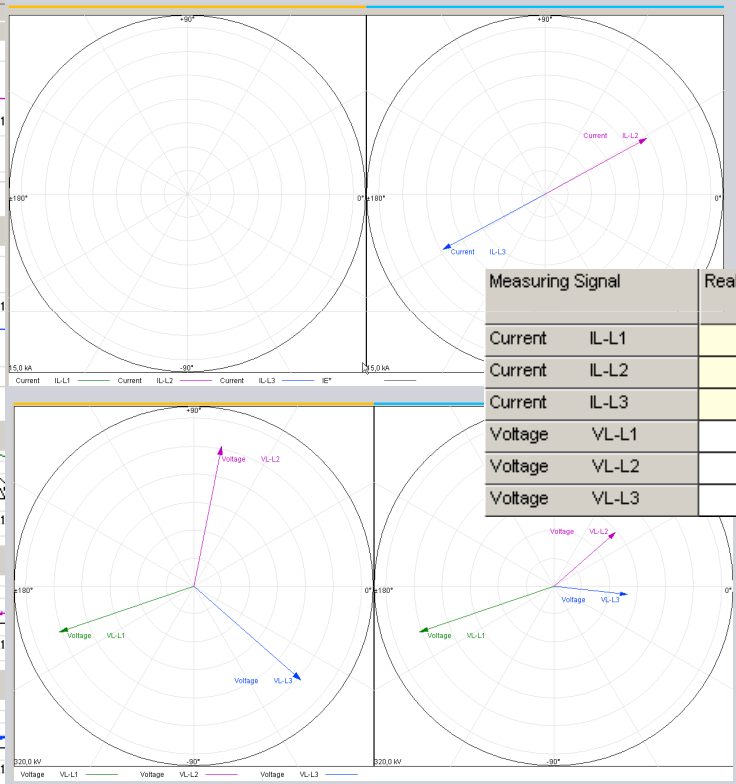
1. Ph-Ph fault location
2. Ph-G fault location
3. Determine Fault Loop direction

Example 1:
Calculate fault location for L2-L3 fault (in km)

SIEMENS

Line length = 50km, ZL=50 (0.0195 + j0.15) Ohm

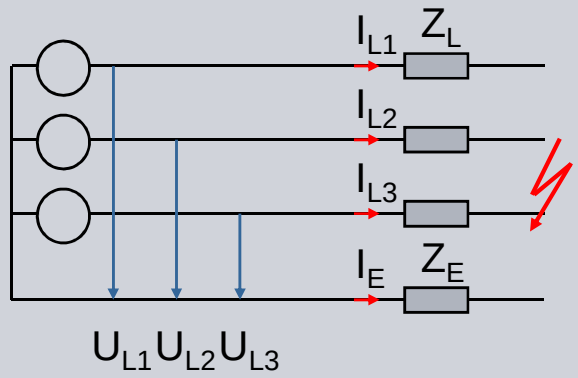




Measuring Signal		Real	Imag
Current	IL-L1	10,0 A	-30,8 A
Current	IL-L2	8,59 kA	4,71 kA
Current	IL-L3	-8,60 kA	-4,68 kA
Voltage	VL-L1	-229 kV	-77,5 kV
Voltage	VL-L2	104 kV	91,7 kV
Voltage	VL-L3	124 kV	-14,2 kV

Example 1:
Solution:

SIEMENS



Measuring Signal		Real	Imag
Current	IL-L1	10,0 A	-30,8 A
Current	IL-L2	8,59 kA	4,71 kA
Current	IL-L3	-8,60 kA	-4,68 kA
Voltage	VL-L1	-229 kV	-77,5 kV
Voltage	VL-L2	104 kV	91,7 kV
Voltage	VL-L3	124 kV	-14,2 kV

$$\underline{U}_{L2\text{-}L3} = \underline{Z}_L \, (\underline{I}_{L2} - \underline{I}_{L3})$$

$$Z_L = \frac{\underline{U}_{L2} - \underline{U}_{L3}}{\underline{I}_{L2} - \underline{I}_{L3}}$$

$$Z_L = \frac{(104 + j91.7) - (124 - j14.2)kV}{(8.59 + j4.71) - (-8.60 - j4.68)kA}$$

$$Z_L = \frac{(-20 + j105.9)kV}{(17.19 + j9.39)kA} = \frac{107.8e^{j100.7°}}{19.59e^{j28.6°}}$$

$$Z_L = 5.5e^{j72.1} = 1.69 + j5.23\Omega$$

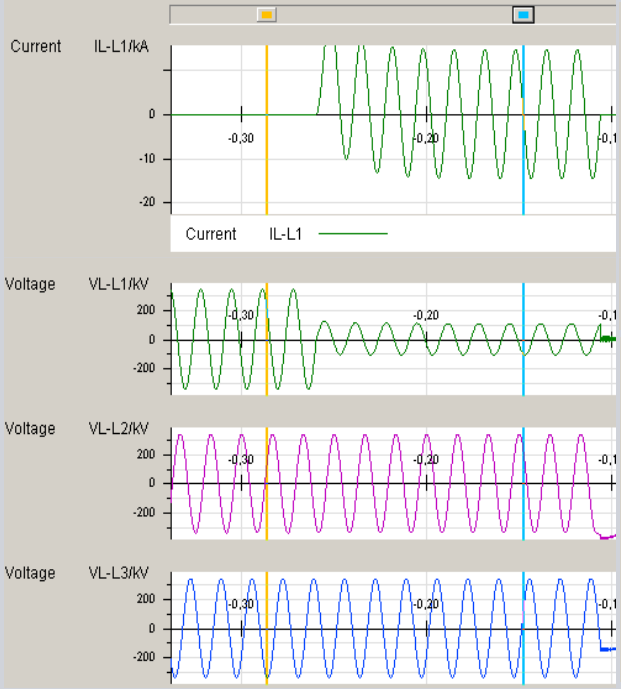
$$Fault\_loc\_km = \frac{5.23\Omega}{0.15\,\Omega/km} = 34.9km$$

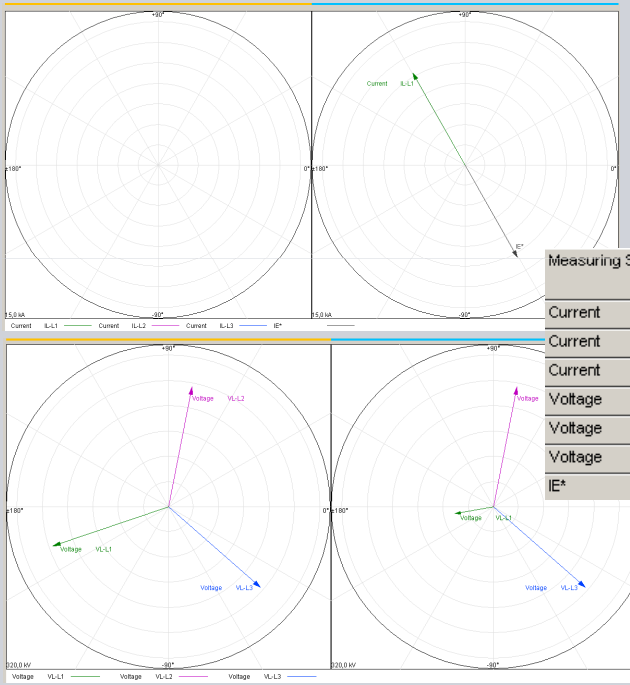
Example 2:
Calculate fault location for L1-G fault (in km)

SIEMENS

Line length = 50km, ZL=50 (0.0195 + j0.15) Ohm

$$ZE = \frac{5}{3}R_L + j\frac{2.07}{3}X_L$$

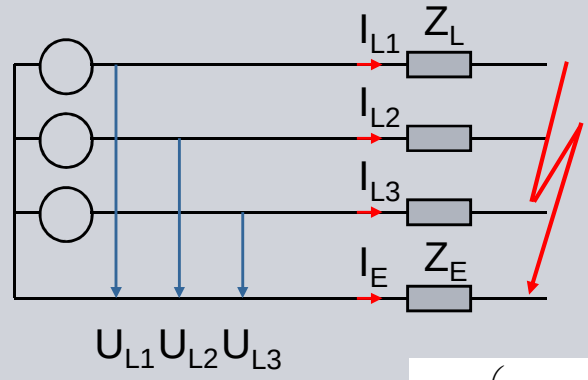




Measuring Signal		Real	Imag
Current	IL-L1	-5,12 kA	8,98 kA
Current	IL-L2	-31,2 A	6,40 A
Current	IL-L3	21,6 A	23,5 A
Voltage	VL-L1	-76,4 kV	-14,3 kV
Voltage	VL-L2	47,2 kV	237 kV
Voltage	VL-L3	181 kV	-159 kV
IE*		5,13 kA	-9,01 kA

Example 2:
Solution:

SIEMENS



$$\underline{V}_{L1} = \underline{I}_{L1} \cdot (R_L + jX_L) - \underline{I}_E \cdot (R_E + jX_E)$$

$$\underline{V}_{L1} = \underline{I}_{L1} \cdot (R_L + jX_L) - \underline{I}_E \left(\frac{5}{3} R_L + j \frac{2.07}{3} X_L \right)$$

$$\underline{V}_{L1} = \left(\underline{I}_{L1} - \frac{5}{3} \underline{I}_E \right) \cdot R_L + j \left(\underline{I}_{L1} - \frac{2.07}{3} \underline{I}_E \right) X_L$$

$$\underline{V}_{L1} = \left(-5.12 + j8.98 - \frac{5}{3}(5.13 - j9.01) \right) \cdot R_L + j \left(-5.12 + j8.98 - \frac{2.07}{3}(5.13 - j9.01) \right) X_L$$

Measuring Signal		Real	Imag
Current	IL-L1	-5,12 kA	8,98 kA
Current	IL-L2	-31,2 A	6,40 A
Current	IL-L3	21,6 A	23,5 A
Voltage	VL-L1	-76,4 kV	-14,3 kV
Voltage	VL-L2	47,2 kV	237 kV
Voltage	VL-L3	181 kV	-159 kV
IE*		5,13 kA	-9,01 kA

$$-76.4 - j14.3 = (-13.67 + j24.00) \cdot R_L + (-15.20 - j8.66) X_L$$

$$-76.4 = -13.67 \cdot R_L - 15.20 \cdot X_L$$

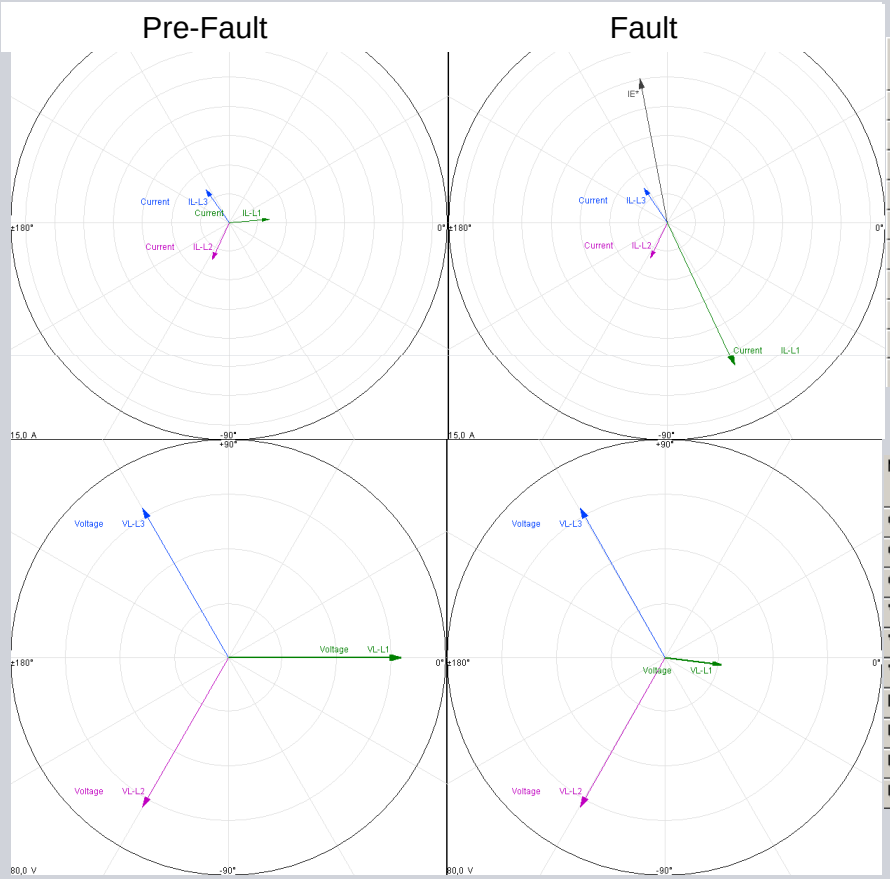
$$-14.3 = 24.00 \cdot R_L - 8.66 \cdot X_L$$

$$X_L = 4.20\Omega$$

$$Fault\_loc\_km = \frac{4.20\Omega}{0.15 \Omega / km} = 28.0km$$

Example 2: Determine direction of all 6 loops - (memory and actual voltage) [K0 = 1]

SIEMENS



Pre-Fault

Measuring Signal		Real	Imag	Value	Phase
Current	IL-L1	2,77 A	0,25 A	2,79 A	5,2°
Current	IL-L2	-1,17 A	-2,53 A	2,79 A	-114,8°
Current	IL-L3	-1,61 A	2,28 A	2,79 A	125,2°
Voltage	VL-L1	63,5 V	0,000 V	63,5 V	0,0°
Voltage	VL-L2	-31,8 V	-55,0 V	63,5 V	-120,0°
Voltage	VL-L3	-31,8 V	55,0 V	63,5 V	120,0°
IE*		0,000 A	-0,001 A	0,0006 A	-61,3°
UL12*		95,3 V	55,0 V	110 V	30,0°
UL23*		0,003 V	-110 V	110 V	-90,0°
UL31*		-95,3 V	55,0 V	110 V	150,0°

Fault

Measuring Signal		Real	Imag	Value	Phase
Current	IL-L1	4,67 A	-9,86 A	10,9 A	-64,7°
Current	IL-L2	-1,17 A	-2,43 A	2,70 A	-115,8°
Current	IL-L3	-1,61 A	2,38 A	2,87 A	124,2°
Voltage	VL-L1	20,6 V	-2,67 V	20,8 V	-7,4°
Voltage	VL-L2	-31,3 V	-55,0 V	63,3 V	-119,7°
Voltage	VL-L3	-31,3 V	55,0 V	63,3 V	119,7°
IE*		-1,88 A	9,91 A	10,1 A	100,8°
UL12*		51,9 V	52,4 V	73,7 V	45,2°
UL23*		0,003 V	-110 V	110 V	-90,0°
UL31*		-51,9 V	57,6 V	77,6 V	132,0°

Example 2:
Solution: Example L1-G

SIEMENS

$$Dir\_L1G \propto \frac{Angle\_\underline{U}_{L1}}{Angle\_(\underline{I}_{L1} - \underline{K0} \cdot \underline{IE})}$$

First calculate the loop current angle

$$Angle\_(\underline{I}_{L1} - \underline{IE}) = Angle\_((4.67 + 1.88) + j(-9.86 - 9.91))$$
$$= Angle\_(6.55 - j19.77)$$
$$= -71.7°$$

Calculate the direction angle (here actual fault voltage)

$$Dir\_angle\_L1G = Angle\_\underline{U}_{L1} - Angle\_(\underline{I}_{L1} - \underline{IE})$$
$$= -7.4 - (-71.7)$$
$$= 64.3° \equiv forward$$

Pre-Fault

Measuring Signal		Real	Imag	Value	Phase
Current	IL-L1	2,77 A	0,25 A	2,79 A	5,2°
Current	IL-L2	-1,17 A	-2,53 A	2,79 A	-114,8°
Current	IL-L3	-1,61 A	2,28 A	2,79 A	125,2°
Voltage	VL-L1	63,5 V	0,000 V	63,5 V	0,0°
Voltage	VL-L2	-31,8 V	-55,0 V	63,5 V	-120,0°
Voltage	VL-L3	-31,8 V	55,0 V	63,5 V	120,0°
IE*		0,000 A	-0,001 A	0,0006 A	-61,3°
UL12*		95,3 V	55,0 V	110 V	30,0°
UL23*		0,003 V	-110 V	110 V	-90,0°
UL31*		-95,3 V	55,0 V	110 V	150,0°

Fault

Measuring Signal		Real	Imag	Value	Phase
Current	IL-L1	4,67 A	-9,86 A	10,9 A	-64,7°
Current	IL-L2	-1,17 A	-2,43 A	2,70 A	-115,8°
Current	IL-L3	-1,61 A	2,38 A	2,87 A	124,2°
Voltage	VL-L1	20,6 V	-2,67 V	20,8 V	-7,4°
Voltage	VL-L2	-31,3 V	-55,0 V	63,3 V	-119,7°
Voltage	VL-L3	-31,3 V	55,0 V	63,3 V	119,7°
IE*		-1,88 A	9,91 A	10,1 A	100,8°
UL12*		51,9 V	52,4 V	73,7 V	45,2°
UL23*		0,003 V	-110 V	110 V	-90,0°
UL31*		-51,9 V	57,6 V	77,6 V	132,0°

Example 2: Solution

SIEMENS

	Mem Volt		Actual Volt		Loop Current	
Loop	**Mag**	**Angle**	**Mag**	**Angle**	**Mag**	**Angle**
L1-G	63,5	0,0	20,8	-7,4	20,8	-71,7
L2-G	63,5	-120,0	63,3	-119,7	12,4	-86,7
L3-G	63,5	120,0	63,3	119,7	7,5	-87,9
L1-L2	110	30,0	73,7	45,2	9,5	-51,8
L2-L3	110	-90,0	110	-90,0	4,8	-84,8
L3-L1	110	150,0	77,6	132,0	13,8	117,2

Loop	Mem Dir Angle	Actual Dir Angle	Direction
L1-G	71,7	64.3	Forward
L2-G	-33,3	-33.0	Reverse
L3-G	207.9	207.6	Reverse
L1-L2	81.8	97.0	Forward
L2-L3	-5.2	-5.2	Forward
L3-L1	32.8	14.8	Forward

Pre-Fault

Measuring Signal		Real	Imag	Value	Phase
Current	IL-L1	2,77 A	0,25 A	2,79 A	5,2°
Current	IL-L2	-1,17 A	-2,53 A	2,79 A	-114,8°
Current	IL-L3	-1,61 A	2,28 A	2,79 A	125,2°
Voltage	VL-L1	63,5 V	0,000 V	63,5 V	0,0°
Voltage	VL-L2	-31,8 V	-55,0 V	63,5 V	-120,0°
Voltage	VL-L3	-31,8 V	55,0 V	63,5 V	120,0°
IE*		0,000 A	-0,001 A	0,0006 A	-61,3°
UL12*		95,3 V	55,0 V	110 V	30,0°
UL23*		0,003 V	-110 V	110 V	-90,0°
UL31*		-95,3 V	55,0 V	110 V	150,0°

Fault

Measuring Signal		Real	Imag	Value	Phase
Current	IL-L1	4,67 A	-9,86 A	10,9 A	-64,7°
Current	IL-L2	-1,17 A	-2,43 A	2,70 A	-115,8°
Current	IL-L3	-1,61 A	2,38 A	2,87 A	124,2°
Voltage	VL-L1	20,6 V	-2,67 V	20,8 V	-7,4°
Voltage	VL-L2	-31,3 V	-55,0 V	63,3 V	-119,7°
Voltage	VL-L3	-31,3 V	55,0 V	63,3 V	119,7°
IE*		-1,88 A	9,91 A	10,1 A	100,8°
UL12*		51,9 V	52,4 V	73,7 V	45,2°
UL23*		0,003 V	-110 V	110 V	-90,0°
UL31*		-51,9 V	57,6 V	77,6 V	132,0°