

## UR Family

# Sensitive Directional Power (ANSI 32) setup and testing

## Application Note

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### Overview

GE's Multilin Universal Relays C60, F60, M60, G30, G60, N60 and T60 is part of the Multilin Series platform of protection relays that has Sensitive Directional Power (ANSI 32) element. The sensitive directional power element responds to three-phase directional power and is designed for reverse power and low forward power applications for synchronous machines or interconnections involving co-generation. The relay measures the three-phase power from either a full set of wye-connected VTs or a full set of delta-connected VTs. In the latter case, the two-wattmeter method is used. See the UR-series instruction manual Metering Conventions chapter 6 for details regarding the power factor, active and reactive power used by the sensitive directional power element

This application note describes how to setup and test sensitive directional power element.

### Sensitive directional power (ANSI 32) settings

SETTINGS ⇒ DOWN GROUPED ELEMENTS ⇒ SETTING GROUP 1(6) ⇒ DOWN POWER ⇒ DOWN SENSITIVE DIRECTIONAL POWER ⇒ DIRECTIONAL POWER 1(2)

<div> <div>■ DIRECTIONAL</div> <div>■ POWER 1</div> </div>	⇔	DIR POWER 1 FUNCTION: Disabled	Range: Disabled, Enabled
	⇕	DIR POWER 1 SOURCE: SRC 1	Range: SRC 1, SRC 2, SRC 3, SRC 4
	⇕	DIR POWER 1 RCA: 0°	Range: 0 to 359° in steps of 1
	⇕	DIR POWER 1 CALIBRATION: 0.00°	Range: 0 to 0.95° in steps of 0.05
	⇕	DIR POWER 1 STG1 SMIN: 0.100 pu	Range: -1.200 to 1.200 pu in steps of 0.001
	⇕	DIR POWER 1 STG1 DELAY: 0.50 s	Range: 0.00 to 600.00 s in steps of 0.01
	⇕	DIR POWER 1 STG2 SMIN: 0.100 pu	Range: -1.200 to 1.200 pu in steps of 0.001
	⇕	DIR POWER 1 STG2 DELAY: 20.00 s	Range: 0.00 to 600.00 s in steps of 0.01
	⇕	DIR POWER 1 BLK: Off	Range: FlexLogic operand
	⇕	DIR POWER 1 TARGET: Self-reset	Range: Self-reset, Latched, Disabled
	⇕	DIR POWER 1 EVENTS: Disabled	Range: Disabled, Enabled

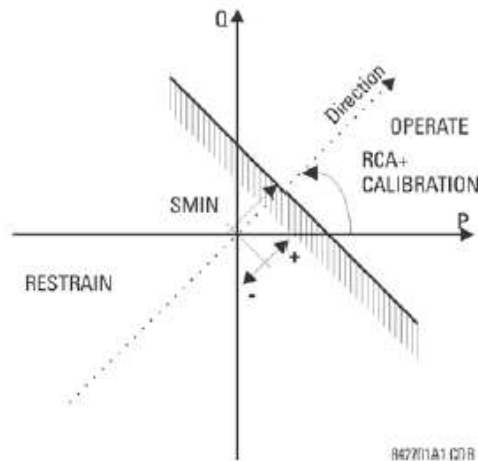
The element responds to the following condition:  $P \cos \emptyset + Q \sin \emptyset > S_{MIN}$

Where:

P and Q are active and reactive powers as measured per the UR metering convention.

$\emptyset$  is a sum of the characteristic (DIR POWER 1 RCA) and calibration (DIR POWER 1 CALIBRATION) angles.

S<sub>MIN</sub> is the minimum operating power.



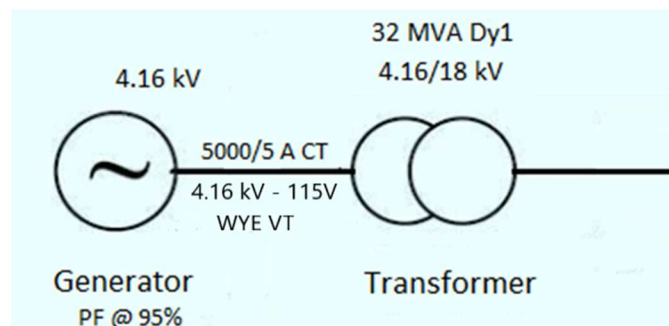
Directional power characteristic

*NOTE: ANSI 32 S<sub>MIN</sub> Base PU for Wye connected VT =  $3 \times CT \text{ primary} \times VT \text{ primary}$ , applicable to all UR firmware versions. For Delta connected VT, S<sub>MIN</sub> Base PU formula applicable for each firmware version are as follows.*

1. UR firmware 7.82 and below, ANSI 32 S<sub>MIN</sub> Base PU =  $3 \times CT \text{ primary} \times VT \text{ primary}$ .
2. UR firmware 7.90 and above, ANSI 32 S<sub>MIN</sub> Base PU =  $\sqrt{3} \times CT \text{ primary} \times VT \text{ primary}$ .

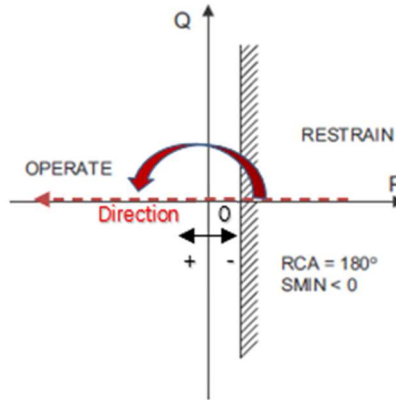
## Example 1

Substation power transformer rated 32 MVA, 18/4.16 kV, Dy1, PF @ 95 lag (Cos  $\Phi$ ). Sensitive directional power setup to alarm for low forward power at 50% and trip at 40% generator MW supply to XFMR. CT = 5000/5 A and VT = 4160/115 V WYE connected (VT ratio at  $1.732 \times 36.17 = 62.65$ ) located at low voltage side of the transformer that connect to the generator.



S<sub>MIN</sub> Base PU =  $3 \times 5000 \times 4160 = 62.4$  MVA, XFMR MW @ 95% PF =  $32 \text{ MVA} \times 0.95 = 30.4$  MW

**Low Forward Power** based on directional power characteristic indicate RCA = 180°, S<sub>MIN</sub> =  $P \cos 180^\circ + Q \sin 180^\circ = -P$ . When characteristic RCA is 180 degrees, direction is rotated 180 degrees counterclockwise and the restrain is located to the right of the S<sub>MIN</sub> line (S<sub>MIN</sub> < 0).



SENS DIR POWER 1 setting should be,

RCA = 180 deg. (assume 0 deg. calibration) and set SMIN < 0 or negative.

Stage 1 SMIN =  $30.40 \times 0.50 = 15.20$  MW, Alarm T/D = 20s, SMIN at -PU =  $-(15.20/62.40) = -0.243$  PU

Stage 2 SMIN =  $30.40 \times 0.40 = 12.16$  MW, Trip T/D = 2s, SMIN at -PU =  $-(12.16/62.40) = -0.194$  PU

Inject secondary phasor current/voltage values as shown below and slowly decrease current magnitude until Sensitive Directional Power 1 STG1 & STG2 PKP/OP activate.

Phasor Current at  $I_A = 1.60 \angle -18.2^\circ$ ,  $I_B = 1.60 \angle -138.2^\circ$ ,  $I_C = 1.60 \angle -258.2^\circ$ , then  $I_1 = 1.60 \angle -18.2^\circ = 1600 \angle -18.2^\circ$

Phasor Voltage at  $V_A = 66.4 \angle 0^\circ$ ,  $V_B = 66.4 \angle -120^\circ$ ,  $V_C = 66.4 \angle -240^\circ$ , then  $V_1 = 66.4 \angle 0^\circ = 4160 \angle 0^\circ$

Three Phase Real Power =  $3 \times I_1 \times V_1 \times \cos \Phi = 3 \times 1600 \times 4160 \times \cos 18.2^\circ = 18.969$  MW

Three Phase Reactive Power =  $3 \times I_1 \times V_1 \times \sin \Phi = 3 \times 1600 \times 4160 \times \sin 18.2^\circ = 6.237$  MVAR

Expected SMIN =  $18.969 \cos 180^\circ + 6.237 \sin 180^\circ = -18.969$  MW

UR Metering Initial Reading, Actual Values, SMIN = - 18.969 MW

PARAMETER	SENS DIR POWER 1
Sens Dir Power Actual	-18969998.000 W

G60	Actual Values: Metering	Screen
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PARAMETER	SOURCE 1
Name	SRC 1
Three Phase Real Power	18.977 MW
Phase A Real Power	6.324 MW
Phase B Real Power	6.318 MW
Phase C Real Power	6.334 MW
Three Phase Reactive Power	6.000 Mvar
Phase A Reactive Power	2.006 Mvar
Phase B Reactive Power	2.007 Mvar
Phase C Reactive Power	1.987 Mvar
Three Phase Apparent Power	19.903 MVA
Phase A Apparent Power	6.635 MVA
Phase B Apparent Power	6.629 MVA
Phase C Apparent Power	6.638 MVA
Three Phase Power Factor	0.953 Lag
Phase A Power Factor	0.952 Lag
Phase B Power Factor	0.952 Lag
Phase C Power Factor	0.953 Lag

G60	Actual Values: Metering: Source	Screen ID: 108
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Stage 1 PKP/OP will activate at approximately  $I_A = 1.277 \angle -18.2^\circ$ ,  $I_B = 1.277 \angle -138.2^\circ$ ,  $I_C = 1.277 \angle -258.2^\circ$ .

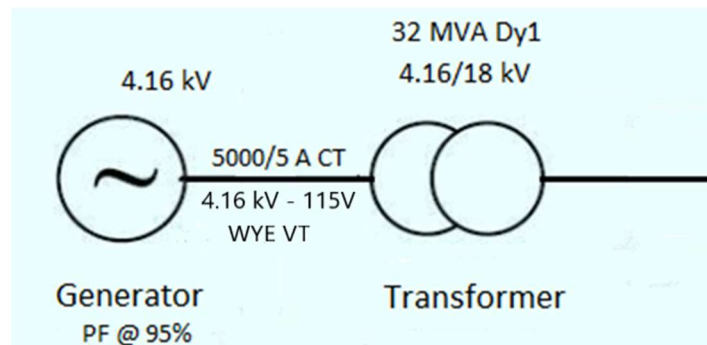
PARAMETER	SENS DIR POWER 1
Sens Dir Power Actual	-15160470.000 W

Stage 2 PKP/OP will activate at approximately  $I_A = 1.020 \angle -18.2^\circ$ ,  $I_B = 1.020 \angle -138.2^\circ$ ,  $I_C = 1.020 \angle -258.2^\circ$ .

PARAMETER	SENS DIR POWER 1
Sens Dir Power Actual	-12104641.000 W

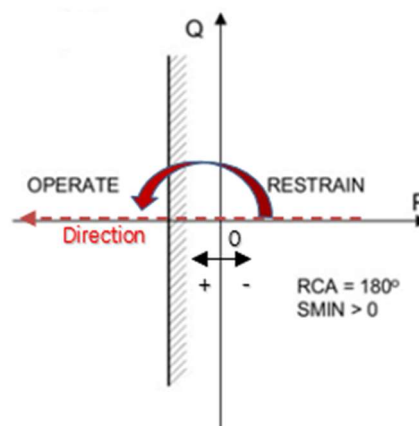
## Example 2

Substation power transformer rated 32 MVA, 18/4.16 kV, Dy1, PF @ 95 lag (Cos  $\Phi$ ). Sensitive directional power setup to alarm for reverse power at 5% and trip at 10% generator MW supply to XFMR. CT = 5000/5 A CT and VT = 4160/115 V WYE connected (VT ratio,  $36.17 \times 1.732 = 62.65$ ) located at low voltage side of the transformer that connect to the generator.



SMIN Base PU =  $3 \times 5000 \times 4160 = 62.4$  MVA, XFMR MW @ 95% PF =  $32 \text{ MVA} \times 0.95 = 30.4 \text{ MW}$

**Reverse Power** based on directional power characteristic indicate  $RCA = 180^\circ$ ,  $SMIN = P \cos 180^\circ + Q \sin 180^\circ = -P$ . When characteristic RCA is 180 degrees, direction is rotated 180 degrees counterclockwise and the restrain is located to the right of the SMIN line ( $SMIN > 0$ ).



SENS DIR POWER 1 setting should be,

RCA = 180 deg. (assume 0 deg. calibration) and set SMIN > 0 or positive.

Stage 1 SMIN =  $30.40 \times 0.05 = 1.52$  MW, Alarm T/D = 20s, SMIN at +PU =  $+(1.52/62.40) = 0.024$  PU

Stage 2 SMIN =  $30.40 \times 0.10 = 3.04$  MW, Trip T/D = 2s, SMIN at +PU =  $+(3.04/62.40) = 0.049$  PU

Inject secondary phasor current/voltage values as shown below and slowly rotate current phase angle clockwise until Sensitive Directional Power 1 STG1 & STG2 PKP/OP activate.

Phasor Current at  $I_A = 1.02 \angle -18.2^\circ$ ,  $I_B = 1.02 \angle -138.2^\circ$ ,  $I_C = 1.02 \angle -258.2^\circ$ , then  $I_1 = 1.02 \angle -18.2^\circ = 1020 \angle -18.2^\circ$

Phasor Voltage at  $V_A = 66.4 \angle 0^\circ$ ,  $I_B = 66.4 \angle -120^\circ$ ,  $I_C = 66.4 \angle -240^\circ$ , then  $V_1 = 66.4 \angle 0^\circ = 4160 \angle 0^\circ$

Three Phase Real Power =  $3 \times I_1 \times V_1 \times \cos \Phi = 3 \times 1020 \times 4160 \times \cos 18.2^\circ = 12.093$  MW

Three Phase Reactive Power =  $3 \times I_1 \times V_1 \times \sin \Phi = 3 \times 1020 \times 4160 \times \sin 18.2^\circ = 3.976$  MVAR

Expected SMIN =  $12.093 \cos 180^\circ + 3.976 \sin 180^\circ = -12.093$  MW

UR Metering Initial Reading, Actual Values, SMIN = 12.093 MW

PARAMETER	SENS DIR POWER 1
Sens Dir Power Actual	-12093916.000 W

G60 Actual Values: Metering Scre

PARAMETER	SOURCE 1
Name	SRC 1
Three Phase Real Power	12.105 MW
Phase A Real Power	4.035 MW
Phase B Real Power	4.030 MW
Phase C Real Power	4.040 MW
Three Phase Reactive Power	3.830 Mvar
Phase A Reactive Power	1.278 Mvar
Phase B Reactive Power	1.284 Mvar
Phase C Reactive Power	1.268 Mvar
Three Phase Apparent Power	12.696 MVA
Phase A Apparent Power	4.233 MVA
Phase B Apparent Power	4.229 MVA
Phase C Apparent Power	4.234 MVA
Three Phase Power Factor	0.953 Lag
Phase A Power Factor	0.953 Lag
Phase B Power Factor	0.952 Lag
Phase C Power Factor	0.953 Lag

G60 Actual Values: Metering: Source Screen ID: 108

Stage 1 PKP/OP will activate at approximately  $I_A = 1.020 \angle -97.5^\circ$ ,  $I_B = 1.020 \angle -217.5^\circ$ ,  $I_C = 1.020 \angle -337.5^\circ$

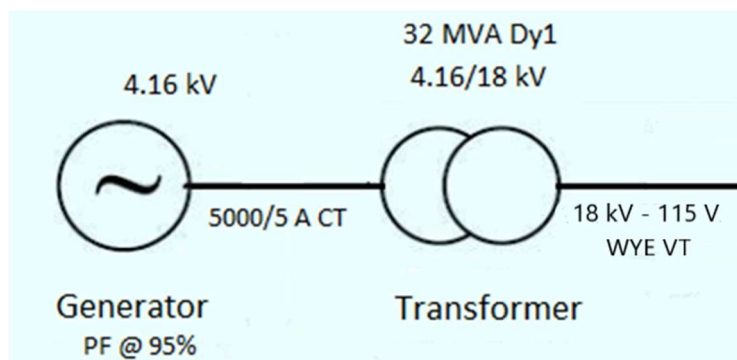
PARAMETER	SENS DIR POWER 1
Sens Dir Power Actual	1527511.000 W

Stage 2 PKP/OP will activate at approximately  $I_A = 1.020 \angle -104.4^\circ$ ,  $I_B = 1.020 \angle -224.4^\circ$ ,  $I_C = 1.020 \angle -344.4^\circ$

PARAMETER	SENS DIR POWER 1
Sens Dir Power Actual	3022078.750 W

### Example 3

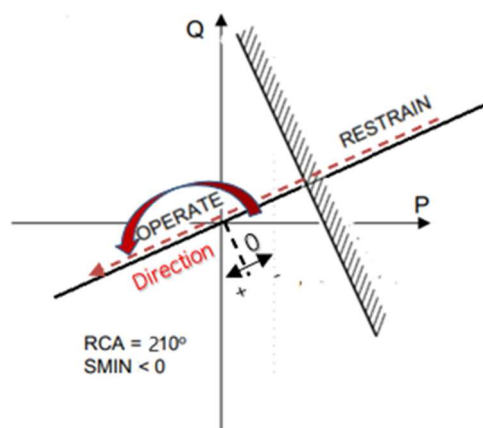
Substation power transformer rated 32 MVA, 18/4.16 kV, Dy1, PF @ 95 lag (Cos  $\Phi$ ). Sensitive directional power setup to alarm for low forward power at 50% and trip at 40% generator MW supply to XFMR. CT located at 4.16 KV LV side of the transformer that connect to the generator = 5000/5 A CT, transformer HV Side VT = 18000/115 V WYE connected.



Considerations due to VT/CT installed at HV/LV windings of the Dy1 transformer:

VT ratio adjusted to reflect LV side voltage,  $4.16 \text{ kV}/18 \text{ kV} = 0.231$ , original VT ratio  $18000/115 = 156.52$   
**New VT Ratio =  $156.52 \times 0.231 \times 1.732 = 62.65$** , then **RCA due to transformer Dy1 and VT at HV side =  $180 + 30 = 210$  deg.** **New PF due to 30 deg. HV VT phase shift will be  $\text{Cos } 48.2^\circ$  ( $\Phi = 18.2 + 30 = 48.2^\circ$ ).** **SMIN Base PU =  $3 \times 5000 \times 4160 = 62.4 \text{ MVA}$** , **XFMR MW @ 95% PF =  $32 \text{ MVA} \times 0.95 = 30.4 \text{ MW}$**

**Low Forward Power** based on directional power characteristic indicate  $\text{RCA} = 210^\circ$ ,  $\text{SMIN} = P \cos 210^\circ + Q \sin 210^\circ = P$ . When characteristic RCA is 210 degrees, direction is rotated 210 degrees counterclockwise and the restrain is located to the right of the SMIN line ( $\text{SMIN} < 0$ ).





SENS DIR POWER 1 setting should be,

RCA = 210 deg. (assume 0 deg. calibration) and SMIN < 0 or negative.

Stage 1 SMIN =  $30.40 \times 0.50 = 15.20$  MW, Alarm T/D = 20s, SMIN at -PU =  $-(15.20/62.40) = -0.243$  PU

Stage 2 SMIN =  $30.40 \times 0.40 = 12.16$  MW, Trip T/D = 2s, SMIN at -PU =  $-(12.16/62.40) = -0.194$  PU

Inject secondary phasor current/voltage values as shown below and slowly decrease current magnitude until Sensitive Directional Power 1 STG1 & STG2 PKP/OP activate.

Phasor Current at  $I_A = 1.60 \angle -48.2^\circ$ ,  $I_B = 1.60 \angle -168.2^\circ$ ,  $I_C = 1.60 \angle -288.2^\circ$ , then  $I_1 = 1.60 \angle -48.2^\circ = 1600 \angle -48.2^\circ$

Phasor Voltage at  $V_A = 66.4 \angle 0^\circ$ ,  $I_B = 66.4 \angle -120^\circ$ ,  $I_C = 66.4 \angle -240^\circ$ , then  $V_1 = 66.4 \angle 0^\circ = 4160 \angle 0^\circ$

Three Phase Real Power =  $3 \times I_1 \times V_1 \times \cos \Phi = 3 \times 1600 \times 4160 \times \cos(48.2^\circ) = 13.309$  MW

Three Phase Reactive Power =  $3 \times I_1 \times V_1 \times \sin \Phi = 3 \times 1600 \times 4160 \times \sin(48.2^\circ) = 14.885$  MVAR

Expected SMIN =  $13.309 \cos 210^\circ + 14.885 \sin 210^\circ = -18.968$  MW

*Note PF change from 95% lag to 67% lag due to 30 deg. phase shift introduced by VT HV side on a Dy1 transformer. Sensitive directional power RCA was adjusted 30 deg. from 180 to 210 deg. to offset VT HV side used for the element.*

UR Metering Initial Reading, Actual Values. SMIN = -18.978 MW

PARAMETER	SENS DIR POWER 1
Sens Dir Power Actual	-18977784.000 W

G60 Actual Values: Metering Screen ID: 108

PARAMETER	SOURCE 1
Name	SRC 1
Three Phase Real Power	13.449 MW
Phase A Real Power	4.478 MW
Phase B Real Power	4.474 MW
Phase C Real Power	4.497 MW
Three Phase Reactive Power	14.687 Mvar
Phase A Reactive Power	4.902 Mvar
Phase B Reactive Power	4.898 Mvar
Phase C Reactive Power	4.888 Mvar
Three Phase Apparent Power	19.915 MVA
Phase A Apparent Power	6.639 MVA
Phase B Apparent Power	6.634 MVA
Phase C Apparent Power	6.642 MVA
Three Phase Power Factor	0.675 Lag
Phase A Power Factor	0.674 Lag
Phase B Power Factor	0.674 Lag
Phase C Power Factor	0.677 Lag

G60 Actual Values: Metering: Source Screen ID: 108

Stage 1 PKP/OP will activate at approximately  $I_A = 1.277 \angle -48.2^\circ$ ,  $I_B = 1.277 \angle -168.2^\circ$ ,  $I_C = 1.277 \angle -288.2^\circ$

PARAMETER	SENS DIR POWER 1
Sens Dir Power Actual	-15162957.000 W

Stage 2 PKP/OP will activate at approximately  $I_A = 1.020 \angle -48.2^\circ$ ,  $I_B = 1.020 \angle -168.2^\circ$ ,  $I_C = 1.020 \angle -288.2^\circ$

PARAMETER	SENS DIR POWER 1
Sens Dir Power Actual	-12105485.000 W

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## For further assistance

For product support, contact the information and call center as follows:

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