



PHASER OPTIONS APPLICATION NOTES

Loss Compensation

General Description

- Phaser Loss Compensation processing adds four Result Registers to the set of slow (one second) Results Registers: Compensated Real Power, Compensated Reactive Power, Loss Real Power, and Loss Reactive Power.
- All quantities are three phase unless otherwise indicated.
- All power variables are at the fundamental frequency (f_o).
- Notation is consistent with and further defined in the *Phaser Installation and Operation Manual*.

Compensated Real Power

$$W_{T_{\text{comp}}} = W_T \pm W_L$$

- $W_{T_{\text{comp}}}$ is Compensated Real Power, the measured Real Power adjusted by the Real Power Loss.
- W_T is Real Power at f_o .
- W_L is Real Power Loss, calculated from applying measured currents and voltages to a circuit model with user entered constants for a transformer and/or distribution conductors. W_L is typically positive for dissipative losses.
- \pm indicates *either* addition or subtraction, user selected via PhaserConfig for frame of reference, side of transformer, etc. The user must determine whether losses are to be added to or subtracted from the measured power.

$$W_L = (W_{Cu} + W_{Fe})$$

- W_{Cu} is real power copper loss; the real power dissipated in the winding of the transformer and/or distribution conductors. Copper losses may be selectively zeroed via PhaserConfig.
- W_{Fe} is real power iron loss; the real power dissipated in the iron core of the transformer. Iron losses may be selectively zeroed via PhaserConfig.

$$W_{Cu} = [W_{FLL} \cdot (I_T / I_{\text{Rated}})^2] + (3 \cdot R_{\text{Line}} \cdot I_T^2)$$

- W_{FLL} is Full Load Loss, the real power loss of the transformer at full load. W_{FLL} is entered by the user via PhaserConfig, either from the nameplate or measurement.
- I_T is measured RMS Three Phase Current.
- I_{Rated} is the transformer current rating. PhaserConfig and Phaser derive this as: $S_{\text{Rated}} / (\sqrt{3} \cdot V_{\text{Rated}})$.
- S_{Rated} , often called Rated VA, is the rated apparent power of the transformer. S_{Rated} is listed on the transformer nameplate, and is user entered via PhaserConfig.
- V_{Rated} is the rated voltage of the transformer, expressed as a line to line quantity. V_{Rated} is listed on the transformer nameplate, and is user entered via PhaserConfig.
- R_{Line} is the per phase resistance of the transmission or distribution line, in ohms. R_{Line} is entered by the user via PhaserConfig. If line resistance is not to be taken into account, set R_{Line} to zero.

$$W_{Fe} = W_{\text{NLL}} \cdot (V_{\text{TT}} / V_{\text{Rated}})^2$$

- W_{NLL} is the No Load Loss, the real power loss of the transformer at no load. W_{NLL} is entered by the user via PhaserConfig, either from the nameplate or measurement.
- V_{TT} is measured RMS three phase line to line voltage.

Summary Equations for Compensated Real Power

$$W_{T_{\text{comp}}} = W_T \pm [W_{Cu} + W_{Fe}]$$

$$W_{T_{\text{comp}}} = W_T \pm [(W_{FLL} \cdot (I_T / I_{\text{Rated}})^2 + 3R_{\text{Line}} \cdot I_T^2) + W_{\text{NLL}} \cdot (V_{\text{TT}} / V_{\text{Rated}})^2]$$

Compensated Reactive Power

$$R_{T_{\text{comp}}} = R_T \pm R_L$$

- $R_{T_{\text{comp}}}$ is Compensated Reactive Power, the measured Reactive Power adjusted by the Reactive Power Loss.
- R_T is Reactive Power at f_o .
- R_L is Reactive Power Loss, calculated from applying measured currents and voltages to a circuit model with user entered constants for a transformer.
- \pm indicates *either* addition or subtraction, the same user selection as for Compensated Real Power.

$$R_L = (R_{Cu} + R_{Fe})$$

- R_{Cu} is copper VAR loss; the reactive power loss associated with the series impedance of a transformer. Copper losses may be selectively zeroed via PhaserConfig.
- R_{Fe} is iron VAR loss; the reactive power loss associated with energy stored in the magnetic core of the transformer. Iron losses may be selectively zeroed via PhaserConfig.

$$R_{Cu} = R_{FLL} \cdot (I_T / I_{T \text{ Rated}})^2$$

- R_{FLL} is Full Load VAR Loss, the Reactive power loss of the transformer at full load.

$$R_{FLL} = Z \cdot S_{\text{Rated}} \cdot \sin[\text{acos}(W_{FLL} / Z \cdot S_{\text{Rated}})]$$

- Z is Transformer Impedance in percent, usually listed on the transformer nameplate. Z is user entered via PhaserConfig.
- $Z \cdot S_{\text{Rated}}$ is the full load apparent power.
- $\text{acos}(W_{FLL} / S_{FL})$ is the full load phase angle.

$$R_{Fe} = R_{NLL} \cdot (V_{TT} / V_{T \text{ Rated}})^4$$

- R_{NLL} is the No Load VAR Loss, the Reactive power loss of the transformer at no load.

$$R_{NLL} = I_e \cdot S_{\text{Rated}} \cdot \sin[\text{acos}(W_{NLL} / I_e \cdot S_{\text{Rated}})]$$

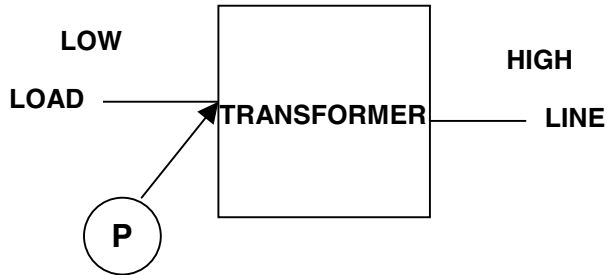
- I_e is Excitation Current, in percent, usually listed on the transformer nameplate. I_e is user entered via PhaserConfig.
- $I_e \cdot S_{\text{Rated}}$ is the no load apparent power.
- $\text{acos}(W_{NLL} / I_e \cdot S_{\text{Rated}})$ is the no load phase angle.

Summary Equations for Compensated Reactive Power

$$R_{T_{\text{comp}}} = R_T \pm \left\{ \frac{R_{Cu}}{Z \cdot S_{\text{Rated}} \cdot \sin[\text{acos}(W_{FLL} / Z \cdot S_{\text{Rated}})]} \cdot (I_T / I_{T \text{ Rated}})^2 + \frac{R_{Fe}}{I_e \cdot S_{\text{Rated}} \cdot \sin[\text{acos}(W_{NLL} / I_e \cdot S_{\text{Rated}})]} \cdot (V_{TT} / V_{T \text{ Rated}})^4 \right\}$$

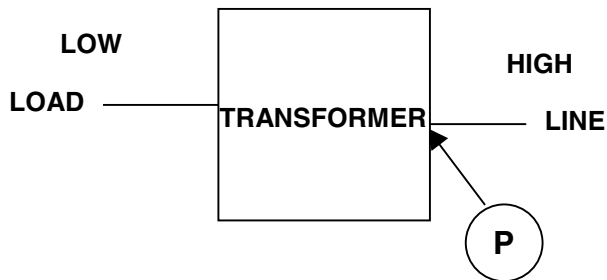
Loss and Compensation Conventions

Example Note: For convenience, assume 100 MW measured, 1 MW loss.



CASE 1: Low Side Phaser

Sign of Load Consumption	Measured	Compensated	Load State
+	+100MW	+101MW	Consumption
+	100MW	99MW	Generate
	100MW	101MW	Consumption
	+100MW	+99MW	Generate



CASE 2: High Side Phaser

Sign of Load Consumption	Measured	Compensated	Load State
+	+100MW	+99MW	Consumption
+	100MW	101MW	Generate
	100MW	99MW	Consumption
	+100MW	+101MW	Generate

Summary and Notes

- Losses are all unsigned (positive)
- Compensated Power = Measured Power \oplus Calculated Loss

\oplus as follows:

Measurement Side	Sign of Load Consumption	\oplus	PhaserConfig Selection
LOW	+	+	"Add Loss"
LOW			"Subtract Loss"
HIGH	+		"Subtract Loss"
HIGH		+	"Add Loss"