Instrument Transformers

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Ratios of Instrument Transformers

1. Transformation Ratio (R)

It is the ratio of the magnitude of the primary phasor to the secondary phasor.

$$R = \frac{|\text{primary phasor}|}{|\text{secondary phasor}|}$$

- For current transformer (C.T.)

$$R = \frac{\text{primary winding current}}{\text{secondary winding current}}$$

- For potential transformer (P.T.)

$$R = \frac{\text{primary winding voltage}}{\text{secondary winding voltage}}$$

2. Nominal Ratio (K_n)

It is the ratio of rated primary winding current (or voltage) to the rated secondary winding current (or voltage).

- For C.T.

$$K_n = \frac{\text{rated primary winding current}}{\text{rated secondary winding current}}$$

- For P.T.

$$K_n = \frac{\text{rated primary winding voltage}}{\text{rated secondary winding voltage}}$$

3. Turns Ratio (n)

- For C.T.

$$n = \frac{\text{number of turns of secondary winding}}{\text{number of turns of primary winding}}$$

- For P.T.

$$n = \frac{\text{number of turns of primary winding}}{\text{number of turns of secondary winding}}$$

4. Ratio Correction Factor

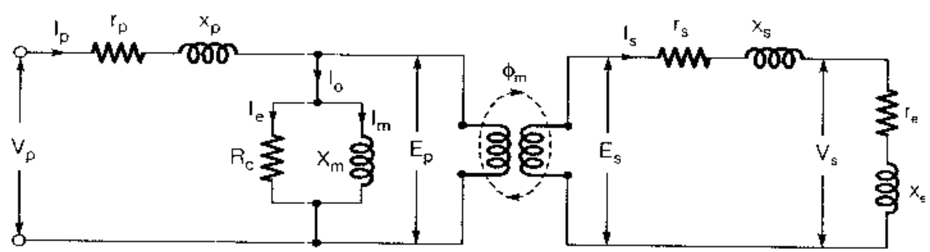
$$RCF = \frac{R}{K_n}$$

Remember:

The ratio marked on the transformers is their nominal ratio.

Current Transformer

Equivalent Circuit



where, r_s, x_s = resistance, reactance of secondary winding

r_e, x_e = resistance, reactance of external burden

E_p, E_s = primary and secondary winding induced voltage

N_p, N_s = number of primary and secondary winding turns

I_p, I_s = primary and secondary winding current

ϕ = working flux of transformer

θ = phase angle of transformer

δ = angle between secondary winding induced voltage and secondary winding current

Δ = phase angle of secondary winding load circuit

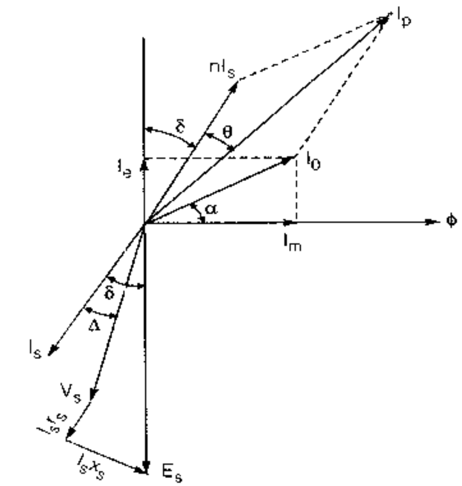
I_0 = exciting current

I_m = magnetizing component of exciting current

I_e = loss component of exciting current

α = angle between exciting current and flux

Phasor Diagram



Phasor diagram of C.T.

- Transformation ratio

$$R = \frac{I_p}{I_s} \simeq n + \frac{I_o}{I_s}\sin(\delta + \alpha)$$

$$R \simeq n + \frac{(I_m \sin\delta + I_e \cos\delta)}{I_s}$$

$$R \simeq n + \frac{I_e}{I_s} \simeq n\left(1 + \frac{I_e}{I_p}\right)$$

where, $I_m = I_o \cos\alpha$

$I_e = I_o \sin\alpha$

- Phase angle

$$\theta \simeq \frac{180}{\pi}\left(\frac{I_m \cos\delta - I_e \sin\delta}{nI_s}\right) \text{ degree}$$

$$\theta \simeq \frac{180}{\pi}\frac{I_m}{I_p} \text{ degree}$$

- Ratio error

$$\text{Ratio error} = \frac{\text{nominal ratio }(K_n) - \text{actual ratio }(R)}{\text{actual ratio }(R)}$$

Remember:

- The primary current of C.T. is depending on load connected to system but it is not depending secondary winding burden.
- Primary winding is single turn or bar winding and secondary has more number of turns to reduce the current at secondary.
- If primary current is very high, it causes reduction in ratio error and phase angle error. So to increase value of primary current the primary is maintain with single turn.
- The secondary number of turns are reduce by 1 or 2 turns then the ratio error reduces.

Potential transformer

- Actual transformation (voltage) ratio

$$R = n + \frac{\frac{I_s}{n}\left[R_p \cos\Delta + X_p \sin\Delta\right] + I_e r_p + I_m x_p}{V_s}$$

- Phase angle

$$\theta = \frac{I_s}{V_s}(X_s \cos\Delta - R_s \sin\Delta) + \frac{I_e x_p - I_m r_p}{nV_s} \text{ rad.}$$

Note:

- C.T. never operates with secondary winding open but P.T. can be operated with secondary winding open.
- Strip wound core is used to reduce ratio error and phase angle error.

Application of C.T. and P.T.

- Multiple operation with a single device.
- Higher current and higher voltages are step down to lower current and lower voltage so that metering is easier.
- Measuring circuit is isolated from the power circuit.
- Low power consumption.
- Replacement is easier.