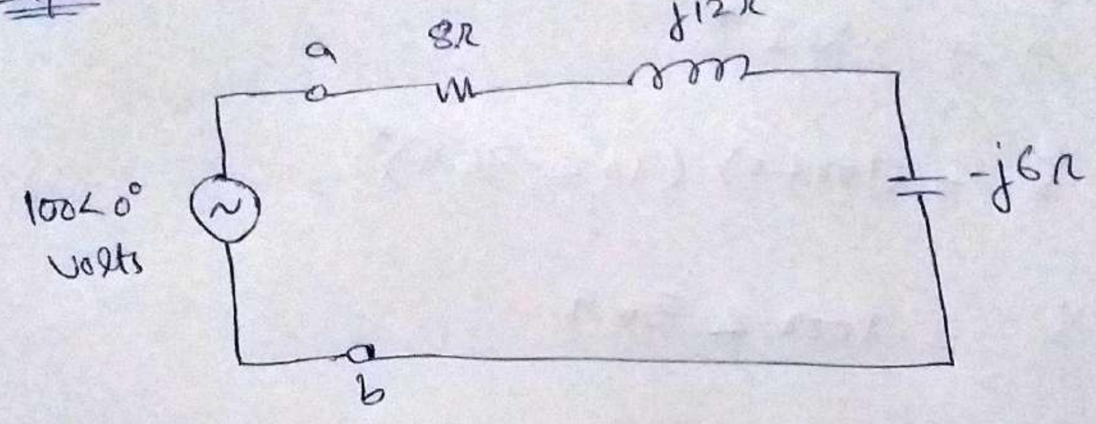
Exple:-



From the following circuit.

ⓐ Solve for Z, I and S at port ab.

ⓑ Solve in PU on basis of $V_{base} = 100$ V and S base = 1000.

Sol:-

ⓐ :-

$$Z_{ab} = 8 + j12 - j6$$

$$= 8 + j6$$

$$Z_{ab} = 10 \angle 36.9^\circ \ \Omega$$

$$I = \frac{V_{ab}}{Z_{ab}}$$

$$I = \frac{100 \angle 0^\circ}{10 \angle 36.9^\circ}$$

$$I = 10 \angle -36.9 \text{ A}$$

$$S = VI^*$$

$$S = (100\angle 0)(10\angle -36.9)^*$$

$$S = 1000\angle 36.9$$

$$S = 800 + j600 \text{ VA}$$

S ↓ Apparent Power; 800 ↓ Real Power; j600 ↓ Reactive Power

$P = 800\ W$; $Q = 600\ VAR$

(b) On the basis of V_{base} and S_{base}

$$Z_{base} = \frac{V_{base}^2}{S_{base}}$$

$$Z_{base} = \frac{(100)^2}{1000}$$

$$Z_{base} = 10\Omega$$

$$I_{base} = \frac{S_{base}}{V_{base}} = \frac{1000}{100} = 10A$$

$$V_{p.u} = \frac{100\angle 0}{100}$$

$$V_{p.u} = 1\angle 0^\circ \ p.u$$

$$Z_{p.u} = \frac{10\angle 36.9^\circ}{10}$$

$$Z_{p.u} = 1\angle 36.9^\circ \ p.u$$

$$I_{p.u} = \frac{V_{p.u}}{Z_{p.u}}$$

$$I_{p.u} = \frac{1\angle 0^\circ}{1\angle 36.9^\circ}$$

$$I_{p.u} = 1\angle -36.9^\circ \ p.u$$

$$S_{p.u} = V_{p.u} \, I_{p.u}^{*}$$

$$S_{p.u} = (1\angle 0^\circ)(1\angle -36.9^\circ)^{*}$$

$$S_{p.u} = 1\angle 36.9^\circ \ p.u$$

Converting to SI Units:-

$$I = (I_{p.u})(I_{base})$$

$$I = (1\angle -36.9^\circ)(10)$$

$$I = 10\angle -36.9 \ A$$

$$Z = (Z_{p.u})(Z_{base})$$

$$Z = (1\angle 36.9^\circ)(10)$$

$$Z = 10\angle 36.9^\circ \ \Omega$$

OR

$$Z = 8 + j6 \ \Omega$$

$$S = (S_{p.u})(S_{base})$$

$$S = (0.8 + j0.6)(1000)$$

$$S = 800 + j600 \ VA$$

⊛ Equivalent Impedence of Transformer in P.U :-

Let us consider a transformer having Z_1 and Z_2, The equivalent impedence referred to primary and secondary. If V_p and V_s are the primary and secondary voltages and are taken as base. Similarly I_p and I_s are also taken as base.

Base impedence in Primary Circuit = V_P/I_p

Base impedence in Secondary Circuit = V_s/I_s

From transformer equation:

Let $V_P/V_S = I_S/I_P = N_P/N_S = K$ → ①

From eq ①:

$$V_P = K V_S \rightarrow ②$$

$$I_P = \frac{1}{K} I_S \rightarrow ③$$

Impedence of Primary:

$$Z_P = \frac{V_P}{I_P} = \frac{K V_S}{\frac{1}{K} I_S}$$

$$Z_P = K^2 \frac{V_S}{I_S}$$

$$Z_P = K^2 Z_S$$

$$Z_P = Z_1 = K^2 Z_2 \rightarrow ④$$

Now in P.U

$$Z_1 P.U = \frac{Z_1}{Z_2} = Z_1 / VP/IP$$

$$Z_1 P.U = Z_1 * \frac{IP}{VP}$$ (Actual value / Base value)

$$Z_2 P.U = Z_2 * \frac{IS}{VS}$$

$$Z_1 P.U = K^2 Z_2 * \frac{\frac{1}{K} Is}{\frac{K Vs}{1}}$$

$$Z_1 P.U = K^2 Z_2 * \frac{1}{K} Is * \frac{1}{K Vs}$$

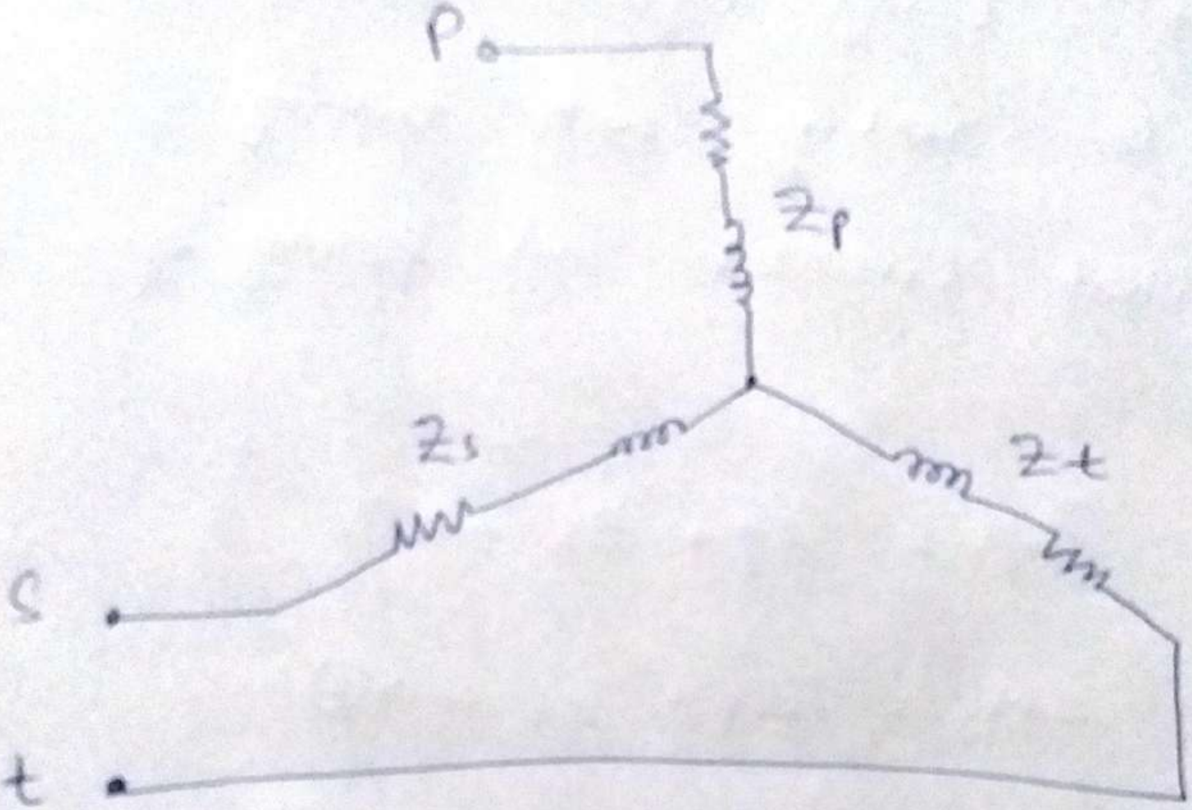
$$Z_1 P.U = Z_2 \cdot \frac{IS}{VS}$$

$$\boxed{Z_1 P.U = Z_2 P.U}$$

Hence P.U equivalent Impedence of T/F is same referred to primary or secondary

(*) Per Unit Impedance of Three Winding Transformer:-

Both the primary and secondary windings of a two-winding transformer have the same KVA ratings but all three windings of a three winding transformer may have different KVA ratings. The equivalent circuit of a three winding transformer is shown below:-



Let Z_{ps} = Leakage impedence measured in primary with secondary short circuited and tertiary open

Z_{pt} = Leakage impedence measured in primary with tertiary short and secondary open

Z_{st} = Leakage impedance measured in secondary with tertiary short circuited and primary open.

Then

$$Z_{ps} = Z_p + Z_s \rightarrow (1)$$

$$Z_{pt} = Z_p + Z_t \rightarrow (2)$$

$$Z_{st} = Z_s + Z_t \rightarrow (3)$$

Solving for Z_p, Z_s and Z_t

We get:-

For Z_p:- Adding eq (1) & eq (2)

$$Z_{ps} = Z_p + Z_s$$

$$Z_{pt} = Z_p + Z_t$$

$$Z_{ps} + Z_{pt} = 2Z_p + (Z_s + Z_t)$$

$$2Z_p = Z_{ps} + Z_{pt} - (Z_s + Z_t)$$

$\therefore Z_s + Z_t = Z_{st}$

$$\boxed{Z_p = \frac{1}{2}(Z_{ps} + Z_{pt} - Z_{st})}$$

Similarly for Z_s

adding eq ① and eq ③

$$\boxed{Z_s = \frac{1}{2}(Z_{ps} + Z_{st} - Z_{pt})}$$

For

$$\boxed{Z_t = \frac{1}{2}(Z_{pt} + Z_{st} - Z_{ps})}$$