CLASS TEST

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MACHINE

(TRANSFORMER + INDUCTION)

ELECTRICAL ENGINEERING

Date of Test : 17/07/2025

ANSWER KEY

1.	(c)	7.	(c)	13.	(d)	19.	(a)	25.	(d)
2.	(b)	8.	(d)	14.	(a)	20.	(d)	26.	(c)
3.	(b)	9.	(d)	15.	(b)	21.	(d)	27.	(b)
4.	(c)	10.	(c)	16.	(c)	22.	(c)	28.	(d)
5.	(a)	11.	(c)	17.	(d)	23.	(d)	29.	(b)
6.	(b)	12.	(a)	18.	(b)	24.	(b)	30.	(c)

DETAILED EXPLANATIONS

1. (c)

For maximum torque (T_{max})

$$s_{max,\,T} = \frac{R_2}{X_2}$$

$$s_{max,\,T} = \frac{1}{4}$$

Synchronous speed, $N_s = \dfrac{120 \times 50}{6} = 1000$ rpm

Now at T_{max} speed of motor,

$$N_r = (1 - s)\,N_s = (1 - 0.25) \times 1000$$

$$N_r = 750 \text{ rpm}$$

2. (b)

Given,

$$V_1 = 1000 \text{ V},$$

$$V_2 = 400 \text{ V}$$

No load current, I_{e1} = 3 A at 0.75 lag p.f.

No load current on *l.v.* side;

$$I_{e2} = I_{e1} \times \frac{V_1}{V_2} = 3.0 \times \frac{1000}{400} = 7.5 \text{ A}$$

At no load, the p.f. remains same on both sides;

then power factor = 0.75 lag

3. (b)

As we can write:

Voltage regulation; $V.R = Z_{pu} \cdot \cos(\theta_{eq} - \phi)$

For leading power factor angle = –30°

$$V.R. = 0.1 \cos(90° + 30°)$$

If resistance is negligible;

then $\theta_{eq} = 90°$

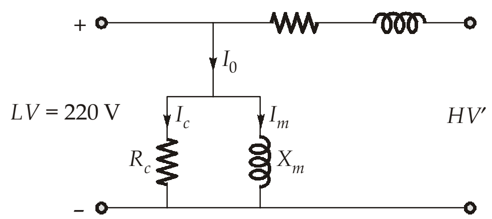
therefore; $V.R. = 0.1\{-\sin 30°\}$

$$= -0.1 \times 0.5 = -0.05$$

$$\% \text{ V.R.} = -5\%$$

4. (c)

Lets take circuit referred to low voltage side,



Watt meter reading = $VI \cos \phi$

$$\cos\phi = \frac{100}{220 \times 2.5} = 0.1818$$

$$\sin\phi = \sin(\cos^{-1}(0.1818)) = 0.9833$$

$$I_c = I_0 \cos\phi = 2.5 \times 0.1818 = 0.4545 \text{ A}$$

$$I_m = I_0 \sin\phi = 2.5 \times 0.9833 = 2.46 \text{ A}$$

$$\therefore \quad R_c = \frac{V}{I_c} = \frac{220}{0.4545} = 484\ \Omega$$

$$X_m = \frac{V}{I_m} = \frac{220}{2.46} = 89.43\ \Omega$$

∴ Option (c) is the only equivalent circuit matching.

5. **(a)**

Impedance under block rotor condition,

$$Z_b = \frac{V_b}{I_b} = \frac{82.5}{9.3} = 8.87\ \Omega$$

Resistance under block rotor condition,

$$R_b = \frac{W_b}{I_b^2} = \frac{500}{(9.3)^2} = 5.78\ \Omega$$

Rotor resistance referred to stator,

$$R_2' = R_b - R_1$$

$$= 5.78 - 2.5 = 3.28\ \Omega$$

6. **(b)**

Rotor input (or) air gap power

$$= 45 - 1.5 = 43.5 \text{ kW}$$

$$s = 0.04$$

Internal mechanical power developed is

$$= 43.5\,(1 - 0.04) = 43.5 \times 0.96 = 41.76 \text{ kW}$$

7. **(c)**

$$T_{st} = 0.8\ T_{\max}$$

$$0.8 = \frac{2\,s_{\max}}{s_{\min}^2 + 1}$$

$$s_{\max}^2 - \frac{2}{0.8}s_{\max} + 1 = 0$$

$$s_{\max}^2 - 2.5\,s_{\max} + 1 = 0$$

$$s_{\max} = 0.5$$

$$\therefore \quad 0.5 = \frac{0.03 + R_{\text{ext}}}{0.18}$$

$$0.09 = 0.03 + R_{\text{ext}}$$

$$R_{\text{ext}} = 0.09 - 0.03 = 0.06\ \Omega$$

8. (d)

We know, $\dfrac{N_{\Delta(P)}}{N_{Y(P)}} = 5$

Also, $\dfrac{N_{\Delta(P)}}{N_{Y(P)}} = \dfrac{V_{\Delta(P)}}{V_{Y(P)}}$

$$V_{Y(P)} = \frac{400}{\sqrt{3}}\text{ V}$$

$$V_{\Delta(P)} = \frac{N_{\Delta(P)}}{N_{Y(P)}} V_{Y(P)} = 5\times\frac{400}{\sqrt{3}} = \frac{2000}{\sqrt{3}}\text{ V}$$

For delta side, $V_{\Delta(L)} = V_{\Delta(P)} = \dfrac{2000}{\sqrt{3}}\text{ V}$

9. (d)

For maximum efficiency at unity power factor using condition,

$$\text{kVA}_m = (\text{kVA})_{fl}\sqrt{\frac{P_i}{P_{cu}}} = 400\sqrt{\frac{700}{2800}} = 400\sqrt{\frac{1}{4}} = 200\text{ kVA}$$

At maximum efficiency,

$$P_c = P_i$$

$$\%\eta_{max} = \frac{200}{200+\dfrac{700}{1000}+\dfrac{700}{1000}} = 99.30\%$$

10. (c)

For a 3-phase induction motor, spatial displacement,

$$\delta = 90 + \phi_2$$

where 'ϕ_2' is power factor angle,

$$\cos\phi_2 = 0.707$$

$$\phi_2 = 45°$$

$$\delta = 90° + 45° = 135°$$

11. (c)

For f_2 = 15 Hz, the slip is

$$s = \pm\frac{f_2}{f_1} = \pm\frac{15}{60} = \pm\frac{1}{4}$$

The synchronous speed, $N_s = \dfrac{120\times f}{P} = \dfrac{120\times 60}{6}$ = 1200 rpm

The speed of the system for f_2 =15 Hz

$$N_r = (1 \pm s)N_s = (1 \pm 0.25)1200 = 900 \text{ and } 1500 \text{ rpm}$$

∴ hence option (c) is correct.

We can check for f_2 = 120 Hz

$$s = \pm\frac{120}{60} = \pm 2$$

$$N_r = (1 \pm 2)\,1200 = -1200 \text{ and } 3600 \text{ rpm}$$

12. (a)

At no load;

$$\text{Back emf, } E_{b0} = V_t - I_{a0}(R_a)$$
$$E_{b0} = 220 - 3(0.5)$$
$$E_{b0} = 218.5 \text{ V}$$

At full load;

$$\text{Back emf, } E_{b\ fl} = V_t - I_{a\ fl}(R_a)$$
$$= 220 - 45\ (0.5)$$
$$E_{b\ fl} = 197.5 \text{ V}$$

As flux is given constant;

then, we can write; $E_b \propto N$

or,
$$\frac{E_{b\,fl}}{E_{b0}} = \frac{N_{fl}}{N_0}$$

$$N_{fl} = \left(\frac{197.5}{218.5}\right) \times 1500$$
$$= 1355.83 \approx 1356 \text{ rpm}$$

13. (d)

Given:

S.C. Test (H.V): 57.5 V, 8.34 A, 284 W

$$Z_{eq} = \frac{57.5}{8.34} = 6.894\ \Omega$$

$$R_{eq} = \frac{284}{(8.34)^2} = 4.083\ \Omega$$

$$X_{eq} = \sqrt{Z_{eq}^2 - R_{eq}^2} = 5.555\ \Omega$$

For voltage regulation to be zero;

$$\text{Power factor; } \cos\phi = \cos\tan^{-1}\left(\frac{R_{eq}}{X_{eq}}\right) = \cos(36.32°)$$

$$\cos\phi = 0.805 \ \text{ leading}$$

14. (a)

Primary is star connected and secondary is delta connected.

$$(V_L)_{primary} = 11000 \text{ V}$$

$$(V_{ph})_{primary} = \frac{11000}{\sqrt{3}} \text{V}$$

$$\frac{(V_{ph})_{sec}}{(V_{ph})_{prim}} = \frac{1}{5}$$

$$\therefore \quad \text{Turns ratio} = \left(\frac{\text{High voltage}}{\text{Low voltage}}\right)_{phase}$$

$$\therefore \quad (V_{ph})_{sec} = \frac{11000}{5\sqrt{3}} \text{V}$$

$$(V_{ph})_{\Delta} = (V_L)_{\Delta}$$

$$\text{Output kVA} = \sqrt{3}V_L I_L$$

$$= \sqrt{3}\times\frac{11000}{5\sqrt{3}}\times 423 = 930.6 \text{ kVA}$$

15. (b)

Given that,

$$V_{OC} = 230 \text{ V},$$
$$I_{OC} = 1.3 \text{ A},$$
$$P_{OC} = 100 \text{ W}$$

$$R_C = \frac{V_{0C}^2}{P_{0C}} = \frac{230^2}{100} = 529\ \Omega$$

Power factor angle,

$$\phi_{OC} = \cos^{-1}\left(\frac{P_{OC}}{V_{OC}I_{OC}}\right) = \cos^{-1}\left(\frac{100}{230\times 1.3}\right) = 70.46°$$

$$X_{\phi} = \frac{R_C}{\tan\phi_{OC}} = \frac{529}{\tan 70.46°} = 187.73\ \Omega$$

Referred to high voltage side,

$$R_C = 529\times\left(\frac{400}{230}\right)^2 = 1600\ \Omega$$

$$X_{\phi} = 187.73\times\left(\frac{400}{230}\right)^2 = 567.8\ \Omega$$

16. (c)

From the given diagram,

$$N_1 : N_2 : N_3 = 9:3:1$$
$$\text{Induced emf} = 400\angle 0° \text{ V}$$

As we know that; $\frac{E_1}{E_2} = \frac{N_1}{N_2}$

$\Rightarrow$ $$E_2 = \frac{N_2}{N_1}E_1 = \left(\frac{3}{9}\right)\times 400\angle 0° = \frac{400}{3}\angle 0° \text{ V}$$

and $\frac{E_1}{E_3} = \frac{N_1}{N_3}$

$\Rightarrow$ $$E_3 = \left(\frac{1}{9}\right)400\angle 0° = \frac{400}{9}\angle 0° \text{ V}$$

Current in secondary winding;

$\Rightarrow$ $$I_2 = \frac{E_2}{R} = \frac{400/3}{20} = \frac{20}{3}\text{A}$$

Current in tertiary winding;

$\Rightarrow$ $$I_3 = \frac{E_3}{-jX_c} = \frac{400/9}{-j5} = \frac{80}{9}\angle 90° \text{ A}$$

I_2 referred to primary side,

$$I_2' = \left(\frac{N_2}{N_1}\right)I_2 = \left(\frac{3}{9}\right)\times\frac{20}{3} = \frac{20}{9}\angle 0°\,\text{A}$$

I_3 referred to primary side,

$$I_3' = \left(\frac{N_3}{N_1}\right)I_3 = \frac{1}{9}\times\frac{80}{9}\angle 90°\,\text{A} = \frac{80}{81}\angle 90°\,\text{A}$$

Then supply current, $$I_1 = \frac{20}{9}\angle 0° + \frac{80}{81}\angle 90°$$

$$= \frac{20}{81}(9 + j4)\,\text{A}$$

17. (d)

Given, $$N_s = \frac{120\times f}{P} = \frac{120\times 50}{4} = 1500 \text{ rpm}$$

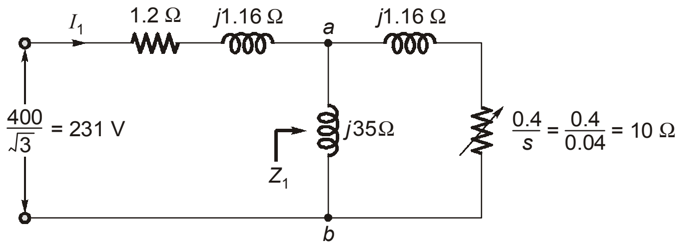
$$N_r = 1440 \text{ rpm}$$

$$\text{Slip, } s = \frac{1500-1440}{1500} = 0.04$$

Rotor resistance at s = 0.04,

$$r_2' = \frac{0.4}{0.04} = 10\ \Omega$$

Consider the circuit diagram shown below,



$$Z_1 = \frac{j35(10+j1.16)}{10+j(35+1.16)}$$

$$= \frac{352.45\angle 96.6°}{37.51\angle 74.5°} = 9.4\angle 22.1°\ \Omega = (8.703 + j\,3.53)\ \Omega$$

Total impedance of circuit,

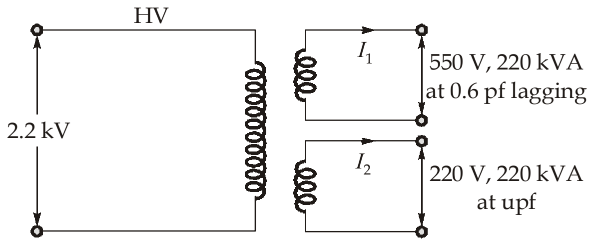
$$\vec{Z}_i = (8.703 + j\,3.53) + (1.2 + j\,1.16)$$

$$= 9.90 + j\,4.69 = 10.955\angle 25.35°\ \Omega$$

Stator current, $$I_1 = \frac{231}{10.955} = 21.09\ \text{A}$$

18. (b)

Consider the below circuit:



Rated current in winding - 1

$$I_1 = \frac{220 \times 1000}{550} = 400\angle -53.13° \text{ A}$$

Rated current in winding - 2

$$I_2 = \frac{220 \times 1000}{220} = 1000\angle 0° \text{ A}$$

Current in HV side due to rated current in winding - 1

$$I_1' = \frac{(400\angle -53.13) \times 0.55}{2.2} = 100\angle -53.13° \text{ A}$$

Current in HV side due to rated current in winding - 2

$$I_2' = \frac{(1000\angle 0°) \times 0.22}{2.2} = 100\angle 0° \text{ A}$$

$$\text{HV side current} = 100\angle -53.13° + 100\angle 0°$$

$$I = 178.885\angle -26.565 \text{ A}$$

$$|I| = 178.885 \text{ A}$$

19. (a)

We know that,

$$\text{Torque, } T = \frac{3}{\omega_{sm}} \times \frac{V^2}{R_2'} s \text{ (for low slip)}$$

Now, T = constant $\quad T \propto V^2 s$

(or) $\quad V_2^2 s_2 = V_1^2 s_1$

(or) $\quad s_2 = \left(\frac{V_1}{V_2}\right)^2 s_1$

(or) $\quad s_2 = 4s_1$,

hence slip increases 4 times,

Also, $\quad T = \frac{3I_2'^2}{\omega_{sm}} \times \frac{R_2'}{s} = \text{const.}$

(or) $\quad I_2'^2 \propto s$

$$\frac{I_2'}{I_1'} = \sqrt{\frac{s_2}{s_1}} = \sqrt{\frac{4}{1}} = 2$$

Hence, current increases by 2 times.

20. **(d)**

Power factor of the load;

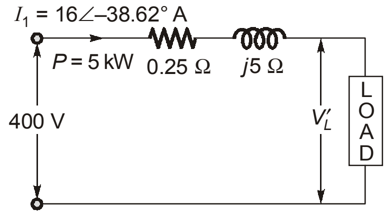
$$\text{p.f.} = \frac{P}{VI} = \frac{5\times10^3}{400\times16}$$

$$\text{p.f.} = 0.781 \text{ lagging}$$

or $$\text{p.f. angle } \phi = \cos^{-1} 0.781 = 38.62°$$

The equivalent circuit of the transformer referred to H.V. side can be shown as below;

From circuit;



$$V_L' = 400\angle 0° - (0.25 + j5) \times 16\angle{-38.62°}$$

$$V_L' = 352.094\angle{-9.81°} \text{ V}$$

The voltage on load side or L.V. side

$$V_L = \frac{352.094}{5}\angle{-9.81°}$$

$$V_L = 70.42\angle{-9.81°} \text{ V}$$

21. **(d)**

$$V_{sc} = 120 \text{ V}, I_{sc} = 9.6 \text{ A}, P_{sc} = 460 \text{ W}$$

$$Z_e = \frac{V_{sc}}{I_{sc}} = \frac{120}{9.6} = 12.5\ \Omega$$

$$R_e = \frac{P_{sc}}{I_{sc}^2} = \frac{460}{(9.6)^2} = 4.99\ \Omega$$

$$R_{lm} = 1.5\ \Omega$$

$$R_2' = R_e - R_{lm} = 4.99 - 1.5 = 3.49\ \Omega$$

Given, $$V_0 = 220 \text{ V}, I_0 = 4.6 \text{ A}, P_0 = 125 \text{ W}$$

Core, friction and windage losses

$$= 125 - (4.6)^2\left(1.5 + \frac{3.49}{4}\right) = 74.8 \text{ W}$$

22. **(c)**

Synchronous speed, $$N_s = \frac{120f}{P} = \frac{120\times50}{4} = 1500 \text{ rpm}$$

Forward slip, $$s_f = \frac{N_s - N_r}{N_s} = \frac{1500-1420}{1500} = 0.053$$

Backward slip, $$s_b = (2 - s) = (2 - 0.053) = 1.947$$

The effective rotor resistance in backward branch

$$= \frac{R_2}{2(2-s)} = \frac{7.5}{2(2-0.053)} = 1.926\ \Omega \approx 1.93\ \Omega$$

23. **(d)**

Given transformer rating 50 kVA, 22 kV/220 V percent resistance = 1% percent reactance = 8%.

Taking hv side voltage as base voltage is 22 kV.

Base apparent power, $S_B = 50$ kVA

As primary is Δ connected.

Phase voltage, V_P = line voltage, V_L

$\therefore$ Base impedance, $$Z_{base} = \frac{3(V_{\phi,base})^2}{S_{base}} = \frac{3\times(22000)^2}{50\times10^3} = 29040\ \Omega$$

The per unit impedance of transformer,

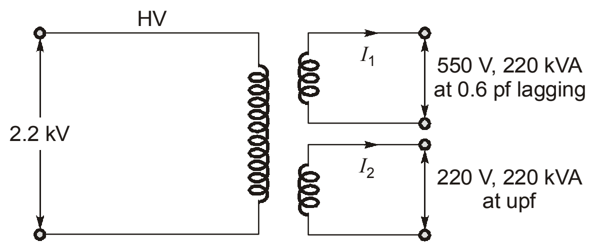
$$Z_{eq\ pu} = 0.01 + j0.08 \text{ pu}$$

$\therefore$ High voltage side impedance,

$$Z_{ph\ hv} = Z_{eq\ pu} \times Z_{base} = (0.01j + j0.08) \times 29040 = 290.40 + j2323.2\ \Omega$$

24. **(b)**

Consider the below circuit:



Rated current in winding - 1

$$I_1 = \frac{220\times1000}{550} = 400\angle-53.13°\text{ A}$$

Rated current in winding - 2

$$I_2 = \frac{220\times1000}{220} = 1000\angle0°\text{ A}$$

Current in HV side due to rated current in winding - 1

$$I_1' = \frac{(400\angle-53.13)\times0.55}{2.2} = 100\angle-53.13°\text{ A}$$

Current in HV side due to rated current in winding - 2

$$I_2' = \frac{(1000\angle0°)\times0.22}{2.2} = 100\angle0°\text{ A}$$

HV side current = $100\angle-53.13° + 100\angle0°$

$I = 178.885\angle-26.565$ A

$|I| = 178.885$ A

25. **(d)**

Given,Starting torque, $T_{st} = 0.65\ T_{fl}$

Short circuit current, $I_{sc} = 5\ I_{fl}$

Full load slip, $s_{fl} = 0.04$

As we know; for auto-transformer starting

$$\frac{T_{st}}{T_{fl}} = x^2\left(\frac{I_{sc}}{I_{fl}}\right)^2 s_{fl}$$

$$\frac{0.65}{1} = x^2\left(\frac{5}{1}\right)^2 \times0.04$$

$$x^2 = \frac{0.65}{25\times0.04}$$

Transformation ratio, $x = 0.806 \approx 0.81$

26. **(c)**

For transformer,

$$\frac{E_2}{E_1} = \frac{N_2}{N_1} = K \text{ (transformation ratio)}$$

the transformation ratio does not depend on frequency

Hence; $$\frac{E_2'}{E_2} = \frac{E_1'}{E_1} = K$$

Here, $$K = \frac{440}{110} = 4$$

therefore, on l.v. side voltage E_2', when h.v. side voltage E_1' = 300 V is,

$$E_2' = \frac{300}{440} \times 110 = 75 \text{ V}$$

The frequency does not change on l.v. side as transformer is a constant frequency machine.

27. **(b)**

The mmf distribution contains a fundamental and a family of space harmonics of order $h = 6m \pm 1$, where m is is positive number.

In a three phase machine, when sinusoidally varying currents flow through the winding, the space harmonic wave rotate at $(1/h)$ times the speed of the fundamental wave. The space harmonic waves rotate in the same direction as the fundamental wave if $h = 6m + 1$ and in the opposite direction if $h = 6m - 1$.

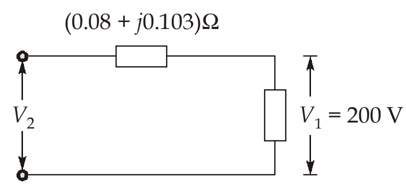
28. **(d)**

By referring the transformer impedance to LV side,

$$R_{LV} = 0.05 + \frac{3}{(10)^2} = 0.08\ \Omega$$

$$X_{LV} = 0.05 + \frac{5.3}{(10)^2} = 0.103\ \Omega$$

Drawing circuit representation,



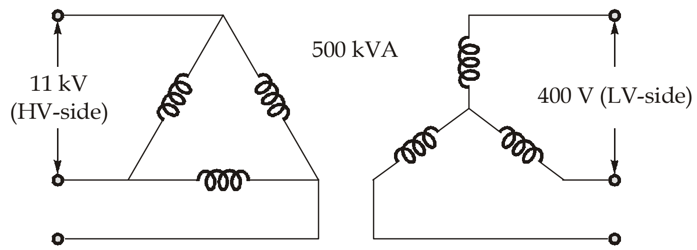
$$\text{Current, } I_2 = \frac{20 \times 1000}{200} = 100 \text{ A}$$

$$\text{Voltage drop} = 100(0.08 \times 0.8 + 0.103 \times 0.6) = 12.58 \text{ V}$$

$$\text{Voltage regulation} = \frac{12.58}{200} \times 100 = 6.29\%$$

29. **(b)**

For given transformer configuration,



Phase current at star side,

$$I_{PY\ (\text{rated})} = \frac{500}{\sqrt{3}\times 0.40} = 721.687\ \text{A}$$

Phase current at delta side,

$$I_{P\Delta\ (\text{rated})} = \frac{500}{3\times 11} = 15.151\ \text{A}$$

$$\text{At lv side, resistance } R_{LV} = \frac{2000}{3\times(721.687)^2} = 1.28\times 10^{-3}\ \Omega$$

$$\text{At hv side, resistance } R_{HV} = \frac{2500}{3\times(15.15)^2} = 3.63\ \Omega$$

Turn ratio,

$$\frac{\text{Phase voltage (hv side)}}{\text{Phase voltage (lv side)}} = \frac{11}{0.40/\sqrt{3}} = 47.63$$

Referred values on delta side (Δ side)

$$R_{eq}\ (\text{HV}) = 3.63 + 1.28\times 10^{-3}\ (47.63)^2 = 6.53\ \Omega\ \text{(per phase)}$$

$$X(\text{p.u.}) = 0.05$$

$$Z_{\text{base (HV)}} = \frac{11000}{15.15} = 726.024\ \Omega$$

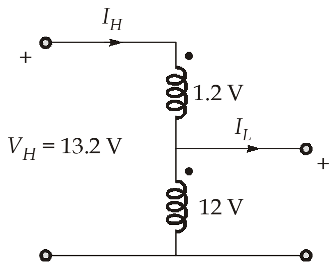
$$X_{\text{eq HV}} = 0.05\times 726.024 = 36.30\ \Omega\ \text{(per phase)}$$

30. (c)

The apparent power rating will be

$$S_{\text{auto}} = \frac{N_{\text{series}} + N_{\text{common}}}{N_{\text{series}}} S_{TW}$$

$$= \frac{1.2+12}{1.2}\times 1000 = 11000\ \text{KVA}$$



The transformer impedance in p.u. system when connected in two winding manner is,

$$Z_{eq} = (0.01 + j0.08)\ \text{p.u.}$$

The apparent power advantage of this auto transformer is 11, so the per unit impedance of the auto transformer is,

$$Z_{eq} = \frac{0.01 + j0.08}{11} = (0.00091 + j0.00727)\ \text{p.u.}$$

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