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NPTEL

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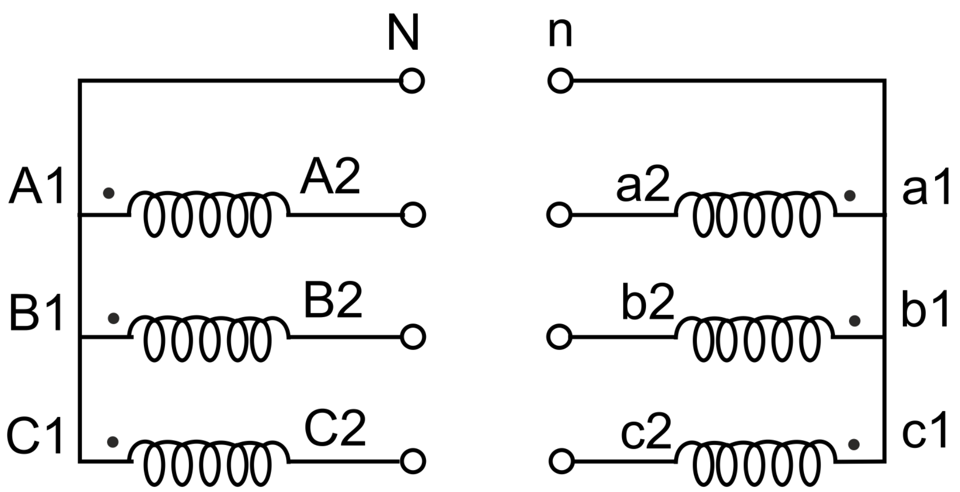
Courses » **Electrical Machines - I**

Announcements **Course** Forum Progress Mentor

Unit 6 - Week 5

Week 5: Assignment

1) Three single phase two winding transformers are connected as shown in figure to form a three phase transformer bank. The High voltage(HV) windings are denoted by "ABC" and low voltage(LV) windings are denoted by "abc". If a thee phase line-to-line voltage of 220V is applied across the high voltage terminal, what is the LV side terminal voltage and its phase with respect to the corresponding HV - side terminal voltage? The turns ratio is 6 : 1. ***10 points***



- 21.16∠ 0^o V
- 21.16∠ 30^o V
- 36.65 ∠ 0^o V
- 36.65 ∠ 30^o V

Accepted Answers:

36.65 ∠ 0^o V

2) Three single phase two winding transformers are connected as shown in figure to form a three phase transformer bank. The High voltage(HV) windings are denoted by "ABC" and low voltage(LV) windings are denoted by "abc". If a thee phase line-to-line voltage of 220V is applied across the high voltage terminal, what is the LV side terminal voltage and its phase with respect to the corresponding HV - side terminal voltage? The turns ratio is 6 : 1. ***10 points***

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Week 10
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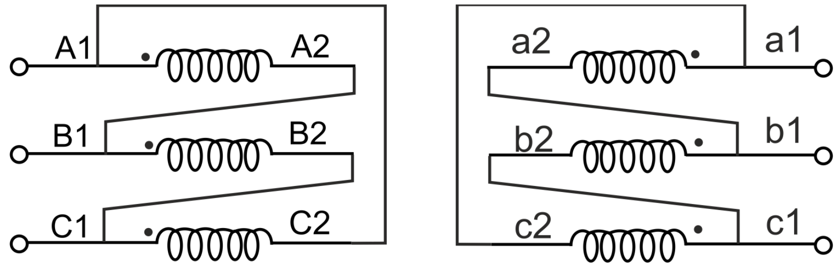
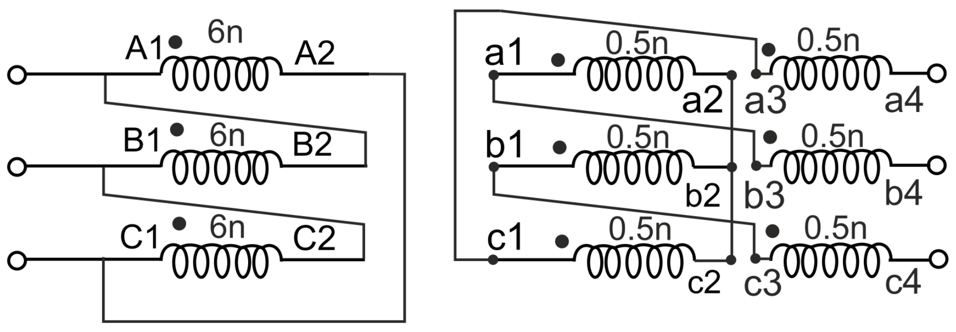
Week 12



- 36.65 ∠ 0^o V
- 21.16 ∠ 30^o V
- 36.65 ∠ 30^o V
- 21.16 ∠ 0^o V

Accepted Answers:
36.65 ∠ 0^o V

3) Three single phase transformers are connected as shown in figure to form a three phase transformer bank. The High voltage(HV) windings are denoted by "ABC" and low voltage(LV) windings are denoted by "abc". If a thee phase line-to-line voltage of 220V is applied across the high voltage terminal, what is the LV side terminal voltage and its phase with respect to the corresponding HV - side terminal voltage? The turns ratio is 6 : 1. The low-voltage side winding is split into two parts of equal number of turns to form zig-zag connection. ***10 points***

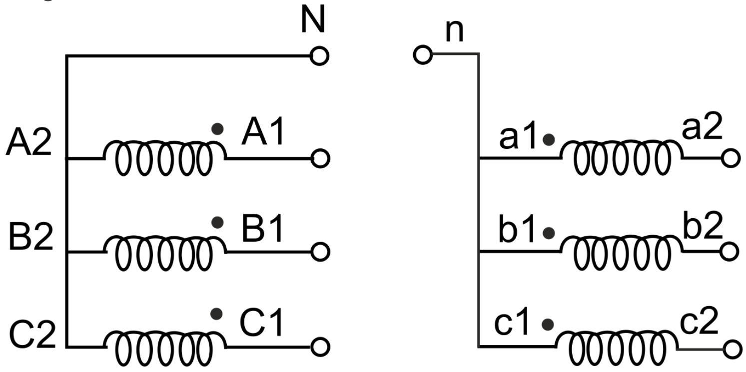


- 32.61 ∠ -30^o V
- 32.61 ∠ 0^o V
- 56.48 ∠ 0^o V
- 56.48 ∠ -30^o V

Accepted Answers:
56.48 ∠ 0^o V

4) Three single phase two winding transformers are connected as shown in figure to form a three phase transformer bank. The High voltage(HV) windings are denoted by "ABC" and low voltage(LV) windings are denoted by "abc". If a thee phase line-to-line voltage of 220V is applied across the high voltage terminal, what is the LV side terminal voltage and its phase with respect to the corresponding HV - side terminal ***10 points***

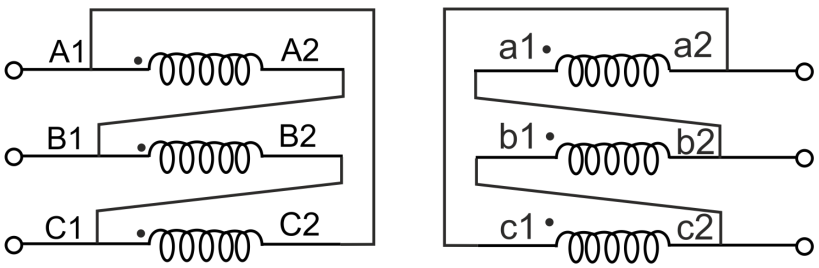
voltage? The turns ratio is 6 : 1.



- 36.65 ∠ 0^o V
- 36.65 ∠ 180^o V
- 36.65 ∠ -30^o V
- 21.16∠ 0^o

Accepted Answers:
36.65 ∠ 180^o V

5) Three single phase two winding transformers are connected as shown in figure to form a three phase transformer bank. The High voltage(HV) windings are denoted by “ABC” and low voltage(LV) windings are denoted by “abc”. If a thee phase line-to-line voltage 220V is applied across the high voltage terminal, what is the LV side terminal voltage and its phase with respect to the corresponding HV - side terminal voltage? The turns ratio is 6 : 1. ***10 points***



- 36.65 ∠ -30^o V
- 36.65 ∠ 180^o V
- 36.65 ∠ 30^o V
- 36.65 ∠ 0^o V

Accepted Answers:
36.65 ∠ 180^o V

6) A 50 kVA 13,800/208 V Δ/Y distribution transformer has a resistance of 0.02 per unit and a reactance of 0.08 per unit. Calculate the transformer’s % voltage regulation at full load and 0.8 PF lagging. Assume that,the transformer secondary is operating at the rated voltage. (Take into account the angle delta between the induced voltage and terminal voltage.)

Note-Please enter only the numeric value while entering your answer. For example if the answer is '25.25%', please enter only the numeric value i.e. 25.25. Please do not enter the '%' or any units. Approximation can be done on your answer. For example if your answer is 0.5356, then 0.53, 0.536, 0.5356 or 0.5 are all acceptable answers.

Accepted Answers:
(Type: Range) 5.5,7.5

10 points

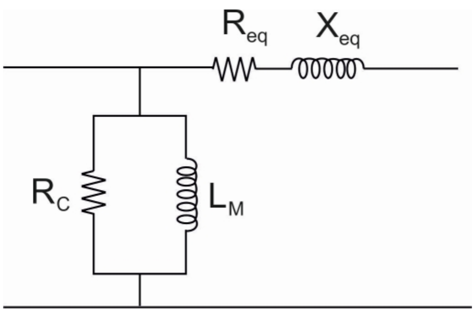
7) A 150-kVA 11000/480-V Δ/Y distribution transformer has the following OC and SC test parameters. The open-circuit test was performed on the low-voltage side of this transformer bank, and the following data were recorded: ***10 points***

Vline,OC = 480V IlineOC = 10A P3φ,OC = 1500W

The short-circuit test was performed on the high-voltage side of this transformer bank, and the following data were recorded:

Vline,SC = 550 V, Iline,SC = 8A P3φ,SC = 3000W

Find the per-phase equivalent circuit of the transformer referred to LV side.



- Rc=153ohm,Xm=28ohm,Req=0.029ohm,Xeq=0.068ohm
- Rc=28ohm,Xm=153ohm,Req=0.068ohm,Xeq=0.029ohm
- Rc=120ohm,Xm=19ohm,Req=0.015ohm,Xeq=0.033ohm
- Rc=19ohm,Xm=120ohm,Req=0.033ohm,Xeq=0.015ohm

Accepted Answers:
Rc=153ohm,Xm=28ohm,Req=0.029ohm,Xeq=0.068ohm

8) Find the voltage regulation of the transformer given in Problem. 8, at the rated load and 0.9 pf lagging.

Note-Please enter only the numeric value while entering your answer. For example if the answer is '25.25%', please enter only the numeric value i.e. 25.25. Please do not enter the '%' or any units. Approximation can be done on your answer. For example if your answer is 0.5356, then 0.53, 0.536, 0.5356 or 0.5 are all acceptable answers.

Accepted Answers:
(Type: Range) 3,4

10 points

9) Find the efficiency of the transformer given in Problem 8 at rated load and 0.9 pf lagging.

Note-Please enter only the numeric value while entering your answer. For example if the answer is '25.25%', please enter only the numeric value i.e. 25.25. Please do not enter the '%' or any units. Approximation can be done on your answer. For example if your answer is 0.5356, then 0.53, 0.536, 0.5356 or 0.5 are all acceptable answers.

Accepted Answers:
(Type: Range) 96.4-97.2

10 points

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Q1.Solution

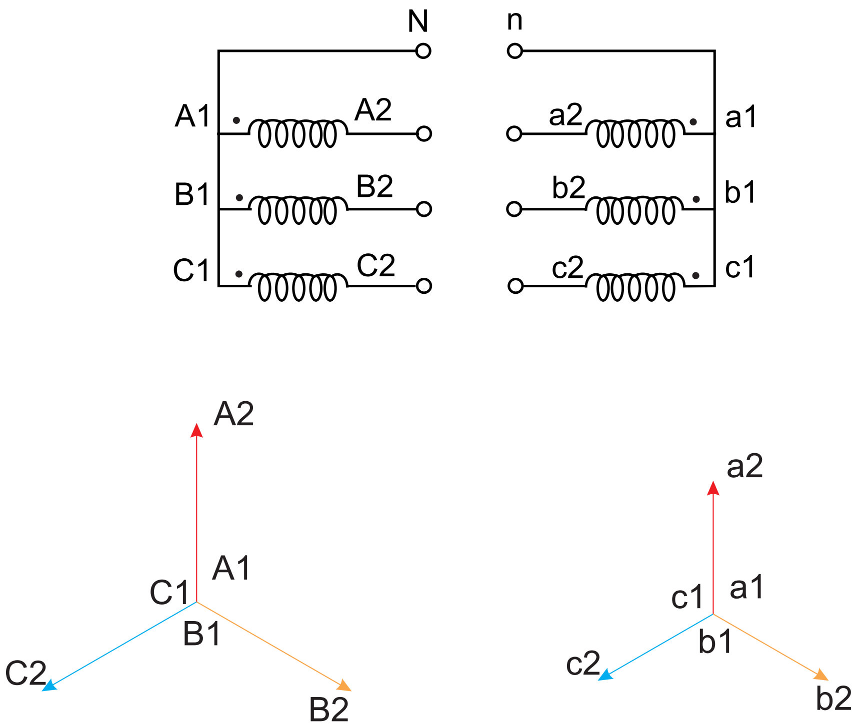


Figure 1:

$$V_{a1a2} = \frac{V_{A1A2}}{\sqrt{3} \times 6} = \frac{220}{\sqrt{3} \times 6} = 21.16V$$

Hence, LV side terminal voltage, $V_{lv} = \sqrt{3} \times 21.16 = \mathbf{36.65V}$

Phase with respect to corresponding HV side voltage, $= 0^o$.

Q2.Solution

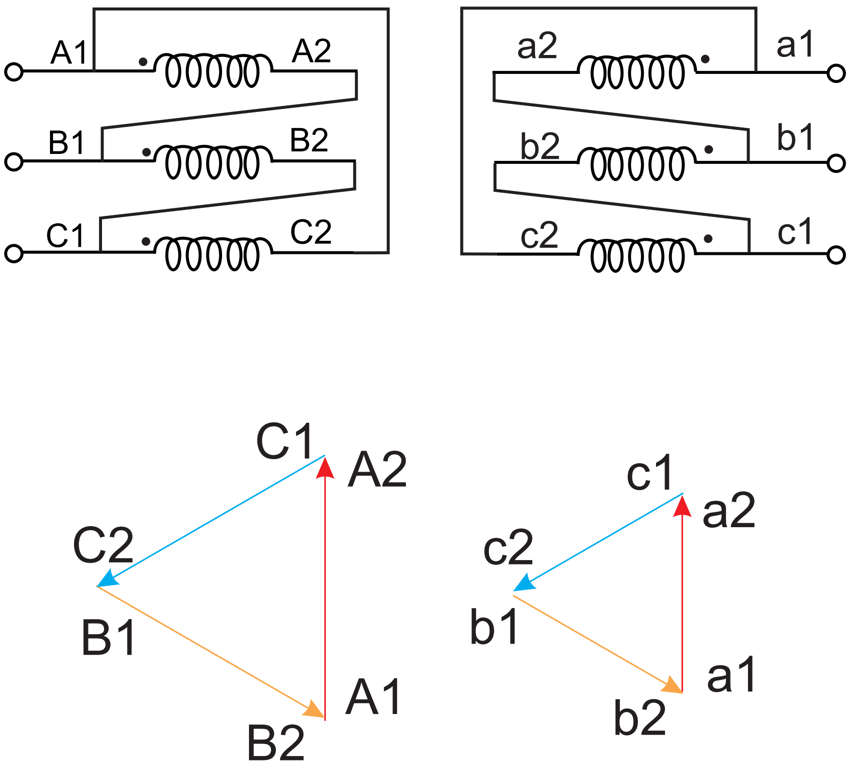


Figure 2:

$$V_{a1a2} = \frac{V_{A1A2}}{6} = \frac{220}{6} = 36.67V$$

Hence, LV side terminal voltage, $V_{lv} = \mathbf{36.65V}$

Phase with respect to corresponding HV side voltage, $= \mathbf{0}^{o}$.

Q3.Solution

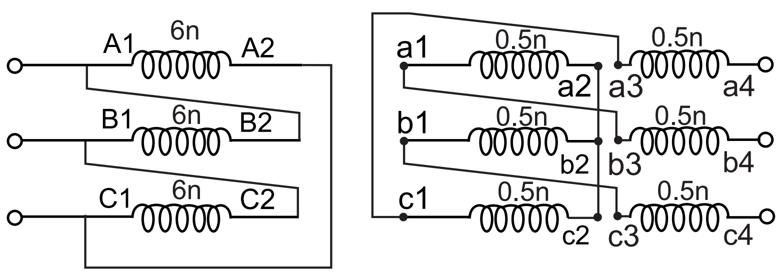
$$V_{c2c1} = \frac{V_{C1C2}\angle -60^o}{12} = \frac{220\angle -60^o}{12} = 18.83\angle -60^o V$$

$$V_{a3a4} = \frac{V_{A2A1}\angle 0^o}{12} = \frac{220\angle 0^o}{12} = 18.83\angle 0^o V$$

$$V_{a2a4} = 18.83\angle -60^o + 18.83\angle 0^o = 32.61\angle -30^o V$$

The line voltage would be leading this voltage by 30 degrees

Hence, LV side terminal voltage, $V_{lv} = \sqrt{3} \times 32.61 = \mathbf{56.48\angle 0^o} V$



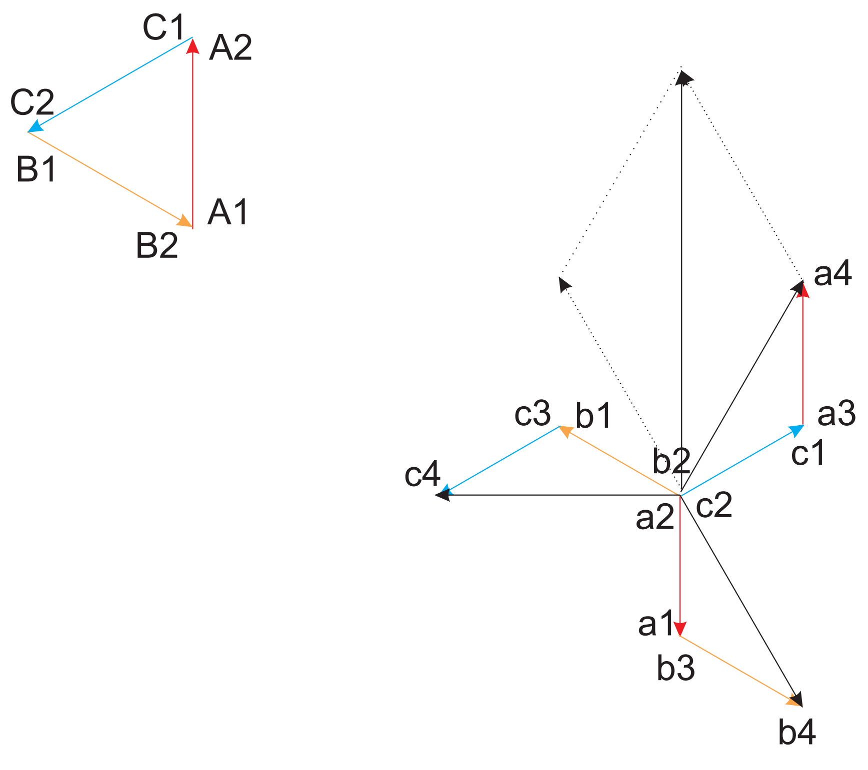


Figure 3:

Q4.Solution

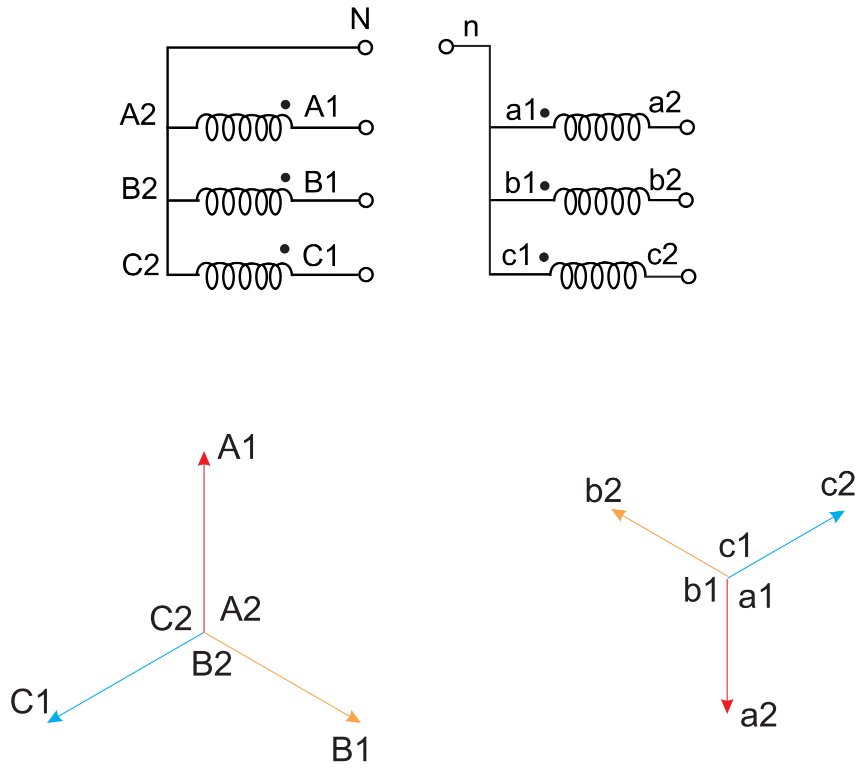


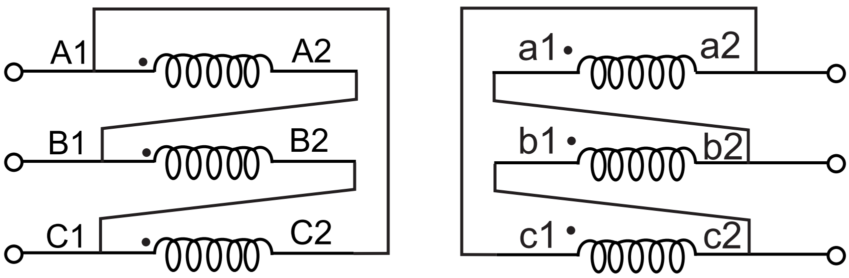
Figure 4:

$$V_{a1a2} = \frac{V_{A2A1}}{\sqrt{3} \times 6} = \frac{220\angle 180^o}{\sqrt{3} \times 6} = 21.16\angle 180^o V$$

Hence, LV side terminal voltage, $V_{lv} = \sqrt{3} \times 21.16 = \mathbf{36.65V}$

Phase with respect to corresponding HV side line voltage, $= \mathbf{180^o}$.

Q5.Solution



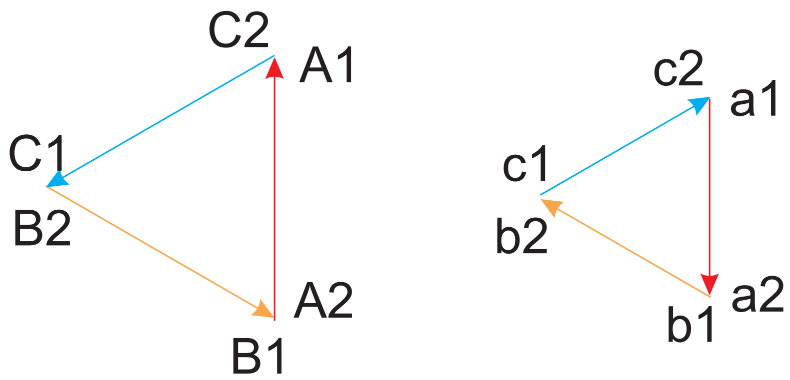


Figure 5:

$$V_{a1a2} = \frac{V_{A1A2}}{6} = \frac{220}{6} = 36.67V$$

LV side terminal voltage, $V_{lv} = -V_{a1a2} = V_{a2a1}$

$$V_{a2a1} = \mathbf{36.65\angle 180^o}V$$

Phase with respect to corresponding HV side voltage, $= 180^o$.

Q6.Solution

$$V_{b2b1} = \frac{V_{B2B1}\angle 60^o}{12} = \frac{220\angle 60^o}{12} = 18.83\angle 60^o V$$
$$V_{a3a4} = \frac{V_{A2A1}\angle 0^o}{12} = \frac{220\angle 0^o}{12} = 18.83\angle 0^o V$$
$$V_{a2a4} = 18.83\angle 60^o + 18.83\angle 0^o = 32.61\angle 30^o V$$

Hence, LV side terminal voltage, $V_{lv} = \sqrt{3} \times 32.61 = \mathbf{56.48}\angle 60^o V$

The line voltage at the HV side is leading corresponding phase voltage by 30 degrees

Hence, phase with respect to corresponding HV side line voltage, $= \mathbf{30}^o$.

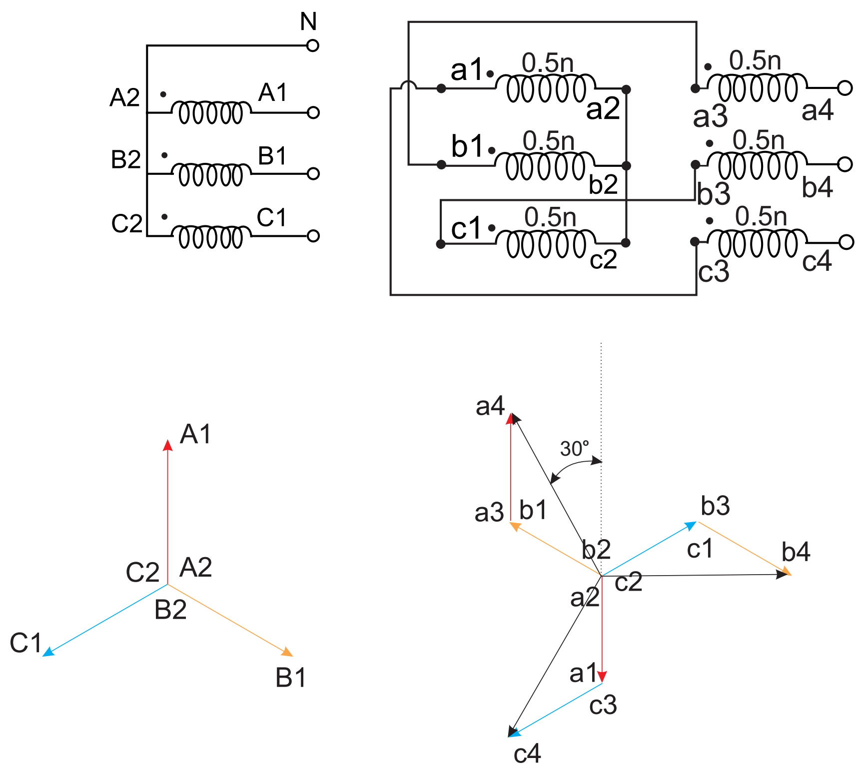


Figure 6:

Q7.Solution

The rating of the transformer bank: $50kVA \quad 13,800/208V$

Base line voltage at high-voltage side, : $13,800V$

Base apparent power of the transformer, : $50kVA$

Since, primary side is Δ connected, its phase voltage is equal to its line voltage.

Primary side base impedance, $Z_{base} = \frac{3V_{base}^2}{S_{base}} = \frac{3 \times 13,800^2}{50,000} = 11,426\Omega$

The per-unit impedance of the transformer is, $Z_{eq\_pu} = 0.02 + j0.08pu$

Hence, the equivalent leakage impedance referred to high-voltage side,

$$Z_{eq\_HV} = (0.02 + j0.08) \times 11,426 = 228.52 + 914.08j$$

The voltage regulation of a three-phase transformer bank can be determined by finding the voltage regulation of any single phase transformer in the bank.

The rated transformer phase voltage on primary is 13,800V.

Hence, the rated phase current on the primary, $I_{rated\_HV} = \frac{50,000}{3 \times 13,800} = 1.208A$

The rated phase voltage on the secondary of the trasnformer is $\frac{208}{\sqrt{3}} = 120.08V$

120.08V in the secondary side, when referred to the primary side is equal to 13,800V

The primary side phase voltage, corresponding to rated voltage at the secondary,

$$V_{ph\_HV} = V'_{ph\_LV} + I_{rated\_HV}\angle -36.86^o \times Z_{eq\_HV}(228.52 + 914.08j)$$

$$= 13,800 + 1.208\angle -36.86 \times (228.52 + 914.08j) = 14,700.78\angle 2.7^o$$

Hence, voltage regulation, VR $= \frac{14700 - 13,800}{13,800} \times 100 = 6.52\%$

Q8.Solution

For the per phase equivalent circuit , per phase quantities have to be considered

Open circuit test

$$V_{phase,oc} = V_{line,oc}/\sqrt{3} = 480/\sqrt{3} = 277V$$

$$I_{phase,oc} = I_{line,oc} = 10A$$

$$P_{per,phase} = P_{3phase}/3 = 1500/3 = 500W$$

$$\therefore Z_{noload} = \frac{V_{phase,oc}}{I_{phase,oc}} = \frac{277}{10} = 27.7ohm$$

$$\text{No load power factor } (\cos\phi) = \frac{500}{277 \times 10} = 0.1804$$

$$\implies \phi = cos^{-1}(0.1804) = 79.61$$

$$\therefore Z_{noload} = 27.7\angle 79.61$$

$$\therefore Y_{noload} = 1/Z_{noload} = 6.516 \times 10^{-3} - j0.0355$$

$$\therefore R_c = 1/6.516 \times 10^{-3} = \textbf{153.45 ohm}, and$$

$$X_m = 1/0.0355 = \textbf{28.16 ohm}$$

Short circuit test

$$V_{phase,sc} = V_{line,sc} = 550V$$

$$I_{phase,sc} = I_{line,sc}/\sqrt{3} = 8/\sqrt{3} = 4.62A$$

$$P_{per,phase} = P_{3phase}/3 = 3000/3 = 1000W$$

$$\therefore Z_{eq} = 550/4.62 = 119.1\text{ohm}$$

$$\text{Power factor } (\cos\phi) = \frac{1000}{550 \times 4.620} = 0.3936$$

$$\implies \phi = cos^{-1}(0.3936) = 66.8$$

$$\therefore Z_{eq} = 119.1\angle 66.8 = 46.9 + j109.47$$

$$\text{This impedance referred to LV side } = \frac{Z_{eq}}{N^2}, \text{N being the turn raio}$$

$$N = \frac{11000}{277} = 39.71$$

$$\therefore R_{eq} = 46.9/39.71^2 = \textbf{0.029 ohm}, \text{ and } X_{eq} = 109.47/39.71^2 = \textbf{0.069 ohm}$$

Q9.Solution

$$Regulation = \frac{V_{nl} - V_{fl}}{V_{fl}} \times 100$$

$$V_{fl} = V_{nl} - I_{fl}(Z_{eq})$$

$$I_{fl}(on the LV side) = \frac{150000}{\sqrt{3} \times 480} = 180.42$$

$$\phi = cos^{-1}(0.9) = 25.84$$

$$= 277 - (180.42\angle 25.84)(0.029 + 0.069j) = 267.014\angle - 1.91$$

$$\therefore Regulation = \frac{277 - 267}{277} \times 100 = \textbf{3.61 \%}$$

Q10.Solution

$$Efficiency = \frac{P_{out}}{P_{in}} \times 100 = \frac{P_{out}}{P_{out} + IronLosses + CopperLosses}$$

Iron loss and full load copper loss are the values obtained from the OC and SC test respectively

$$= \frac{150000 \times 0.9}{15000 \times 0.9 + 1500 + 3000} = \textbf{96.77\%}$$