

12) Three-Phase Transformers

To meet the demand for three-phase power transmission, transformer connections compatible with three-phase operations are needed. We can achieve the transformer connections in two ways: by connecting three single-phase transformers, thereby forming a so-called *transformer bank*, or by using a special three-phase transformer. For the same kVA rating, a three-phase transformer is always smaller and cheaper than three single-phase transformers. When single-phase transformers are used, one must ensure that they have the same turns ratio n to achieve a balanced three-phase system. There are four standard ways of connecting three single-phase transformers or a three-phase transformer for three-phase operations: Y-Y, Δ - Δ , Y- Δ , and Δ -Y.

For any of the four connections, the total apparent power S_T , real power P_T , and reactive power Q_T are obtained as

$$S_T = \sqrt{3} V_L I_L \quad \dots(12.1)$$

$$P_T = S_T \cos \theta = \sqrt{3} V_L I_L \cos \theta \quad \dots(12.2)$$

$$Q_T = S_T \sin \theta = \sqrt{3} V_L I_L \sin \theta \quad \dots(12.3)$$

Where, V_L = line voltage , I_L = line current

(V_{Lp} = line voltage for the primary side, V_{Ls} = line voltage for the secondary side)

(I_{Lp} = line current for the primary side, I_{Ls} = line current for the secondary side)

For Y-Y & Δ - Δ transformer in Fig.12.1(a)(b),

$$V_{Ls} = n V_{Lp} \quad \dots(12.4a)$$

$$I_{Ls} = \frac{I_{Lp}}{n} \quad \dots(12.4b)$$

For Y- Δ , transformer in Fig.12.1(c),

$$V_{Ls} = \frac{n V_{Lp}}{\sqrt{3}} \quad \dots(12.5a)$$

$$I_{Ls} = \frac{\sqrt{3} I_{Lp}}{n} \quad \dots(12.5b)$$

For Δ -Y, transformer in Fig.12.1(d),

$$V_{Ls} = n \sqrt{3} V_{Lp} \quad \dots(12.6a)$$

$$I_{Ls} = \frac{I_{Lp}}{n \sqrt{3}} \quad \dots(12.6b)$$

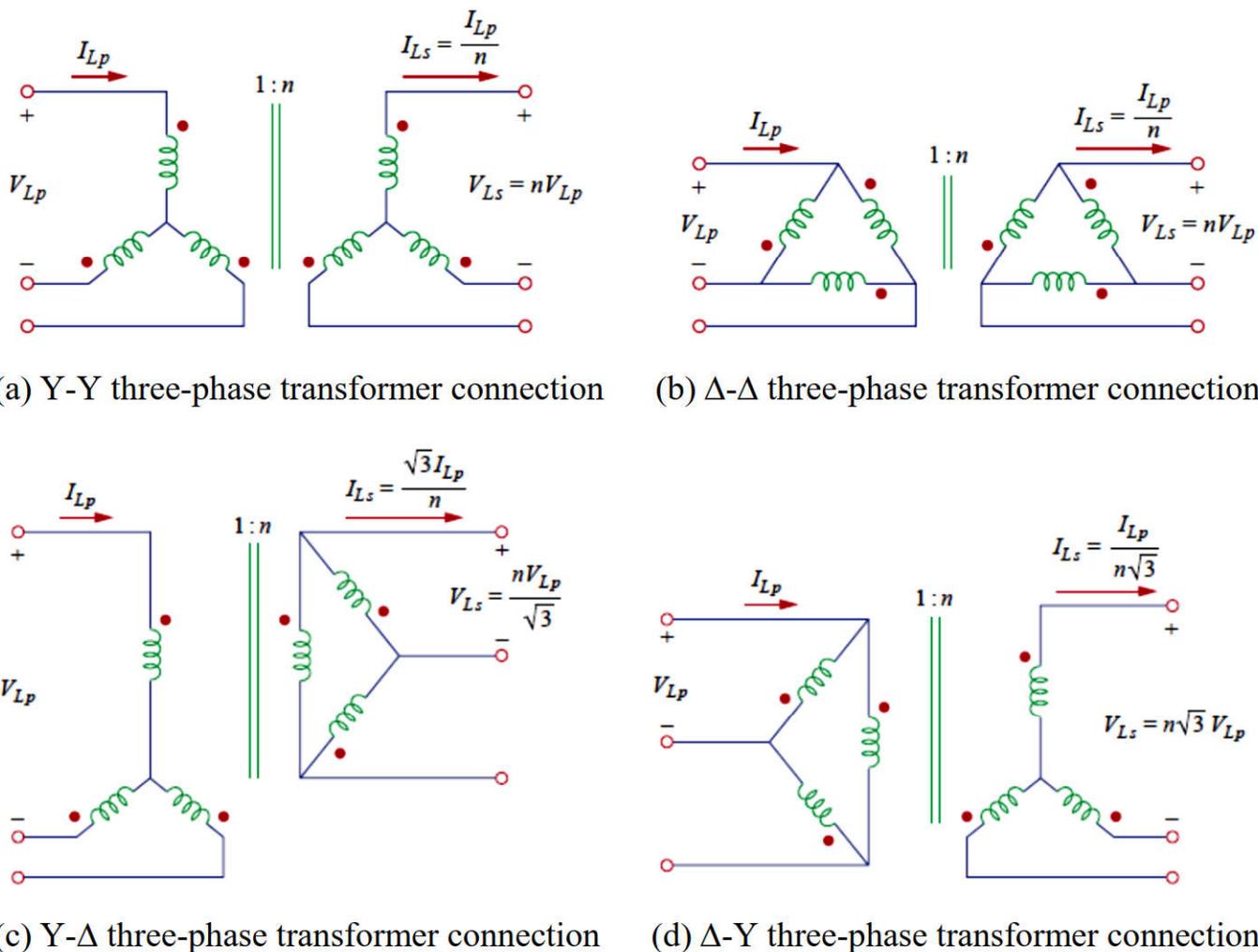


Fig.12.1

Example 14: The 42-kVA balanced load depicted in Fig. is supplied by a three-phase transformer. (a) Determine the type of transformer connections. (b) Find the line voltage and current on the primary side. (c) Determine the kVA rating of each transformer used in the transformer bank. Assume that the transformers are ideal.

Solution:

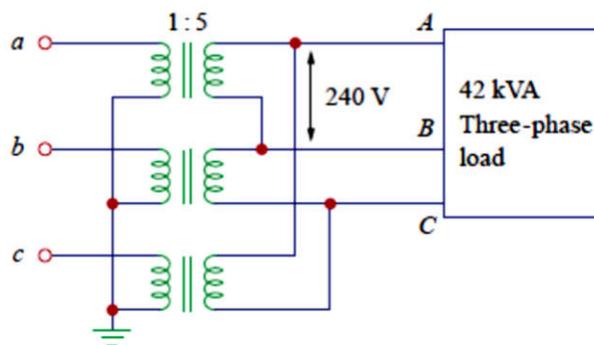
(a) The transformer is Y-Δ connected

(b)

$$I_{Ls} = \frac{S_T}{\sqrt{3} V_{Ls}} = \frac{42000}{\sqrt{3} \times 240} = 101 \text{ A}$$

$$I_{Ls} = \frac{\sqrt{3} I_{Lp}}{n} \rightarrow 101 = \frac{\sqrt{3} I_{Lp}}{5}$$

$$\therefore I_{Lp} = 292 \text{ A}$$



$$V_{Ls} = \frac{nV_{Lp}}{\sqrt{3}} \rightarrow 240 = \frac{5V_{Lp}}{\sqrt{3}}$$

$$\therefore V_{Lp} = 83.14 \text{ V}$$

(C) Because the load is balanced, each transformer equally shares the total load and since there are no losses (assuming ideal transformers), the kVA rating of each transformer is

$$S = \frac{S_T}{3} = 14 \text{ kVA}$$

Or from primary side Y

$$V_{Lp} = V_{Ls} = 240$$

$$I_{Ls} = \frac{I_{Lp}}{\sqrt{3}} = \frac{292}{\sqrt{3}} = 58.34 \text{ A}$$

$$S = 240 \times 58.34 = 14 \text{ kVA}$$

Or you can find it from secondary side Δ

H.W.12: A three-phase - transformer is used to step down a line voltage of 625 kV, to supply a plant operating at a line voltage of 12.5 kV. The plant draws 40 MW with a lagging power factor of 85 percent. Find: (a) the current drawn by the plant, (b) the turns ratio, (c) the current on the primary side of the transformer, and (d) the load carried by each transformer.

Answer: (a) 2.1736 kA, (b) 0.02, (c) 43.47 A, (d) 15.69 MVA.

H.W. : find i_1 , i_2 , and i_3 in Fig.

Answer:

$$I_1 = 0.4654 \angle -70.25^\circ \text{ A}$$

$$I_2 = 0.2114 \angle -75.75^\circ \text{ A}$$

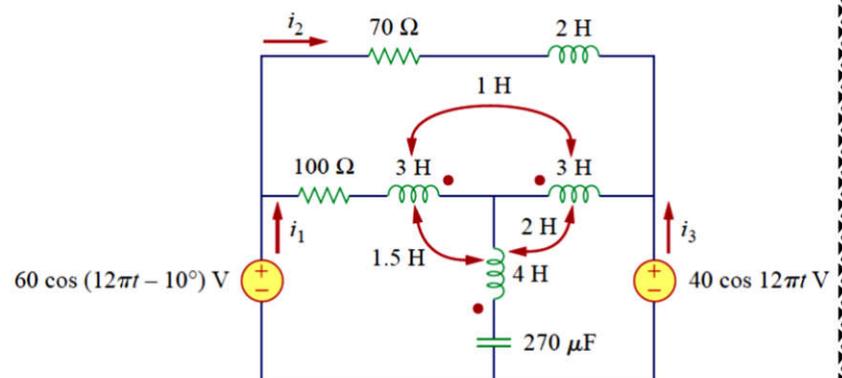
$$I_3 = 0.1095 \angle 17.15^\circ \text{ A}$$

Or

$$i_1 = 0.4654 \cos(12\pi t - 70.25^\circ) \text{ A}$$

$$i_2 = 0.2114 \cos(12\pi t - 75.75^\circ) \text{ A}$$

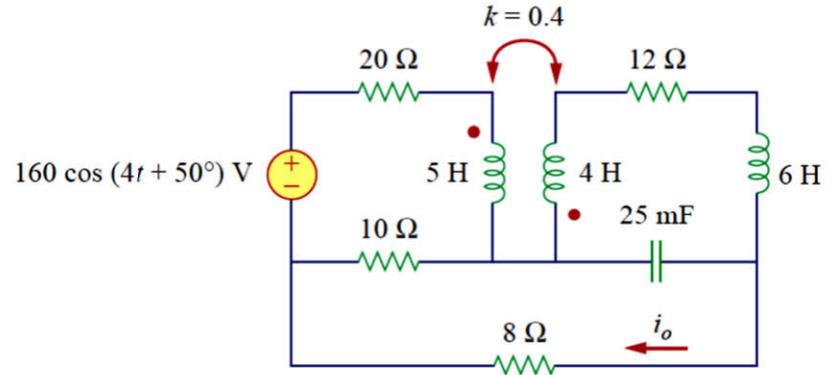
$$i_3 = 0.1095 \cos(12\pi t + 17.15^\circ) \text{ A}$$



H.W. : find i_o in Fig.

Answer:

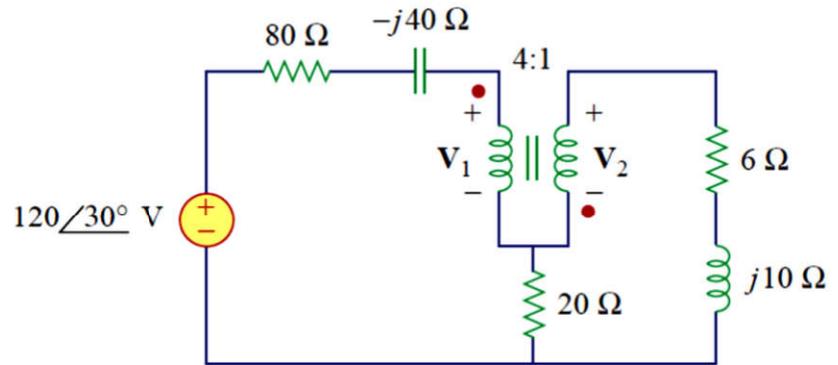
$2.012 \cos(4t + 68.52^\circ) \text{ A}$



H.W. : find V_1 & V_2 in the ideal transformer circuit of Fig.

Answer:

$91.12 \angle 37.92^\circ \text{ V},$
 $22.78 \angle -142.1^\circ \text{ V}$



H.W. : find V_1 & V_2 in the ideal transformer circuit of Fig.

Answer:

$138.82 \angle 28.65^\circ \text{ V}, 208.2 \angle -151.4^\circ \text{ V}$

