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A13

15

BASIC ELECTRICAL ASSIGNMENT-4

1) Calculate the active and reactive current components in each phase of a star connected 10,000V, 3 phase alternator supplying 5000 KW at a power factor of 0.8. If the total current remains the same when the load power factor is raised to 0.9, find the new output.

(soln):- we have,

$V_L = 10{,}000V$

$P = 5000 KW$

$\cos\phi = 0.8$

$P = 3 V_{ph} I_{ph} \cos\phi$

$V_{ph} = \frac{V_L}{\sqrt{3}}$ for a star system

$\Rightarrow 5000 \times 10^3 = \sqrt{3} \times 10000 \times I_{ph} \times 0.8$

$I_{ph} = \frac{5 \times 10^{6-2}}{0.8 \times \sqrt{3} \times 10^2}$

$I_{ph} = 360.84$ amp

Active component of current $= I_{ph} \cos\phi$

$= 360.84 \times 0.8$

$= 289A$

reactive component of current $= I_{ph} \sin\phi$

$= 360.84 \sqrt{1-(0.8)^2}$

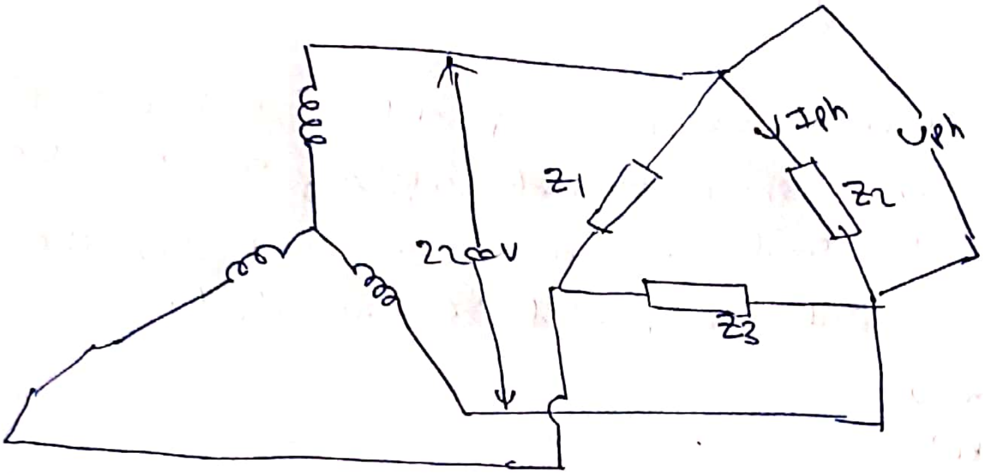
$= 266A$

If power factor $= 0.9$

$P = \sqrt{3} \times 10^4 \times 360.84 \times 0.9$ $[\because I_{ph} = 360.84$ amp$]$

$P = 5625$ KW

2) A 3-phase star-connected alternator feeds a 2000 hP-delta connected induction motor having a P.F. of 0.95 and an efficiency of 0.93. Calculate the current and the active and reactive components in (a) each alternator phase (b) each motor phase. The line voltage is 2200 V.



(b) we have,

$\cos\phi = 0.85$

From the diagram,

$V_{ph} = 2200V$

Actual power consumed $= \frac{2000 \times 746}{0.93} = 1604301.075$ watt

$P = 3 V_{ph} I_{ph} \cos\phi$

$\Rightarrow 1604301.075 = 3 \times 2200 \times I_{ph} \times 0.85$

$I_{ph} = 286A$

$\therefore$ Each motor phase current $= 286A$

Active component $= 286 \cos\phi$

$= 286 \times 0.85$

$= 243.1A$

reactive component $= 286 \sin\phi$

$= 286 \sqrt{1-(0.85)^2}$

$= 286 \times 0.526$

$= 150.436A$

(c) we have, $I_{ph} = 286A$

we know for a delta connected system,

$I_L = \sqrt{3} I_{ph}$

$\Rightarrow I_L = 286 \times 1.732$

$I_L = 496A$

Active component $= 496 \times 0.85$

$= 421A$

reactive component $= 496 \times 0.52$

$= 262A$

3.) A balanced star connected load of 8+6j Ω per phase is connected to a 3 phase, 230V supply. Find the line current, power factor, power, reactive volt ampere and total volt-amperes.

Soln) we have, $Z = 8+6j$

$V_L = 230V$

Power factor $\cos\phi = \frac{8}{\sqrt{8^2+6^2}} = \frac{8}{10} = 0.8$

$V_{ph} = \frac{V_L}{\sqrt{3}}$ for a star system

$\Rightarrow V_{ph} = 132.79V$

$I_{ph} = I_L$

$P = 3 V_{ph} I_{ph} \cos\phi$ - (i)

$I_{ph} = \frac{V_{ph}}{Z_{ph}}$

$|Z_{ph}| = \sqrt{(8)^2+(6)^2} = 10\Omega$

$I_{ph} = \frac{132.79}{10} = 1.3279 A \times 10$

$\boxed{I_L = 1.3279A} \times 10$

$\boxed{I_L = 13.3A}$

$P = 132.8 \times 3 \times 13.3 \times 0.8$

$P = 1412.99 W \times 3$

$P = 4250W$

Line voltage $V_L = \frac{\text{input kVA} \times 1000}{\sqrt{3} I_L}$

$kVA = \frac{V_L \times \sqrt{3} I_L}{1000}$

$VA = \sqrt{3} \times 230 \times 13.3$

$VA = 5280 VA$

$RVA = \sqrt{VA^2 - W^2}$

$RVA = \sqrt{(5280)^2 - (4250)^2}$

$RVA = 3130 VA$

9) A balanced 3-phase star connected load of 150 kW takes a leading current of 100A with a line voltage of 1100V, 50 Hz. Find the circuit constants of the load per phase.

(soln) we have,

$V_L = 1100V$

$V_{ph} = \frac{1100}{\sqrt{3}} = 635.08V$

$P = 150 kW$

$I_{ph} = 100A$

$P = 3 V_{ph} I_{ph} \cos\phi$

$150 \times 10^3 = 3 \times 635.08 \times 100 \times \cos\phi$

$\cos\phi = \frac{15 \times 10^4}{3 \times 635.08 \times 100}$

$\cos\phi = 0.787 - (i)$

$Z = R + \frac{j}{\omega C}$ [∵ current is leading, the circuit must be capacitive]

$|Z_{ph}| = \sqrt{R^2 + \frac{1}{\omega^2 C^2}}$

$I_{ph} = \frac{V_{ph}}{Z_{ph}}$

$100 = \frac{635.08}{\sqrt{R^2 + \left(\frac{1}{\omega C}\right)^2}}$

$\sqrt{R^2 + \left(\frac{1}{\omega C}\right)^2} = 6.35 - (ii)$

From (i),

$\frac{R}{\sqrt{R^2 + \left(\frac{1}{\omega C}\right)^2}} = 0.787$

$\frac{R}{6.35} = 0.787$

$R = 6.35 \times 0.787$

$\boxed{R = 5\Omega}$

putting the value of R in (ii) and putting $\omega = 100\pi$

$\sqrt{25 + \left(\frac{1}{100\pi \cdot C}\right)^2} = 6.35$

$\left(\frac{1}{100\pi \cdot C}\right)^2 = (6.35)^2 - 25$

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$$\left(\frac{1}{100\pi \cdot C}\right)^2 = 15.32$$

$$\boxed{C = 810\mu F}$$

5:) A balanced star-connected load is supplied from a symmetric 3 phase, 400 V system. The current in each phase is 30A and lags 30° behind the phase voltage. Find (a) the phase voltage and (b) the total power. Draw the vector diagram showing the currents and voltages.

(Soln) We have,

$V_L = 400V$, $I_{ph} = 30A$

Since the system is symmetric,

$$\therefore V_{ph} = \frac{V_L}{\sqrt{3}} = \frac{400}{\sqrt{3}} = 231\,V.$$

$\cos\phi = \cos 30 = \frac{\sqrt{3}}{2}$ (given)

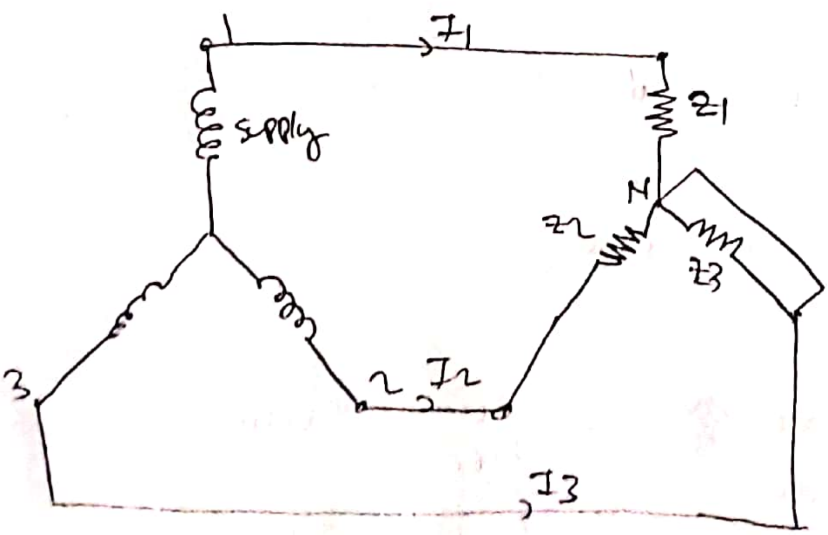
$$\Rightarrow P = 3V_{ph} I_{ph} \cos\phi$$

$$P = 3 \times 231 \times \cancel{30}^{15} \times \frac{\sqrt{3}}{\cancel{2}}$$

$$P = 45 \times 231 \times \sqrt{3}$$

$$P = 18\,kW$$

6:) Three equal star connected inductors take 8 kW at power factor 0.8 when connected to 460V, 3 phase, 3 wire supply. Find the line current if one inductor is short circuited.



(soln) we have,

$V_L = 460V$

$\cos\phi = 0.8$

$P = 8kW$

$P = 3 V_{ph} I_{ph} \cos\phi$

since it is a star connected load

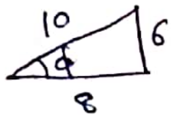
$\Rightarrow V_{ph} = \frac{V_L}{\sqrt{3}} = \frac{460}{\sqrt{3}} = 265.58$ volts

$8000 = 3 \times 265.58 \times I_{ph} \times 0.8$

$I_{ph} = 12.55$ amp

$|Z_{ph}| = \frac{265.58}{12.55}$

$|Z_{ph}| = 21.16\,\Omega$



$\tan\phi = \frac{6}{8}$

$\phi = \tan^{-1}\frac{3}{4}$

$\phi = 37°$

$\therefore \boxed{Z = 21.16\angle 37°}$ [∵ Load is inductive]

Let, $V_1 = 265.58\angle 0$

$V_2 = 265.58\angle -120$

$V_3 = 265.58\angle 120$

since, the circuit is short circuited,

p.d. across $Z_1 = V_1 - V_3$

$= 265.58\angle 0 - 265.58\angle 120$

$Z = 21.16\angle 37°$

$\therefore$ current across $Z_1 = \frac{dV}{Z} = \frac{265.58\angle 0 - 265.58\angle 120}{21.16\angle 37}$

$= \frac{265.58 - [-132.79 + 230j]}{16.918 + 12.696j}$

$I_1 = \frac{398.37 - 230j}{16.918 + 12.696j}$

$$|I_1| = \frac{\sqrt{(398.37)^2 + (230)^2}}{\sqrt{(16.928)^2 + (12.696)^2}}$$

$$\boxed{I_1 = 21.79\ \text{amp}}$$

similarly, p.d. across $Z_2 = 265.58\angle -120 - 265.58\angle 120$

$$\Delta V = -132.79 - 230j - [-132.79 + 230j]$$

$$\Delta V = -460j$$

$$I_2 = \frac{-460j}{16.928 + 12.69j}$$

$$|I_2| = \frac{460}{\sqrt{(16.928)^2 + (12.69)^2}}$$

$$\boxed{I_2 = 21.79\ \text{amp}}$$

since the above system is a 3 wire system, $I_N = 0$

$$\therefore I_1 + I_2 + I_3 = I_N$$

$$\text{or } I_1 + I_2 + I_3 = 0$$

$$\frac{398.37 - 230j}{16.928 + 12.696j} - \frac{460j}{16.928 + 12.696j} + I_3 = 0$$

$$I_3 = \frac{460j - 398.37 + 230j}{16.928 + 12.696j}$$

$$I_3 = \frac{690j - 398.37}{16.928 + 12.696j}$$

$$\boxed{I_3 = 37.6\ \text{amp}}$$

7.) In the two wattmeter method of power measurement in a 3 phase circuit, the readings of the wattmeter are 1000W and 300W. What is the pf of the load? prove the formula used.

(h) we know,

$W_1 = \sqrt{3} V_P I_P \cos(30-\phi)$ -(i)

$W_2 = \sqrt{3} V_P I_P \cos(30+\phi)$ (ii) in a two wattmeter system where,

V_P = phase voltage

I_P = phase current

ϕ = phase angle

Add (i) and (ii)

$W_1 + W_2 = \sqrt{3} V_P I_P [2\cos(30)\cos(-\phi)]$ [$\because \cos C + \cos D = 2\cos\left(\frac{C+D}{2}\right)\cos\left(\frac{C-D}{2}\right)$]

$W_1 + W_2 = 3 V_P I_P \cos\phi$ -(iii)

subtracting (ii) from (i)

$W_1 - W_2 = \sqrt{3} V_P I_P [-2\sin(30)\sin(-\phi)]$ [$\because \cos C - \cos D = -2\sin\left(\frac{C+D}{2}\right)\sin\left(\frac{C-D}{2}\right)$]

$W_1 - W_2 = \sqrt{3} V_P I_P \sin\phi$ -(iv)

Dividing (iii) and (iv)

$\frac{W_1 + W_2}{W_1 - W_2} = \sqrt{3}\cot\phi$

putting the value of W_1 & W_2

$\frac{\cancel{1500}\,5}{\cancel{900}\,3} = \sqrt{3}\cot\phi$

$\frac{5}{3\sqrt{3}} = \cot\phi$

$\phi = \cot^{-1}\left(\frac{5}{3\sqrt{3}}\right)$

$\phi = 46.1°$

$\therefore$ power factor $= \cos\phi = \cos(46.1)$

$\boxed{\cos\phi = 0.693}$

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8.) A 3-phase balanced load power was measured by two wattmeter method. If the readings of the two wattmeters so connected are 5 and 0.5 kW, the latter reading being obtained after reversal of current coil connections. Calculate the power factor of the load.

Soln) we have, $W_1 = 5$ kW

since the latter reading is being obtained after reversal of current coil connections, $\therefore W_2 = -0.5$ kW

we know,

$$\frac{W_1 + W_2}{W_1 - W_2} = \sqrt{3} \cot\phi$$

Putting the values of W_1, W_2

$$\frac{5 - 0.5}{5 + 0.5} = \sqrt{3} \cot\phi$$

$$\frac{9}{11} = \sqrt{3} \cot\phi$$

$$\phi = 64.71^\circ$$

$\therefore$ power factor $= \cos\phi$

$= \cos(64.71)$

$\boxed{\text{P.f.} = 0.427}$

9.) Two wattmeters are used for measuring the power input and the power factor of an over-excited synchronous motor. If the readings of the meters are -2 and 7 kW respectively, calculate the input and power factor of the motor.

Soln) we have, $W_1 = -2$ kW

$W_2 = 7$ kW

Input power $= W_1 + W_2$

$= 7 - 2$

$= 5$ kW

Also, $\frac{W_1 + W_2}{W_1 - W_2} = \sqrt{3} \cot\phi$

$\frac{7 - 2}{} = \sqrt{3} \cot\phi$

$\frac{-5}{9} = \sqrt{3}\cot\phi$

$\cot\phi = \frac{-5}{9\sqrt{3}}$

$\tan\phi = -\frac{9\sqrt{3}}{5}$

$\phi = -72.2^\circ$

$P.f. = \cos(-72.2)$

$= 0.305$ (lead).

10.) A 3-phase delta-connected balanced load consists of a resistance of 10Ω in series with an inductive reactance of 17.32Ω. If the circuit is connected to 440V, 50Hz supply and the total power consumed is 14,520 W, what is the reading read by each wattmeter?

(soln) we have,

$Z = 10 + 17.32j$

$\cos\phi = \frac{10}{\sqrt{100 + (17.32)^2}}$

$\cos\phi = \frac{10}{20}$

$\cos\phi = 0.5 \Rightarrow \phi = 60^\circ$

we know, $\frac{w_1 + w_2}{w_1 - w_2} = \sqrt{3}\cot\phi$

putting the value of ϕ

$\frac{w_1 + w_2}{w_1 - w_2} = 1$

$\boxed{w_2 = 0 \;\&\; w_1 = 14520W}$

12.) A 3-phase motor draws a line current of 50A from 220V source while starting. The pf is 0.4. Find the readings of the two wattmeters connected to measure power.

(soln) we have, ~~IL = 50A~~ $I_L = 50A$, $V_L = 220V$

Let, the given system be a star connected system,

$\therefore P = 3 \times V_P \times I_P \cos\phi$

$w_1 + w_2 = 3 \times \frac{V_L}{\sqrt{3}} \times 50 \times 0.4$ [$\because$ p.f. = 0.4]

$w_1 + w_2 = \sqrt{3} \times 220 \times 50 \times 0.4$

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$W_1+W_2 = 7621$

$W_1+W_2 = 7.621\ kW$ —(i)

Also,

$$\frac{W_1+W_2}{W_1-W_2} = \sqrt{3}\cot\phi$$

$$\Rightarrow \frac{7.621}{W_1-W_2} = \sqrt{3}(0.43629)$$

$W_1-W_2 = 10.08$ —(ii)

Add (i) & (ii)

$2W_1 = 17.7$

$\boxed{W_1 = 8.85\ kW}$

Putting the value of W_1 in (i)

$W_2 = 7.621 - 8.85$

$\boxed{W_2 = -1.23\ kW}$

11) The power input to a 2000 V, 50 Hz 3 phase motor running on full load at an efficiency of 90% is measured by two wattmeters which indicate 300 kW and 100 kW respectively. Calculate (i) input (ii) power factor (iii) line current

Soln) We have, $V_{ph} = 2000\ V$

$W_1 = 300\ kW$, $W_2 = 100\ kW$

As $\frac{W_1+W_2}{W_1-W_2} = \sqrt{3}\cot\phi$

$\frac{400}{200} = \sqrt{3}\cot\phi$

$\cot\phi = \frac{2}{\sqrt{3}}$

$\phi = 40.89^\circ$

Power factor $= \cos\phi = \cos(40.89)$

$\boxed{1.6 = 0.756}$

Power input $= W_1+W_2$

$= 300+100$

$= 400\ kW$

$P = 3 V_{ph} I_{ph} \cos\phi$

$\Rightarrow 400 \times 10^3 = 3 \times 2000 \times \frac{I_L}{\sqrt{3}} \times 0.756$

$200 = \sqrt{3} \times I_L \times 0.756$

$I_L = \frac{200}{\sqrt{3} \times 0.756}$

$I_L = 152 A$

Input power = 400 kW

Efficiency = 90%

$\therefore$ output power = 400×0.9

$= 360$ kW

In hp = $\frac{360 \times 1000}{746} = 490$ h.p.

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