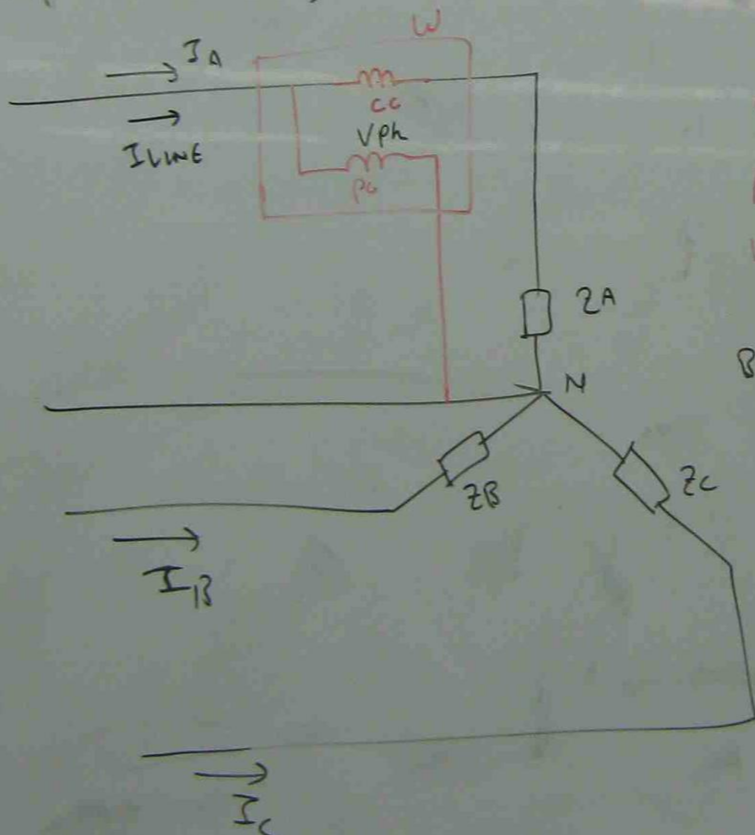
CALCULATION OF POWER IN STAR CONNECTED BALANCED LOAD

POWER MEASUREMENT BY ONE WATT METER METHOD

3ϕ BALANCED LOAD $\longrightarrow$ TOTAL 3ϕ POWER = 3x 1ϕ POWER

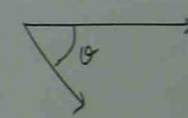


CC – CURRENT COIL

PC – POTENTIAL COIL

W – WATT METER

BALANCED



$V_{PHASE} = \frac{V_{LINE}}{\sqrt{3}}$

λ $I_{LINE} = I_{ph}$

1ϕ POWER = $V_{ph} I_{ph} \cos\theta$

$$\boxed{1\phi \text{ POWER} = \frac{V_{LINE}}{\sqrt{3}} \times I_{LINE} \times \cos\theta}$$

3ϕ POWER = 3 x WATT METER READING

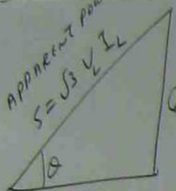
BALANCED

$$3\phi \text{ POWER} = 3 \times 1\phi \text{ POWER}$$

$$= 3 \times \frac{V_{LINE}}{\sqrt{3}} \times I_{LINE} \cos\theta$$

$$\boxed{3\phi \text{ POWER} = \sqrt{3}\, V_{LINE} \times I_{LINE} \cos\theta}$$

POWER TRIANGLE



Pb IN 3ϕ SYSTEM THE FOLLOWINGS ARE VOLTAGE AND CURRENT

$I_A = 24\angle -30^\circ$ A, $I_B = 24\angle -150^\circ$ A, $I_C = 24\angle 90^\circ$ A

$V_{AN} = 240\angle 0^\circ$ V, $V_{BN} = 240\angle -120^\circ$ V, $V_{CN} = 240\angle +120^\circ$ V

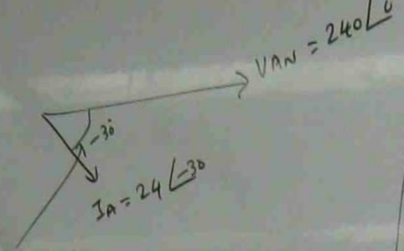
FIND TOTAL POWER IN TWO WAYS.

METHOD (1)

A PHASE POWER $= V_{ph} I_{ph} \cos\theta$

$= V_{AN} I_{AN} \cos\theta^{V_{AN}}_{I_{AN}}$

$I_{AN} = I_A = 24A$



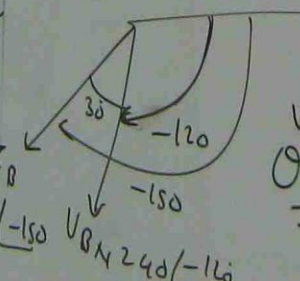
$\theta^{V_{AN}}_{I_{AN}} = 30^\circ$

$P_A = 240 \times 24 \cos 30$

$= 5760 \times 0.866$

$P_A = 4988$ W

$P_B = V_{BN} I_{BN} \cos\theta^{V_{BN}}_{I_{BN}}$

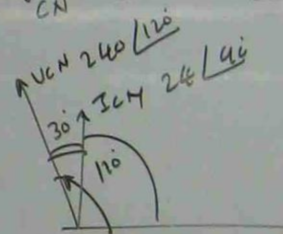


$\theta^{V_{BN}}_{I_{BN}} = 30^\circ$

$P_B = 240 \times 24 \cos 30$

$= 4988$ W

$P_C = V_{CN} I_{CN} \cos\theta^{V_{CN}}_{I_{CN}}$



$= 240 \times 24 \times \cos 30$

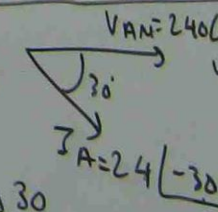
$P_C = 4988$ W

$P_T = P_A + P_B + P_C = 4988 + 4988 + 4988$

$= 14964$ W

METHOD (2)

$P_T = \sqrt{3} V_{LINE} I_{LINE} \cos\theta$

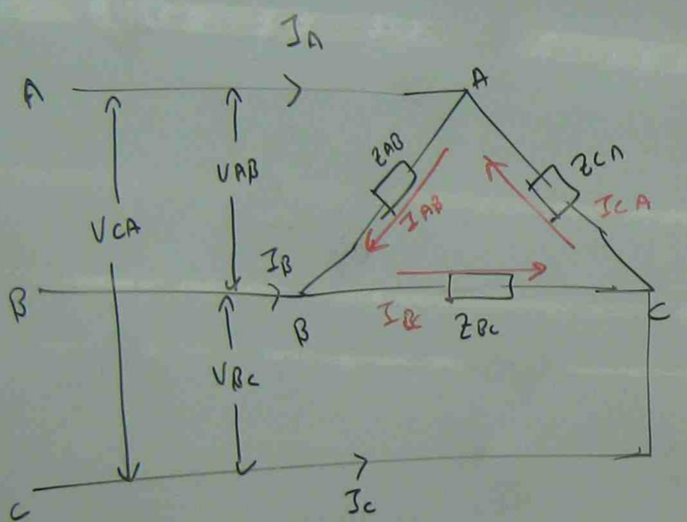


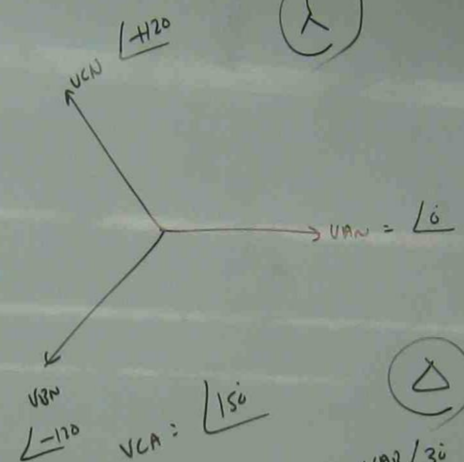
$= 1.7321 \times (\sqrt{3} V_{ph}) \times 24 \times \cos 30$

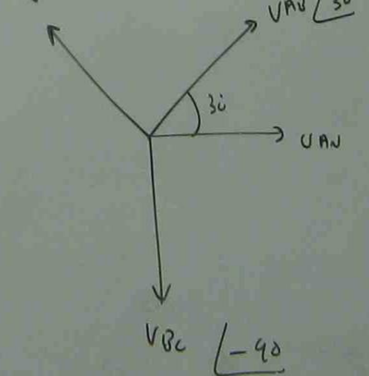
$= 1.7321 (1.7321 \times 240) \times 24 \times 0.866$

$= 14964$ W

THREE PHASE DELTA CONNECTED BALANCED LOADS







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

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

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

SEQUENCE

A B C

A → B → C

A POINT

$$I_A + I_{CA} = I_{AB}$$

$$I_A = I_{AB} - I_{CA}$$

B POINT

$$I_B + I_{AB} = I_{BC}$$

$$I_B = I_{BC} - I_{AB}$$

C POINT

$$I_C + I_{BC} = I_{CA}$$

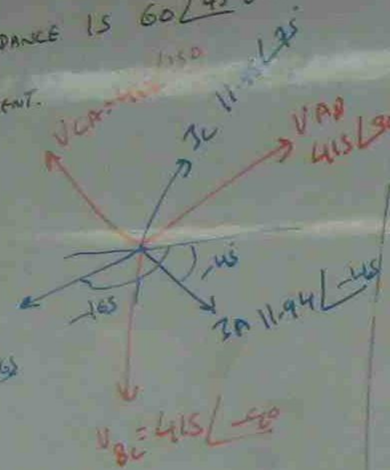
$$I_C = I_{CA} - I_{BC}$$

Pb 3ϕ 3WIRE 415V ABC SYSTEM SUPPLIES A Δ CONNECTED LOAD WHOSE PHASE IMPEDANCE IS $60\angle 45^\circ\ \Omega$

FIND PHASE CURRENT & LINE CURRENT.

DRAW PHASOR DIAGRAM.

METHOD (1)



$I_A = 6$

$I_B = I$

$$Z_{AB} = Z_{BC} = Z_{CA} = 60\angle 45^\circ\ \Omega$$

$$V_{AB} = 415\angle 30^\circ\ V$$

$$V_{BC} = 415\angle -90^\circ\ V$$

$$V_{CA} = 415\angle +150^\circ\ V$$

$$I_{AB} = \frac{V_{AB}}{Z_{AB}} = \frac{415\angle 30}{60\angle 45} = 6.9\angle 30-45 = 6.9\angle -15^\circ\ A$$

$$I_{BC} = \frac{V_{BC}}{Z_{BC}} = \frac{415\angle -90^\circ}{60\angle 45} = 6.9\angle -90-45 = 6.9\angle -135^\circ\ A$$

$$I_{CA} = \frac{V_{CA}}{Z_{CA}} = \frac{415\angle 150}{60\angle 45} = 6.9\angle 150-45 = 6.9\angle 105^\circ\ A$$

$$I_A = I_{AB} - I_{CA} = 6.9\angle -15 - 6.9\angle 105$$

$$= 6.9\left(\cos(-15) + j\sin(-15)\right) - 6.9\left(\cos 105 + j\sin 105\right)$$

$I_{A} = 6.66 - j1.78 + 1.78 - j6.66 = 8.44 - j8.44 = \sqrt{8.44^2 + 8.44^2} \angle -\tan^{-1}\frac{8.44}{8.44} = 11.94 \angle -45^\circ$ A

$I_B = I_{BC} - I_{AB} = 6.9\angle -135 - 6.9\angle -15$

$= 6.9(\cos(-135) + j\sin(-135)) - 6.9(\cos 15 - j\sin 15)$

$= -4.88 - j4.88 - 6.66 + j1.78$

$= -11.54 - j3.1 = \sqrt{11.54^2 + 3.1^2} \angle -\left(180 - \tan^{-1}\frac{3.1}{11.54}\right)$

$I_B = 11.95 \angle -165^\circ$ A

$I_C = I_{CA} - I_{BC} = 6.9\angle 105 - 6.9\angle -135$

$= 6.9(\cos 105 + j\sin 105) - 6.9(\cos(-135) + j\sin(-135))$

$= -1.78 + j6.66 + 4.88 + j4.88$

$= 3.1 + j11.54 = \sqrt{3.1^2 + 11.54^2} \angle \tan^{-1}\frac{11.54}{3.1}$

$= 11.95 \angle 75^\circ$ A

PHASE CURRENT = 6.9 A

LINE CURRENT = $\sqrt{3} \times I_{PHASE} = 1.732 \times 6.9 = 11.95$ A

$j\sin 105)$

pb 1

A DELTA CONNECTED LOAD HAS THREE IMPEDANCES

Z_a = 300 Ω IN SERIES WITH 500 mH INDUCTOR.

Z_b = 150 Ω IN SERIES WITH 20 μF CAPACITOR

Z_c = 600 mH INDUCTOR

LINE VOLTAGE = 415 V

FREQUENCY = 50 HZ. USE E_{ab} AS REFERENCE

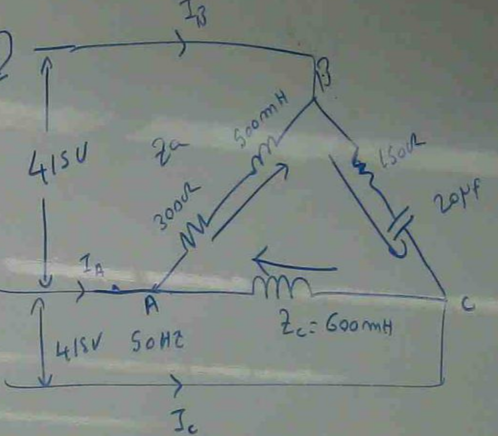
CALCULATE ALL LINE CURRENTS IN POLAR FORM

pb 2

A VOLTAGE $V = 300 \sin 3000t$ IS APPLIED TO RESISTANCE 250 Ω IN SERIES WITH 5 μF CAPACITOR.

CALCULATE
(a) APPARENT POWER IN VA
(b) REAL POWER IN WATT
(c) REACTIVE POWER VAR
(d) CIRCUIT POWER FACTOR
(e) POWER TRIANGLE

pb 1



ABC

Z_a (Z_{ab})
$$Z_a = 300 + j\,2\pi f L = 300 + j\,2\times 3.1416 \times 50 \times 500\times10^{-3}$$
$$= 300 + j157 = \sqrt{300^2+157^2}\ \angle \tan^{-1}\frac{157}{300}$$
$$Z_a = 338.5\ \angle 27.6^\circ\ \Omega$$

Z_b (Z_{bc})
$$Z_b = 150 - j\frac{1}{2\pi f C} = 150 - j\frac{1}{2\times 3.1416\times 50\times 20\times10^{-6}}$$
$$= 150 - j\frac{10^6}{314.16\times 20} = 150 - j159\ \Omega$$
$$= \sqrt{150^2+159^2}\ \angle -\tan^{-1}\frac{159}{150}$$

$Z_b = 218.5 \angle -46.66° \ \Omega$

$Z_c = j 2\pi f L = j\, 2 \times 3.1416 \times 50 \times 600 \times 10^{-3}$

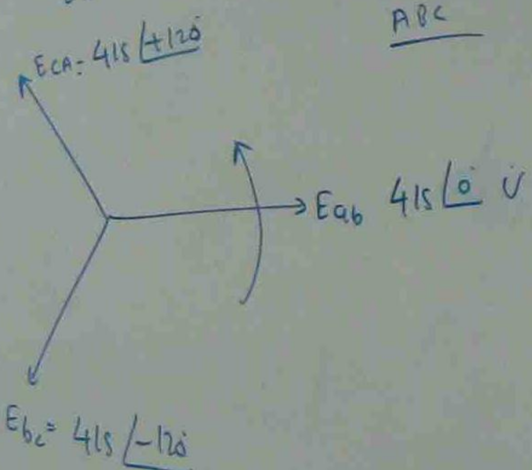
(Z_{ca})

$= j\, 314.16 \times 600 \times 10^{-3}$

$= j\, 188.49$

$Z_c = 188.49 \angle 90° \ \Omega$

ABC



$I_{AB} = \frac{E_{AB}}{Z_{AB}} = \frac{415 \angle 0}{Z_a} = \frac{415 \angle 0}{338.5 \angle 27.6}$

$= 1.225 \angle -27.6$ Amp

$I_{BC} = \frac{E_{BC}}{Z_{BC}} = \frac{415 \angle -120}{Z_b} = \frac{415 \angle -120}{218.5 \angle -46.66}$

$= 1.9 \angle -120 + 46.66$

$= 1.9 \angle -73.34$ Amp

$I_{CA} = \frac{E_{CA}}{Z_{CA}} = \frac{415 \angle +120°}{Z_c} = \frac{415 \angle 120}{188.49 \angle 90°}$

$= 2.2 \angle 30°$ Amp

AT A   Flow in = Flow out

$I_A + I_{CA} = I_{AB}$

$I_A = I_{AB} - I_{CA}$

$= 1.225 \angle -27.6 - 2.2 \angle 30$

$I_A = 1.225(\cos 27.6 - j \sin 27.6) - 2.2(\cos 30 + j \sin 30)$

$= 1.225(0.886 - j0.463) - 2.2(0.866 + j0.5)$

$I_A =$

AT

I

$$I_A = (1.085 - j0.567) - (1.9 + j1.1) = 1.085 - j0.567 - 1.9 - j1.1$$

$$= -0.815 - j1.667 = \sqrt{0.815^2 + 1.667^2}\ \angle -\left(180 - \tan^{-1}\frac{1.667}{0.815}\right)$$

$$= 1.855\ \angle -(180 - 63.94)$$

$$= 1.855\ \angle -116.06 \text{ Amp}$$

AT (B) $I_B + I_{AB} = I_{BC}$

$$I_B = I_{BC} - I_{AB} = 1.9\angle -73.34 - 1.225\angle -27.6$$

$$= 1.9(\cos 73.34 - j\sin 73.34) - (1.085 - j0.567)$$

$$= 1.9(0.286 - j0.958) - 1.085 + j0.567$$

$$= 0.543 - j1.82 - 1.085 + j0.567$$

$$= -0.542 - j1.253$$

$$= \sqrt{0.542^2 + 1.253^2}\ \angle -\left(180 - \tan^{-1}\frac{1.253}{0.542}\right)$$

$$= 1.365\ \angle -(180 - 66.6) = 1.365\ \angle -113.4 \text{ A}$$

AT (C) $I_C + I_{BC} = I_{CA} \rightarrow I_C = I_{CA} - I_{BC}$

$$I_C = 2.2\angle 30 - 1.9\angle -73.34$$

$$= (1.9 + j1.1) - (0.543 - j1.82)$$

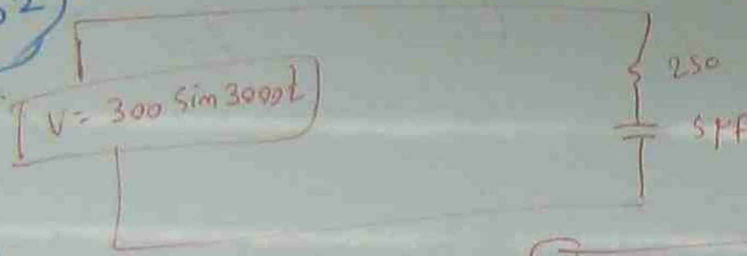
$$= 1.9 + j1.1 - 0.543 + j1.82 = 1.357 + j2.92$$

+jsin30)

$$I_C = \sqrt{1.357^2 + 2.92^2}\ \angle \tan^{-1}\frac{2.92}{1.357} = 3.22\ \angle 65 \text{ A}$$

j0.5)

pb2



$300 \sin 3000t + 30° = \frac{300}{\sqrt{2}} \angle 30°$

$300 \sin 3000t - 20° = \frac{300}{\sqrt{2}} \angle -20°$

$$V = \frac{300}{\sqrt{2}} \angle 0$$

$$= \frac{300}{1.4142} \angle 0 = 212.13 \angle 0° \ V$$

$$\omega = 2\pi f = 3000$$

$$250 - j\frac{1}{2\pi f c} = 250 - j\frac{1}{3000 \times 5 \times 10^{-6}}$$

$$= 250 - j\frac{10^6}{15000} = 250 - j66.66$$

$$Z = \sqrt{250^2 + 66.66^2} \angle -\tan^{-1}\frac{66.66}{250}$$

$$Z = 258.73 \angle -14.9° \ \Omega$$

$$I = \frac{V}{Z} = \frac{212.13\angle 0°}{258.73\angle -14.9} = 0.819\angle 14.9° \ A$$

(a) APPARENT POWER $= VI = 212.13 \times 0.819$

$= 173.73$ VA

(b) REAL POWER = APPARENT POWER $\cos\theta$

$= 173.73 \cos 14.9$

$= 173.73 \times 0.966$

$= 167.88$ WATT

(c) REACTIVE POWER = APPARENT POWER $\sin\theta$

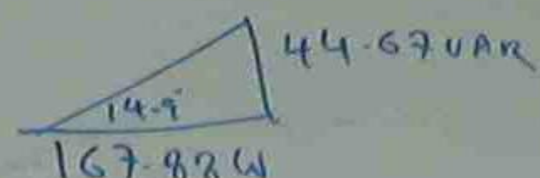
$= 173.73 \sin 14.9$

$= 173.73 \times 0.257$

$= 44.67$ VAR

(d) $PF = \cos\theta = \cos 14.9 = 0.966$ LEADING (CAPACITIVE LOAD)

(e)



$$I_{AB} = \frac{E_{AB}}{Z_{AB}} = \frac{415 \angle 0}{Z_a} = \frac{415 \angle 0}{338.3 \angle 27.6}$$

$$= 1.225 \angle -27.6 \text{ Amp}$$

$$I_{BC} = \frac{E_{BC}}{Z_{BC}} = \frac{415 \angle -120}{Z_b} = \frac{415 \angle -120}{218.5 \angle -46.66}$$

$$= 1.9 \angle -120 + 46.66$$

$$= 1.9 \angle -73.34 \text{ Amp}$$

$$I_{CA} = \frac{E_{CA}}{Z_{CA}} = \frac{415 \angle +120}{Z_c} = \frac{415 \angle 120}{188.49 \angle 90}$$

$$= 2.2 \angle 30 \text{ Amp}$$

AT (A) Flow in = Flow out

$$I_A + I_{CA} = I_{AB}$$

$$I_A = I_{AB} - I_{CA}$$

$$= 1.225 \angle -27.6 - 2.2 \angle 30$$

$$I_A = 1.225(\cos 27.6 - j\sin 27.6) - 2.2(\cos 30 + j\sin 30)$$

$$= 1.225(0.886 - j0.463) - 2.2(0.866 + j0.5)$$

$$I_A = (1.085 - j0.567) - (1.9 + j1.1) =$$

$$= -0.815 - j1.667 = \sqrt{0.815^2 + 1.667^2}$$

$$= 1.855 \angle -($$

$$= 1.855 \angle -$$

AT (B) $I_B + I_{AB} = I_{BC}$

$$I_B = I_{BC} - I_{AB} = 1.9 \angle -73.34$$

$$= 1.9(\cos 73.34 - j\sin 73.34) -$$

$$= 1.9(0.286 - j0.958) -$$

$$= 0.543 - j1.82 - 1.085$$

$$= -0.542 - j1.253$$

$$= \sqrt{0.542^2 + 1.253^2} \angle -$$

$$= 1.365 \angle -(180 - 66$$

AT (C) $I_C + I_{BC} = I_C$

$$I_C = 2.2 \angle 30 - 1.9 \angle$$

$$= (1.9 + j1.1) - (0$$

$$= 1.9 + j1.1 - 0.543$$

$$I_C = \sqrt{1.357^2 + 2.92^2} \angle \tan^{-1}$$

pb 3

SOLVE THE FOLLOWING

$$3 + j5 + \frac{(5+j3)(4+j6) + (7-j3)^2}{8+j10}$$

$$3 + j5 + \frac{\left(\sqrt{5^2+3^2}\,\angle \tan^{-1}\frac{3}{5}\right)\left(\sqrt{4^2+6^2}\,\angle -\tan^{-1}\frac{6}{4}\right) + \left(\sqrt{7^2+3^2}\,\angle -\tan^{-1}\frac{3}{7}\right)^2}{\sqrt{8^2+10^2}\,\angle \tan^{-1}\frac{10}{8}}$$

$$\boxed{(a\angle\theta)^n = a^n\angle n\theta}$$

$$3+j5 + \frac{5.83\angle 31 \times 7.21\angle -56.3 + (7.615\angle -23.17)^2}{12.8\angle 51.3}$$

$$3+j5+\frac{42.03\angle 31-56.3 + 7.615^2\angle -23.17\times 2}{12.8\angle 51.3} = 3+j5+\frac{42.03\angle -25.3 + 58\angle -46.34}{12.8\angle 51.3}$$

$$3+j5+\frac{42.03(\cos 25.3-j\sin 25.3)+58(\cos 46.34-j\sin 46.34)}{12.8\angle 51.3}$$

$$3+j5+\frac{42.03(0.904-j0.427)+58(0.69-j0.72)}{12.8\angle 51.3}$$

$$3+j5+\frac{38-j18+40-j41.76}{12.8\angle 51.3}$$

$$3+j5+\frac{78-j59.76}{12.8\angle 51.3}$$

$$3+j5+\frac{\sqrt{78^2+59.76^2}\,\angle -\tan^{-1}\frac{59.76}{78}}{12.8\angle 51.3}$$

$$3+j5+\frac{98.26\angle -37.45}{12.8\angle 51.3}$$

$$3+j5+7.67\angle -37.45-51.3$$

$$3+j5+7.67\angle -88.75$$

$$3+j5+7.67(\cos 88.75-j\sin 88.75)$$

$$3+j5+7.67(0.0218-j0.999)$$

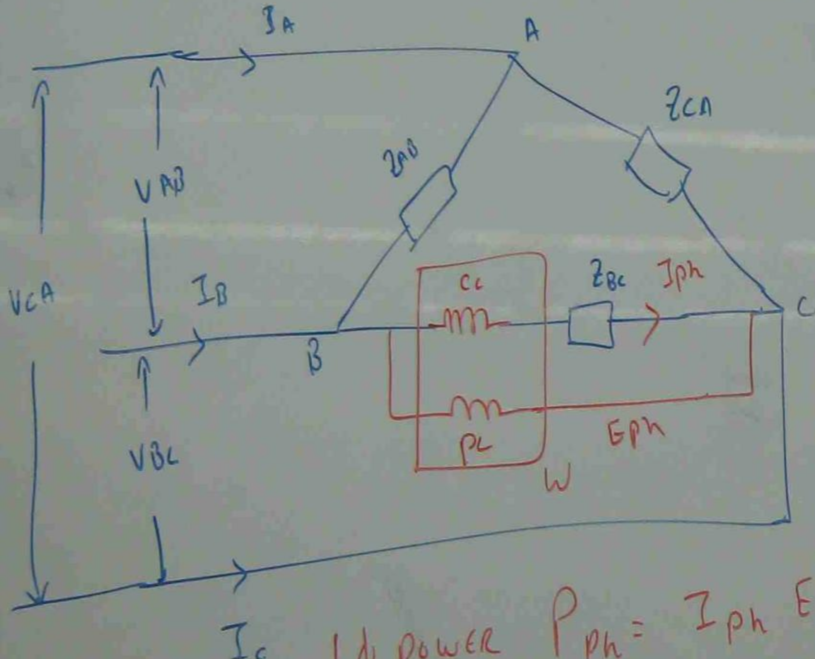
$$3+j5+0.167-j7.6$$

$$3.167-j2.6$$

$$\sqrt{3.167^2+2.6^2}\,\angle -\tan^{-1}\frac{2.6}{3.167}$$

$$4.1\angle -39.35 \quad //$$

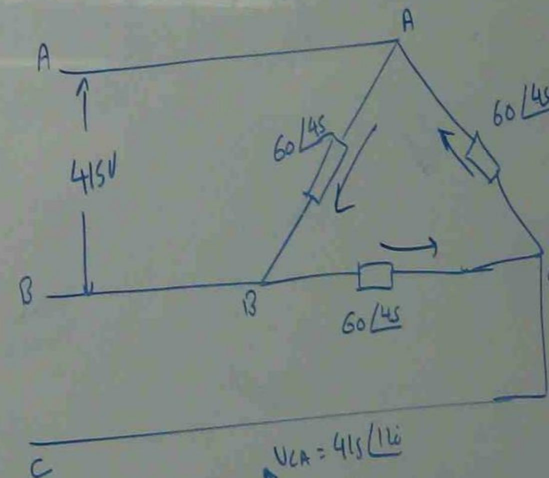
CALCULATION OF POWER IN DELTA CONNECTED BALANCE LOADS

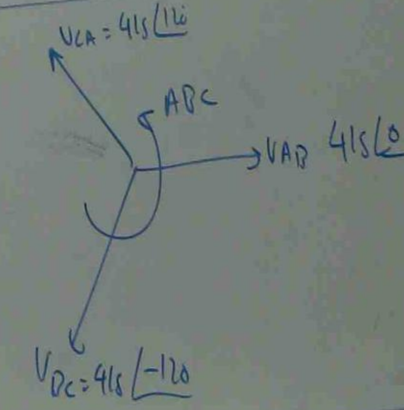


1φ POWER $P_{ph} = I_{ph}\, E_{ph} \cos\theta^{I_{ph}}_{E_{ph}}$

3φ POWER = $3 \times P_{ph}$

Ex A 3φ 3WIRE 415V ABC SYSTEM SUPPLIES A DELTA CONNECTED LOAD WHOSE IMPEDANCE IS $60\angle 45\ \Omega$. CALCULATE 3φ POWER





$$I_{AB} = I_{ph} = \frac{V_{AB}}{Z_{ph}} = \frac{415\angle 0}{60\angle 45} = 6.91\angle -45 \text{ Amp}$$

$$V_{ph} = V_{AB}\ (\text{line}) = 415\ V$$

$$\Delta$$

$$I_{ph} = 6.91\angle -45$$

$$\cos\theta = \cos 45 = 0.707$$

$$P_{ph} = V_{ph}\ I_{ph} \cos\theta$$

$$= 415 \times 6.91 \times 0.707$$

$$= 2027.42 \text{ WATT}$$

$$3\phi \text{ POWER} = 3 \times P_{ph} = 3 \times 2027.42$$

$$= 6082.28 \text{ WATT}$$

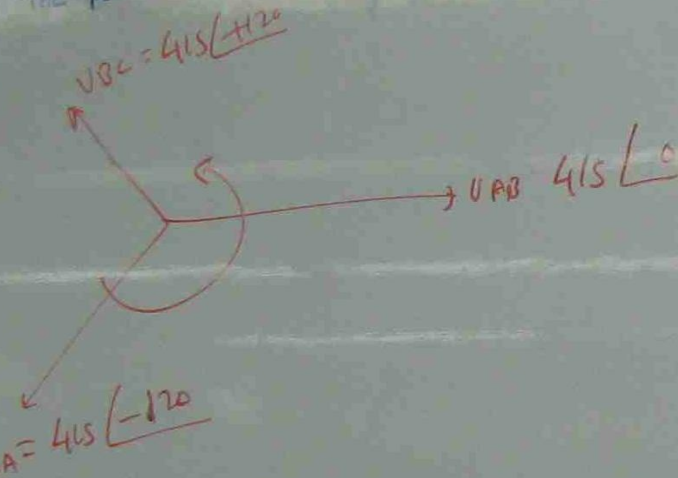
$$= 6.082 \text{ kW}$$

Q IN PREVIOUS PROBLEM, IF PHASE SEQUENCE IS ACB (OR) CBA, FIND THE POWER AND LINE CURRENT.

A B C +

A CB −

CBA



$I_{AB} = I_{ph} = \frac{V_{AB}}{Z_{AB}} = \frac{415\angle 0}{60\angle 45} = 6.91\angle{-45} \leftarrow I_{ph}$

$P_{ph} = V_{ph} I_{ph} \cos\theta = 415 \times 6.91 \cos 45 = 2027.41$

3ϕ POWER $= 3 P_{ph} = 3 \times 2027.41 = 6082$

$= 6.082$ KW

3ϕ BALANCED Δ

$I_{LINE} = \sqrt{3} \times I_{ph} = 1.7321 \times 6.91 = 11.95$ Amp