***

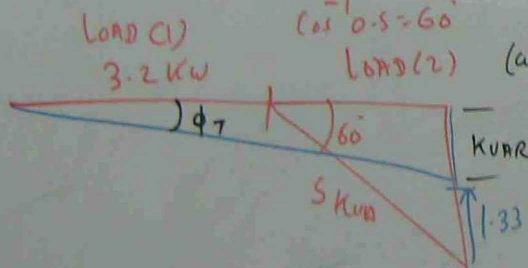
A 250 Vrms 50Hz SOURCE IS SUPPLYING THE FOLLOWING LOADS

LOAD 1 - 3.2 KW

LOAD 2 - 5 KVA 0.5 PF LAGGING

LOAD 3 - 1.33 KVAR LEADING (PURE CAPACITANCE)

CALCULATE (a) TOTAL LOAD (b) TOTAL POWER FACTOR (c) THE VALUE OF ADDITIONAL CONNECTED COMPONENT WHICH WILL IMPROVE POWER FACTOR TO 95%



(a) $KW_T = 3.2 + 5\cos 60$

$= 3.2 + 5 \times 0.5 = 3.2 + 2.5$

$= 5.7$ KW

(b) $KVAR_T = 5\sin 60 - 1.33$

$= 5 \times 0.866 - 1.33$

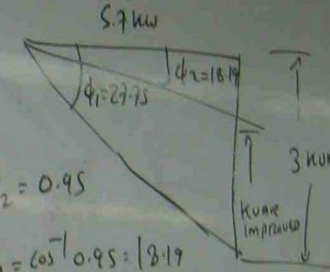
$= 4.33 - 1.33 = 3$ KVAR

$$\tan\phi_T = \frac{KVART}{KWT} = \frac{3}{5.7} = 0.5263$$

$\phi_T = \tan^{-1} 0.5263 = 27.75°$

$PF_{TOTAL} = \cos 27.75 = 0.884$ LAGGING

$\phi_1 = 27.75°$



$PF_2 = 0.95$

$\phi_2 = \cos^{-1} 0.95 = 18.19$

KVAR IMPROVED $= KW(\tan\phi_1 - \tan\phi_2)$

$= 5.7(\tan 27.75 - \tan 18.19)$

$= 5.7(0.526 - 0.328)$

$= 1.128$ KVAR

$$\frac{E_{ph}^2}{X_c} = KVAR$$

$$\frac{E_{ph}^2}{\frac{1}{2\pi fC}} = KVAR$$

$2\pi fC \times E_{ph}^2 = KVAR$

$$C = \frac{KVAR}{2\pi f \times E_{ph}^2}$$

$$= \frac{1.128 \times 10^3}{2 \times 3.1416 \times 50 \times 250^2}$$

$= 5.74 \times 10^{-5}$ F

$= 57.4\ \mu F$

NEED TO CONNECT IN PARALLEL

① A STAR CONNECTED LOAD HAS THREE IMPEDANCES $Z_A = 5\Omega$, $Z_b = 27.5$ mH, $Z_C = 5\Omega$ RESISTOR IN SERIES WITH 367 μF CAPACITOR. THREE PHASE 3 WIRES LINE VOLTAGE = 300 V. PHASE SEQUENCE A, B, C, . USING E_{an} AS REFERENCE, CALCULATE (i) ALL LINE CURRENTS

(ii) VOLTAGE OF STAR POINT OF LOAD WITH RESPECT TO NEUTRAL POINT OF SUPPLY

② A STAR CONNECTED LOAD HAS $Z_a = 5\Omega$, $Z_b = 27.5$ mH, $Z_C = 5\Omega$ RESISTOR IN SERIES WITH 367 μF CAPACITOR. PHASE SEQUENCE A, C, B USE E_{AN} AS REFERENCE, CALCULATE

(i) ALL LINE CURRENTS

(ii) VOLTAGE OF STAR POINT WITH RESPECT TO NEUTRAL POINT OF SUPPLY.

① $Z_A = 5\Omega$

$Z_b = 2\pi f L = 2\times 3.1416\times 50\times 27.5\times 10^{-3} = 8.66\Omega$

$= j8.66\Omega$

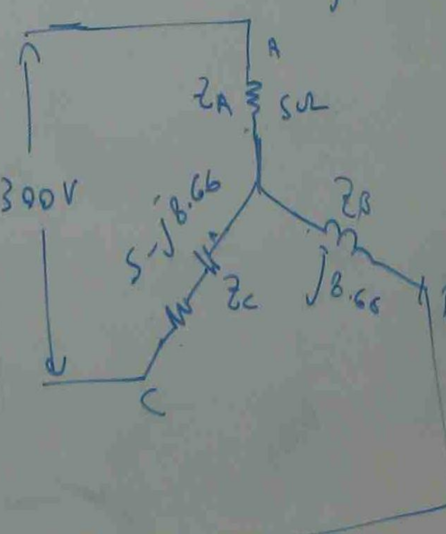
$= 8.66\angle 90^\circ$

$Z_c = R - jX_c = 5 - j\dfrac{1}{2\pi f C}$

$= 5 - j\dfrac{1}{2\times 3.1416\times 50\times 367\times 10^{-6}}$

$= 5 - j\dfrac{10^6}{2\times 3.1416\times 50\times 367}$

$= 5 - j8.66\Omega = 10\angle -60^\circ$



$27.5\times10^{-3} = 8.66\Omega$

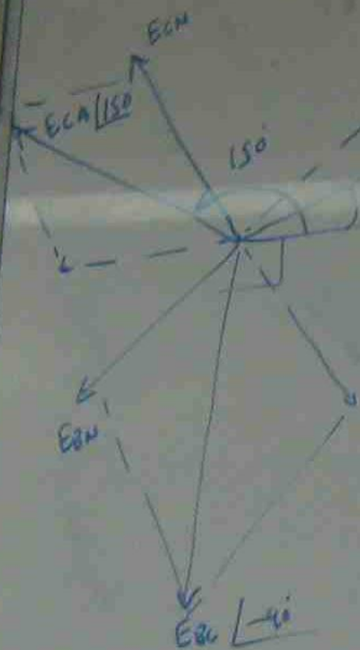
$= j\,8.66\Omega$

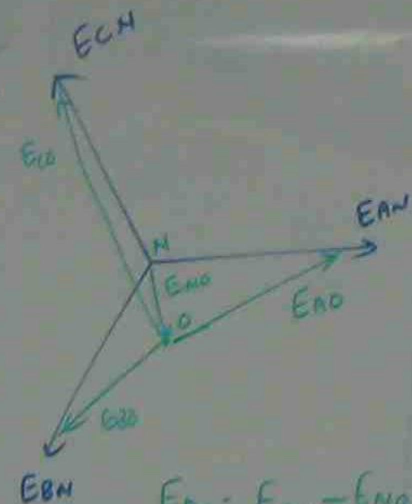
$= 8.66\angle 90^\circ$

$\times 367\times10^{6}$

367

$10\angle -60^\circ$





LINE VOLTAGE

$E_{AB} = 300\angle 30^\circ$ V

$E_{BC} = 300\angle -90$ V

$E_{CA} = 300\angle +150^\circ$ V

$E_{AN} = \frac{300}{\sqrt{3}}\angle 0 = 173.21\angle 0^\circ$

$E_{BN} = 173.2\angle -120$

$E_{CN} = 173.2\angle +120^\circ$

$E_{AO} = E_{AN} - E_{NO}$

$E_{BO} = E_{BN} - E_{NO}$

$E_{CO} = E_{CN} - E_{NO}$

$E_{NO} = ?$

$$E_{NO} = \frac{E_{AN} \times Y_A + E_{BN}\, Y_B + E_{CN}\, Y_C}{Y_A + Y_B + Y_C} = \frac{173.2\angle 0 \times \frac{1}{Z_A} + 173.21\angle -120 \times \frac{1}{Z_B} + 173.2\angle 120 \times \frac{1}{Z_C}}{\frac{1}{Z_A} + \frac{1}{Z_B} + \frac{1}{Z_C}}$$

$$= \frac{173.2\angle 0 \times \frac{1}{5} + 173.2\angle -120 \times \frac{1}{8.66\angle 90} + 173.2\angle 120 \times \frac{1}{10\angle -60}}{\frac{1}{5} + \frac{1}{8.66\angle 90} + \frac{1}{10\angle -60}}$$

$$= \frac{34.6\angle 0 + 19.9\angle -210 + 17.3\angle 180}{0.2 + 0.115\angle -90 + 0.1\angle 60}$$

$$= \frac{34.6 + 19.9(\cos 210 - j\sin 210) + 17.3(\cos 180 + j\sin 180)}{0.2 + 0.115(\cos 90 - j\sin 90) + 0.1(\cos 60 + j\sin 60)}$$

$$= \frac{34.6 + 19.9(-0.866 + j0.5) + 17.3(-1 + j0)}{0.2 + 0 - j0.115 + 0.05 + j0.0866} = \leftrightarrow 0.25 - j0.028$$

$$= \frac{34.6 - 17.14 + j9.95 - 17.3}{\sqrt{0.25^2 + 0.028^2}\ \angle -\tan^{-1}\frac{0.028}{0.25}}$$

$$= \frac{0.16 + j9.95}{0.25\angle -6.4} = \frac{9.95\angle 89}{0.25\angle -6.4}$$

$E_{NO} = 39.8\angle 95.4$ V

$E_{AO} = E_{AN} - E_{NO}$

$= 173.2\angle 0 - 39.8\angle 95.4$

$= 173.2 - 39.8(-0.094 + j0.995)$

$= 173.21 + 3.74 - j39.6$

$= 176.95 - j39.6$

$= 181.32\angle -12.57$ V

$I_A = E_{AO} \times Y_A$

$= \frac{181.32\angle -12.57}{5\angle 0}$

$= 36.26\angle -12.57$ A

Chairs
desks

$$E_{BO} = E_{BN} - E_{NO} = 173.2\angle{-120} - (-3.74 + j39.6)$$
$$= 173.2(\cos 120 - j\sin 120) + 3.74 - j39.6$$
$$= 173.2(-0.5 - j0.866) + 3.74 - j39.6$$
$$= -86.6 - j150 + 3.74 - j39.6 = -82.86 - j189.6$$

$$= \sqrt{82.86^2 + 189.6^2}\ \angle{-180 - \tan^{-1}\frac{189.6}{82.86}}$$
$$= 206.9\angle{-(180 - 66.39)} = 206.9\angle{-113.61}\ V$$

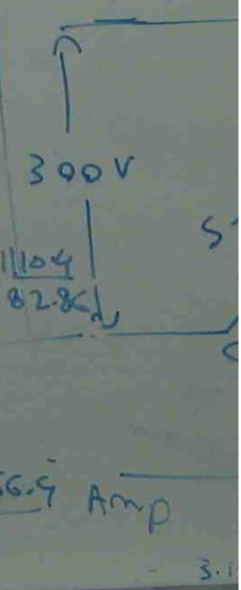
$$I_B = E_{BO} \times Y_B = 206.9\angle{-113.61} \times 0.115\angle{-90}$$
$$= 23.79\angle{-203}\ A$$

$$E_{CO} = E_{CN} - E_{NO} = 173.2\angle{120} - (3.74 - j39.6)$$
$$= 173.2(-0.5 + j0.866) - (-3.74 + j39.6)$$
$$= -86.6 + j150 + 3.74 - j39.6$$
$$= -82.86 + j110.4 = \sqrt{82.86^2 + 110.4^2}\ \angle{(180 - \tan^{-1}\frac{110.4}{82.86})}$$
$$= 138\angle{-(180 - 53.1)} = 138\angle{-126.9}\ V$$
$$I_C = E_{CO} \times Y_C = 138\angle{-126.9} \times 0.1\angle{60} = 13.8\angle{-66.9}\ \text{Amp}$$

① $Z_A = 5\Omega$

$Z_b = 2$

$Z_c = R$



(2) $Z_A = 5\Omega$

$Z_b = 2\pi f L = 2\times 3.1416\times 50\times 27.5\times 10^{-3} = 8.66\Omega$

$= j\,8.66\Omega$

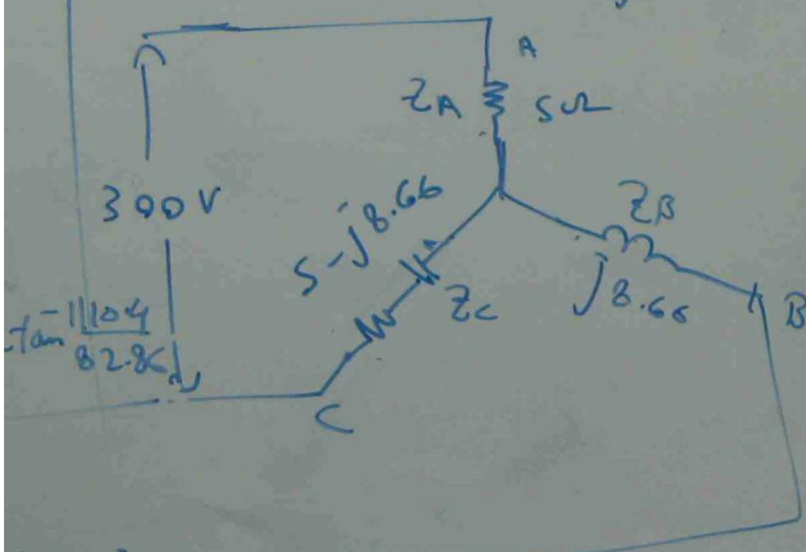
$= 8.66\angle 90^\circ$

$Z_c = R - jX_c = 5 - j\dfrac{1}{2\pi f c}$

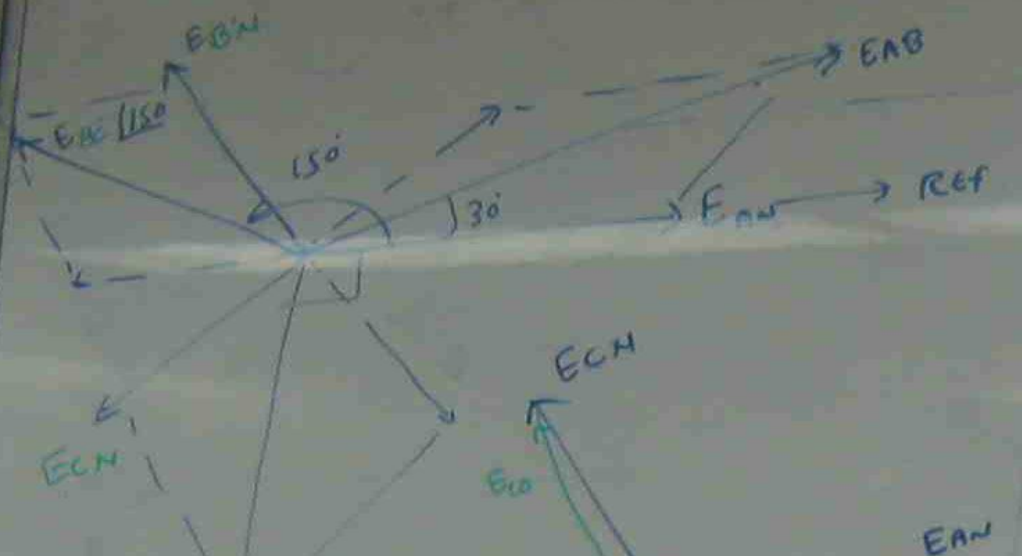
$= 5 - j\dfrac{1}{2\times 3.1416\times 50\times 367\times 10^{-6}}$

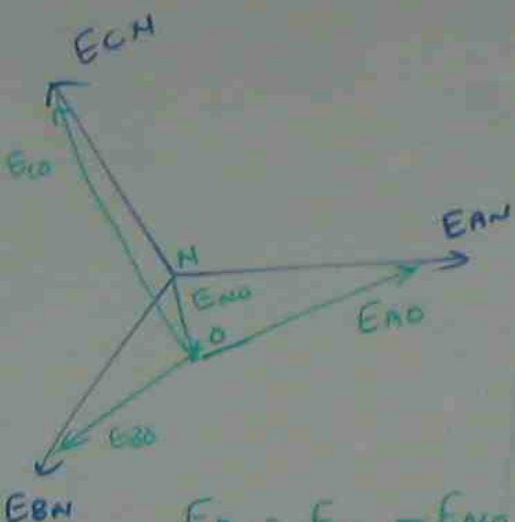
$= 5 - j\dfrac{10^6}{2\times 3.1416\times 50\times 367}$

$= 5 - j8.66\,\Omega = 10\angle -60^\circ$



$\angle -66.9$ Amp





LINE VOLTAGE

$E_{AB} = 300\angle 30^\circ$ V

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$E_{AN} = \frac{300}{\sqrt{3}}\angle 0 = 173.21\angle 0^\circ$

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$E_{AO} = E_{AN} - E_{NO}$

$E_{BO} = E_{BN} - E_{NO}$

$E_{CO} = E_{CN} - E_{NO}$

$E_{NO} = ?$

$$E_{NO} = \frac{V_{AN} Y_A + V_{BN} Y_B + V_{CN} Y_C}{Y_A + Y_B + Y_C}$$

$$= \frac{173.2\angle 0 \times 0.2\angle 0 + 173.2\angle 120 \times 0.115\angle -90 + 173.2\angle -120 \times 0.1\angle 60}{0.2\angle 0 + 0.115\angle -90 + 0.1\angle 60}$$

$$= \frac{34.6\angle 0 + 19.9\angle 30 + 17.3\angle -60}{0.25 - j0.028}$$

$$= \frac{60.66\angle -4.7}{0.25\angle -6.4} = 242.6\angle 1.7 = 242.5 + j7.2$$ ✓

$$E_{AO} = E_{AN} - E_{NO} = 173.2\angle 0 - (242.5 + j7.2) = 173.2 - 242.5 - j7.2$$

$$= -69.5 - j7.2 = 69.9\angle -174$$ ✓

$$E_{BO} = E_{BN} - E_{NO} = 173.2\angle 120 - (242.5 + j7.2) = (-86.5 + j149.8) - (242.5 + j7.2)$$

$$= -329 + j142.6 = 358.6\angle 156.6$$ ✓

$$E_{CO} = E_{CN} - E_{NO} = 173.2\angle -120 - (242.5 + j7.2) = (-86.5 - j149.8) - (242.5 + j7.2)$$

$$= -329 - j157 = 364.5\angle -154.5$$ ✓

$I_A = E_{AO} Y_A = 69.9\angle -174 \times 0.2 = 14\angle -174$ Amp

$I_B = E_{BO} Y_B = 358.6\angle 156.6 \times 0.115\angle -90 = 41.2\angle 67$ Amp

$I_C = E_{CO} Y_C = 364.5\angle -154.5 \times 0.1\angle 60 = 36.5\angle -94$ Amp

A 415V RMS 50HZ SOURCE SUPPLIES THE FOLLOWING PARALLEL LOADS

LOAD 1 - 100 KVA 0.75 PF LAGGING

LOAD 2 - 50 KW 0.8 PF LAGGING

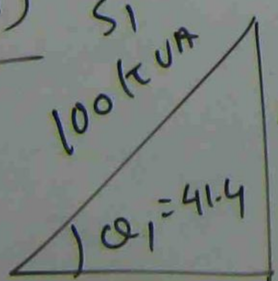
LOAD 3 - 20 KVAR 90 DEG LEAD

LOAD 4 - 60 KW, 90 KVAR LEADING.

DETERMINE (a) TOTAL REAL POWER (b) REACTIVE POWER (c) APPARENT POWER (d) POWER FACTOR.

ALSO DETERMINE THE CAPACITANCE REQUIRED PER PHASE TO RAISE POWER FACTOR TO 0.95

LOAD (1)

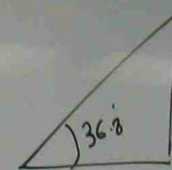


$\theta_1 = \cos^{-1} 0.75 = 41.4^\circ$

$P_1 = 100 \cos 41.4 = 75\ kW$

$Q_1 = 100 \sin 41.4 = 66.1\ kVAR$

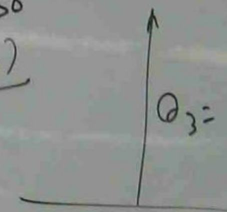
LOAD (2) $\theta_2 = \cos^{-1} 0.8 = 36.8^\circ$



$Q_2 = P_2 \tan 36.8 = 50 \tan 36.8 = 37.5\ kVAR$

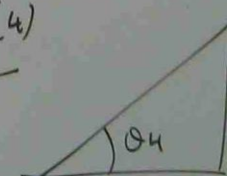
$P_2 = 50$

LOAD (3)



$Q_3 = 20\ kVAR$

LOAD (4)



$Q_4 = 90\ kVAR$

$P_4 = 60\ kW$

$P_T = P_1 + P_2 + P_3 + P_4 = 75 + 50 + 0 + 60$
$= 185\ kW$

$Q_T = Q_1 + Q_2 + Q_3 + Q_4 = 66.1 + 37.5 + 20 + 90$
$= 213.6\ kVAR$

3 KVAR

$$\tan\theta_T = \frac{KVAR_T}{KW_T} = \frac{2136}{185} = 1.154$$

$$\theta_T = \tan^{-1} 1.154 = 49^\circ$$

$$PF_T = \cos\theta_T = \cos 49 = 0.656$$

$$\theta_{T_1} = 49^\circ$$

$$PF_{T_2} = 0.95 \qquad \cos\theta_{T_2} = 0.95, \quad \theta_{T_2} = \cos^{-1} 0.95 = 18.2^\circ$$

$$KVAR(\text{improved}) = KW_T(\tan\theta_{T_1} - \tan\theta_{T_2})$$

$$= 185(\tan 49 - \tan 18.2)$$

$$= 185(1.154 - 0.328) = 152.81 \text{ KVAR}$$

$$\frac{KVAR(\text{improved})}{3} = \frac{E_{ph}^2}{\frac{1}{2\pi f C}}$$

$\frac{152.81 \times 10^3}{3} = E_{ph}^2 \times 2\pi f c$

$50.93 \times 10^3 = \left(\frac{415}{\sqrt{3}}\right)^2 \times 2 \times 3.1416 \times 50 \times c$

$c = \frac{50.93 \times 10^3}{(240)^2 \times 314.16} = 2.814 \times 10^{-3} \, f = 2.814 \times 10^{-3} \times 10^{6} \, \mu F$

$= 2.814 \times 10^3$

$= 2814 \, \mu F$

$Z_a = 50 + j0\ \Omega$

$Z_b = 50 + j150\ \Omega$

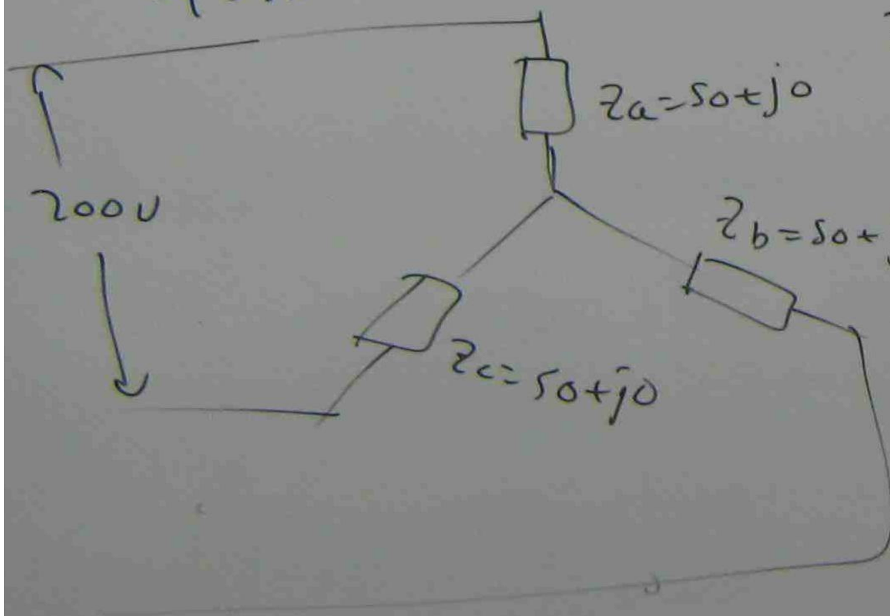
$Z_c = 50 + j0\ \Omega$

SEQUENCE A, B, C   STAR CONNECTION

3 PHASE 3 WIRE. LINE VOLTAGE = 200V

CALCULATE POWER CONSUMED BY LOAD

BY USING DELTA EQUIVALENT



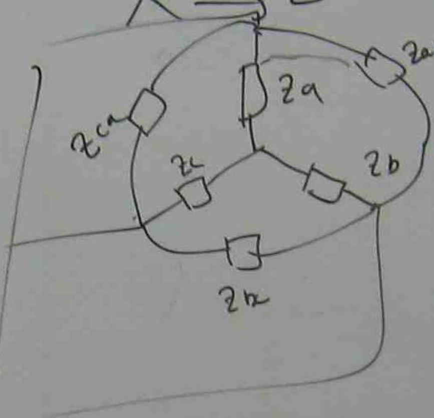
$Z_a = 50\angle 0$

$Z_b = \sqrt{50^2+150^2}\ \angle \tan^{-1}\frac{150}{50}$

$= 158.1\angle 71.56$

$Z_c = 50\angle 0$

$Y \longrightarrow \Delta$ CONVERSION



$$Z_{ab} = \frac{Z_a Z_b + Z_b Z_c + Z_c Z_a}{Z_c}$$

$$Z_{bc} = \frac{Z_a Z_b + Z_b Z_c + Z_c Z_a}{Z_a}$$

$$Z_{ca} = \frac{Z_a Z_b + Z_b Z_c + Z_c Z_a}{Z_b}$$

.56

$$Z_{ab} = \frac{50\angle 0 \times 158.1\angle 71.56 + 158.1\angle 71.56 \times 50\angle 0 + 50\angle 0 \times 50\angle 0}{50\angle 0}$$

$$= \frac{7905\angle 71.56 + 7905\angle 71.56 + 2500}{50\angle 0}$$

$$Z_{ab} = \frac{2 \times 7905(\cos 71.56 + j\sin 71.56) + 2500}{50\angle 0}$$

$$\frac{15810\,(0.316 + j0.948) + 2500}{50\angle 0}$$

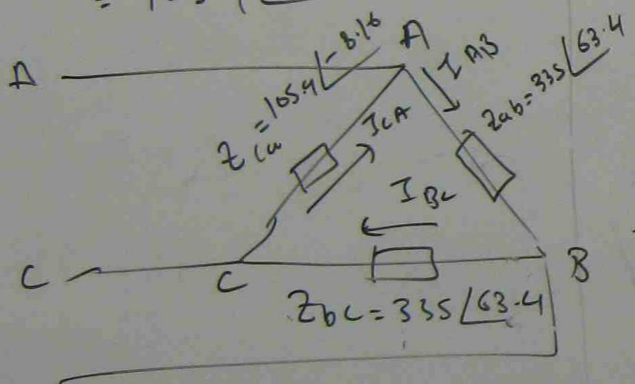
$$\frac{4995 + j\,14987 + 2500}{50\angle 0}$$

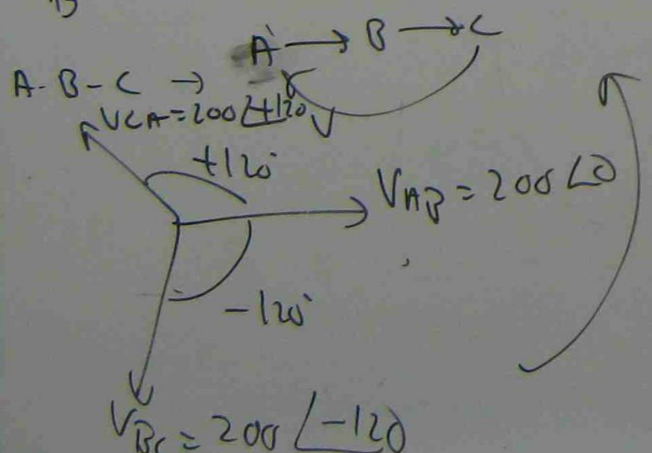
$$\frac{7495 + j\,14987}{50\angle 0}$$

$$Z_{ab} = \frac{16756\angle 63.4}{50\angle 0} = 335\angle 63.4$$

$$Z_{bc} = \frac{16756\angle 63.4}{50\angle 0} = 335\angle 63.4\ \Omega$$

$$Z_{ca} = \frac{16756\angle 63.4}{158.1\angle 71.56} = 105.9\angle -8.16\ \Omega$$

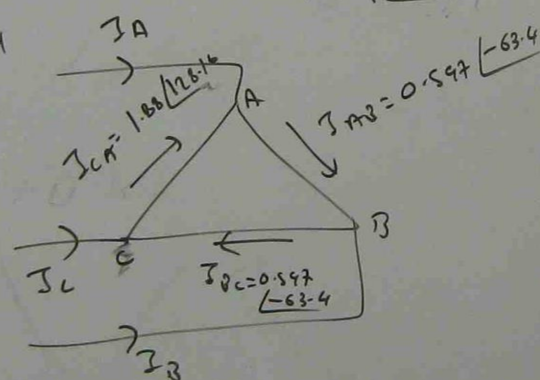




$$I_{AB} = \frac{V_{AB}}{Z_{ab}} = \frac{200\angle 0}{335\angle 63.4} = 0.597\angle -63.4 \text{ Amp.}$$

$$I_{BC} = \frac{V_{BC}}{Z_{bc}} = \frac{200\angle -120}{335\angle 63.4} = 0.597\angle -183.4 \text{ Amp}$$

$$I_{CA} = \frac{V_{CA}}{Z_{CA}} = \frac{200\angle +120}{105.9\angle -8.16} = 1.88\angle 128.16 \text{ Amp.}$$



AT A point

Flow IN = Flow out

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

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

$= 0.597\angle -63.4 - 1.88\angle 128.16$

$= 0.597(\cos 63.4 - j\sin 63.4) - 1.88(\cos 128.16 + j\sin 128.16)$

$P_T = I_{AB}^2 Z_{AB} \cos$

$0.597(0.447 - j0.894) - 1.88(-0.617 + j0.786)$

$0.266 - j0.531 + 1.159 - j1.477$

$1.425 - j2 = 2.455\angle -54.5$ Amp

$I_A = 2.455\angle -54.5$ Amp

AT B $\quad I_B + I_{AB} = I_{BC}$

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

$=$

AT C $\quad I_C + I_{BC} = I_{CA}$

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

$=$

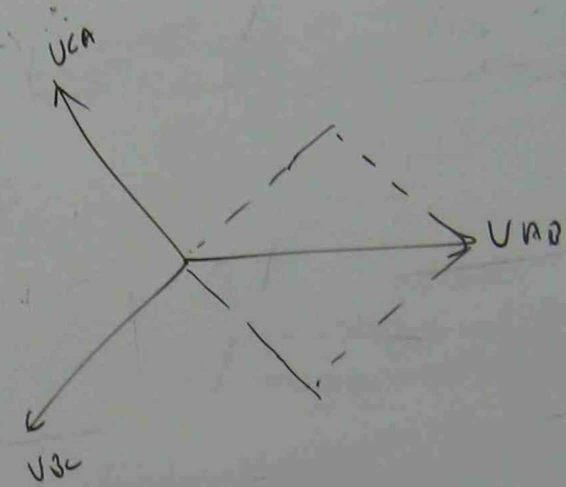
$P_T = I_{AB}^2 R_{AB} + I_{BC}^2 R_{BC} + I_{CA}^2 R_{CA}$

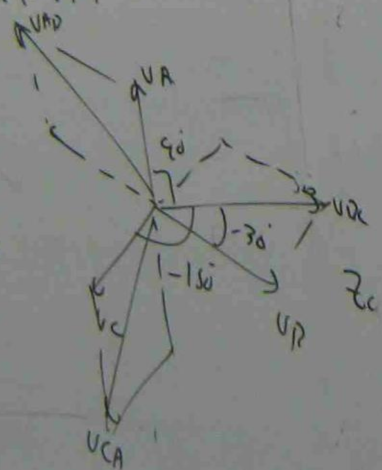
$= (0.597)^2 \left[Z_{AB}\cos\theta\right] + (0.597)^2 \left[Z_{BC}\cos\theta\right]$
$+ (1.88)^2 \left[Z_{CA}\cos\theta\right]$

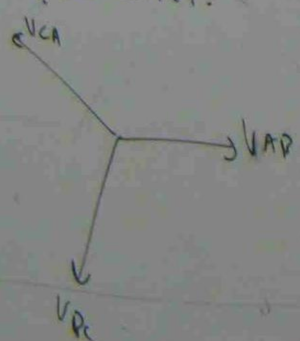
$= (0.597)^2 \left[335\cos 63.4\right] + (0.597)^2 \left[335\cos 63.4\right]$
$+ (1.88)^2 \left[105.4\cos(-8.16)\right]$

$= 0.356 \times 149.99 + 0.356 \times 149.99 + 353 \times 0.4898$

$= 456$ WATT.







$V_A = \dfrac{\text{LINE VOLTAGE}}{\sqrt{3}} = \dfrac{200}{\sqrt{3}} = 115.4\text{ V}$

$V_{BC} = \angle 0$ $\quad V_A \angle 90°$ $\quad V_B \angle -30$, $\quad V_C \angle -150°$

$V_{BC} = \angle -120 \rightarrow V_A \angle 90-120$ $\quad V_B \angle -30-120$ $\quad V_C \angle -150-120$

$V_A \angle -30°$ $\quad V_B \angle -150°$ $\quad V_C = \angle -270°$

$115.4 \angle -30°$ (V_A), $\quad 115.4 \angle -150°$ (V_B), $\quad 115.4 \angle -270$ (V_C)

ph

A STAR CONNECTED LOAD HAS 3 IMPEDANCES

$Z_a = 100\Omega$ RESISTOR WITH 400 mH INDUCTOR

$Z_b = 120\Omega$ RESISTOR WITH $10\,\mu F$ CAPACITOR

$Z_c = 250\Omega$ RESISTOR.

LINE VOLTAGE = 75 V, 60 HZ

PHASE SEQUENCE ABC.

USE E_{AB} AS REFERENCE, CALCULATE

ALL CURRENTS IN POLAR FORM

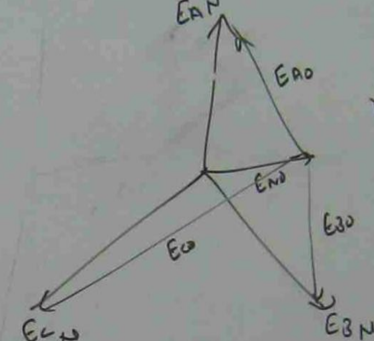
(i) ALL CURRENTS IN STAR POINT WITH

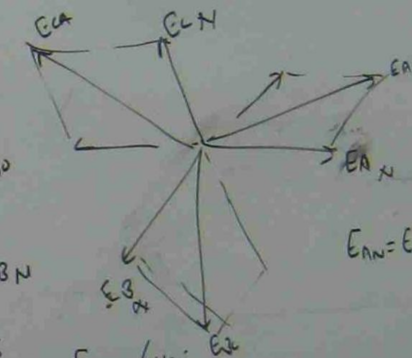
(ii) VOLTAGE OF STAR POINT WITH RESPECT TO NEUTRAL POINT.

$$Z_a = 100 + j2\pi fL = 100 + j2 \times 3.1416 \times 60 \times 400 \times 10^{-3}$$
$$= 100 + j150 = 180 \angle 56.3^\circ \ \Omega$$

$$Z_b = 120 - j\frac{1}{2\pi fC} = 120 - j\frac{1}{2 \times 3.1416 \times 60 \times 10 \times 10^{-6}}$$
$$= 120 - j265.25 = 291 \angle -65.6\,\Omega$$

$$Z_c = 250 \angle 0^\circ \ \Omega$$





$$E_{AN} = E_{BN} = E_{CN} = \frac{75}{\sqrt{3}}$$
$$= 43.3V$$

$E_{AB}\angle 30^\circ$, $E_{AN}\angle 0$, $E_{BN}\angle -120^\circ$, $E_{CN}\angle +120^\circ$,

E_{AB} REFERENCE $\longrightarrow$ $E_{AB}\angle 0$

$E_{AB}\angle 30-30$, $E_{AN}\angle 0-30$, $E_{BN}\angle -120-30$, $E_{CN}\angle +120-30$

$E_{AB}\angle 0$, $E_{AN}\angle -30$, $E_{BN}\angle -150$, $E_{CN}\angle 90^\circ$

$43.3\angle -30$, $43.3\angle -150$, $43.3\angle 90^\circ$

$$E_{NO} = \frac{E_{AN}Y_A + E_{BN}Y_B + E_{CN}Y_C}{Y_A + Y_B + Y_C}$$

$$= \frac{\frac{E_{AN}}{Z_A} + \frac{E_{BN}}{Z_B} + \frac{E_{CN}}{Z_C}}{\frac{1}{Z_A} + \frac{1}{Z_B} + \frac{1}{Z_C}}$$

$$Y_A = \frac{1}{Z_A} = \frac{1}{180\angle 56.3}$$
$$= 0.0055\angle -56.3$$

$$Y_B = \frac{1}{Z_B} = \frac{1}{291\angle -65.6}$$
$$= 0.0034\angle 65.6$$

$$Y_C = \frac{1}{Z_C} = \frac{1}{250}$$
$$= 0.004$$

$$E_{NO} = \frac{43.3\angle{-30} \times 0.0055\angle{-56.3} + 43.3\angle{-150} \times 0.0034\angle{65.6} + 43.3\angle{90} \times 0.004}{0.0055\angle{-56.3} + 0.0034\angle{65.6} + 0.004}$$

$$= \frac{0.238\angle{-86.3} + 0.147\angle{-84.4} + 0.1732\angle{90}}{0.0055(\cos 56.3 - j\sin 56.3) + 0.0034(\cos 65.6 + j\sin 65.6) + 0.004}$$

$$= \frac{0.238(\cos 86.3 - j\sin 86.3) + 0.147(\cos 84.4 - j\sin 84.4) + 0.1732(\cos 90 + j\sin 90)}{0.132 - j0.0929 + 0.0029 + j0.0031 + 0.004}$$

$$= \frac{0.0153 - j0.237 + 0.0143 - j0.0146 + j0.1732}{0.1389 - j0.089}$$

$$= \frac{0.0296 - j0.0784}{0.1389 - j0.089}$$

$$= \frac{0.0838\angle{-69.3}}{0.16496\angle{-32.6}}$$

$$= 0.51\angle{-26.3} \checkmark$$

$$E_{AO} = E_{AN} - E_{NO}$$
$$= 43.3\angle{30} - 0.51\angle{-26.3}$$
$$= 43.3(\cos 30 - j\sin 30) - 0.51(\cos 26.3 - j\sin 26.3)$$
$$= 37.5 - j21.65 - 0.457 + j0.225$$
$$= 37 - j21.425$$
$$= 42.75\angle{-30}$$

$$I_A = \frac{E_{AO}}{Z_A} = \frac{42.75\angle{-30}}{180\angle{56.3}}$$
$$= 0.221\angle{-86.3}\ \text{A}$$

$$E_{BO} = E_{BN} - E_{NO}$$
$$= 43.3\angle{-150} - 0.51\angle{-26.3}$$
$$=$$

$$I_B = \frac{E_{BO}}{Z_B}$$

$$E_{CO} = E_{CN} - E_{NO}$$
$$= 43.3\angle{90} - 0.51\angle{-26.3}$$
$$=$$

$$I_C = \frac{E_{CO}}{Z_C} =$$