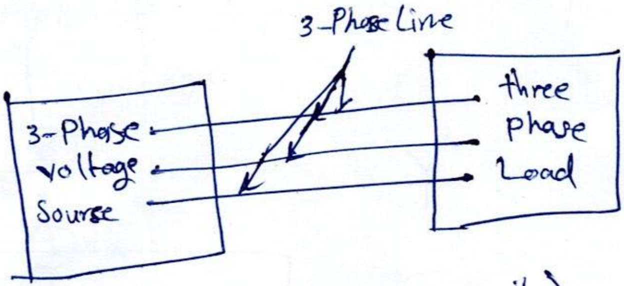
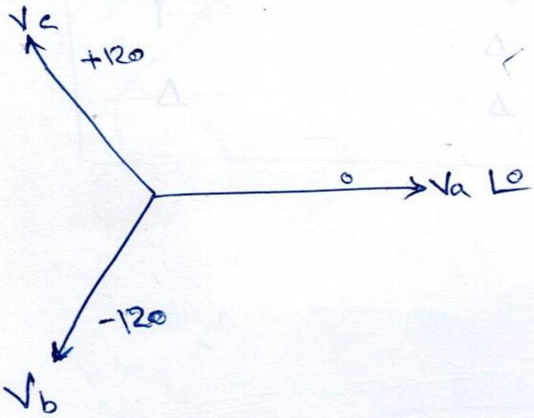
Lect-8

Three-Phase

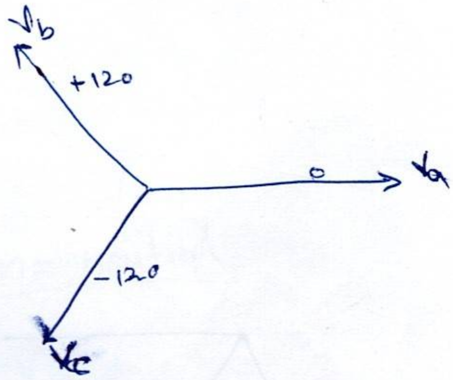


(a basic 3-Phase circuit)

Positive (abc) sequnce



Negative (acb) sequence



I

$V_a = V_{m_{ax}} \angle 0$
$V_b = V_m \angle -120$
$V_c = V_m \angle +120$

$V_a = V_m \angle 0$
$V_b = V_m \angle +120$
$V_c = V_m \angle -120$

Source ⟶ Line ⟶ Load

$$\boxed{V_a + V_b + V_c = 0}$$

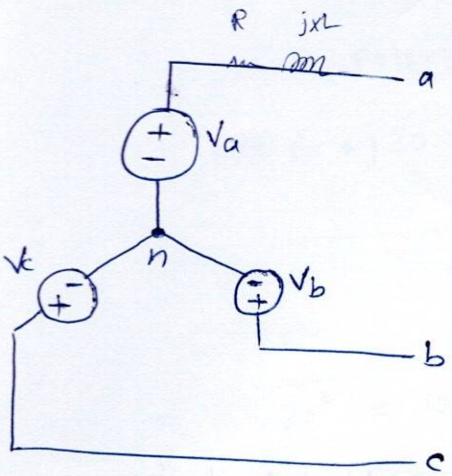
* مواصفات 3-phase

* توليد الطاقة ونقلها وتوزيعها بكميات كبيرة يتطلب ربطها بطريقة 3-phase بدلاً من single φ لأنه يحتمل power عالية جداً.
* تعتمد على مصادر الفولتية.
* 3-ملفات مرتبطة مع بعض. مصنوعة بطريقة identical متساوية من حيث المادة وعدد اللفات والاقطاب.
* الفولتيات تكون متساوية من حيث القيمة والتردد ماعدا الطور (phase) ، بـ $\boxed{120^\circ}$

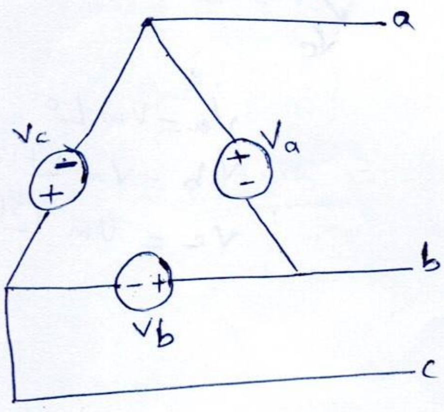
* shift by 120°

طريقة الربط للمصدر Y أو Δ

وكذلك بالنسبة للـ Load

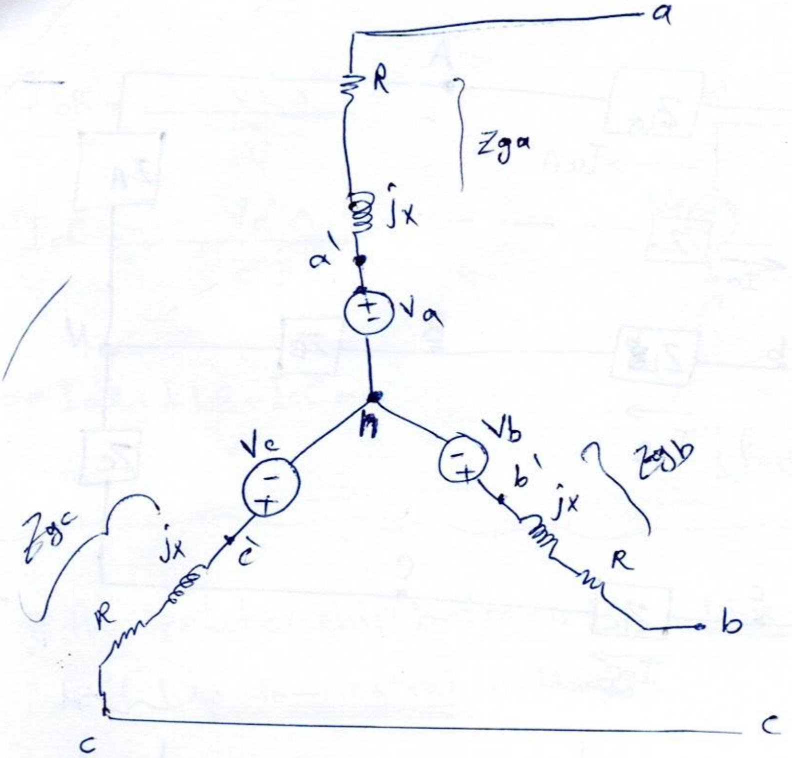


Source	Load
Y	Y
Y	Δ
Δ	Y
Δ	Δ

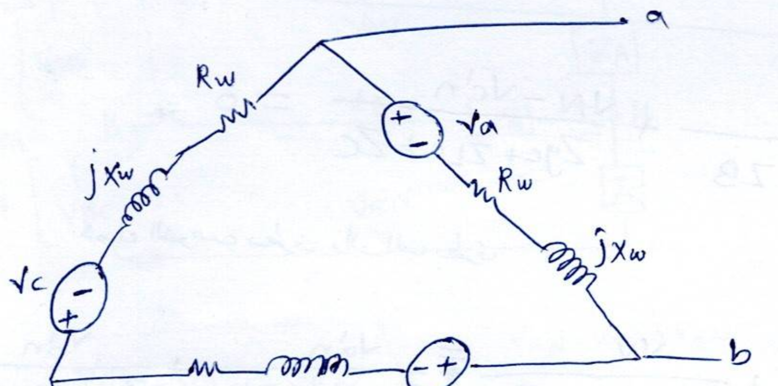


Δ

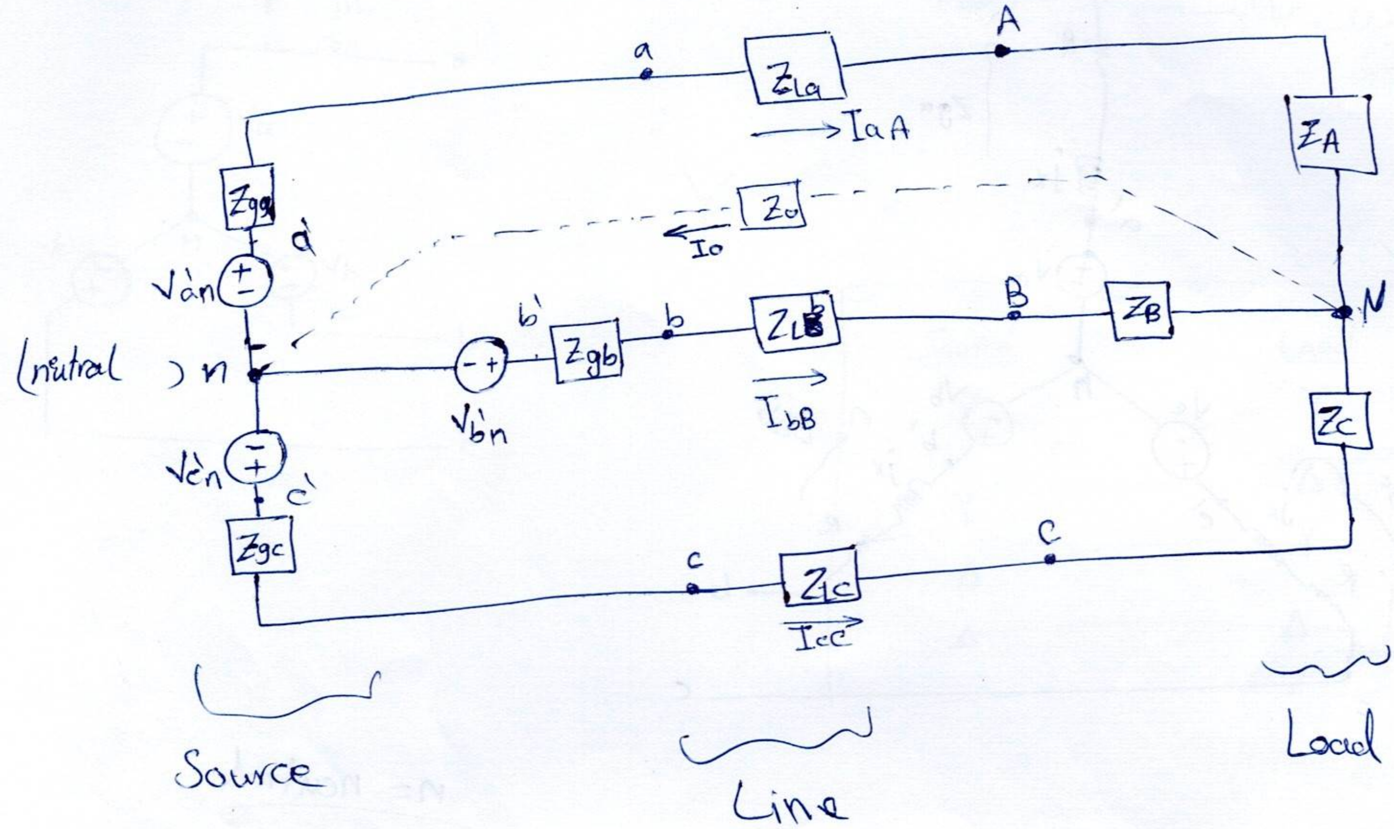
- دائما طريقة الحل تحتسب على Y. نحول من Δ ← Y ونكمل الحل.
- Δ الملف يحتوي على impedance Z. يعني مقاومة ومحاثة $Z_g = (R + jX_L)$ ممانعة داخلية
- * تعتبر الممانعة خارج المصدر لتحليل الدائرة.


a
R
Zga
jx
a'
Va
n
Vc
Vb
b'
jx
Zgb
Zgc
jx
c'
R
R
b
c
c

n= neutral


a
Rw
Va
jXw
Rw
jXw
Vc
Rw
jXw
Vb
b
c

Analysis of the Wye – Wye circuit (Y – Y)



الاحرف الصغيرة للمصدر

الاحرف الكبيرة للحمل

مجموع التيارات

$$\frac{V_N}{Z_0} + \frac{V_N - V_{a'n}}{Z_{ga} + Z_{La} + Z_A} + \frac{V_N - V_{b'n}}{Z_{gb} + Z_{Lb} + Z_B} + \frac{V_N - V_{c'n}}{Z_{gc} + Z_{Lc} + Z_C} = 0$$

نحول الموجب بطرف والسالب بطرف

$$\frac{V_N}{Z_0} + \frac{V_N}{Z_{ga} + Z_{La} + Z_A} + \frac{V_N}{Z_{gb} + Z_{Lb} + Z_B} + \frac{V_N}{Z_{gc} + Z_{Lc} + Z_C} = \frac{V_{a'n}}{Z_{ga} + Z_{La} + Z_A} + \frac{V_{b'n}}{Z_{gc} + Z_{Lb} + Z_B}$$

$$+ \frac{V_{c'n}}{Z_{gc} + Z_{Lc} + Z_c}$$

$$\boxed{Z_\phi = Z_{ga} + Z_{La} + Z_A = Z_{gb} + Z_{Lb} + Z_B = Z_{gc} + Z_{Lc} + Z_c}$$

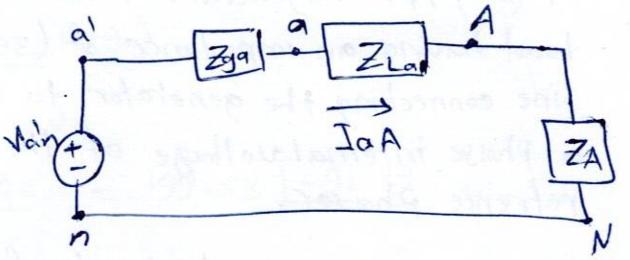
$$\therefore \; V_N \left(\frac{1}{Z_0} + \frac{3}{Z_\phi} \right) = \frac{V_{a'n}}{Z_\phi} + \frac{V_{b'n}}{Z_\phi} + \frac{V_{c'n}}{Z_\phi}$$

$$= \frac{V_{a'n} + V_{b'n} + V_{c'n}}{Z_\phi}$$

$$I_{aA} = \frac{V_{a'n}}{Z_\phi}$$

$$I_{bB} = \frac{V_{b'n}}{Z_\phi}$$

$$I_{cC} = \frac{V_{c'n}}{Z_\phi}$$



(single-phase equivalent cct.)

$$I_0 = I_{aA} + I_{bB} + I_{cC} = 0$$

(first step in analyzing a 3-phase cct.)

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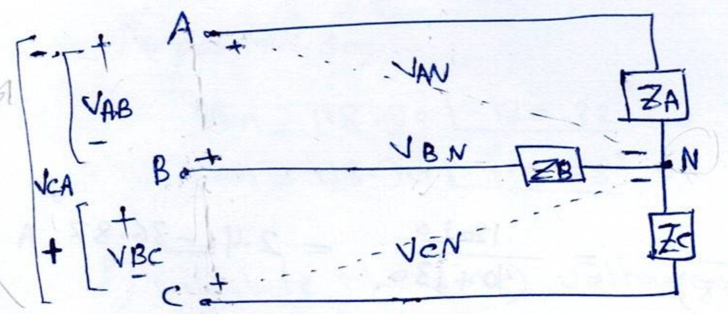
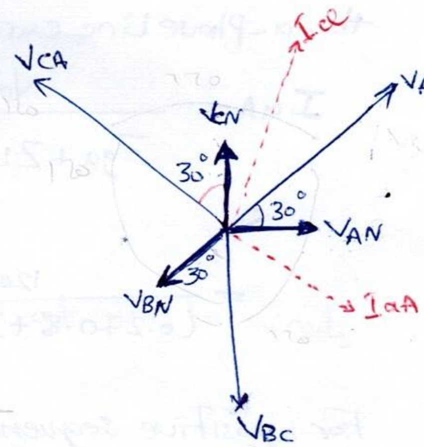
* the relationship between the Line-to-line voltages and line-to-neutral voltages.

← ناخذ جزء من تحليل دارة Y load





$$\boxed{\begin{aligned} V_{AB} &= V_{AN} - V_{BN} \\ V_{BC} &= V_{BN} - V_{CN} \\ V_{CA} &= V_{CN} - V_{AN} \end{aligned}}$$

$V_{AN} = V_{AB} + V_{BN}$

$V_{BN} = V_{BC} + V_{CN}$

$V_{CN} = V_{CA} + V_{AN}$

* V_{AB}, V_{BC}, V_{CA} → Line-to-Line voltages
* V_{AN}, V_{BN}, V_{CN} → Line-to-neutral voltages

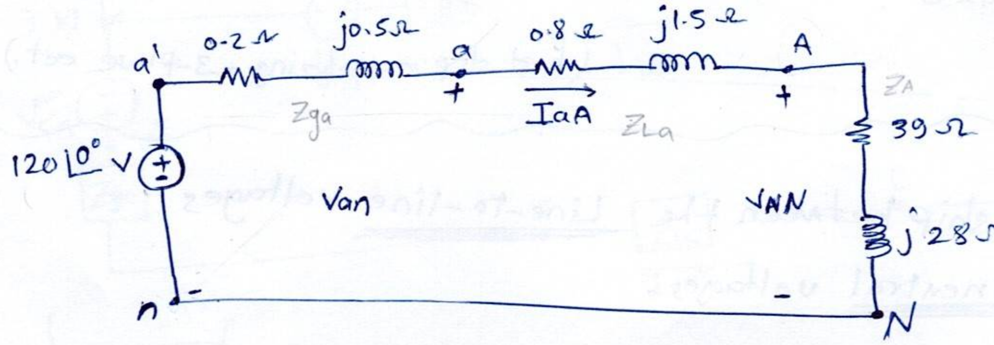
$$\boxed{V_{AB} = (\sqrt{3} \angle 30^\circ) V_{AN}}$$ positive sequence

$V_{BC} = V_{AB} \angle -120$

$V_{CA} = V_{AB} \angle +120$

Example: A balanced 3-Phase Y-connected generator with positive sequence has an impedance of $(0.2+j0.5)\ \Omega/\phi$ and an internal voltage of $(120)\ V/\phi$. The generator feeds a balanced 3-phase Y-connected load having an impedance of $(39+j28)\ \Omega/\phi$. The impedance of the Line connecting the generator to the load is $(0.8+j1.5)\ \Omega/\phi$. The a-phase internal voltage of the generator is specified as the refrence phasor.

a) constract the a-phase equivalent cct. of the system.



b) Calculate the three Line current I_{aA}, I_{bB}, I_{cC}.

the a-Phase Line current is

$$I_{aA} = \frac{V_{a'n}}{Z_{ga}+Z_{La}+Z_A}$$

$$= \frac{120\angle 0}{(0.2+0.8+39)+j(0.5+1.5+28)} = \frac{120\angle 0}{\underset{50\angle 36.86^\circ}{40+j30}} = 2.4\angle -36.87^\circ\ A$$

For apositive sequence phase →

$$I_{bB} = 2.4\angle -36.87^\circ - 120^\circ = 2.4\angle -156.87^\circ\ A.$$

$$I_{cC} = 2.4\angle -36.87 + 120^\circ = 2.4\angle 83.13^\circ\ A.$$

c) Calculate the three phase Voltage at load, V_{AN}, V_{BN}, V_{CN}.

$$V_{AN} = Z_A * I_{aA}$$

$$= (39+j28) * (2.4\angle -36.87) = 115.22\angle -1.19^\circ\ V.$$

$$V_{BN} = 115.22\angle -1.19^\circ - 120^\circ = 115.22\angle -121.19^\circ\ V.$$

$$V_{CN} = 115.22\angle -1.19+120 = 115.22\angle 118.81^\circ\ V.$$

calculated the line voltage V_{AB}, V_{BC}, V_{CA} at the terminals of the load.

Line, phase

$$V_{AB} = (\sqrt{3}\angle 30^\circ) V_{AN}$$
$$= (\sqrt{3}\angle 30) * (115.22 \angle -1.19)$$
$$= 199.58 \angle 28.81 \text{ V.}$$

$$V_{BC} = 199.58 \angle 28.81 - 120 = 199.58 \angle -91.19^\circ \text{ V.}$$

$$V_{CA} = 199.58 \angle 28.81 + 120 = 199.58 \angle 148.81^\circ \text{ V.}$$

e) calculate the phase voltages at the terminals of the generator V_{an}, V_{bn}, V_{cn}.

$$V_{an} = V_{a'n} - V_{ga}$$
$$= 120 \angle 0 - [(0.2 + j0.5) * (2.4 \angle -36.87)]$$
$$= 120 \angle 0 - 1.29 \angle 31.33$$
$$= 118.90 - j0.67$$
$$= 118.90 \angle -0.32 \text{ V.}$$

For positive seq

$$V_{bn} = 118.90 \angle -120.32^\circ \text{ V}$$
$$V_{cn} = 118.90 \angle 119.68^\circ \text{ V.}$$

f) Calculate the line voltages V_{ab}, V_{bc}, V_{ca} at the terminals of the genertor

$$V_{ab} = (\sqrt{3}\angle 30) V_{an}$$
$$= (\sqrt{3}\angle 30)(118.90 \angle -0.32)$$
$$= 205.94 \angle 29.68^\circ \text{ V.}$$

$$V_{bc} = 205.94 \angle -90.32^\circ \text{ V.}$$

$$V_{ca} = 205.94 \angle 149.68^\circ \text{ V.}$$

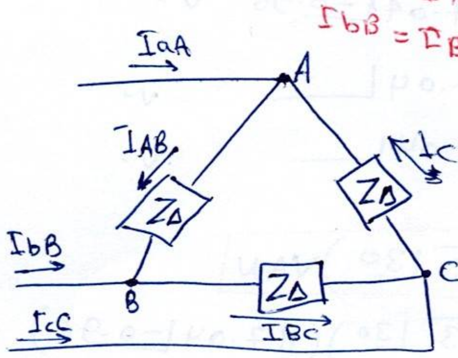
g) Repeat (a — f) for a negative sequence phase.

* Analysis of the Wye – Delta cct. Y – Δ

$$\boxed{Z_Y = \frac{Z_\Delta}{3}}$$

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

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



$I_{aA} = \sqrt{3}\,\angle{-30}\, I_\varphi$

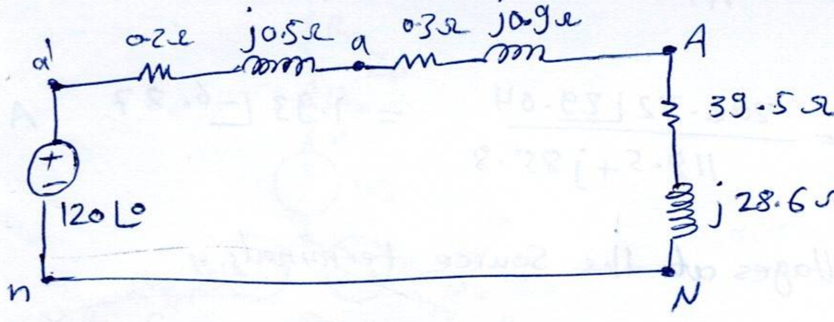
$$\boxed{I_{AB} = \left(\frac{1}{\sqrt{3}} \angle 30\right) I_{aA}}$$ positive

$I_{AB} = I_\varphi$

Ex: The Y_connected Source in Ex(1) feeds a Δ-connected load through adistribution line having an impedance of $(0.3 + j0.9\ \Omega)/\phi$. The load impedance is $(118.5 + j85.8)\ \Omega/\varphi$. Use the a-phase internal voltage of the generator as the refrence.

a) Construct a single-phase equivalent circuit of the 3-phase system.

$$Z_Y = \frac{Z_\Delta}{3} = \frac{118.5 + j85.8}{3} = 39.5 + j28.6\ \ \Omega/\varphi$$



b) calculate the line current I_{aA}, I_{bB}, I_{cC}

$$I_{aA} = \frac{V_{a'n}}{Z_{ga} + Z_{La} + Z_A}$$

$$= \frac{120\angle 0}{(0.2 + 0.3 + 39.5) + j(0.5 + 0.9 + 28.6)}$$

$$= \frac{120\angle 0}{40 + j30} = 2.4\angle{-36.87^\circ}\ \text{A}$$

$I_{bB} = 2.4\angle{-156.87^\circ}$ A , $I_{cC} = 2.4\angle 83.13^\circ$ A

c) calculate the phase voltages at the load terminals.

$V_{AN} = (39.5 + j28.6)(2.4 \angle -36.87)$
$= 117.04 \angle -0.96$ v.

$V_{BN} = 117.04 \angle$ ______ v.

$V_{CN} = 117.04 \angle$ ______ v.

$\boxed{V_{AB} = (\sqrt{3} \angle 30^\circ) V_{AN}}$
$= (\sqrt{3} \angle 30^\circ)(117.04 \angle -0.96) = 202.72 \angle 29.04$ v.

$V_{BC} = 202.72 \angle -90.96$ v.
$V_{CA} = 202.72 \angle 149.04$ v.

d) Calculate the Phase current of the load. $Y \rightarrow I_\phi = I_L$

$I_{AB} = (\frac{1}{\sqrt{3}} \angle 30)\, I_{aA} = 1.39 \angle -6.87$ A $\quad \Delta \rightarrow V_\phi = V_L$

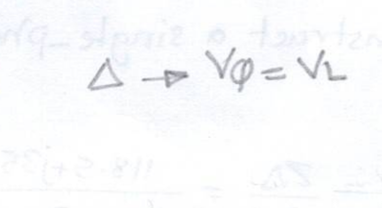
$I_{BC} = 1.39 \angle -126.87$ A
$I_{CA} = 1.39 \angle 113.13$ A.

or $\longrightarrow I_{AB} = \frac{V_{AB}}{Z_\phi} = \frac{202.72 \angle 29.04}{118.5 + j85.8} = 1.93 \angle -6.87$ A

V_{ab}

e) Calculate the line voltages at the source terminals.

$V_{an} = (39.8 + j29.5)(2.4 \angle -36.87) = I_{aA}(Z_{La} + Z_A)$
$= 118.90 \angle -0.32$ v.



The line voltage V_{ab} is

$\boxed{V_{ab} = (\sqrt{3} \angle 30) V_{an}}$
$= 205.94 \angle 29.68$ v.

$V_{bc} = 205.94 \angle -90.32$ v.

$V_{ca} = 205.94 \angle 149.68$ v.

طريقة اخرى لل(ب) د $\underline{V_{an}}$

$V_{an} = V_{a'n} - V_{ga}$
$V_{ga} = I_{aA} * Z_{ga}$
$= (2.4 \angle -36.87)(0.2 + j0.5$
$= 1.29 \angle -35.68$
$V_{an} = 120 \angle 0 - 1.29 \angle -35.68$
$= 120 - 1.047 - j0.75$
$= 118.95 - j0.75$
$= 118.95 \angle -0.36$ v.