ElCoM
ELECTRICAL COMPUTER MECHATRONICS

تقدم لجنة ElCoM الاكاديمية

دفتر لمادة:

أنظمة القوى الكهربائية

من شرح:

د.محمود سعادة

جزيل الشكر للطالب:

محمد جدوع

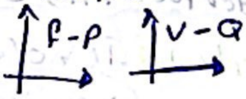
Generate ① → transmit ② → Consume (Distribution) ③

one-line digram

Generation (توليد)

بتم عن طريق synchronous generator

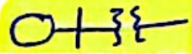
→ Droop characteristic



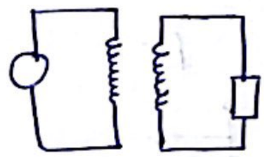
xFMR → (substation)

* doesnot change frequency.
* changes the voltage level.

Bus ↳ Interconnection two different element. (Similar to node in a circuit).



inside substation



* Bus Bar : نقطة وصل (قطعة معدنية)

* يجب ان يكون هناك توازن بين gen. and Load

---

* What is the purpose of the power system?
  - to deliver power to the user.

① high quality
② Low cost. → ① Cost of generation. ② cost of transmission. ③ cost of distribution. ④ miss. Cost. (تكاليف اخرى) → ① Cost of fuel. ② efficiency.
③ high reliability → ① no interaction. (to deliver power without interactions).

* In any power system Generation has to meet the demand. (Load)

Energy conversion

mech. → $\boxed{\text{sync.}}$ → elc.

τ , ω $\qquad$ V , I

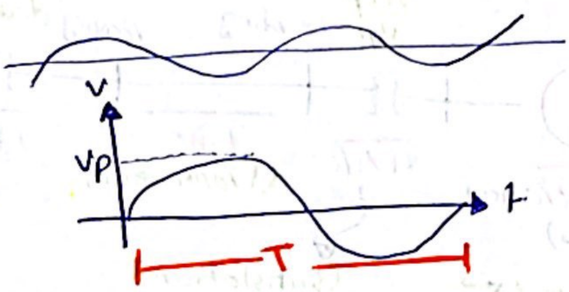
Load ↓ , w ↑ , f ↑ → داخل المنازل $f = 50 Hz \mp 5\%$

Load ↑ , w ↓ , f ↓

* العلاقة العكسية بين Load , fri. تسمى Droop charac.

* load shedding ∝ ← اشي مش مرغوب فيه. ∝
* Brotection. ∝
* selectivity: to minimze affective Area. ✓

* **high quality** → ① Voltage level. (220v) ② freq. ③ T.H.D.

Ac wave from → ① Sinosoidal.


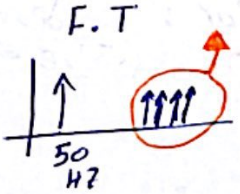
خصائص → ① peak ② phase ③ $freq. = 50HZ = \frac{1}{T}$

$loss = I^2 R$

DC


⇒ AC

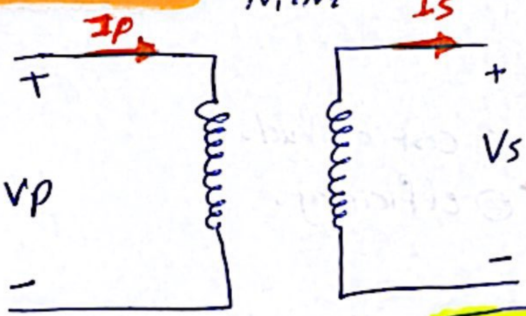
تشويش + ripple

F.T


* Non Linear devices (R, C, L) that introduce harmonics to the system.

power electrines: ① chargers → charge batteries DC
Ac to Dc
Dc to Ac
② car. ③ inverter
④ power supply. ⑤ UPS

Transformer

$N_1 : N_2$


step up transformer $\boxed{V_s >> V_p}$

Ideal ⇒ no loss ⇒ $P_{in} = P_{out}$

$|V_p||I_p| = |V_s| \uparrow |I_s| \downarrow$

$$\boxed{\frac{V_p}{V_s} = \frac{N_1}{N_2}}$$

هاد الهدف من transf. هو تقليل التيار عشان يقل Loss. (يقل التيار عن طريق زيادة الفولتية).
وبالتالي برسل power لمسافات ابعد.

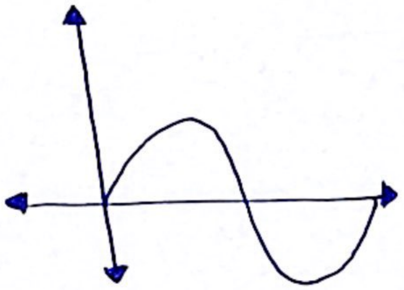
* **transformer ⇒ only in AC**

① storage system: (Energy) we don't mean high voltage. (batteries)
② transmission system: HVDC.

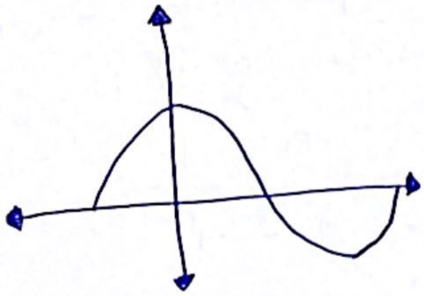
*كل ما زادت freq. كل ما زادت تكلفة النظام وقل حجمه.

* 10 HZ ⇒ 10 cycle / sec.
* 50 HZ ⇒ 50 cycle / sec.

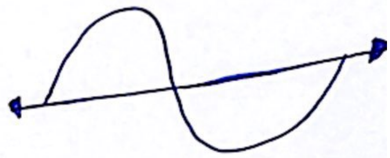
(8 جرب بالصين (التردد)).
(عشان هيك بستخدم 50HZ).



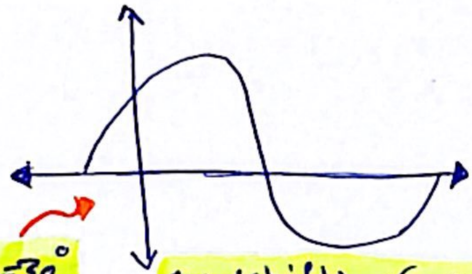
sin



cos



sinusoidal

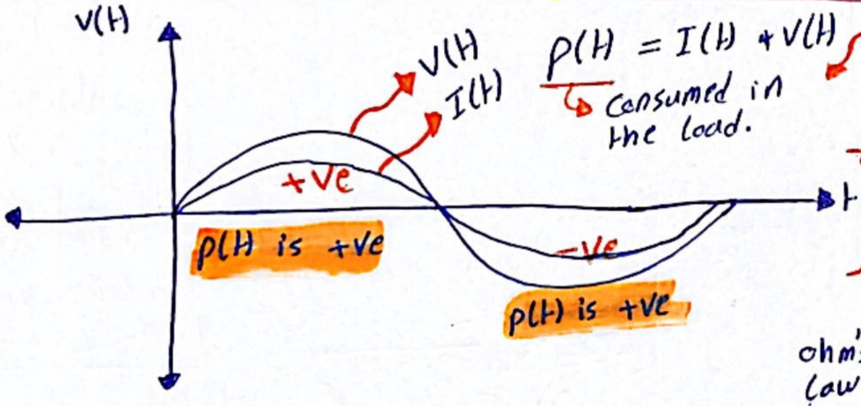


shift = 30°

sin (shift) or cos(shift)

* Any system has two refranse:
① voltage level. frequency (ground)?
② $t = 0$.

*you always get to choose refrance. (ONCE)



$p(t) = I(t) * v(t)$ → consumed in the load.

$V_{avg} = Zero$, $I_{avg} = Zero$

$v(t) = V_p \sin(\omega t + \theta)$

$$\text{Average } v(t) = \int_0^T \frac{V_p \sin(\omega t + \theta)}{T}$$

$$i(t) = \frac{v(t)}{R} = \frac{V_p}{R} * \sin(\omega t + \theta)$$

ohm's law

* Average Ac voltage is always Zero.

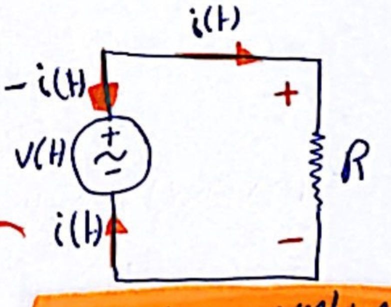
* $$\text{Average power} = \int_0^T \frac{p(t)}{T} dt$$

$$p(t) = \int_0^T \frac{v(t)\, I(t)}{T} dt$$

* $p(t)$: instantaneous power.

power consumed in gen. $= i(t) * v(t) = -p(t)$ ← $-i(t)$

power generated in gen. $= i(t) * v(t) = p(t)$ ← $i(t)$



passive sign convention

$V = I * R$

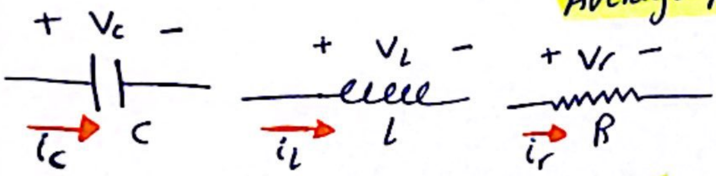
$P = V * I$

* the current entering the +ve terminal as voltage is defined. (consumed power) (الطاقة المستهلكة)

Average power = Zero

$I = C\frac{dV}{dt}$

$V = L\frac{di}{dt}$



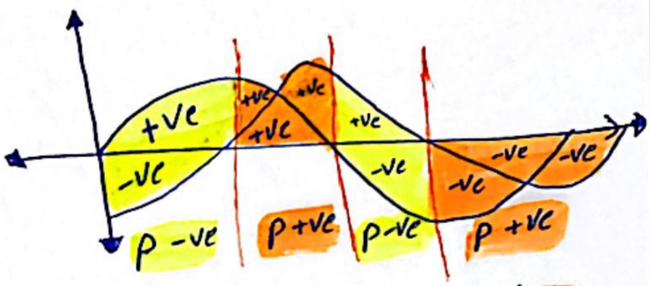
$\sin' = \cos$ → shift 90°

$\cos' = -\sin$ → shift 90°

$i_c = C\frac{dv}{dt}$ → تقاوم التغير في الفولتية

$V_L = L\frac{dI}{dt}$ → تقاوم التغير في ~~التيار~~

$V_r = I * R$ → تقاوم مرور التيار



* المساحة متساوية.

$V_c(t) = V_m e^{j(wt+\theta)}$

$\frac{dV}{dt} = V_m e^{j(wt+\theta)} * jw$

$i_c = C V_m jw e^{j(wt+\theta)}$

$i_c|_{t=0} = jwC V_c$

$\boxed{Z_c = \frac{V_c}{I_c}}$ $Z_c = \frac{1}{jwC}$

$Z_L = \frac{V_L}{I_L}$

$Z_L = jwL$

$\boxed{7}$

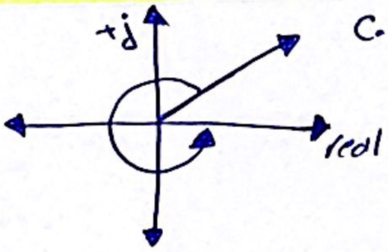
* $e^{j\theta} = \cos\theta + j\sin\theta$

$V(t) = V_m \cos(wt+\theta) + V_m j \sin(wt+\theta)$

→ $V(t) = V_m(\cos(wt+\theta) + j\sin(wt+\theta))$

→ $V(t) = V_m e^{j(wt+\theta)}$ → $|_{w=0}$ → $V(t) = V_m e^{j\theta}$ →

$V(t) = V_m\cos(wt+\theta)$ ⇄ $V_m e^{j\theta}$



C.C.W rotation at w → $w = 2\pi f$

* $V(t) = V_m e^{j(wt+\theta)}$ → only used to explain Z.

* passive Linear circuit

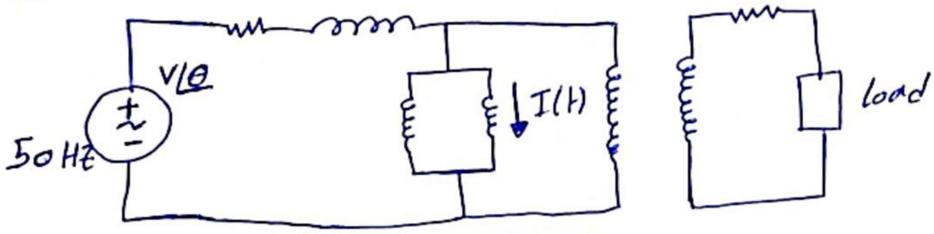
XFmR
Motors
gener.
transm.
inductors
capac.

← مكونات اعي سيركت جذول مابغيرو على freq.

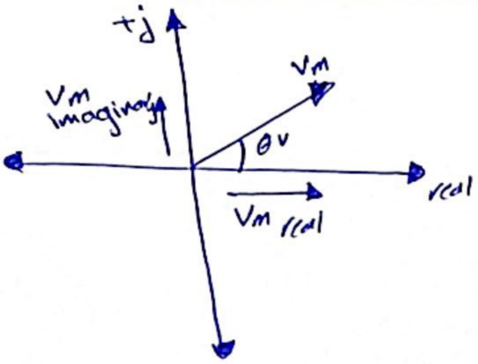
* عشان اغير على freq. لازم ادخل على السيركت non-Linear elements $\boxed{8}$

tip * you shoud never have "t & j" in the same equation.
* you either solve in the time domain only "t & No j" or in the freq. domain No "t".

Q) what is freq. of I(t) ?



sol → freq of I(t) = 50 HZ



polar → $V_m \angle \theta_v$
rect → $V_{m_{real}} + jV_{m_{imag}}$

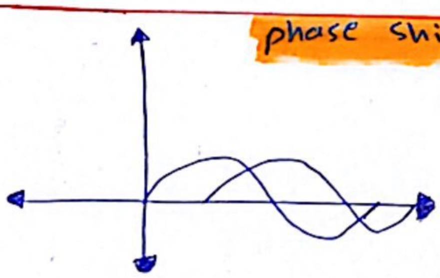
* تحويل من polar إلى rect. :

① $V_m e^{j\theta}$, $V_m \angle \theta = V_m \cos\theta + j\, V_m \sin\theta$

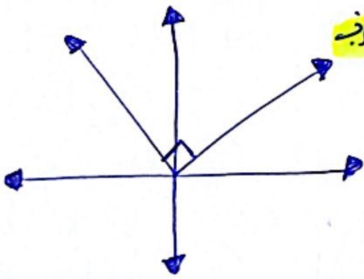
② $V_m = \sqrt{(V_m \cos\theta)^2 + (V_m \sin\theta)^2}$

$\boxed{9}$ ③ $\theta = \tan^{-1}\left(\frac{\cancel{V_m} \sin\theta}{\cancel{V_m} \cos\theta}\right)$

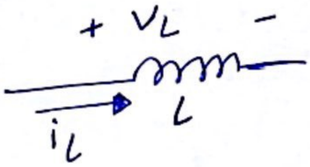
phase shift



→



ضرب * jw → ازاحة بمقدار 90°
→ rotation or phase shift 90°

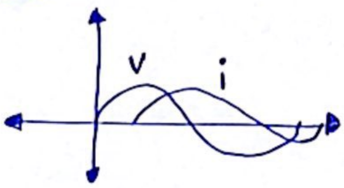


* +ve area of v(t) , i(t) equal −ve area.

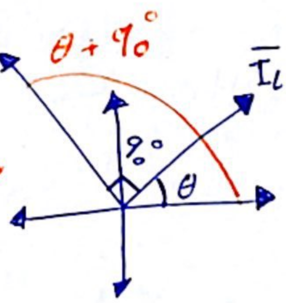
$V_L = L\frac{di}{dt}$

$\times jw = 90°$

→



→



c.c.w

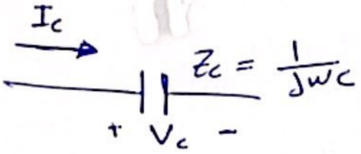
$V_L = I_L * Z_L$

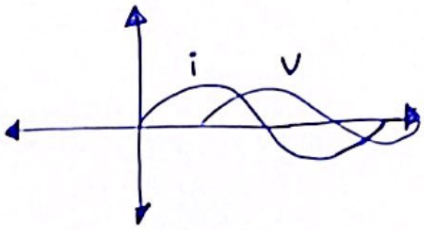
$V_L = \underset{+90}{jwL}\, I_L$ → lagging phase shift

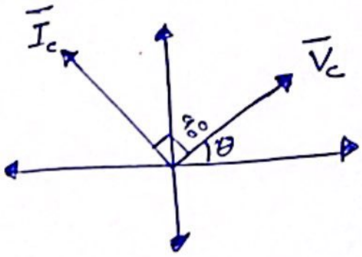
* $P_{avg} = \int_0^T \frac{P(t)}{T}\, dt = \text{Zero}$
L or c

* فرق الزاوية بين V , I ← 90°
I Lag V

$\boxed{10}$







$V_c = I_c * Z_c$

$V_c = I_c * \frac{1}{jwc}$

$V_c = -jwc\, I_c$ → Leading

I Lead V

$-90°$

$\theta_V = 30 \rightarrow \theta_I = -60$

$-60 \rightarrow 180 - 60 = 120$

* دائماً الأصل في المقارنات ((Lagg., Lead)) هو الجهد V .

* Average voltage and average current are zero. → ① We don't care about Average V or I. ② we care about average power. ③ Therefore we defined RMS V & I to make Pavg calculation easier.

$$\text{Average power} = \int_0^T \frac{P(t)}{T}\, dt = \int_0^T \frac{V(t) * I(t)}{T}\, dt$$

ohm's Law
$V = I * R$
* Resistive load.

$$= \int_0^T \frac{V^2(t)}{\underbrace{R\,T}_{\text{ثوابت}}}\, dt = \int_0^T \frac{I^2(t) * R}{T}\, dt$$

ثابت

ثابت

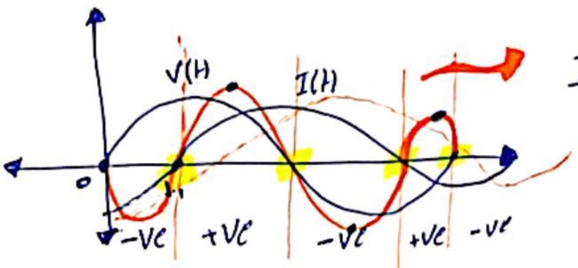
$$= \frac{1}{R}\left[\left[\frac{\int_0^T V^2(t)}{T}\, dt\right]^{\frac{1}{2}}\right]^2 = R\left[\left[\frac{\int_0^T I^2(t)}{T}\, dt\right]^{\frac{1}{2}}\right]^2$$

* root of mean of square RMS of V(t) — Vrms

* root of mean of square RMS I — Irms.

$$\text{Eq: } V(t) = \frac{V_{rms}^2}{R} = I_{rms}^2 * R$$

* if we have an inductive or capacitive load?



inductive
I lagg V

* عند الصفر و π قيمة
Pavg = Zero.

* عند اي نقطة غير الصفر و π
Pavg = +ve

(Source من load الى)
(consume) استهلاك طاقة.

t = 0
t = t₁ , t₁ > 0

* $i(t - t_1) = i(0) =$
when $t = t_1$

* time shift.

* كل ما زاد الزمن كل ما صار تأخير اكثر. (Lagging).

* عند نقاط التقاطع مع x-axis ⇐ P = Zero

* pure inductance
Area +ve = Area -ve
and phase shift = 90°

* phase angle $\theta_v - \theta_i$
$\theta_v - \theta_i > 0$ → lead.

* freq of V & I = 50 HZ

* freq of P =

* كل دورة للتيار يقابلها دورتين للباور.

* power will oscillate at twice the freq.

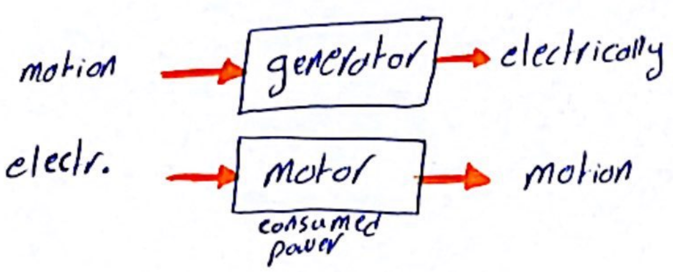
* phase angle Zero ? بنطبقوا على بعض بالتالي تصبح كل المساحات موجبة (Resist.)

* P -ve → supply.

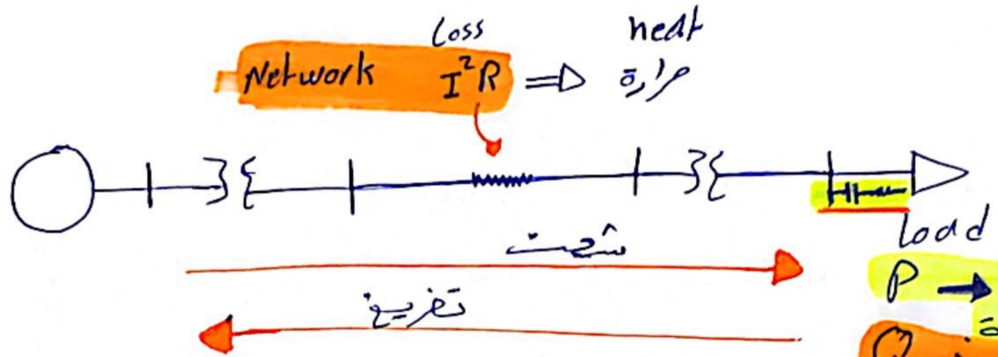
Q : Reactive power.

P : Average power. → the actuall power bieng consumed by the load.

ex : ① light.
② heat.
③ Washer, fan (motion) → real → rate of energy bieng consumed → converted from elect. to other form of energy.
→ reactive → rate of energy bieng stored and released.



* Power factor correction (معامل القدرة)



P → يتم تحويلها الى شكل اخر من اشكال الطاقة

+ve Q → تبقى طاقة كهربائية

(تخزين ← تفريغ)

* total reactive power reduced

-ve Q

+ve Q

$\bar{S}$: Complex power

$\bar{S} = P + jQ$ → real number

$P = |S| \cos\theta$

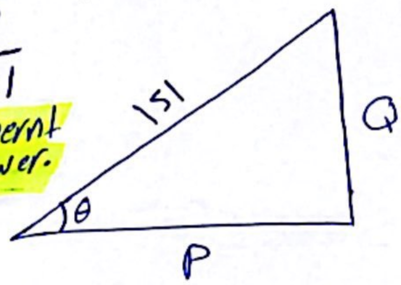
$Q = |S| \sin\theta$

$\theta = \theta_v - \theta_i$

$\theta = \tan^{-1}\left(\frac{Q}{P}\right)$

$P.f = \frac{P}{|S|}$

$|S|$: Apperent power.



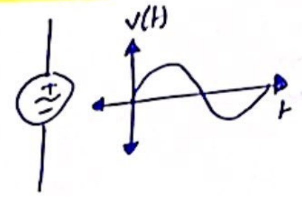
3ϕ → 3 single phase

- → 3ϕ Lines.
- → 3ϕ Source
- → 3ϕ Load
- → 3ϕ XFMR

→ 3ϕ system.

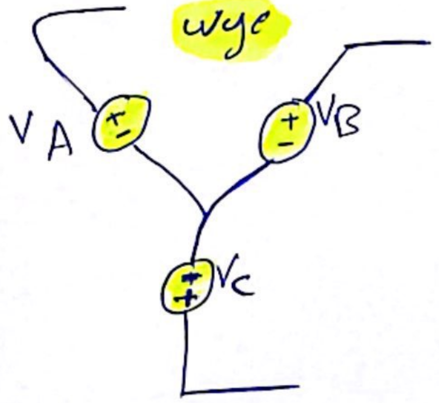
3ϕ source.

1ϕ

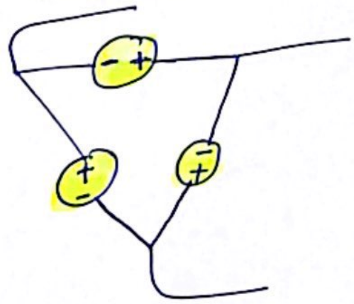


3ϕ source

wye



Dalta



17

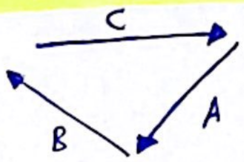
① Balanced 3ϕ Source → ① $|V_A| = |V_B| = |V_C|$.

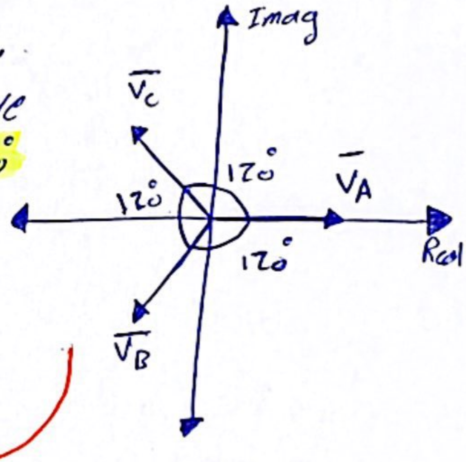
② Angle $\theta_A, \theta_B, \theta_C$ are equally spaced → $120°$ phase shift between each two consecative phases. متتاليين

② unbalanced 3ϕ Source.

$$\frac{360}{3} = 120°$$

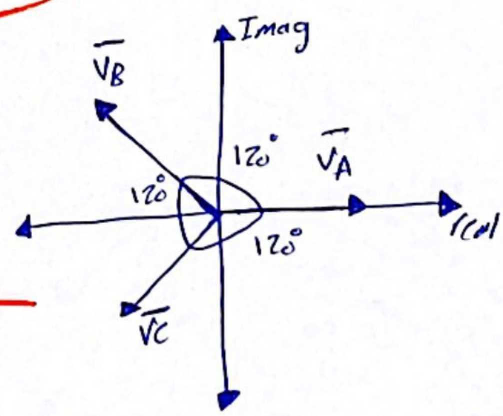
* $\overline{V}_A + \overline{V}_B + \overline{V}_C = \text{Zero}$





$\overline{V}_A \rightarrow \overline{V}_C \rightarrow \overline{V}_C$

ACB sequance.
(-ve sequance)

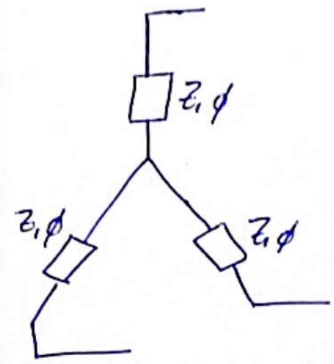


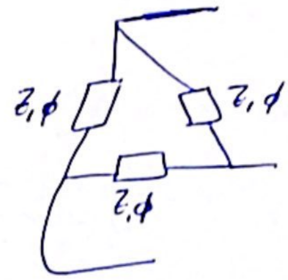
$\overline{V}_A \rightarrow \overline{V}_B \rightarrow \overline{V}_C$

ABC sequance
(+ve sequance)

18

3 ϕ load:

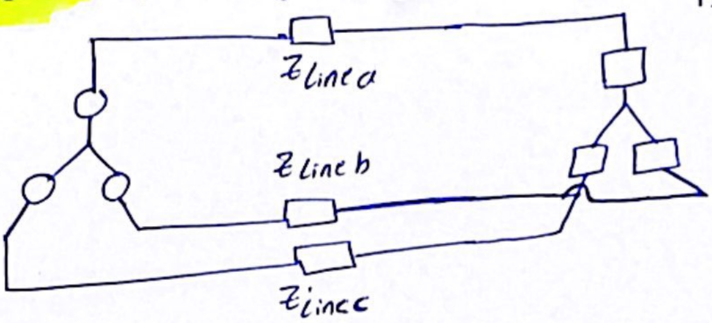




→ for 3 ϕ loads to be balanced $Z_a = Z_b = Z_c = Z_\phi$

* $p_t(t) = p_a(t) + p_b(t) + p_c(t)$ → always true

3 ϕ ystem: → if every empedents in the system is balanced, the system is balanced:
1. source.
2. load.
3. Line.



19

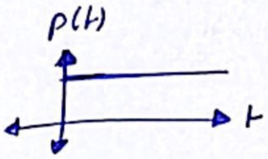
---

* in balanced three phase system:

1. the current pussing in the system will also be balanced.
2. each phase will consume the same amounte of real and reactive power.

$P_A = P_B = P_C$

3. $P_{3,\phi}(t) = \text{constant}.$



* power in 3 ϕ system:

$P_{3\phi} = 3 * P_{1,\phi}$

$Q_{3,\phi} = 3 * Q_{1,\phi}$

$S_{3,\phi} = 3 * S_{1,\phi}$

$S_{1,\phi} = \bar{V}_{1\phi} * \bar{I}^*_{1,\phi} = |V|_{1\phi} |I|_{1\phi} \angle \theta_v - \theta_i$

* $P_{source} = P_{Line} + P_{Load}$

* P_{Line}

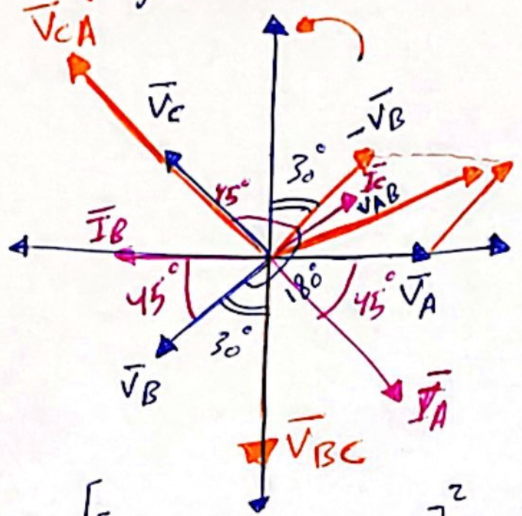
* P_{Load}

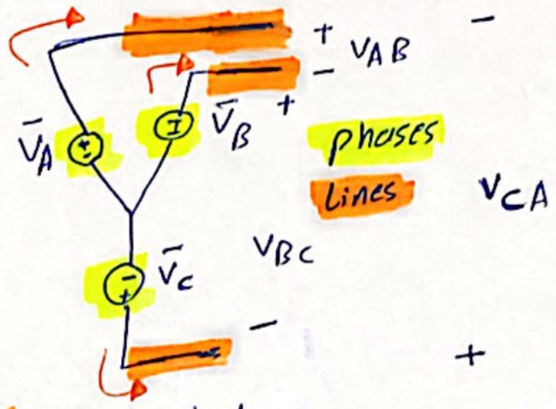
$S_{3,\phi} = 3 * \bar{V}_{1,\phi} * \bar{I}_{1,\phi} = 3 |V| |I| \angle \theta_v - \theta_i$

wye connection $= 3 * \frac{|V_L|}{\sqrt{3}} * I_L * \angle V_{V,1\phi} - \theta_{i,1\phi} = \sqrt{3}\, |V_L| |I_L| \angle \theta_{v1\phi} - \theta_{i,1\phi}$ 20

20

* V & I in 3 phase:
(wye - connected 3 ϕ source)





* V_A, V_B and V_C are phase Voltages.

* فرق الزاوية بين V_{AB} و I_A $75°$.

$$V_{AB} = \left[\left[|V_A| + |V_A|\cos(60)\right]^2 + \left[|V_A|\sin(60)\right]^2\right]^{1/2} \angle \tan^{-1}\frac{|V_A|\sin 60}{|V_A| + |V_A|\cos 60}$$

* V_{AB} & V_{BC} & V_{CA} are Line voltages.

* $V_{AB} = \bar{V}_A - \bar{V}_B = \bar{V}_A + (-\bar{V}_B)$

$$V_{AB} = \sqrt{3}\ |V_A| \angle 30°$$

$\angle V_A + 30°$

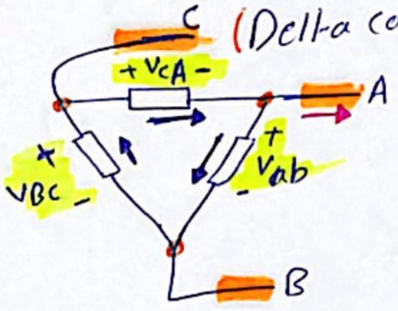
* $V_{AB} = |V_A|\angle 0 + |V_A|\angle 60°$
$= V_A \angle 0 + |V_A|\cos(60) + j|V_A|\sin(60)$

21

---

* $|V_{AB}| = |V_{BC}| = |V_{CA}|$
* In a wye connection Line current & phase currents are equal.

(Delta connection)



* تكملة محاضرات سلايد 20 :

$$\theta_{V_{1,\phi}} - \theta_{I_{1,\phi}} = \theta$$

$$\bar{S}_{3,\phi} = P_{3,\phi} + jQ_{3,\phi}$$

$$P = \sqrt{3}\ |V_L||I_L| \cos\theta$$

$$Q = \sqrt{3}\ |V_L||I_L| \sin\theta$$

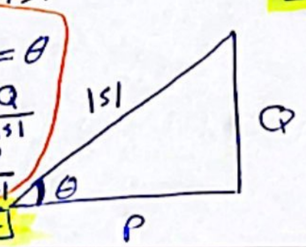
$$|S| = \sqrt{3}\ |V_L||I_L|$$

$$P.f = \frac{P}{|S|}$$

$$\tan^{-1}\frac{Q}{P} = \theta$$

$$\sin\theta = \frac{Q}{|S|}$$

$$\cos\theta = \frac{P}{|S|}$$



22

ما بنضرب بـ 3

* زاوية $S_{3,\phi}$ تساوي زاوية $S_{1,\phi}$.

* $pf_{3\phi} = pf_{1,\phi}$

load old

P_{old}

Q_{old} → inductive

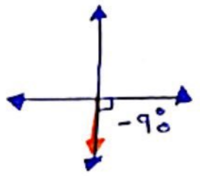
$S_{old} = P + jQ$ (Q → +ve)

new

load + capacitor

P_{old} ; Q → −ve , $P = 0$

Q_{old} $\quad Z = \frac{1}{j\omega C} = \frac{-j}{\omega C} = \frac{1}{\omega C}\angle -90^\circ$



→ $P = 0$

$|S| = \sqrt{Q^2 + P^2}$

$\theta = \tan^{-1}\left(\frac{Q}{P}\right)$

V = 0.95 → 1.05

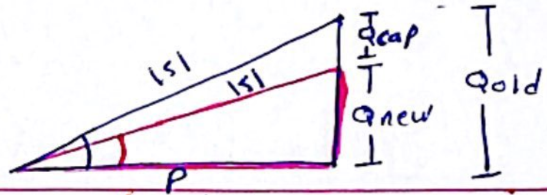
220 V

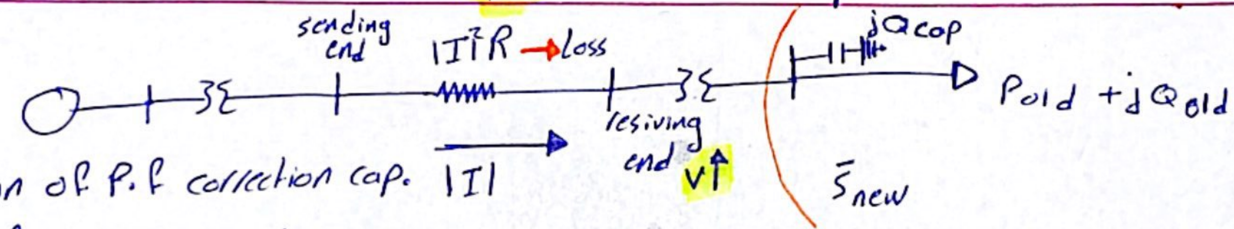
* $P_{new} = P_{old}$

$Q_{new} = Q_{old} + Q_{cap.}$

+ve $\quad$ −ve

$Q_{new} < Q_{old}$





* Addition of P.f collection cap.
* power factor improved.
* |I| ↓ .
* $|I^2| * R$ ↓ Loss. ①
* efficiency ↑ .

* Voltage drop. ↓ ②

((قيمتها 0.95 → 1.05)) 1 → 220

* P.f = 0.7 → 0.95

$\boxed{1 \; X}$

* $Q_{cap} = Q_{old}$ *

مابتغير لانو بتغير قيمة

* Q_{new} = −ve

* تكاليف اكثر

*

* per-unit :

* power system quantities such as voltage, current, power and impedance are often expressed in per-unit or percent of specified base values.

* for example if a base voltage of 20 kV is specified then the voltage 18 kV is (18/20) = 0.9 per unit or 90% .

* calculations can then be made with per-unit quantities rather than with the actual quantities.

* one advantage of the per-unit system is that by properly specifying base quantities the transformer equivalent circuit can be simplified.

* The ideal transformer winding can be eliminated such that voltages, currents, and external impedance and admittances expressed in per-unit do not change when they are refelled from one side of a transformer to the other.

* This is a significant advantage when Analyzing large systems with hundreads of transformers.

large systems → generation, transmission, distribution

* The other advantage is that per-unit impedances of electrical systems components usually lie within a narrow numerical range when the equipment of similer type ratings are used as base values.

بيعرف

↳ gross errors are easly distracted.

* شغلات بقدر احسبها باستخدام per unit :

→ power.
→ voltage.
→ Impedance.
→ current.
→ ~~inductance (time domain)~~
→ ~~capacitor.~~
→ real and reactive power.

time domain فقط

* usually manufacturers specify impedances in per-unit.

$$\boxed{\text{per unit quantity} = \frac{\text{Actual quantity}}{\text{base value of quality}}}$$

unitless

~~has a unit~~

~~has a unit~~

* base values are real number.
* Therefore, the angle of the per unit quantity is the same as the angle of the actual quantity

$$S = P + jQ$$
$$Z = R + jX$$
$$Y = G + jB$$

* Two independent base values can be arbitrarily selected at one point in a power system.
على نحو استبدادي

* You need to have the following base values:

① base voltage.
② base current. = base Power / base Voltage
③ base impedance. = base voltage / base current.
④ base power.

* other basese has to follow electrical Lows.

* one point in a power system → is devided into Zouns for the purpose of p.u calculations.
→ the Zouns devided by XFMR.

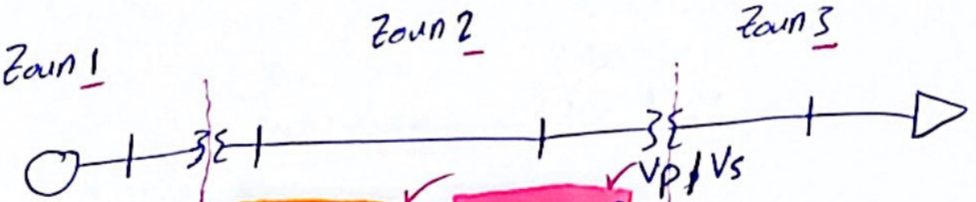
① $P_{base\,1\phi} = Q_{base\,1\phi} = S_{base\,1\phi}$

② $I_{base} = \dfrac{S_{base\,1\phi}}{V_{baseLN}}$

③ $Z_{base} = R_{base} = X_{base} = \dfrac{V_{baseLN}}{I_{base}} = \dfrac{V^2_{baseLN}}{S_{base\,1\phi}}$

④ $Y_{base} = G_{base} = B_{base} = \dfrac{1}{Z_{base}}$

* Two important Rules:
① the value of $S_{base\,1\phi}$ is the same for the entire power system of concern.
اهتمام
② the ratio of the voltage bases on either side of a transformer is selected to be the same as the ratio of the transformer voltage ratings.



$S_{base\ Zoun1}$

$S_{base\ Zoun2} = S_{base\ Zoun3} = S_{base\ Zoun1}$

$V_{base\ Zoun1}$

$V_{base\ Zoun2}$

$V_{base\ Zoun3}$

* كل element إلها rated power مختلفة.

name plate
used a base values
S_{rated}
V_{rated}
$Z_{p.u}$

$Z_{p.u} = \dfrac{Z_{actual}}{Z_{base}}$ → قيمة ثابتة

$Z_{base} = \dfrac{V^2_{base}}{S_{base}}$ → ?

selected as machine rated value.

Example 3.3 (109): A single-phase two-winding transformer is rated 20 kVA, 480/120 Volts, 60 HZ. The equivalent leakage impedance of the transformer referred to the 120 volt winding, denoted winding 2, is $Z_{eq2} = 0.0525\angle 78.13\ \Omega$ (Actual). Using the transformer ratings as base values, determine the per unit leakage impedance referred to winding 2 and referred to winding 1.

$\rightarrow S_{base} = 20\ kVA$

$V_{base1} = 480\ V$

$V_{base2} = 120\ V$

$$Z_{base2} = \frac{V_{base2}^2}{S_{base}} = \frac{120^2}{20k}$$

$$\boxed{Z_{base2} = 0.72\ \Omega}$$

→ base values are always real number.

$$Z_{2p.u} = \frac{Z_{Actual(eq)}}{Z_{base}} = \frac{0.0525\angle 78.13}{0.72\angle 0}$$

$$\boxed{Z_{2p.u} = 0.0729\angle 78.13\ \text{per unit}}$$

$$Z_{base1} = \frac{480^2}{20k} = 11.52\ \Omega$$

$$Z_{eq1(Actual)} = a^2 Z_{eq2} = \left(\frac{N_1}{N_2}\right)^2 Z_{eq2}$$

$$= \left(\frac{480}{120}\right)^2 * 0.0525\angle 78.13$$

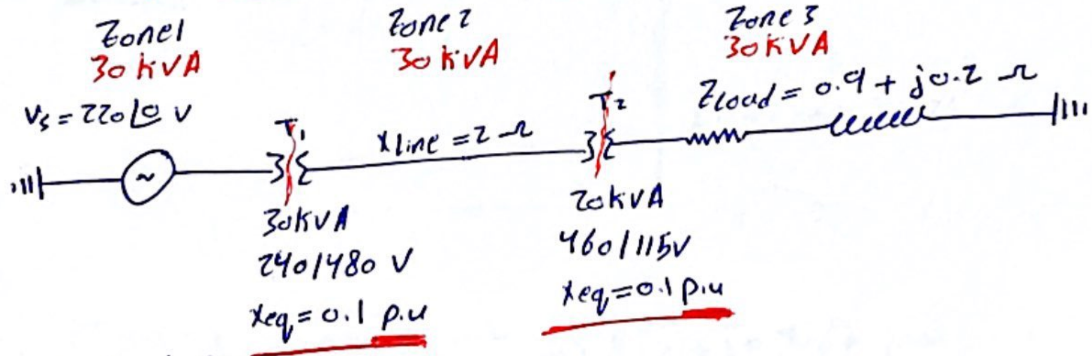
$$\boxed{Z_{eq1} = 0.84\angle 78.13\ \Omega}$$

$$Z_{1p.u} = \frac{Z_{eq(Actual)}}{Z_{base}} = \frac{0.84\angle 78.13}{11.52}$$

$$\boxed{Z_{1p.u} = 0.0729\angle 78.13\ \text{per unit}}$$

$$\frac{V_{base1}}{V_{base2}} = \frac{V_{rated1}}{V_{rated2}} = \frac{480}{120}$$

Example 3.4 (112): $S_{base} = 30\ KVA$, $V_{base1} = 240\ V$

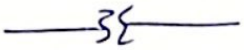


* two important Rules:

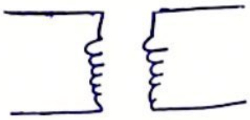
① Arbitrary choose two values and calculate the other two.

② The base power is the same for the entire system.

③ The ratio of the transformer voltage rating.



one line Diagram system.
↳ is not Circuit.



Circuit model

Zone 1

$30\,kVA = S$

$240\,V = V_{base}$

$Z_{base1} = \frac{V_{base}^2}{S_{base}} = \frac{240^2}{30k} = 1.92\,\Omega$

$I_{base} = \frac{V_{base}}{Z_{base}} = \frac{S_{base}}{V_{base}} = \frac{30k}{240}$

$= 125\ A$

Zone 2

$S = 30\,kVA$

$V_{base} = \frac{480}{240} \times 240 = 480\,V$

$Z_{base2} = \frac{480^2}{30k} = 7.68\,\Omega$

$I_{base} = \frac{30k}{480} = 62.5\,A$

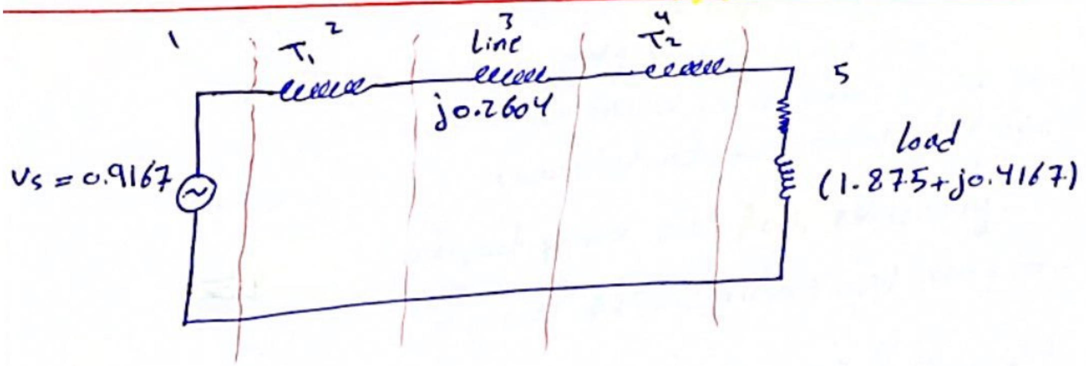
Zone 3

$S = 30\,kVA$

$V_{base} = \frac{115}{460} \times 480 = 120\,V$

$Z_{base3} = \frac{120^2}{30k} = 0.48\,\Omega$

$I_{base} = \frac{30k}{120} = 250\,A$



$Z_{load\,p.u} = \frac{Z_{Actual}}{Z_{load\,base}} = \frac{0.9 + j0.2}{0.48} = 1.875 + j0.4167\ p.u$
(Zone 3)

$V_{s\,p.u} = \frac{220}{240} = 0.9167\angle 0\ p.u.$
(Zone 1)

$Z_{Line} = R + jX = j2 \rightarrow Z_{Line\,p.u} = \frac{j2}{7.68} = j0.2604\,p.u$
(Zone 2)

$$X_{T_2(Actual)} = X_{T_2\,pu\,old} * Z_{base2\,old}$$

* p.u value is the same refered to either side of the transformer.

$$X_{T_2\,pu\,new} = \frac{X_{T_2(Actual)\,zoun\,2}}{Z_{base\,new\,zoun\,2}}$$

* Actual is different when refered to primary or secondary

proper base values.

① same base power for entire system.

② V same tran. ratio.

$$X_{T_2\,p.u\,zoun\,2} = 0.1 * \underbrace{\left(\frac{460^2}{20k}\right)}_{Z_{base2\,old}} \Big/ \underbrace{\frac{480^2}{30k}}_{Z_{base2\,new}} = 0.1378\ p.u$$

$Z_{base2\,new}$ (we used these base value for the system).

$$\underset{(primary)}{X_{p.u\,new}} = X_{p.u\,old} * \left(\frac{460}{480}\right)^2 * \frac{30k}{30k} = 0.1378\ p.u$$

V_{old}, V_{new}, S_{new}, S_{old}

$$\underset{(secondary)}{X_{T_2\,p.u}} = 0.1 * \left(\frac{115}{120}\right)^2 * \frac{30k}{20k} = 0.1378\ p.u$$

33

Ex: A three phase bank of three 75 KVA single phase transformers steps down the three phase primary feeder voltage from 12.47 KV to 208/120 V and is connected as shown below. The three phase bank is supplying a three phase wye-connected induction motor load operating at 0.75 power factor, 90 kW output power and 80% efficiency.

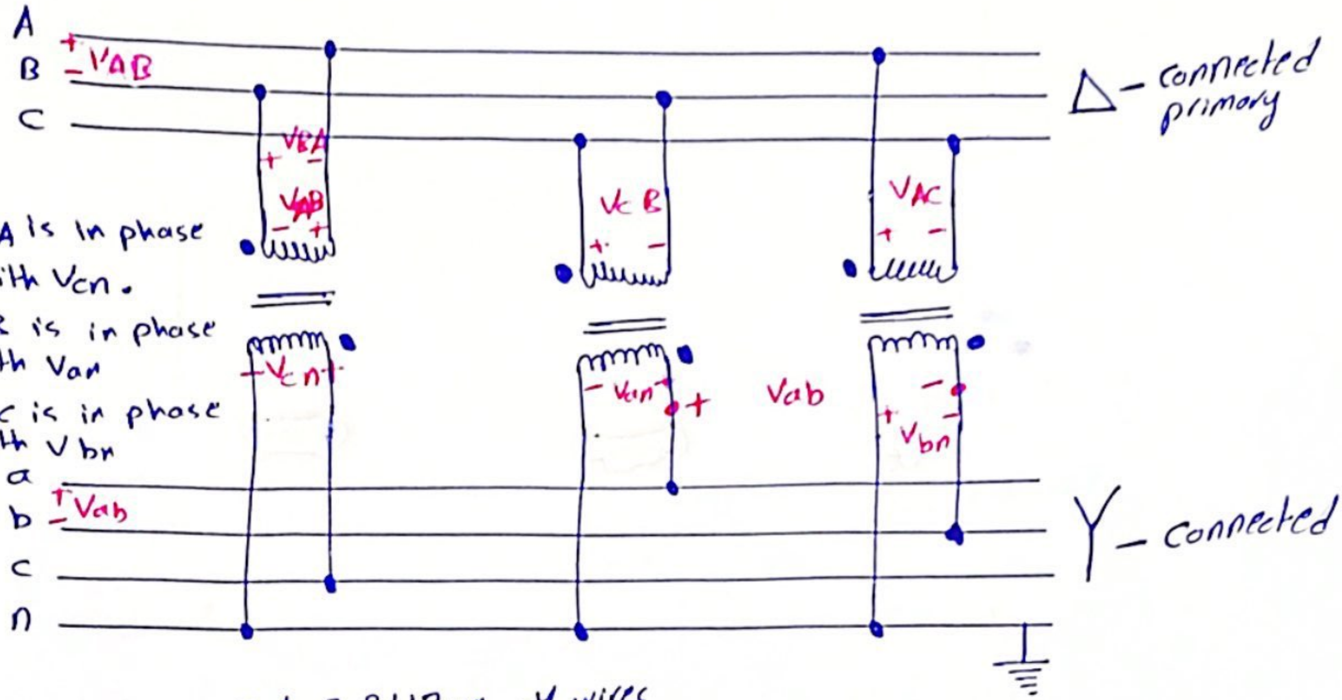
a) Draw two phasor diagrams for the primary and secondary voltages.

b) Determine the phase difference between $\overline{V_{AB}}$ & $\overline{V_{ab}}$.

c) Determine the line current (mag. & angle) flowing into each secondary-phase conductor, the current (mag. & angle) flowing in each primary winding. and the line current (mag & angle) flowing in each phase of the primary feeder.

→ Feeder = Line

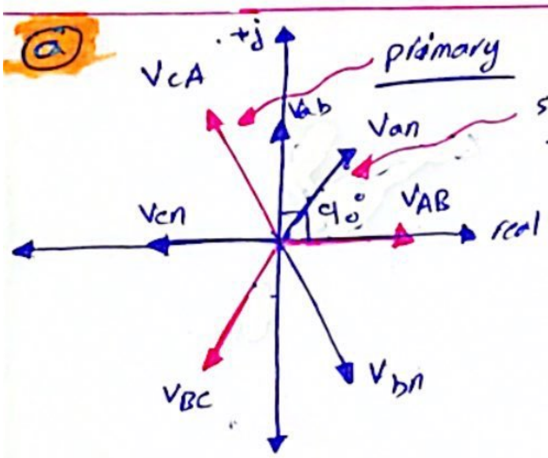
3ϕ , 12.47 , 3 wires



* V_{BA} is in phase with V_{cn}.
* V_{CB} is in phase with V_{an}
* V_{AC} is in phase with V_{bn}

3ϕ , 208/120v , 4 wires
Line phase

a)



primary

secondary

Van , Vbn , Vcn
abc sequance
+ve

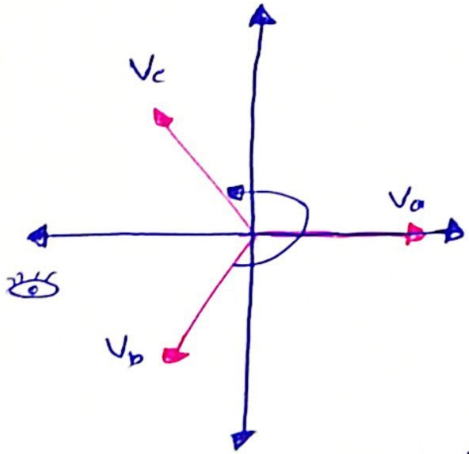
B) Vab leads VAB by 90°.

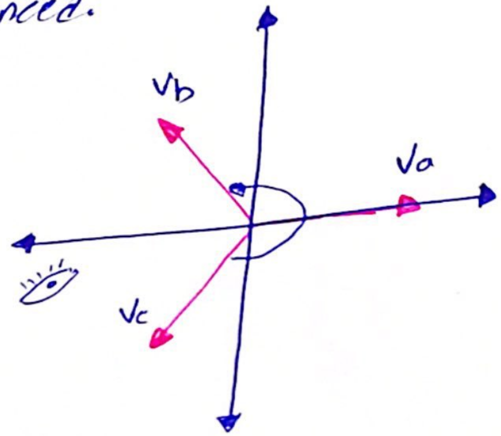
or VAB lags Vab by 90°.

or VAB leads Vab by −90°. 270°.

or Vab lags VAB by 270°. −90°.

*both are balanced.





V_c, $\underline{V_a, V_b, V_c}$, V_a, V_b

abc

+ve sequence

V_b, $\underline{V_a, V_c, V_b}$, V_a, V_c

acb

-ve sequence

$\theta_a - 120^\circ = \theta_b$

$\theta_b - 120^\circ = \theta_c$

$\theta_c - 120^\circ = \theta_a$

*θ_a lead θ_b by 120°.

*θ_b lead θ_c by 120°.

*θ_c lead θ_a by 120°.

$\theta_a + 120^\circ = \theta_b$

$\theta_b + 120^\circ = \theta_c$

$\theta_c + 120^\circ = \theta_a$

CH-4

① Copper
② Aluminum
} → used in Transmission line.

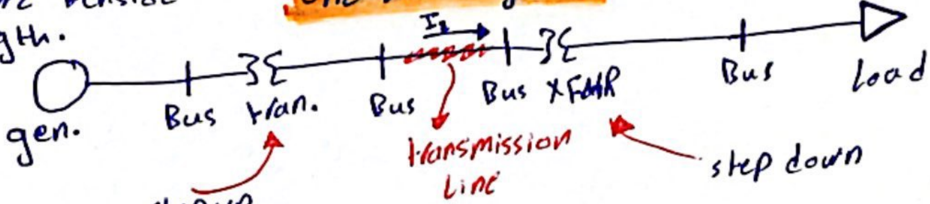
- Copper:

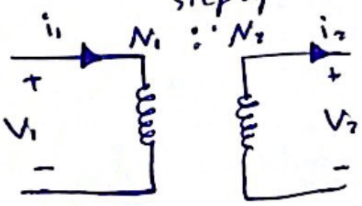
① has better conductivity.
② more expensive.
③ havier.
④ Less flexible.
⑤ has more tenside streagth.

- Aluminum: → has replaced capper as most used.

① cheaper.
② loss conductivity.
③ Lighteweight.
④ more flexable.
⑤ has less tenside streaght.

one line diagram





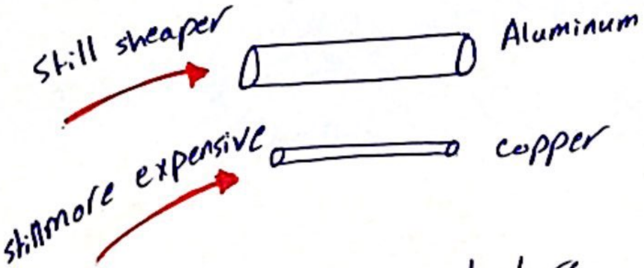
$$\left.\begin{aligned}\frac{V_1}{V_2} &= \frac{N_1}{N_2} \\ \frac{I_1}{I_2} &= \frac{N_2}{N_1}\end{aligned}\right\} \quad V_1 < V_2 \longrightarrow I_2 < I_1$$

$$\frac{V_1}{V_2} = \frac{I_2}{I_1}$$

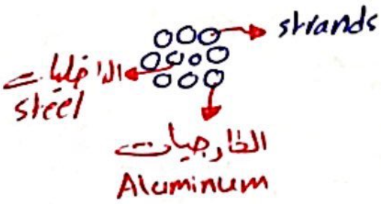
copper R↓

Aluminum R↑

$Loss = I^2 R$



* we use Aluminum conductors with Large CrossSection area to over come its higher resistivity.



* ACSR ⇒ Aluminum conductor steel reinforced.

* Conductors are made from strands for the following reonse: twisting (spiraling)

① flexability.
② flexability in menafratering.

* to hold strands together.

* typicaly overhead transmission line are Bore {no insulator}.

L, C, R parameters → we will in the transmission line moodle

① R (Resistance)

$$R_{dc,T} = \frac{\rho_T l}{A} \ (\Omega)$$

l: Length (m)

A: cross-sectional Area (m^2)

ρ_T: Resistivity (Ω m) at temp T

*Resistance depends on:

① material.

② length.

③ cross-section.

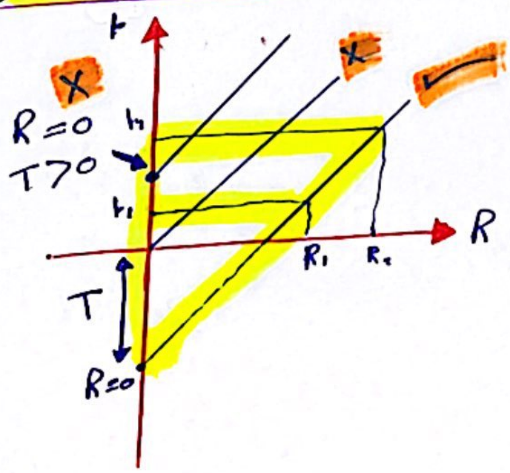
④ temperature.

⑤ spiraling. (حلزونية) → length أطول 1.02 41

⑥ frequency (skin effect).

* effective area is less than Actual Area.

* Ac res. > dc res.



$$\frac{R_2}{R_1} = \frac{T + t_2}{T + t_1}$$

T: depends on material

TABLE 4.3 (175)
4.1

* The point of steel:
① increase tensile strength.

* cmil: unit of measurement of Area.

1 cmil = Area (circle of diameter 1 mil)

1 mil = $\left(\frac{1}{1000}\right)$ inch

1 inch = 2.54 cm

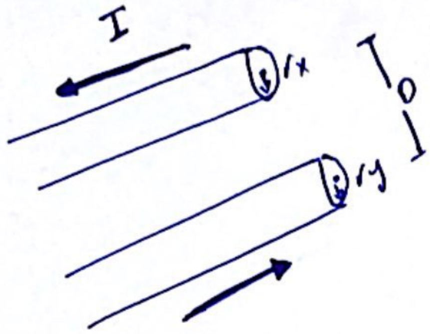
1 mile = 1.609 km

1 fout = 12 inch

حفظ

*INDUCTANCE:

- Single phase, two wire line (Solid)



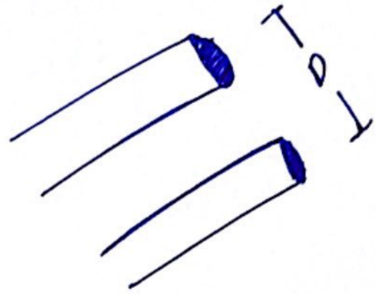
$$l_x = 2\times10^{-7}\ln\frac{D}{r_x'}\ \text{H/m}$$

$$l_y = 2\times10^{-7}\ln\frac{D}{r_y'}\ \text{H/m}$$

$$r_x' = e^{-1/4} r_x$$

$$r_y' = e^{-1/4} r_y$$

- Single phase stranded conductor:



$$l = 2\times10^{-7}\ln\frac{D}{GMR} \rightarrow \text{from table}$$

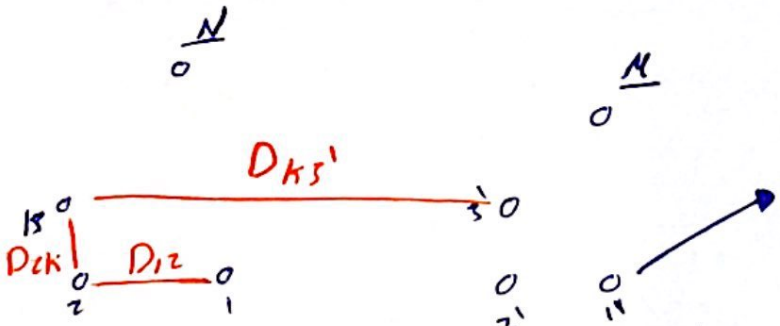
GMR: Geometric mean radius.

---

① Single phase Solid.
② Single phase stranded.
③ Single phase Bundle → حزمة
(Same conductor sharing the same current).

-Double circuit: not electrically ~~connected~~ connected.

*Single phase Bundled stranded conductor.



conductor x

conductor y

$$l_x = 2\times10^{-7}\ln\left(\frac{D_{xy}}{D_{xx}}\right)$$

$$D_{xy} = \left(\prod_{k=1}^{N}\prod_{m=1'}^{M} D_{KM}\right)^{\frac{1}{MN}}$$

$$\rightarrow (D_{11'} \cdot D_{12'} \cdot D_{1M} \cdot D_{21'} \cdot D_{22'} \cdot D_{2M} \text{ ---- } D_{NM})^{\frac{1}{MN}}$$

$$D_{xx} = \left(\prod_{k=1}^{N}\prod_{m=1}^{N} D_{KM}\right)^{\frac{1}{N^2}}$$

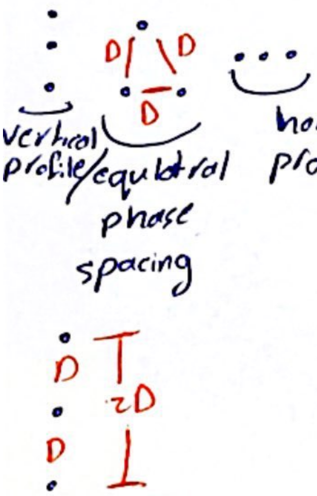
$$\rightarrow D_{11} \cdot D_{12} \cdot D_{13} \text{ ---- } \cdot D_{1N}$$
$$D_{21} \cdot D_{22} \text{ ---- } D_{2N}$$
$$\text{---- } D_{NN}$$

Solid → r'
stranded → GMR → from table

$L = 2\times10^{-7} \ln\left(\frac{D}{r'}\right)$ ⟹ Solid, single phase, not stranded, not bundled.

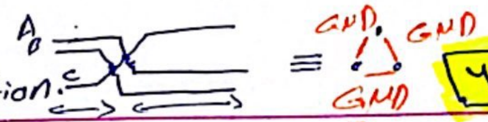
① 3ϕ (GMD)

→ $L = 2\times10^{-7} \ln\left(\frac{GMD}{r'}\right)$ geometric mean distance



⟹ Inductance of 3ϕ cond. will not be equal.

⟹ transposition.

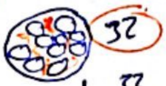


$GMD = (D * D * 2D)^{\frac{1}{3}}$

② Stranded (GMR)

→ $L = 2\times10^{-7} \ln\left(\frac{D}{GMR}\right)$

Geometric mean radius.

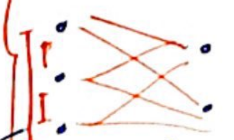


$D_{xx} = \left(\prod_{m=1}^{32}\prod_{n=1}^{32} D_{mn}\right)^{\frac{1}{32^2}}$

** we never Calculate GMR of stranded cond. we use table **

③ Bundled. (D_{xy})

$L = 2\times10^{-7} \ln\left(\frac{D_{xy}}{D_{xx}}\right)$



$D_{xy} = \left(\prod_{n=1}^{3}\prod_{m=1}^{2} D_{nm}\right)^{\frac{1}{3*2}}$

$D_{xx} = \left(\prod_{n=1}^{3}\prod_{m=1}^{3} D_{mn}\right)^{\frac{1}{9}}$

D_{11} D_{22} $D_{32} = D_{23}$

r' r'

④ 3ϕ, stranded

$L = 2\times10^{-7} \ln\left(\frac{GMD}{GMR}\right)$

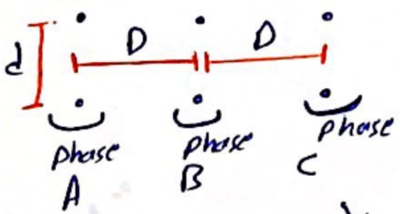
⑤ 3ϕ, Bundled, solid

$L = 2\times10^{-7} \ln\left(\frac{GMD}{D_{xx}}\right)$

45

---

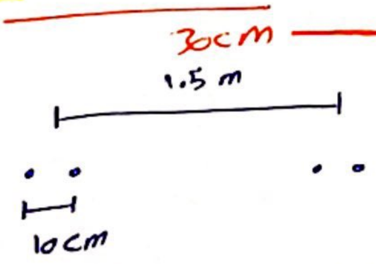
⑤



$GMD = (D * D * 2D)^{\frac{1}{3}}$ $D >> d$

$GMD =$

⑥ 1ϕ, Bundled.



$D_{xy} = (1.5m * 1.6 * 1.4 * 1.5)^{\frac{1}{4}}$
$= 1.498 \approx 1.5\ m$

$D_{xy} = (20 * 40 * 20 * 30)^{\frac{1}{4}}$
$= 29\ cm \neq 30cm$

*Capacitance of 1ϕ Solid transmission Line:

$C_{xy} = \frac{\pi \epsilon}{\ln(D/r)}$ F/m

radius not r'

$C_{xn} = 2 * C_{xy}$

*for 3ϕ

$C_{an} = \frac{2\pi\epsilon}{\ln(D/r)}$ F/m

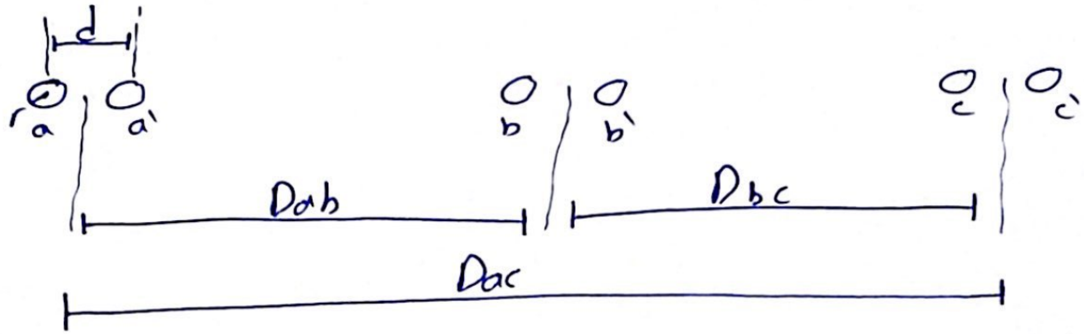
do not use r'

① effect of stranding
- uses GMR instead of r. (for inductance only).

② effect of bundling
- uses GMD instead of D.

46

* $d = 15\,cm$
* $D_{ab} = D_{bc} = 3\,m$



- $C_{an} = \dfrac{2\pi\epsilon}{\ln\left(\dfrac{GMD}{GMR}\right)}$ use with bundling only.

- $GMD = (D_{ab} * D_{bc} * D_{ac})^{\frac{1}{3}}$

- $GMR = (r * d)^{\frac{1}{2}} = \left(\dfrac{D_{aa}}{r} * \dfrac{D_{aa'}}{d} * \dfrac{D_{a'a'}}{r} * \dfrac{D_{a'a}}{d}\right)^{\frac{1}{4}}$