ElCoM
ELECTRICAL COMPUTER MECHATRONICS

تقدم لجنة ElCoM الاكاديمية

تلخيص لمادة:

انظمة قوة كهربائية

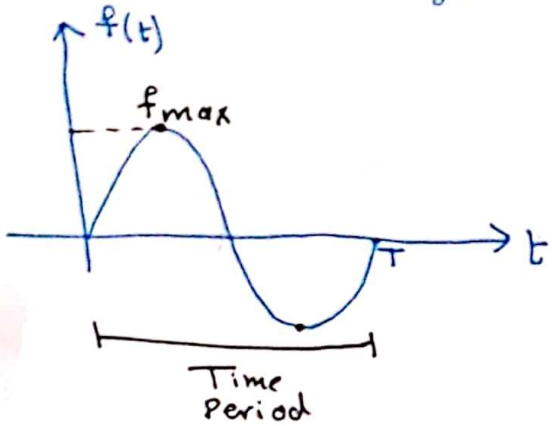
جزيل الشكر للطالب:

اسامة هيكل

Power system

* Ac circuits:-

A sinusoidal voltage or current has
- maximum value
- Time period
- constant frequency
- Phase shift
- sine OR cosine



$f(t) = F_{max} \cos(wt + \delta)$

* $w = 2\pi f$ $\left(\frac{rad}{s}\right)$: anguler frequency
* $f = \frac{1}{T}$ $(Hz \equiv s^{-1})$: number of repeating wave per second
* $T = \frac{1}{f}$ (s) : time to complete one full-wave

The reasons of using Ac in Power systems:-

- To transmit power we use high voltage, But at the load you need to low voltages. And the Ac is easy to raise and lower. ⇒ Being ABle to convert voltage levels with transformer
- Benifits:- high Power efficiency
  low current (less heat)
  high voltage

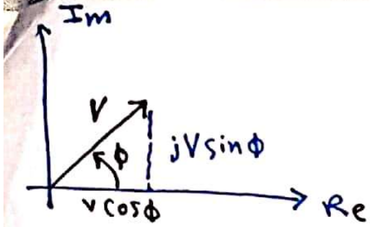
---

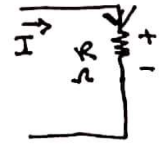
* $v(t) = V_m \cos(wt + \phi)$ → time-domain form (instantaneous value)

$V = V_{rms} \angle \phi$ → Poler form

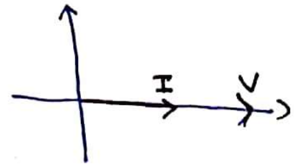
$V = V_{rms}\, e^{j\phi}$ → exponontial form

$V = V\cos\phi + jS\sin\phi$ → rectanguler form





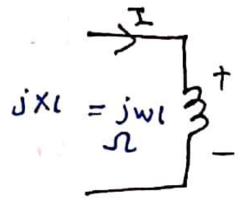
$\boxed{V = IR}$

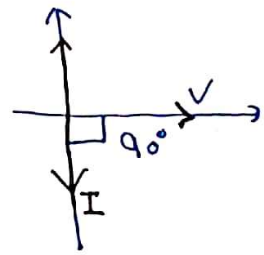


⊗ Inphase

(Resistive).

$\boxed{V = jX_L I}$



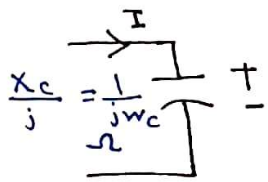


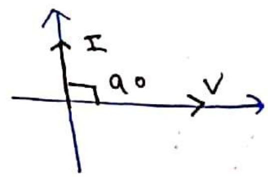
⊗ I lag V

By 90

(Inductive)

$\boxed{V = \frac{X_c}{j} I}$





⊗ I lead V

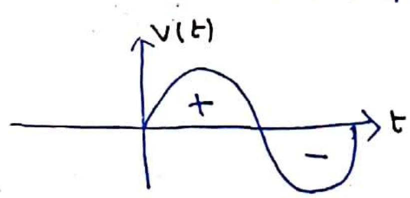
By 90

(capicitive)

Average (mean) vlaue and Root mean Value square :-

- $V_{avg} = \frac{1}{T}\int_0^T v(t)\,dt$

$= \frac{1}{T}\int_0^T V_m \cos(wt)\,dt = 0$



$V^2_{avg} = \frac{1}{T}\int_0^T V_m^2 \cos^2(wt)\,dt$

$= \frac{1}{T}\int_0^T \left(\frac{V_m^2}{2} + \cancel{\frac{V_m^2}{2}\cos(2wt)}^{\,0}\right)$

$V^2_{avg} = \frac{T V_m^2}{2T} \Rightarrow V_{rms} = \sqrt{V^2_{avg}} = \frac{V_m}{\sqrt{2}}$ → DC Value

Rms Value

effective Value

As we see the avg of Sinusoid is zero and the avg power is propotional to avg volrage Square $(P = \frac{V^2}{R})$ then the Rms is useful

⊗ The Rms gives the DC Value

[2.2] Power is The rate of change of energy respect to time. $P = \frac{dE}{dt}$ $\frac{\text{joule}}{\text{sec}} \equiv \text{Watt}$

Purely Resistive load ($I(t)$ inphase with $V(t)$)

The instan. power absorbed by the resistor has an (avg value) = (Rms) and AC term with zero avg

$$P_R(t) = v(t)\, i(t) = V_{max} \cos(wt+\delta)\, I_{max} \cos(wt+\delta)$$
$$= V_{max} I_{max} \cos^2(wt+\delta)$$
$$= \frac{V_{max} I_{max}}{2} + \frac{V_{max} I_{max}}{2} \cos(2wt+2\delta)$$
$$\underbrace{\frac{V^2}{R},\ I^2R}_{P_R} = \underbrace{V_{rms} I_{rms}} + V_{rms} I_{rms} \cos(2wt+2\delta) \quad (W)$$

Purely Inductive load (I lag V by 90)

The instan power absrobed by induqor is a double freq sinusoid (AC term) without any avg value ~~(RMS)~~ for inductor

$$P_L(t) = V_{max} \cos(wt+\delta)\, I_{max} \cos(wt+(\delta-90^\circ))$$
$$\oplus\!= V I_L \sin(2wt+\delta) \quad , I_L = I_{rms} \sin(\delta-(\delta-90)) = I_{rms} \text{ pure}$$

$\cos(\theta-90) = \sin(\theta)$

$\sin(\theta+90) = \cos(\theta)$

$\cos(\theta+90) = -\sin(\theta)$

$\sin(\theta-90) = -\cos(\theta)$

$\sin(\theta \pm 180) = -\sin(\theta)$

$\cos(\theta \pm 180) = -\cos(\theta)$

Purely capicitive load (I leads V by 90)

Same as inductor

$$P_C(t) = v(t)\, i(t)$$
$$= \ominus V I_C \sin(2wt+2\delta) \ , \quad I_C = I_{rms} \sin(\delta-(\delta+90)) = -I_{rms}$$

pure

For general load

$p(t) = v(t)\, i(t)$

$= V_{max}\cos(\omega t + \delta)\, I_{max}\cos(\omega t + \beta)$

$= \frac{V_{rms} I_{rms}}{2}\left[\cos(\delta-\beta) + \cos(2\omega t + \delta + \beta)\right]$

$= \frac{V_{rms} I_{rms}}{2}\left[\cos(\delta-\beta) + \cos(\underbrace{2\omega t + \delta + \delta}_{A} - \underbrace{(\delta-\beta)}_{B})\right]$

$= V_{rms} I_{rms}\left[\cos(\delta-\beta) + \cos(2\omega t + 2\delta)\cos(\delta-\beta) + \sin(2\omega t + 2\delta)\sin(\delta-\beta)\right]$

$= \underbrace{VI\cos(\delta-\beta) + VI\cos(2\omega t + 2\delta)\cos(\delta-\beta)}_{\text{instantaneous power absorbed by resistor}} + \underbrace{VI\sin(\delta-\beta)\sin(2\omega t + 2\delta)}_{\text{instantaneous power absorbed by reactive load}}$

> ⊛ $\cos A \cdot \cos B = \left(\cos(A+B) + \cos(A-B)\right)\frac{1}{2}$
>
> ⊛ $\cos(A+B) = \cos A\cos B + \sin A\sin B$

---

* AVG power / Real power / active power in the load is just in the resistor equal $\rightarrow P = VI\cos(\delta-\beta)$

$= \frac{V_m I_m}{2}\cos(\delta-\beta) = V I_R$ ($I\cos(\delta-\beta)$)

$= \frac{V^2}{R}$ W

* Reactive Power is the Amplitude of double freq Power of reactive load $\Rightarrow Q = VI\sin(\delta-\beta)$

$= \frac{V^2}{X_x}$ Volt Amper Reactive $\boxed{Var}$

⊛ $\cos(\delta-\beta) \rightarrow$ Power factor

Power factor lagging: inductive load ($\beta < \delta$) I lag V (سالبة)

Power factor leading: capicitive load ($\beta > \delta$) I lead V (موجبة)

Unity power factor: Resistive load ($\beta = \delta$) I inphase V (صفر)

بالزاوية θ_I θ_V الزاوية

P is: Total energy absorbed by a load during time	Q is: max value of instan power absorbed by reactive component

⊛ Complex power :-

$$S = VI^* = V_{rms} I_{rms} \angle \delta - \beta$$

$$= V_{rms} I_{rms} e^{j(\delta - \beta)}$$

$$= \underbrace{V_{rms} I_{rms} \cos(\delta - \beta)}_{P} + \underbrace{j \sin(\delta - \beta) V_{rms} I_{rms}}_{Q}$$

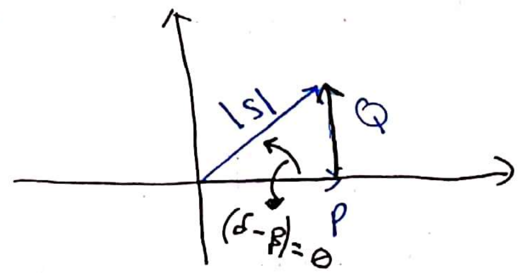
$$= P + jQ$$

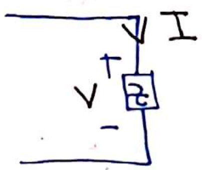
$|S|$ is appearent power

$$|S| = V_{rms} I_{rms}$$

$$= \frac{P}{Pf}$$

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



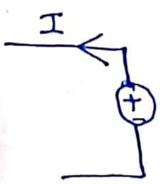


⊛ P +ve → absorbed real power

P −ve → delivered real power

Q +ve → absorbed ~~real po~~ reactive power

Q −ve → Delivered reactive power



P +ve → Delivered real power

P −ve → absorbed // //

Q +ve → Deliverd react power

Q −ve → react power is absorbed

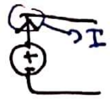
$S_R = \frac{V^2}{R}$ $\quad P_R = \frac{V^2}{R}$ W $\quad Q_R = 0$ $\quad$ ABsorbed

$S_L = \frac{jV^2}{X_L}$ $\quad P_L = 0$ $\quad Q_R = \frac{V^2}{X_L}$ $\quad$ ABsorbed

$S_C = \frac{-jV^2}{X_C}$ $\quad P_C = 0$ $\quad Q_C = -\frac{V^2}{X_C}$ $\quad$ Delivered

← sin(-90)

Ex 2.3 source delivers 100 KW , Pf = 0.8 lagging

* Delivers → 

* $P = 100\,KW$ → absorbed by resistor

البور بكل أنواعه دائما تجمع

* $P_f = 0.8$ lagging → inductive

$Q = Q_L + Q_R = Q_L + 0 = Q_L$ → Cap قبل اضافة

$Q = Q_L + Q_C + Q_R = Q_L + Q_C$ → Cap بعد اضافة

$P = P_R$ → قبل اضافة ، بعد اضافة

So To find $Q(\text{after}) = Q_L + Q_C$

you need to find $Q_L = Q(\text{Before})$

$Q_L = V I \sin(\delta - \beta)$

$(\delta - \beta) = \cos^{-1}(0.8) = 36.8$

$\boxed{\sin(\delta - \beta) = 0.6}$ $\boxed{I = \frac{P}{V \cos(\delta - \beta)}}$

$\boxed{Q_L = P \frac{\sin(\delta - \beta)}{\cos(\delta - \beta)}}$

أكيد بعد الاضافة رح تتغير زاوية التيار فأعطاني Pf جديدة

$(\delta - \beta') = \cos^{-1}(0.95) = 18.19$

$I = \frac{P}{V \cos(\delta - \beta')}$

$Q_{tot} = V I \sin(\delta - \beta')$
$= P \tan(\delta - \beta')$

مهم ملاحظة بعد المثال

$Q_{tot} = Q_L + Q_C$

$\boxed{Q_C = Q_{tot} - Q_L}$

2.5

3 Phase Circuit give more power at the same amperrage

---

2 connections → Y connection → 4 wires

→ Δ connection → 3 wires

Balanced connections :

↓

* Balanced Source (Y or Δ)
mean : For Y
The phase Voltages same magnitude and 120° phase difference +ve seq

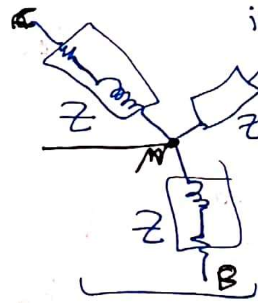
$V_{an} = V_p \angle 0°$ lead

$V_{bn} = V_p \angle -120$ lead

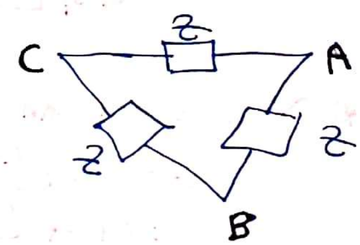
$V_{cn} = V_p \angle -240 = V_p \angle +120$

$I_n = I_a + I_b + I_c = 0$

* Balanced load (Y or Δ)
mean :- all loads identical in mag and phase



Y



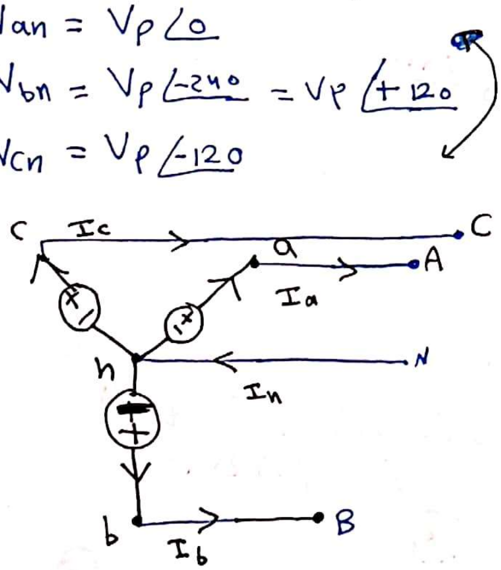
---

and -ve seq if

$V_{an} = V_p \angle 0$

$V_{bn} = V_p \angle -240 = V_p \angle +120$ lead

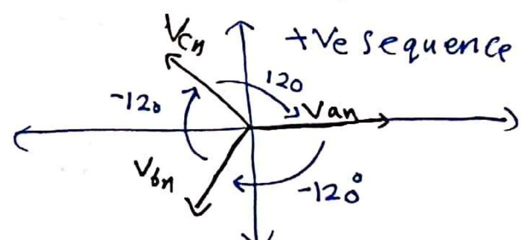
$V_{cn} = V_p \angle -120$ lead



and $V_{an} + V_{bn} + V_{cn} = 0$

and $V_{AB} + V_{BC} + V_{CA} = 0$

The line to neutral called phase voltages V_{an}, V_{bn}, V_{cn}

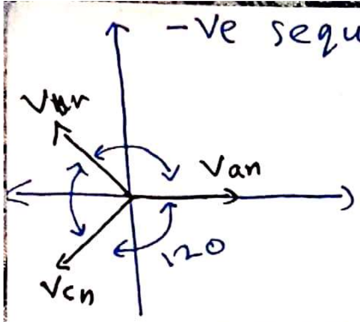


- Van lead Vbn by 120
- Van lead Vcn by 240

and

- Von Lag Vcn by 120
- Vbn lag Vcn by 120

ABC



Van leads Vcn by 120 | ACB

Van leads Vbn by 240

Vcn leads Vbn by 120

Line Voltages → line to line (+ve seq Vab leads Vbc leads Vca by(120, 120)

⊛ $V_{ab} = V_{an} - V_{bn}$ (Vab leads Van by(30))

$= \sqrt{3}\, V_p \angle 30$ $V_{ab} = \sqrt{3}\, V_{an} \angle 30$

⊛ $V_{bc} = V_{bn} - V_{cn} =$ (Vbc leads Vbn by 30)

$= \sqrt{3}\, V_p \angle 30-120$ $V_{bc} = \sqrt{3}\, V_{bn} \angle 30$

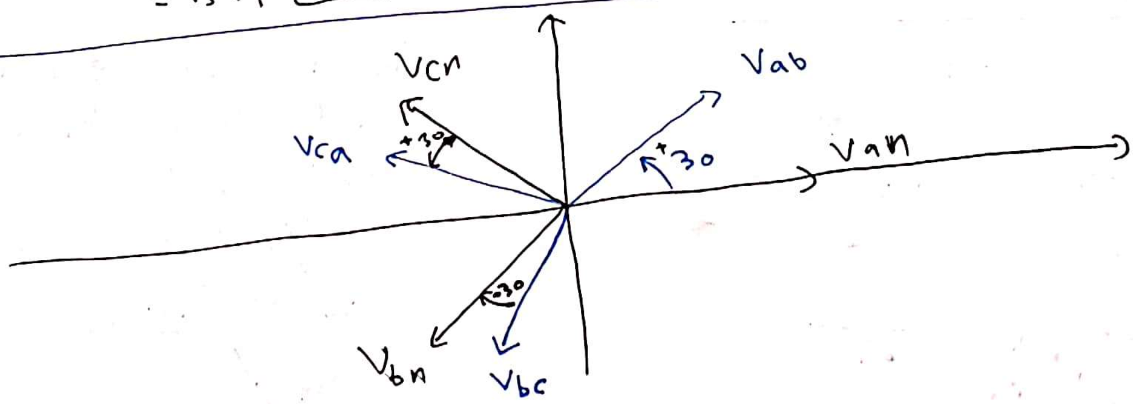
$= \sqrt{3}\, V_p \angle -90$

⊛ $V_{ca} = V_{cn} - V_{an}$ (Vca leads Vcn by 30)

$= \sqrt{3}\, V_p \angle \overset{-90-120}{-240} + 30$ $V_{ca} = \sqrt{3}\, V_{cn} \angle 30$

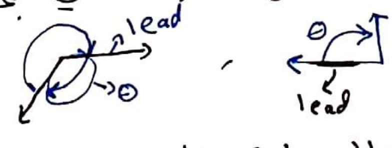
$= \sqrt{3}\, V_p \angle -210$

$= \sqrt{3}\, V_p \angle 150$

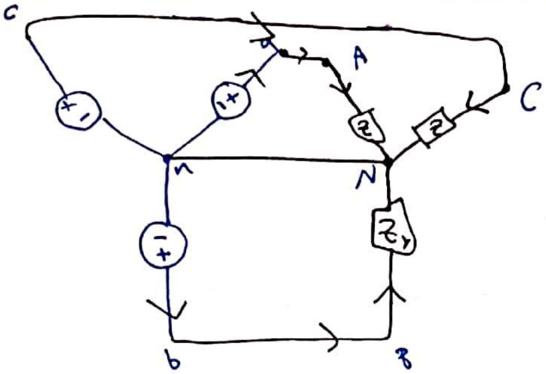


الطريقة نحدد فيها lead و lag في رسمة (Phaser)

① مع عقارب الساعة  اللي بمر عليه أول هو lead اللي بعده بهذا المقدار

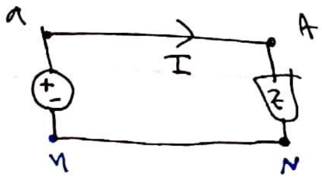


② عكس عقارب الساعة اللي بمر عليه أول lag العبده بهذا المقدار 

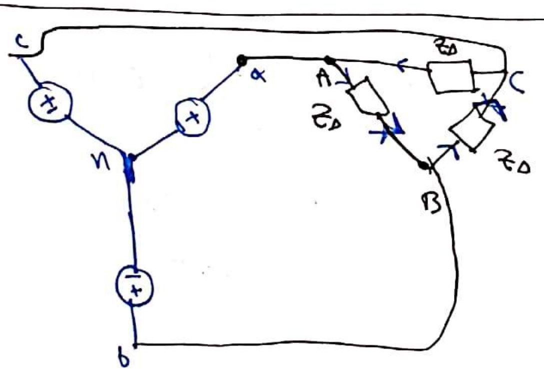


Y – Y

The per phase is (line to neutral)



$$, \quad I_a = \frac{V_{an}}{Z}$$



Y – Δ

$V_{\Delta CA} = V_{Y CA}$, $V_{\Delta BC} = V_{Y BC}$, $V_{\Delta AB} = V_{Y AB}$

$$I_{AB} = \frac{V_{\Delta AB}}{Z_\Delta} = \frac{V_{Y AB}}{Z_\Delta} = \frac{\sqrt{3}\, V_{an} \angle 30}{Z_\Delta}$$

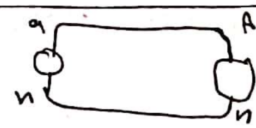
$$I_{BC} = \frac{\sqrt{3}\, V_{bn} \angle -90}{Z_\Delta}, \quad I_{CA} = \frac{\sqrt{3}\, V_{cn} \angle 150}{Z_\Delta} \quad \Bigg\} \text{ phase currents}$$

$$\underbrace{I_a}_{\text{scale}} = \sqrt{3}\, I_{AB} \angle -30 \rightarrow \text{lag}$$

يعني الفاز ٣٠ بيتأخر

---

if convert Δ to Y then



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

$$I_a = I_A = \frac{V_{an}}{Z_Y} = \frac{V_{AB} \angle -30}{\sqrt{3}\, Z_Y} \quad , \quad V_{an} = \frac{V_{AB} \angle -30}{\sqrt{3}}$$

Balanced Y currents :-

Phase current = line current

$I_{an} = I_{aA}$ $\quad$ $I_n = I_{an} + I_{bn} + I_{cn} = 0$

$I_{bn} = I_{bB}$ $\quad$ and the phase differenee as voltage

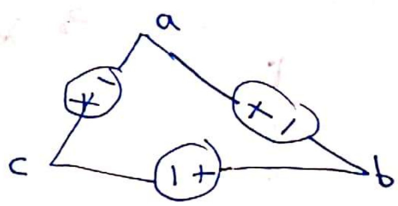
$I_{cn} = I_{cC}$

* $I_{an} = I_a = I\angle\theta$
* $I_b = I\angle\theta - 120$
* $I_c = I\angle\theta - 240$

For Δ :-

Same as Y the sum of line voltages or phase voltages and the sum of line/phase current equal zero.

* Phase voltage = line voltage



$V_{ab} = V_p\angle 0$

$V_{bc} = V_p\angle -120$

$V_{ca} = V_p\angle +120$

line current ~~leads~~ lag phase current by 30° and a factor $= (\sqrt{3})$

---

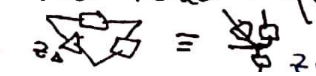
* Balanced does not mean that the lines lossless, (without Z)

* To analyze 3 phase Balanced system you need to solve it per phase (single phase with singleload) then $\boxed{KVL}$

if Δ − Δ → no proplems

if Y − Y → no proplems

if Y − Δ → then convert the load to (Y)

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

* Power in 3 Phase Balanced Circuits :-

Power in general is Voltage (times) current

Power in genral is allways sum

instan

Power in each phase given by

$P_a(t) = V_{an}(t)\, i_a(t)$, $P_b(t) = V_{bn}(t)\, i_b(t)$, $P_c(t) = V_{cn}(t)\, i_c(t)$

$$P_{3\phi}(t) = P_a(t) + P_b(t) + P_c(t)$$

$$= 3 V_\phi I_\phi \cos(\delta - \beta)$$

$$= \underbrace{\sqrt{3}\, V_{LL} I_L \cos(\delta - \beta)}_{\text{total instanous power}} \ (W)$$

Delivered by 3-ϕ Balanced Condition and Constant

يعني انا طالع من داخل لو absorb

if Y

$V_\phi = \dfrac{V_L}{\sqrt{3}}$, $3V_\phi = \sqrt{3}\, V_L$

$I_\phi = I_L$

if Δ

$V_\phi = V_L$

$I_\phi = \dfrac{I_L}{\sqrt{3}}$ $\qquad 3I_\phi = \sqrt{3}\, I_L$

$$S_{3\phi} = S_a + S_b + S_c$$

$$= 3V_{Ln} I_L \cos(\delta - \beta) + j\,3V_{Ln} I_L \sin(\delta - \beta)$$

$$= P_{3\phi} + j\,Q_{3\phi} = 3V_{LN} I_L \angle \delta - \beta$$

$$|S_{3\phi}| = \sqrt{3}\, V_{LL} I_L \quad (VA)$$

$$= 3 V_{LN} I_L \quad (VA)$$

حيث أنه
دايما فرق بين
زاوية تيار وجهد
هو نفسه وما غنشوف
نفسه

---

in 3-ϕ motor the current enter the phase then is absorbed and same equations.

* And equation of power identical for Δ - loads , Y - loads

Ex 2.5 - 3-Φ Balanced Source with $V_P = 4160$ V

- two 3-Φ Balanced motor parallel

first motor :- $P = 400 (kw)$ $P_f = 0.8$ lagging

second motor :- $S = 150K (VA)$ $P_f = 0.9$ leading

lagging → absorbed (Q) → +ve

leading → delivered (Q) → -ve

induction motor →

$P = 400 kw$

$|S| = S^2 = P/p.f = 500k$ VA

$Q = \sqrt{S^2 - P^2} = 300$ Kvar $\boxed{\text{absorbed}}$

synchronous motor →

$|S| = 150k$ VA

$P = |S| \cdot P_f = 135$ kw

$Q = \sqrt{S^2 - P^2} = 65.4$ Kvar $\boxed{\text{Delivered}}$

$= -65.4$ Kvar

Compounded motor → total Power in each of → induction, → synch

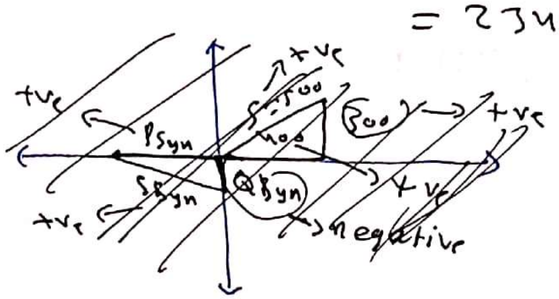
$P_{com} = P_i + P_{syn} = 535$ KW

$\cancel{S_{com}} = \cancel{S_i} + \cancel{S_{yn}} \Rightarrow$ غلط

$Q_{com} = Q_i + Q_{syn}$

$= 300 + -65.4 = \cancel{\ldots}$

$= 234.6$ Kvar absorbed الأكبر

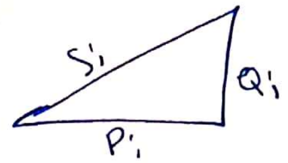


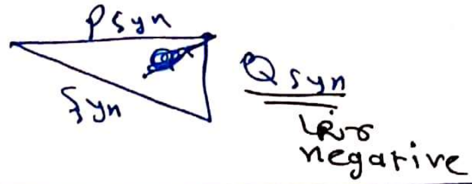
note :-

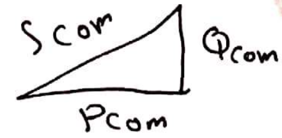
* absorbed + absorbed = absorbed
* Delivered + Delivered = Delivered

But absorbed + Delivered = طرح و . حسب الأكبر

(a)







(b) $P_f = \frac{P}{S} = 0.916$ lagging

(c) $S_{3\phi} = 3 I_\phi V_\phi$

$= \sqrt{3} I_L V_L$

واي
هنا ما حكى

$I_L = \frac{S_{3\phi}}{\sqrt{3} V_L} = \frac{584.?}{(\sqrt{3})(4160)} = I_\phi = 81.4 \text{ A}$

(d) Power factor unity mean → ~~$\cos\theta = 1$~~ ~~$\sin\theta = 0$~~

no reactive power

then $Q_{new} = Q_{com} + Q_{add} = 0$

$Q_{add} = Q_{com}$

if this absorbed then Q_{add} Deliverd
لحتى يلغو بعض

(x) $Q_{com} = 234.6$ KVar absorbed

$Q_{add} = 3 \frac{V^2}{X_c} \Rightarrow X_c = \frac{3V^2}{Q_{com}}$

3-Phase

~~$X_c = Q_{com}$~~

$= 221.3\ \Omega$

(e) line current

بما انه الغينا Q بس
P ما الها دخل مضارة
$S = \sqrt{P^2 + Q^2} = \sqrt{P^2} = P$

$P_{3\phi} = 3 I_\phi V_\phi P_f = S P_f$

$= \sqrt{3} I_L V_\phi P_f = S P_f$

$I_L = \frac{S P_f}{\sqrt{3} V_\phi} = \frac{P}{\sqrt{3} V_\phi} = 74.3 = I_\phi$

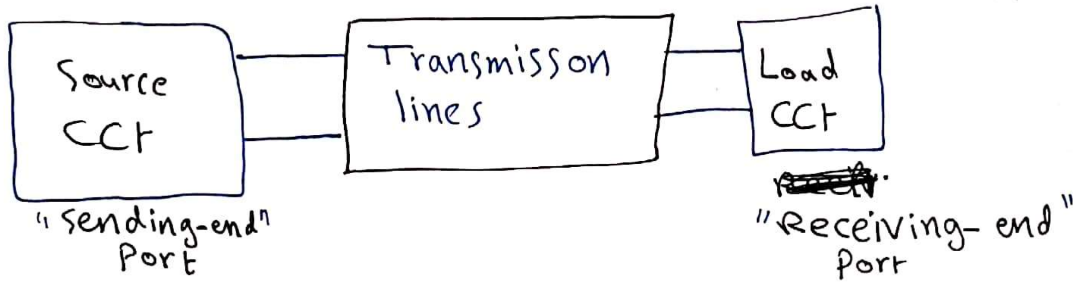
واي

CH-5 Transmisson lines خطوط النقل

بشكل أساسي يوجد طريقتين للبث

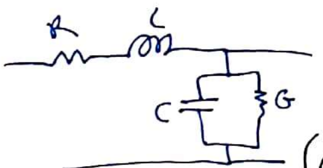
① بث لاسلكي (wireless) ويكون بالعادة لمجموعة واسعة من الاشخاص والنقل بالهواء (free space) ويسمى (unguided)

② بث عن طريق الأسلاك (Transmisson Lines) وتعمل على نقل الطاقة من السورس للـ Load (Gaided) "بين نقطتين" من سورس إلى لود



لحتى يسهل تحليل النظام وعمل معادلات عليه فلازم نعمل (Circuit model)

الـ Transmisson lines بتتكون على الأقل من موصلين بينهم مادة عازلة وتتكون من 2 terminals



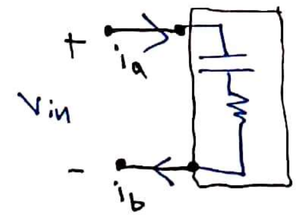
* الموصل له مقاومة R وإذا كان موصل مثالي $R = 0$
* ويوجد تأثير مغناطيسي نحصل (L)
* وبسبب وجود مادة عازلة بين موصلين ← يوجد (C)
* ومادة عازلة لها موصلية G واذا مثالية $G = 0$

بعد تمثيله في دارة منفرد نعمل KCL و KVL

* Two port network

Port : منفذ : pair of terminals which current enter network and leave from other terminal

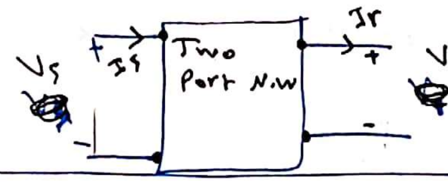
Ex:- one port network



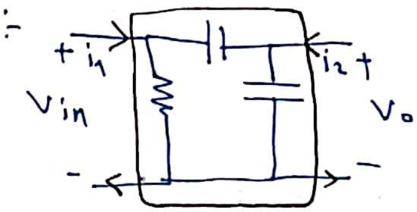
$\boxed{i_a = i_b}$

$\boxed{Z_{in} = \frac{V_{in}}{i_a}}$

* Two Port network :- one pair of input (Source → 2 terminal)
→ one pair of output (load → 2 terminals)



Ex:-



حتى نتحكم بالسستم رح نعمل معادلة بين Vs و Vr و Is و Ir
و أعرف شو تأثير انبت على اوتبت

⊛ one of the methods to represent relation Between input and output is (ABCD) Parameters

السورس انبت
لود اوتبوت

- $V_1 = AV_2 + BI_2$
- $I_1 = CV_2 + DI_2$

⊛ in matrix Form :

$$\begin{bmatrix} V_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_2 \\ I_2 \end{bmatrix}$$

⊛ ABCD, Depends on Transmisson-lines parameters (R, L, C, G)

⊛ A, D → constant (Dimensonless بدون وحدة)

⊛ B → ohm

⊛ C → $(\text{ohm})^{-1}$ ≡ Simens

⊛ $AD - BC = 1$

To calculate A, B, C, D

① output → O.C → $I_r = 0$, $A = \frac{V_1}{V_2}$, $C = \frac{I_1}{V_2}$ $(\text{ohm})^{-1}$

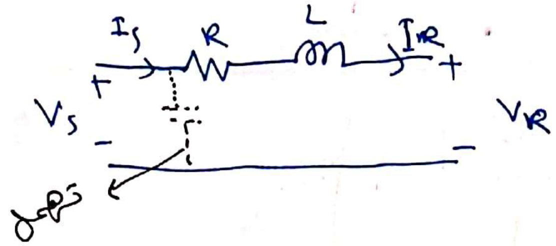
② output → S.C → $V_r = 0$, $D = \frac{I_1}{I_2}$, $B = \frac{V_1}{I_2}$ (ohm)

③ input → S.C → $V_s = 0$, $A = \frac{I_2}{I_1}$, $B = \frac{V_2}{I_1}$ (ohm)
output → Source

* Transmisson lines models :- (Approximations) *

if T.L length less than 25 Km and 60-Hz

ويسمي ← Short T.L و نقطع ال Capicitor



$KVL \rightarrow V_s = V_R + I_s Z \quad , I_s = I_R$

$KCL \rightarrow I_s = I_R + 0$

Compared to ABCD equation

$\boxed{A = 1}$ $\boxed{B = Z}$ $\boxed{C = 0}$ $\boxed{D = 1}$

OR ~~Output O.C → A = V1/V2 = Vs/VR = 1~~

$V_s = A V_R + B I_R$

$I_s = C V_R + D I_R$

if output O.C $\rightarrow I_R = 0 \quad , I_s = 0 \quad , V_R = V_s$

$$A = \frac{V_s}{V_R} = 1 \quad , \quad C = \frac{I_s}{V_R} = 0$$

if output S.C $\rightarrow I_R = I_s \quad , V_R = 0$

$$D = \frac{I_1}{I_2} = 1 \quad , \quad B = \frac{V_1}{I_2} = Z$$

if input S.C $\rightarrow A = \frac{I_2}{I_1} = 1 \quad , \quad B = \frac{V_2}{I_1} = Z$

IN matrix form

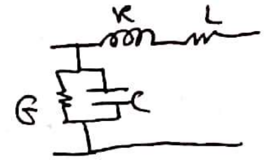
$$\begin{bmatrix} V_s \\ I_s \end{bmatrix} = \begin{bmatrix} 1 & Z \\ 0 & 1 \end{bmatrix} \begin{bmatrix} V_R \\ I_R \end{bmatrix}$$

Scanned with CamScanner

* The transmisson line have 2 imporrent elements:-

1- series impedence $z = R + jwL$ Ω/m

2- Shunt Admitance $y = G + jwC$ Ω^{-1}/m

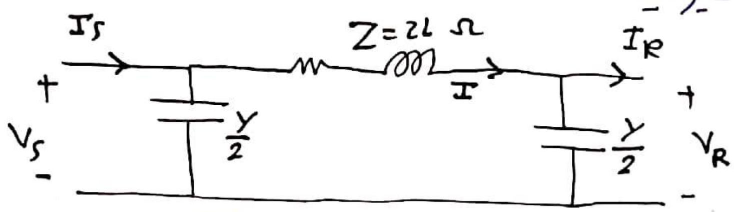


* For Transmisson lines to over head 60 - HZ

اهمل (G)

* إذا طول الـ T.L من $(250 - 25)$ (كم / Km) على تردد 60 HZ يسمى meduim T.Lines

و لا نهمل تأثير الـ (Shunt Admitance) و يقسم إلى قسمين $Y = \left(\frac{Y}{2} + \frac{Y}{2}\right)$ جزء بداية السيركيت و جزء نهاية السيركيت



T.L meduim model

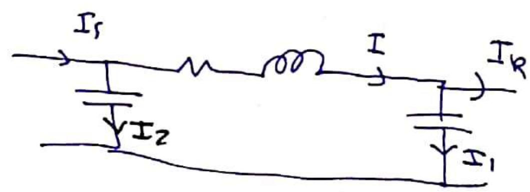
Normal π model

Recall :- For any impedence Z $V = IZ$, $I = \frac{V}{Z}$

For any Admitance Y $V = \frac{I}{Y}$, $I = VY$.

---

* method 1 to Solve ABCD :-



KVL :- $V_S = IZ + V_R$

to find I :-

$$I = I_R + I_1$$

$$= I_R + V_R\left(\frac{Y}{2}\right)$$

then

$$V_S = I_R Z + V_R \frac{YZ}{2} + V_R$$

$$= V_R \underbrace{\left(1 + \frac{YZ}{2}\right)}_{A} + I_R \underbrace{Z}_{B}$$

$\therefore A = 1 + \frac{YZ}{2}$

$\therefore B = Z$ Ω

Scanned with CamScanner

* and $I_s = I + I_2$

$$= I_1 + I_R + I_2$$

* $I_s = \frac{V_R Y}{2} + I_R + \frac{V_s Y}{2}$, $V_s = \left(1+\frac{YZ}{2}\right)V_R + ZI_R$ *

$$I_s = \frac{V_R Y}{2} + I_R + \left(\left(1+\frac{YZ}{2}\right)V_R + ZI_R\right)\frac{Y}{2}$$

$$= V_R\frac{Y}{2} + I_R + \frac{YV_R}{2}\left(1+\frac{YZ}{2}\right) + \frac{YZ}{2}I_R$$

$$= V_R\frac{Y}{2} + \frac{YV_R}{2}\left(1+\frac{YZ}{2}\right) + \left(\frac{YZ}{2}+1\right)I_R$$

$$= V_R Y(0.5 + 0.5 + 0.25YZ)$$

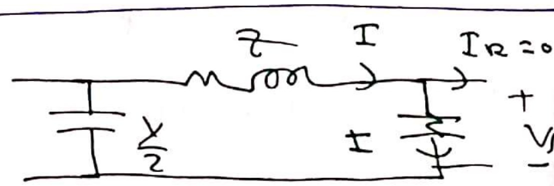
$$= YV_R\left(1+\frac{YZ}{4}\right) + \left(1+\frac{YZ}{2}\right)I_R$$

$\div C = Y\left(1+\frac{YZ}{4}\right)$ (Ω^{-1})

$\div D = \left(1+\frac{YZ}{2}\right) = A$

method 2 :-

$$A = \frac{V_s}{V_R}\Big|_{I_R=0}$$



* $V_s = I(Z) + I\left(\frac{2}{Y}\right)$

* $V_R = \left(\frac{2}{Y}\right)I$

* $\frac{V_s}{V_R} = \frac{I\left(Z+\frac{2}{Y}\right)}{I\ \frac{2}{Y}}$

$$= \frac{\left(\frac{ZY+2}{Y}\right)}{\frac{2}{Y}}$$

$$= \frac{ZY^2+2Y}{2Y}$$

$$\boxed{A = \left(\frac{ZY}{2}+1\right)}$$

Voltage Regulation:-

نسبة

* طريقة لحساب ↑ التغير في فولتية (Reciving end) يعني V_R (عند load)

قبل اضافة load و بعد اضافة load ← V_{RNL} مع العلم أن V_S ثابتة

V_{RFL}

Note at no load $I_R = 0$

$$A V_{RNL} = V_S$$

$$\boxed{V_{RLN} = \frac{V_S}{A}}$$

* Percent $VR = \dfrac{|V_{RLN}| - |V_{RFL}|}{|V_{RFL}|} 100\%$

التغير من (no load لـ full load يكون مع بور فاكتور معينة)

---

* $|V_{RNL}| > |V_{RFL}| \Rightarrow VR\%$ +ve → lagging power factor
* $|V_{RNL}| < |V_{RFL}| \Rightarrow VR\%$ −ve → leading load pf
* $|V_{RNL}| = |V_{RFL}| \Rightarrow VR\% = 0$ → unity power factor (?)

---

* T.L Voltages decreases when heavily loaded ثقيل
* T.L Voltages increases when lightly loaded خفيف

5.1 Three-phase, 60Hz, 345 kV, 200 Km → meduim

$z = 0.032 + j\,0.35 \ \frac{\Omega}{Km}$

$y = j\,4.2 \times 10^{-6} \ \frac{\Omega^{-1}}{Km}$

at full load at Reciving end → $P = 700\,MW$

$PF = 0.99$ leading → current load $(\cos^{-1}(.99))$

$V_R = (0.95)$ of rated

$= (0.95)(345)$

(A) – Z, Y, A, B, C, D

$A = D = \left(1 + \frac{YZ}{2}\right) =$

* $Z = zL = (200)(0.32 + j\,0.35) = 70.29 \angle 84.78^\circ \ \Omega$
* $Y = yL = (200)(j4.2 \times 10^{-6}) = .8.4 \times 10^{-4} \angle 90^\circ \ \Omega^{-1}$

$\Rightarrow A = D = 1 + 0.0295 \angle 174.78^\circ$

* $B = Z = 70.29 \angle 84.78 \ \Omega$
* $C = Y\left(1 + \frac{YZ}{4}\right)$

$= 8.277 \times 10^{-4} \angle 90.08$

(B) :- $V_S = A V_R + B I_R$, $V_R = (0.95)(345) = 327.8\,KV$

$I_S = C V_R + D I_R$

But note that 345 is Line Voltage to find phase Voltage

$\tilde{V}_R = \frac{327.8}{\sqrt{3}} = 189.2 \angle 0^\circ$

$V_S = \cdots$

then $\tilde{I}_R = \frac{\tilde{V}_R}{1} \times \frac{2}{Y}$

$I_S = \cdots$

OR:-

$\Rightarrow P_S = 3 \tilde{V}_S \tilde{I}_S \cos(\theta_{V_S} - \theta_{I_S})$

$= \sqrt{3}\, V_{S_{LL}} I_{S_{LL}} \cos(\theta_{V_S} - \theta_{I_S})$

$= 730.5\,MW$

$P_R = 3 \tilde{I} \tilde{V} \cos(\theta)$

$\tilde{I}_R = \frac{700M \ \cos^{-1}(.99)}{(3)(0.99)(189.2)K} = 1.245 \angle 8.11 \ KA$

(c) Percent VR :-

$V_{RLN} = \frac{V_S}{A} = 356.3\ K\ (V_{LL})$ line

Percent VR $= \frac{V_{RNL} - V_{RFL}}{V_{RFL}} =$ → $V_R = 3.45\ (SW)$ / line

$= 8.7\ \%$

---

d. $\frac{1.8KA}{I}$ → 2×0.9

e. $P_S = P_{loss} + P_R$

$P_{loss} = 30.5\ MW$

Percent EFF $= \frac{P_R}{P_S}\ 100\% = 95.8\%$

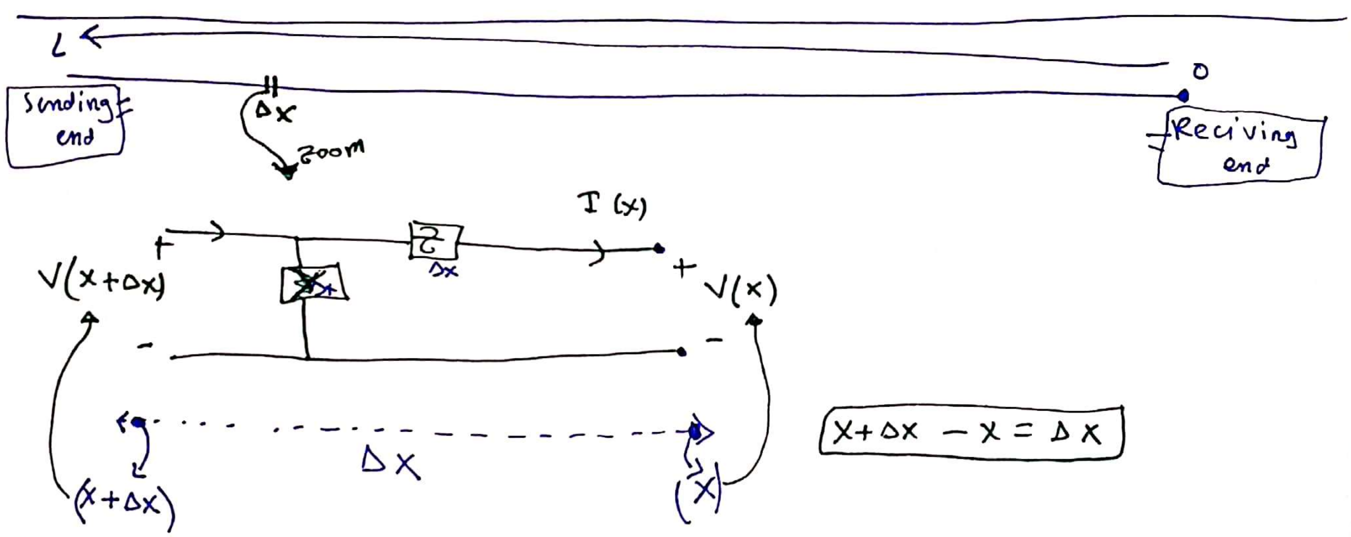
5.2

بالنسبة للـ long وهو أكبر من طول medium ورح نقسم السلك
اللي طوله (L) إلى عدد لا نهائي من الاجزاء وكل جزء طوله Δx
وتؤول Δx إلى زيرو ورح نحسب الفولتج و التيار ومن ثم نعممهم
ليصيرو معادلات عامة لحساب الفولتج أو التيار عند أي نقطة
و هيك بكون جاهز اعرف شو فولتية الـ load عند مسافة (0)
و شو فولتية الـ source عند مسافة (L)

يعني الـ Voltage والـ Current هما function of Distance بالفيزر دومين أما تايم دومين

$V(t, x)$

$\tilde{V}(x)$



$$\boxed{x+\Delta x - x = \Delta x}$$

KVL :-

$$V(x+\Delta x) = I(x)\, Z\Delta x + V(x)$$

$$\frac{V(x+\Delta x) - V(x)}{\Delta x} = Z\, I(x) \Rightarrow \Delta x \to 0$$

$$\frac{dV(x)}{dx} = \overset{\Omega/m}{Z}\, I(x) \quad \text{—— equation (1)} \to \text{KVL}$$

$$\frac{dI(x)}{dx} = \overset{\mho/m}{Y}\, V(x) \quad \text{—— equation (2)} \to \text{KCL}$$

لكن بدي أنا معادلة خاصة بكل من Voltage و Current

* $\left(\frac{dV(x)}{dx} = z I(x)\right)$

* $\frac{d^2 V(x)}{dx} = z I'(x)$, $\frac{dI(x)}{dx} = y V(x)$

leads to →

* $\frac{d^2 V(x)}{dx} - z\left(y V(x)\right) = 0$ → معادلة تفاضلية تصف معدل تغير الجهد مع المسافة و اذا حليناها بنكون طلعنا معادلة الجهد

solution :-

* $V(x) = A_1 e^{\gamma x} + A_2 e^{-\gamma x}$ (volt)

* A_1, A_2 → integration constant
  unit :- volt

* γ: propagation constant (ثابت البث)
  و يعتمد على (G, C, L, R)

$\gamma = \sqrt{zy}$ (m^{-1})

$= \sqrt{\frac{\Omega}{m} \frac{\Omega^{-1}}{m}}$

$= \sqrt{\frac{1}{m^2}}$

$\gamma = \frac{1}{m} = m^{-1}$

---

and $I(x) = \frac{A_1 e^{\gamma x} - A_2 e^{-\gamma x}}{z/\gamma}$ ⇒ $\frac{z}{\gamma} = \frac{z}{\sqrt{zy}} = \frac{\sqrt{z}\sqrt{z}}{\sqrt{z}\sqrt{y}}$

$= \frac{A_1}{Z_c} e^{\gamma x} - \frac{A_2}{Z_c} e^{-\gamma x}$ $= \frac{\sqrt{z}}{\sqrt{y}} = \sqrt{\frac{z}{y}} = Z_c$ (Ω)

⇒ $I(x) = B_1 e^{\gamma x} - B_2 e^{-\gamma x}$, Amper

B_1, B_2 → unit Amper

* Z_c : characterestics impedance (Ω)
  و تعتمد على R, L, C, G ووحدة اوم ومهمة كثير
  وثابتة لكل trans. Line و هي برمز تساوي $\frac{A_1}{B_1}$
  و أفضل قيمة هي 50 (Ω) بتعطي أقل loss للـ power

لإيجاد قيمة الثوابت A_2 ، A_1 نحتاج معادلتين وحدة من جهد ووحدة من تيار

at $x=0 \rightarrow V_R\ ,\ I_R$ (Reciving end)

$$V_R = V(0) \quad , \quad I(0) = I_R$$

$$V(0) = V_R = A_1(1) + A_2(1) \quad — \ (1)$$

$$I(0) = I_R = \frac{A_1}{Z_c} - \frac{A_2}{Z_c} \quad — \ (2)$$

$$A_1 = \frac{V_R + Z_c I_R}{2} \quad , \quad A_2 = \frac{V_R - Z_c I_R}{2}$$

هيك صار عنا معادلات جاهزة للجهد وتيار وبحتاج اعوض مسافة بدي اياها وبحل السؤال :-

لكن لسا ما وصلت للمعادلة الأم ← ABCD لحتى اعوضهم للـ long

Parameter

$$V(x) = A_1 e^{\gamma x} + A_2 e^{-\gamma x} = \frac{V_R e^{\gamma x}}{2} + \frac{Z_c I_R e^{\gamma x}}{2} + \frac{V_R e^{-\gamma x}}{2} - \frac{Z_c I_R}{2} e^{-\gamma x}$$

نفس شكل ABCD equation

$$V(x) = V_R\left(\frac{e^{\gamma x} + e^{-\gamma x}}{2}\right) + I_R\left(\frac{e^{\gamma x} - e^{-\gamma x}}{2}\right) Z_c$$

$$I(x) = \frac{1}{Z_c}\underbrace{\left(\frac{e^{\gamma x} - e^{-\gamma x}}{2}\right)}_{\sinh \gamma x} V_R + I_R \underbrace{\left(\frac{e^{\gamma x} + e^{-\gamma x}}{2}\right)}_{\cosh \gamma x}$$

$$A(x) = \frac{e^{\gamma x} + e^{-\gamma x}}{2} = \cosh \gamma x = D(x)$$

$$B(x) = \sinh(\gamma x)$$

$$C(x) = \frac{1}{Z_c} \sinh(\gamma x)$$

هسا معادلات فوق شو؟ هما عبارة عن معادلة الفولتية والتيار عند اي مسافة بدلالة فولتية وتيار load فإذا عوضت $X = L$ صارت معادلة لفولتية وتيار source بدلالة فولتية وتيار load

$$A = \cosh \gamma L = D$$
$$B = \sinh(\gamma L)$$
$$C = \frac{1}{Z_c} \sinh(\gamma L)$$

$$V(L) = A V_R + B I_R$$

$$I(L) = C V_R + D I_R$$

5.2 (Ex) :- 3-phase → Line-line 765, 60 Hz
+ve sequence , L = 300 km
long

* $z = 0.0165 + j0.3306 = 0.3310 \angle 87.14 \ \Omega/km$

* $y = j4.674 \times 10^{-6} \ S/km$

Calculate ABCD :-

to find ABCD → find (γL)

find (Z_c)

* $\gamma = \sqrt{zy} =$

* $Z_c = \sqrt{\frac{z}{y}} = 266.1 \angle -1.43 \ \Omega$

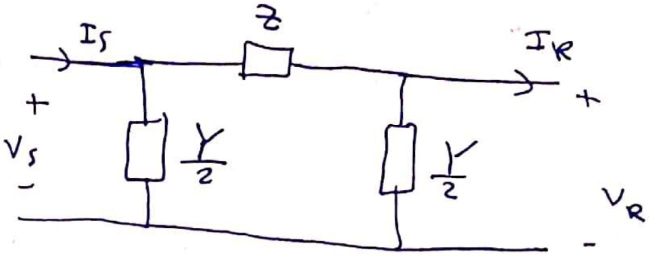
* $\gamma L = (300)\gamma = 0.373 \angle 88.57 \ (m^{-1} \ m)$ → per unit
بدون وحدة

* $A = \cosh \gamma L$ → ماتعوض بالآلة
حاسبة كونه فيه
complex
نفكه :-

نفكها ثم $e^{\gamma L} = 1 \angle \gamma L$

5.3 :- Equivalent π circuit :-

~~Normal~~ nominal π circuit :-



$$A = D = 1 + \frac{YZ}{2}, \quad B = Z\ (\Omega)$$

$$C = Y\left(1 + \frac{YZ}{4}\right)\ (S)$$

In equivalent π circuit :- Z converted to Z'

$\frac{Y}{2}$ converted to $\frac{Y'}{2}$

Same ABCD equations

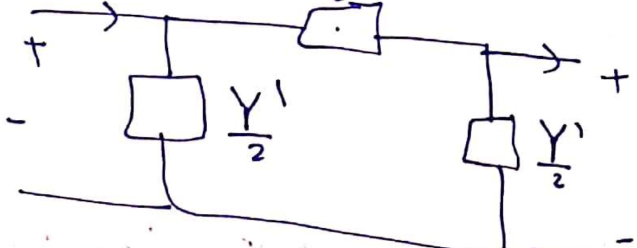
where $Z' = Z_c \sinh(\gamma l) = Z F_1 = Z \frac{\sinh(\gamma l)}{\gamma l}$

where F_1 is correction factor to convert Z from Normal (π) to eqquivalent (π)

where $\frac{Y'}{2} = \frac{Y}{2} F_2 = \frac{Y}{2} \underbrace{\left(\frac{\tanh(\gamma l/2)}{(\gamma l/2)}\right)}_{F_2} = \frac{\tanh(\gamma l/2)}{Z_c}$

and F_2 is correction factor to convert $\frac{Y}{2}$ from normal (π) to equivalent (π)

⊛ Equivalent π Circuit



5.4 lossless lines :-

غاما

* حكينا أنه (γ) بتأثر كثير على نوع السلك لانه بيتأثر بـ(R ، L ، C ، G)
و(γ) بتكون من (α و β) وواحد بأثر عل amplitude وواحد بأثر عل phase

زي ما منعرف البور تحسب من الـ Amplitude
حيث لو أرسلت (propagate بث) فولتج معين بـ Amplitude معين
وكان $\boxed{\alpha = 0}$ بالتالي رح تضل Amplitude مثل ما هي لحتى توصل الـ مستقبل
و هيك ما في أي خسارة بين مرسل و مستقبل و بيسمى
" lossless transmission line "

lossless transmisson line :-

* كذلك مثل ما لا مهمة و Z_c مهمة لنفس السبب واذا كانت
real أو Complex بعرف بدهو

* احنا منعرف انه البور الحقيقي تستهلك في (R و G) حيث لحتى
نحكي انه ما عنا (loss) بالنسبة للأسلاك لازم نحكي انه فش (R و G)

lossless transmisson line:

is :- Perfect conductor with $R = 0$

Perfect dielectric with $G = 0$

$z = j\omega L + (0)$ $\quad \frac{\Omega}{m}$

$y = j\omega C + (0)$ $\quad \frac{S}{m}$

$$Z_c = \sqrt{\frac{z}{y}} = \sqrt{\frac{j\omega L}{j\omega C}} = \sqrt{\frac{L}{C}}\ \Omega \rightarrow \text{pure real}$$

$$\gamma = \sqrt{zy} = \sqrt{(j\omega L)(j\omega C)} = j\omega\sqrt{LC}\ (m^{-1}) \rightarrow \text{pure imaginary}$$

$$\gamma = \alpha + j\beta = 0 + j\underbrace{\omega\sqrt{LC}}_{\beta}\ (m^{-1})$$

← مثل ما قلنا فوق ما في (α)

* Z_c in lossless is called surge impedence

Scanned with CamScanner

* ⊛ ABCD in lossless :-

⊛ $A(x) = D(x) = \cosh(\gamma x) = \cosh(j\beta x) = \cos(\beta x)$

$\frac{e^{j\beta x} + e^{-j\beta x}}{2}$

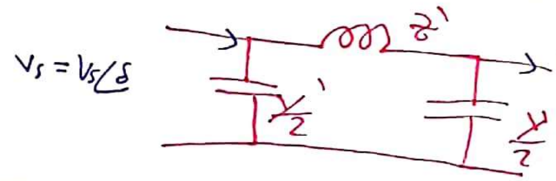
⊛ $B(x) = Z_c \sinh(\gamma x) = j Z_c \sin(\beta x) = j\sqrt{\frac{L}{C}} \sin(\beta x)\ \Omega$

$$\boxed{B(x) = Z' = j Z_c \sin(\beta x) = j X'\ \Omega}$$

⊛ $\frac{Y'}{2}$ in lossless :- $= \left(\frac{j\omega C l}{2}\right)$ S

length

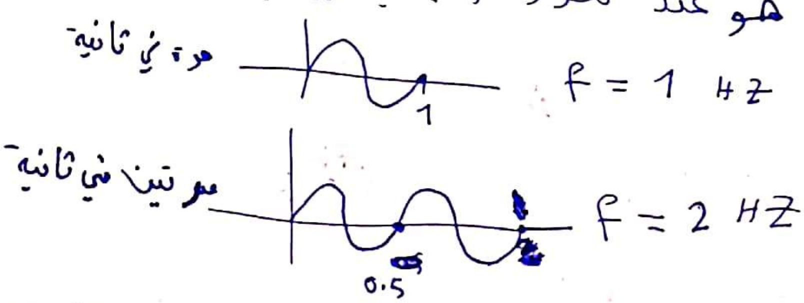
Z' : Pure inductive , Y' = Pure Capacitive



: equivalent π circuit

⊛ Wave length :- (λ)

frequency :- → لواحدة هو عدد تكرار الموجة في الثانية ⊛

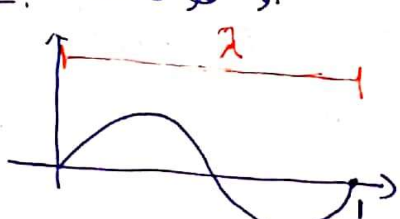


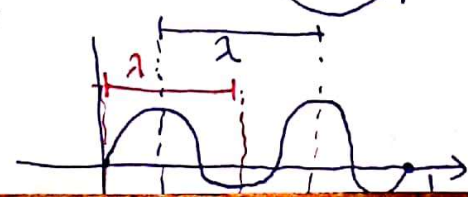
⊛ الطول الموجي هو مسافة من بداية الموجة لنهايتها

أو هو مسافة بين قاعين أو قمتين (زي كأنك بولك تاخد time period)

⊛ ملاحظ طول موجي تقل ~~[illegible]~~ بس تردد يزيد وممكن تعريفه

⊛ ~~[illegible]~~ هو مسافة لازمة للموجة تمشي (2π)





* لكن في شيء مهم نعرفه مش شرط اذا تغير واحد منهم يتغير الثاني يعني (التردد وطول موجي) لانه في عنا عامل ثالث بأثر وبتأثر فيهم
+ هو السرعة الموجية

⊛ $\lambda : m$

⊛ $f : \frac{1}{s}$

⊛ $\lambda f = \frac{(m)}{(s)} \rightarrow$ speed

phase velocity ← $u_p = \lambda f$

⊛ بالاسلاك التردد ما بتغير لكن الأمواج سرعتها تتغير حسب وسط بالفراغ سرعتها تساوي سرعة الضوء (3×10^8)
لكن اذا تغير الوسط عندها سرعة تقل بسبب وجود معوقات فلما تتغير السرعة بتأثر طول موجي علما انه التردد ما بتغير لانه مثبت

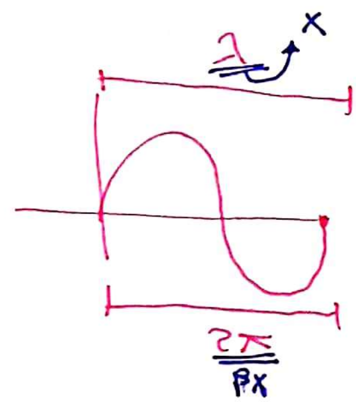
$$V(x) = A(x) V_R + B(x) I_R$$

$$= \cos(\beta x) V_R + B(x) I_R$$

when $\beta x = 2\pi$ then

then $x = \frac{2\pi}{\beta} = \lambda$ (m)

(منقدر نوخذ x إنها: λ لانه قلنا به نقيس (λ) منتحرك من بداية موجة لنهايتها $\boxed{2\pi}$)



⊛ $\lambda = \frac{2\pi}{w\sqrt{LC}} = \frac{1}{f\sqrt{LC}}$ m

⊛ $u_p = f\lambda = \frac{1}{\sqrt{LC}}$ ⊛ :- velocity of propagation (phase velocity)
سرعة الموجات (فولتية وتيار)

⊛ for overhead lines $u_p = 3 \times 10^8 \frac{m}{s}$

$\lambda \Rightarrow$ for $\boxed{f = 60\ Hz} = 5000\ Km = 3100\ mi$

* surge impedence loading (SIL)

⊛ هسسه surge impedence يعني Z_c ← و loading تعني (load نوعه Z_c)

بالمختصر سلكنا load قيمته Z_c وتساوي $\sqrt{\frac{L}{C}}$

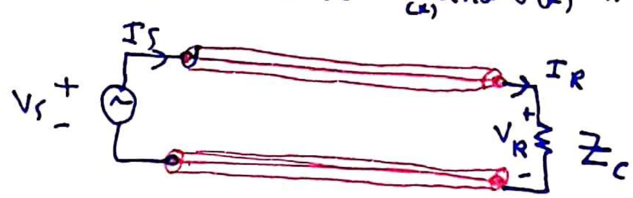
بنفس وقت احنا لسه بال (lossless) طيب؟ مع دروسنا شو رح يأثر

⇐ البور اللي رح تروح بالسلك شو رح تكون؟ ← ① ⇒ Q absorbed in L (series)

② Q generated in C (shunt)

المحصلة رح يلغو بعض و هي حالة خاصة عندما load يساوي Z_c

* it is also called netural load
* in Surge impedence load ÷ Voltage and currant <u>in phase</u> All points
* surge impedenc load is the ideal load Because $I_{(x)}$ and $V_{(x)}$ is uinform along line



⇒ loss less line terminated by resistanc $= \sqrt{\frac{L}{C}} = Z_c$

* $I_R = \frac{V_R}{Z_c}$ A

SIL ÷ is the power delivered by alossless line to a load equal to surge impedence $Z_c = \sqrt{\frac{L}{C}}$

$$V(x) = \cos(\beta x) V_R + j Z_c \sin(\beta x) I_R$$

$$= \cos(\beta x) V_R + j \cancel{Z_c} \sin(\beta x) \frac{V_R}{\cancel{Z_c}}$$

$$= e^{j\beta x} V_R$$

$|V(x)| = |V_R|$ V → شو معناه؟

حط $l = x$

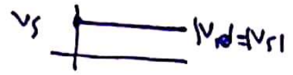
$|V(l)| = |V_R|$

$V_s = V_R$ → يعني فولتية ثابتة عطول الـ line

وبسمو هالاشي ← at SIL

Voltage profile is flat

شو معنى flat ؟ انه فولتية دايماً ما بتتغير نفسه من x=(L)ل x=0



and $I(x) = e^{j\beta x} \dfrac{V_R}{Z_c}$

$\Rightarrow |I(x)| = \dfrac{|V_R|}{Z_c}$

هسا بتوقع complex power شو رح تكون ؟ أكيد real كوله مكينا أساسا انه

$Q_L = Q_C$

$\underline{\underline{Q_L - Q_C = 0}}$

$$S(x) = P(x) + jQ(x) = V(x)\, I^*(x)$$

$$= \left(e^{j\beta x} V_R\right)\left(e^{-j\beta x} \frac{V_R}{Z_c}\right)$$

$$= \frac{|V_R|^2}{Z_c} \rightarrow \text{ثابتة} \rightarrow \text{منطقي}$$

real

The real power flow along a lossless line at SIL $(Z_L = Z_c)$ remains constant from sending end ⟷ reciving end

and reactive power is zero

$SIL = \dfrac{V^2_{rated}}{Z_c}$ → the real power Delivered or SIL

rated Voltage

ملاحظة

- rated Voltage used for single phase line
- rated line-line Voltage used for total power three Phase line

Voltage Profiles:-

هس حكينا انه SIL هو ideal load فالوضع العملي مارح يكون load يساوي SIL

ممكن يكون اكبر او اقل سوي اعتمادا على :-

① line length

② line compensation , during heavy load conditions

بالتالي مارح تكون flat (constant) الفولتية

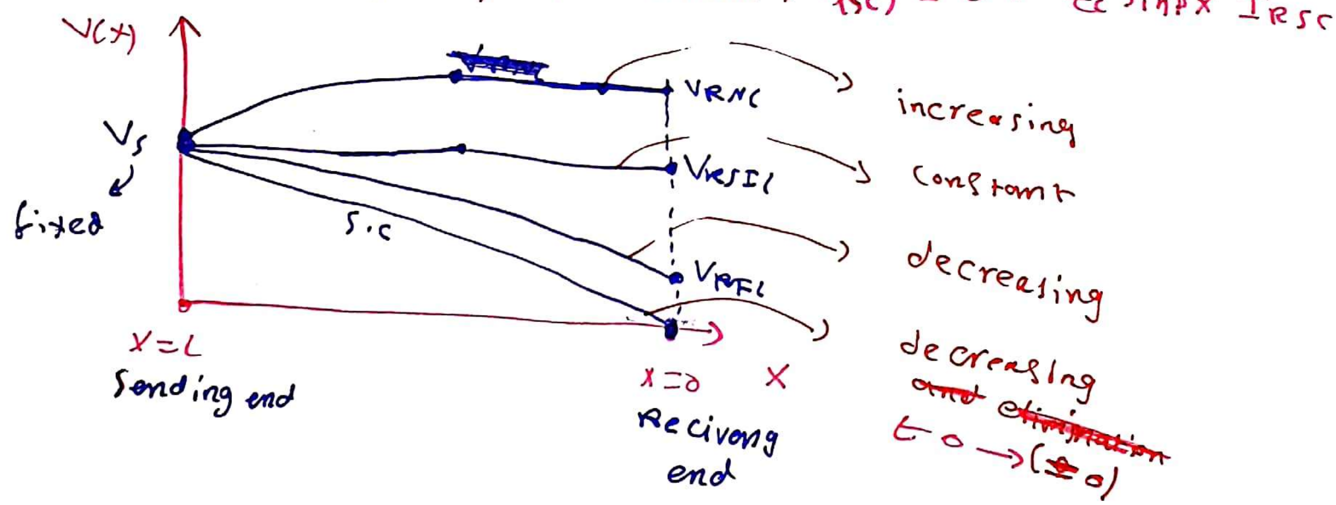
---

1. No load → $I_R = 0$, $V_R = \frac{V_S}{A} = \frac{V_S}{\cos(\beta l)}$ → Yr <1

يعني $V_S < V_R$ بالتالي الفولتية حالتها increasing

2. at load $= Z_C$ (SIL) $V_S = V_{R\,SIL}$ (flat)

3. at load (S.C) $V_{R_{SC}} = 0$, I_R maximum , $V(SC) = 0 + Z_C \sin\beta x \, I_{RSC}$



Case 3:- Vs decrease to (0) at Reciving-end as (x) Varied

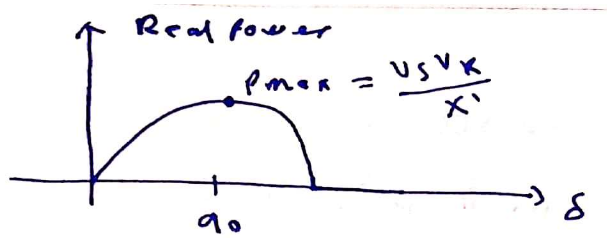
The full load voltage depends on the specification of I_{FL} and it's above V_{SC} and less than V_{RSIL}

⊛ مثل ما احنا شايفين عنا فرق بين No load و Full load و هاض اشي بيعني

انه كل ما زاد طول السلك المشكلة بتكبر تاخد (more severe) Reciving end regulation percent

أكثر

والحل الها هو Compensation methods لتقليل تقلبات (fluctuation) الفولتية



③ Real power for lossless as δ varying

* Loadability : is defined at the exent (مدى) of load can flow through line without exceeding (تجاوز) the limitations.

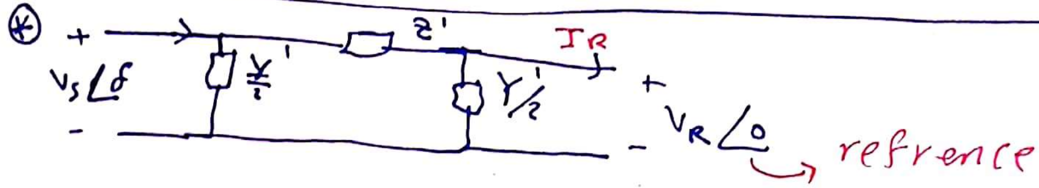
* Line loadability : defined as Percentage of SIL

what is the limitations ? :

1. thermal limit : heating of transmisson line
2. Voltage drop limit
3. Steady State Stability limit.

* هدول اي load ما بصير يتجاوزهم "أبداً".

*



$$* \quad I_R = \frac{V_s - V_R}{Z'} = \frac{V_s e^{j\delta} - V_R}{jX'} - \frac{j\omega c' l}{2} V_R$$

$$* \quad S = \frac{j(V_R V_s \cos\delta - V_R^2)}{X'} + \frac{V_R V_s}{X'} + \frac{j\omega c l}{2} V_R^2$$

$$* \quad P = \underbrace{P_s = P_R}_{\text{lossless}} = Re(S_R) = \frac{V_R V_s}{X'} \sin\delta$$

Note at SIL

$V_R = V_s$, $\delta = 90$

$P = V_R^2$

For fixed V_R, V_s

$$P_{max}\Big|_{\delta=90} = \frac{V_R V_s}{X'} \Rightarrow$$ theoretical steady state stability limit of lossless line

$P_{min} = 0$

ولا يمكن تجاوز هالقيمة وهاي بتفقد مزامنتها اذا تعدتها

* Power max of lossless in terms of SIL

$$P = \frac{V_R V_S}{x'} \sin\delta = \frac{V_S V_R}{Z_c \sin\beta l} \sin\delta = \frac{V_S V_R}{Z_c} \frac{\sin\delta}{\sin\left(\frac{2\pi l}{\lambda}\right)}$$

$$P = \frac{V_{s\,pu} V_{R\,pu} (SIL) \sin\delta}{\sin\left(\frac{2\pi l}{\lambda}\right)}$$

$$P_{max}\Big|_{\delta = 90} = \frac{V_{s\,pu} V_{R\,pu} (SIL)}{\sin\left(\frac{2\pi l}{\lambda}\right)}$$

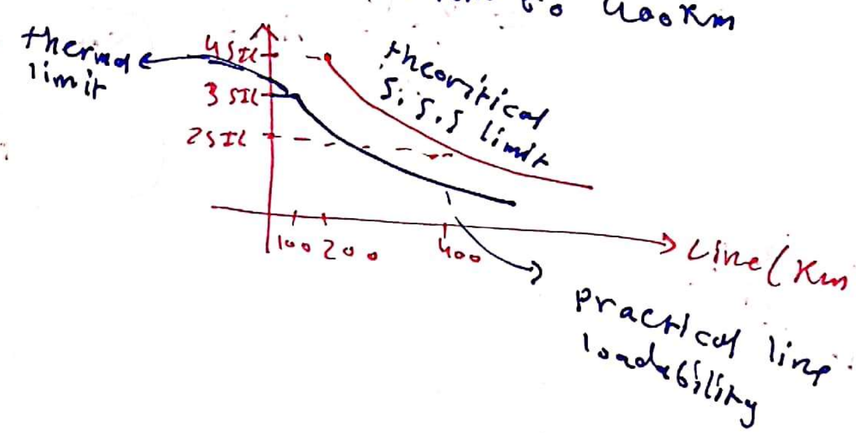
; Where $V_{s\,pu}$, $V_{R\,pu}$ is rated line Voltages in per unit.

Two factors affecting the (S-S-S- limit)

* it increases with the square of line voltage
* it decreasing with line length

For $V_{s\,p.u} = 1 = V_{R\,p.u}$, $\lambda = 5000\,km$

the theoritical steady state stability limit Decrease from 4(SIL) to 2(SIL) from 200 Km to 400 Km



Line loadability

(*) الفكرة بالوضع العملي مارح نوصل لل theoritical S.S.S. limit رح يكون اقل شوي .

. See book (for numbers)

(*) Note for less than 25 km Short line

Loadability is limited : by ① thermal rating

② terminal equipment rating

not by voltage drop

or stability considerations

Ex: 5.6: A: Practical line loadability

Given or from 5.2

$\delta = 35^\circ$ $V_R = 0.95$ p.u

$\boxed{V_S = 765\ V}$, $\boxed{V_R = 0.95 V_S}$, $Z' = 97.0\angle 87.2$

$\theta_A = 0.209$

then $P_R = 3247$ MW

ما نكون وصلنا lossy
العليا من max

لو افترضنا بكون وصلنا هي

Practical not theoritical , provided that thermal and voltage drop not exceeded

(*) لو رجعنا لل fig عند 300 km رح نلاحظ 3277 قريبة جدا من 3247

(B) $P_R = 3 V_R I_R\, pf = \sqrt{3}\, V_R I_R\, pf$, $pf = 0.986$

$V_R = 0.95 V_S$

3247 = لها هاد رح نوصلها Based on Practical لما

$I_{R_{FL}} = 7.616$ kA

(C) $V_S = A V_R + B I_R = A V_{R_{FL}} + B I_{R_{FL}}$

كله given أو محسوب عدا $V_{R_{FL}}$

$V_{R_{FL}} = 420.77$ kV$_{L-N}$

Scanned with CamScanner

5.5 maximum Power Flow $\Rightarrow$ for lossy lines

Let $A = \cosh(\gamma l) = A\angle\theta_A$

$B = Z' = Z'\angle\theta_Z$

$V_S = V_S\angle\delta$

$V_R = V_R\angle 0$

* $\xrightarrow{\text{ABCD equation}}$ $I_R = \dfrac{V_S - AV_R}{B} = \dfrac{V_S e^{j\delta} - AV_R e^{j\theta_A}}{Z' e^{j\theta_Z}}$

⊛ $S_R = V_R I_R^* = V_R\left(\quad \right)^*$

$$= \frac{V_R V_S e^{j(\theta_Z - \delta)}}{Z'} - \frac{AV_R^2}{Z'} e^{j(\theta_Z - \theta_A)}$$

then $P_R = Re(S_R) = \dfrac{V_R V_S}{Z'}\cos(\theta_Z - \delta) - \dfrac{AV_R^2}{Z'}\cos(\theta_Z - \theta_A)$

(general) يعتبر

$Q_R = Im(S_R) = \dfrac{V_R V_S}{Z'}\sin(\theta_Z - \delta) - \dfrac{AV_R^2}{Z'}\cos(\theta_Z - \theta_A)$

⊛ الشي وحيد متغير في المعادلة هو (δ) حتى اعلى قيمة للبور لما (cos) = 1

يعني لما $\delta = \theta_Z$ بكونوا ماكس بور

general — lossless or not

$$P_{R\max} = \frac{V_R V_S}{Z'} - \frac{AV_R^2}{Z'}\cos(\theta_Z - \theta_A)$$

---

in lossless $\theta_A = 0$ $\theta_Z = 90$ and $Z' = jX'$

then equation become for lossless.

(d) $\text{Percent } V_R = \dfrac{V_{RNL} - V_{RFL}}{V_{RFL}} \times 100\% = \dfrac{V_S/A - V_{RFL}}{V_{RFL}} 100\%$

اذا معطية $V_s = (765)$

بنحول لـ V_{RFL} $\left(\dfrac{\text{line}}{-\text{line}}\right)$

$= \underline{\underline{12.72\%}}$

رقم كبير

(e) The thermal limit is max rated current

From table $\doteq 1.2$ KA

and for four conductors

$\underline{\underline{4.8 \text{ KA}}}$

$I_{RFL} < 4.8 \text{ KA} \rightarrow ✓$ thermal limit

$\dfrac{V_S}{V_R} \geq 0.95 \longrightarrow ✓$ Voltage drop limite

$\text{percent } V_R = 12.72\%$ too much

But in 5.7 may be solutions to increase loadalbility

Scanned with CamScanner

تعويض

5.7 RActive compensation Techniques.

هي طريقة لتحسين وتطوير أداء ال system في Ac
وذلك في جانبين :

① Load compensation :- and objective is :-

(i) increase the power factor of the system
(ii) balance real power from the system
(iii) Compensate percent VR
(4) Eliminate current harmonic

② Voltage support :- main purbose to decrease the Voltage fluctuation

(*) To improve the stability......

And Because Reactive Power is :- required to maintain the voltage to deliver Active Power
But when there is not enough Reactive Power the Voltage get down and not possible to re deliver enough active power

(*) And required to regulate the power factor of the system
we need to compensate ReActive Power (VAR)

The methods Are :-

* Shunt compensation. Device connected in parallel
* series compensation, Device Connected in series
* Synchronous condensers.
* Static VAR Compensators.
* Static compensators.

Scanned with CamScanner

① shunt Compensator :- * shunt reactors (inductor)

* shunt capicitors

* and it's connected at selected points along EH lines from each phase to neutral

* shunt reactors :- * absorbs reactive power and
* Reduce over voltages by consuming Q
* Reduce transient over voltages

But * it reduce line loadability if they not removed under full load

* shunt capicitors :- * Deliver Reactive Power And increase Transmisson Voltages During load conditions (maintain the voltage level)

* The series compensator can connected anywhere in the line.

2 kinds :- capicitve mode or inductive mode

* series capicitors :- (some times used on long lines to increase line loadability)

* (Reduce net series impedence of line with the capicitor banks, reduce line Voltage drop increase S.S.S. Limit, increase loadability

Disadvantage :- see Book (لولم نكتب)

5:a ⇒ shunt inductors → shunt compensation

75% compensation

at full load it's removed

$I_{FL} = 1.9 KA$, $V_{FL} = 730 KV$, $PF = 1$

A: Find percent VR:

$V_{RNL} = \frac{V_S}{A}$ A from Ex 5.2 = $0.9313 \angle 0.209°$

$V_S = A V_R + B I_R$

$= \vec{A} \vec{V}_{RFL} + \vec{B} \vec{I}_{RFL}$

$V_S = 766.0 \ KV_{L-L}$

(*) $V_{RNL} = \frac{V_S}{A} = 822.6 \ KV_{L-L}$

$V_{RFL} = 730 KV$

$VR\% = \frac{822.6 - 730}{730} 100 = 12.68\%$

(B) $\frac{Y'}{2} = \frac{3.7}{10^7} + j \frac{7.094}{10^4} S$ → from previous Example

$Y' = 2(\quad\quad)$

$= 7.4 \times 10^{-7} + j 14.188 \times 10^{-4} S$

with compensation → shunt

$Y_{eq} = Y' - 75\% Y' = 3.547 \times 10^{-4} \angle 89.88$ → $\frac{Y'}{2} - \frac{N_{sh}}{100} \frac{Y'}{2}$

so $Z_{eq} = Z' = 97.0 \angle 87.2$ from 5.2 Because no series compensation

---

(C) $A_{eq} = 1 + \frac{Y_{eq} Z_{eq}}{2}$ → compen

$= 0.9828 \angle 0.05$

(*) $V_{RNL} = \frac{V_S}{A} = 779.4 \ KV_{LL}$

(*) $VR\% = 6.77\%$ → أقل → أحسن

V_{RFL} → same (removed) لأنه 1