ElCoM
ELECTRICAL COMPUTER MECHATRONICS

تقدم لجنة ElCoM الاكاديمية

تلخيص قوانين لمادة:

انظمة القوى

جزيل الشكر للطالب:

زيد الدراغمة

Power system

* Ch-3:

$v(t) = V_m \cos(\omega t + \theta)$ // time Domain (Instantaneous value)

$V = V_{rms} \angle \theta$ // polar form

$V = V_{rms} e^{j\theta}$ // exponantial form

$V = V\cos\theta + j\sin\theta$ // rectangular form

• Resistor

$I_R = \frac{V}{R}$, I inphase with V

$P_R(t) = VI + VI\cos(2\omega t + 2\delta)$

• Inductar

$I_L = \frac{V}{jX_L}$, $jX_L = j\omega L$, I Lag V by 90°

$P_L(t) = VI_L \sin(2(\omega t + \delta))$

• Capacitor

$I_C = \frac{V}{-jX_C}$, $-jX_C = \frac{1}{j\omega C}$, I lead V by 90°

$P_C(t) = -VI_C \sin[2(\omega t + \delta)]$

* for general Load (RLC)

$p(t) = \underbrace{VI_R[1 + \cos(2(\omega t + \delta))]}_{\text{P(t) absorb by Resistor}}$

$+ \underbrace{VI_x \sin[2(\omega t + \delta)]}_{\text{P(t) absorb by Reactive}}$

P_{AVG}, Real P, active P

$P = VI\cos(\delta - \beta)$, $[P] = W$

Reative P , $[Q] = VAr$

$Q = VI\sin(\delta - \beta)$, $Q = P\tan(\delta - \beta)$

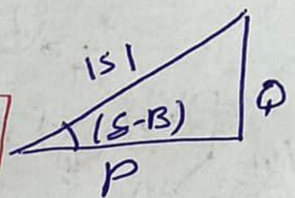
$S = \sqrt{P^2 + Q^2}$ $\Rightarrow Q = \sqrt{P^2 - S^2}$

$PF = \cos(\delta - \beta) = \frac{P}{S} = \frac{P}{\sqrt{P^2 + Q^2}}$

$(\delta - \beta) = \tan^{-1}(Q/P)$

$\underset{\text{complex P}}{S} = P + jQ = VI^* = VI\angle\delta-\beta$

$\underset{\text{apperant P}}{|S|} = VI = \frac{P}{PF} = \sqrt{Q^2 + P^2}$



$S_R = \frac{V^2}{R}$, $P_R = \frac{V^2}{R}$, $Q_R = 0$

ABsorbed

$S_L = \frac{jV^2}{X_L}$, $P_L = 0$, $Q_L = \frac{V^2}{X_L}$, ABsorbed

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

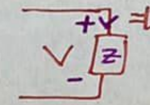
Power factor (PF)

$PF = \cos(\delta - \beta)$ زاوية I زاوية V

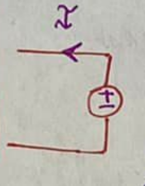
• PF Laging ⇒ Inductive L ($\beta < \delta$)
I lag V , (الزاوية سالبة)

• PF leading ⇒ Capacitive L ($\beta > \delta$)
I lead V (الزاوية موجبة)

• PF unity ⇒ Resistive L
($\beta = \delta$) I inphase V (الزاوية صفر)



P +ve ⇒ absorbed real power
P -ve ⇒ delivered real power
Q +ve ⇒ absorbed reactive power
Q -ve ⇒ delivered reactive power



P +ve ⇒ Delivered real power
P -ve ⇒ absorbed real power
Q +ve ⇒ Delivered react power
Q -ve ⇒ absorbed reactive power

*Balnce Conection

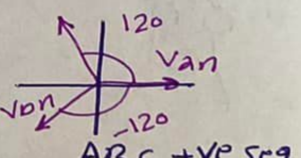
- Balnced Source	- Balanced Load
phase voltage same Mag & 120 phase difference	all Loads Identecal in mag & phase

+ve seq

$V_{an} = V_p\angle 0°$

$V_{bn} = V_p\angle -120°$

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



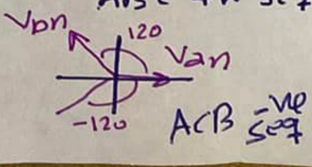
ABC +ve seq

-ve seq

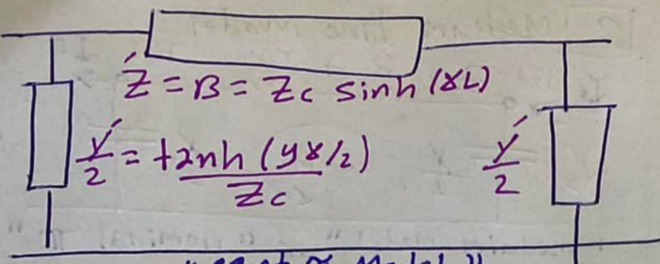
$V_{an} = V_p\angle 0°$

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

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



ACB -ve seq



" eqnt π Model "

$$Z' = B$$

$$\frac{Y'}{2} = \frac{\tanh(y\gamma/2)}{Z_c} = \frac{\cosh\gamma L - 1}{Z_c \sinh\gamma L} = \frac{A-1}{B}$$

متطابقات لتسهيل العمليات الحسابية :

- $\cosh\gamma L = \frac{e^{\gamma L} + e^{-\gamma L}}{2}$
- $\sinh\gamma L = \frac{e^{\gamma L} - e^{-\gamma L}}{2}$

$\Rightarrow$ * $\cosh(\alpha L + j\beta L) = \frac{1}{2}\left[e^{\alpha L}\angle\beta L + e^{-\alpha L}\angle -\beta L\right]$

* $\sinh(\alpha L + j\beta L) = \frac{1}{2}\left[e^{\alpha L}\angle\beta L - e^{-\alpha L}\angle -\beta L\right]$

* lossless transmission line :

- For lossless line $\boxed{R = G = 0}$ - perfect Condutor with $R=0$
- perfict delectric with $G=0$

$Z = j\omega L + \boxed{0}$ (R)
$y = j\omega C + \boxed{0}$ (G)
$\Rightarrow Z_c = \sqrt{\frac{Z}{y}} = \sqrt{\frac{L}{C}}\ \Omega$

& $\gamma = \alpha + j\beta = \boxed{0} + j\underbrace{\omega\sqrt{LC}}_{\beta}$ (α)

$\Rightarrow \gamma = j\beta\ m^{-1}$

- Z_c in lossles called Surge Impednce

- ABCD in lossles (بنعوض عن $\gamma = j\beta$)

- $A(x) = D(x) = \cosh(\gamma x) = \cosh(j\beta x) = \cos(\beta x) = D$
- $B(x) = Z_c \sinh(\gamma x) = j Z_c \sin(\beta x) = j\sqrt{\frac{L}{C}}\sin(\beta x) \Rightarrow j Z_c \sin(\beta x)\ \Omega$
- $C(x) = \frac{\sinh(\gamma x)}{Z_c} = \frac{j\sin(\beta x)}{\sqrt{L/C}}$ S

* wave length : (λ)

$\lambda = \frac{2\pi}{\beta}$ (rad / km)

β → جزء الـ Img من γ قبل الضرب بالطول

* Velocity of propagation : (λf)

$\lambda f = \frac{2\pi f}{\beta} = \frac{1}{\sqrt{LC}}$ (km / s)

↳ سرعة الإنتشار وتكون تقريباً تساوي سرعة الضوء (3×10^8)

* Reactive compensation Techniqus :

طريقة لحل مشكلة الـ efficiency القليلة والـ Voltage Regulation العالية

* Sires comp : مما يؤدي لتحسين اداء النظام.

- Consist of a capacitor bank in sieres with each phase conductor of the line
- Reduce sires Impednce $Z\downarrow$
- Reduce Voltage drop → $VR\downarrow$

] adv

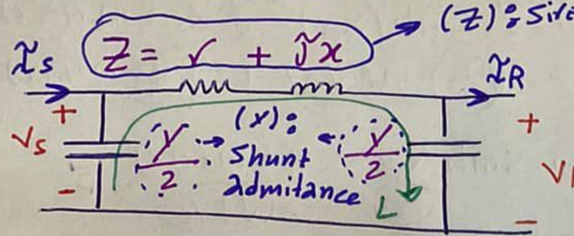
* Compensation factor $= \frac{x_c}{x_L}$

- كيف تتم هذه العملية ؟

- we degined Capacitance of the capacitor bank can be determined by compensation for a spesific amount of the Total Inductive reactance of the Line.

Ch-5: Transmission Line

1 Short line Model:



* Usually applied to lines less than 80 Km
* Capacitance otten be Ignored

$$Z = (R + jx_L)L$$

$$\boxed{Z = (R + j2\pi fL)\,\underline{L}}$$ Length of Transmission line

$$\boxed{Y = G + j\omega C}$$ $$[Y] = \Omega^{-1}/m$$

$\boxed{\cdot V_s = Z I_R + V_R}$, KVL (loop L)

$\boxed{\cdot I_s = I_R}$, بسبب إهمال المواسعات

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

- $V_s = AV_R + BI_R$
- $I_s = CV_R + DI_R$

بضرب كل صف بعامود

A.B.C.D parmeters

$\Rightarrow \boxed{A = D = 1}$

$\boxed{B = Z}$, $\boxed{C = \text{zero}}$ بسبب إهمال وجود المواسعات

Ω

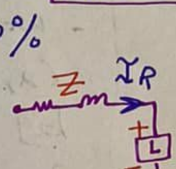
* Voltage Regulation (VR):

$$\boxed{V_{RNL} = \frac{V_s}{A}}$$

$$V_R = \frac{|V_{R(NL)}| - |V_{R(FL)}|}{|V_{R(FL)}|} \times 100\%$$

كل ما كانت قليلة أفضل

$$\boxed{V_R = \frac{|\frac{V_s}{A}| - |V_R|}{|V_R|} \times 100\%}$$



حالة الـ NL ← التيار = صفر

$\boxed{V_R = V_s}$

- $|V_{RNL}| > |V_{RFL}| \Rightarrow VR$ +ve $\Rightarrow$ laging pf (أسوأ حالة)
- $|V_{RNL}| < |V_{RFL}| \Rightarrow VR$ −ve $\Rightarrow$ leading pf (أفضل حالة)
- $|V_{RNL}| = |V_{RFL}| \Rightarrow VR = 0 \Rightarrow$ unity pf or pf=100 (وسط)

* efficienty

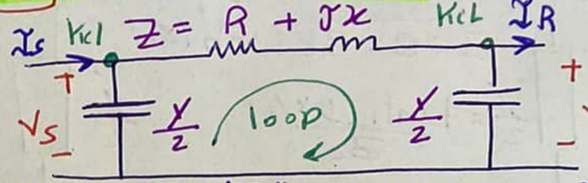
كل ما كانت اقرب لـ 100 أفضل

$$\boxed{\eta = \frac{P_R}{P_S} \times 100\%}$$

$$\boxed{S_s = 3V_s I_s^*}$$

$$\boxed{I_R = \frac{S_R^*}{3V_R}}$$

2 Medium Line Model



"meduim model" or "nominal π"

* typically ranging from 80 to 250 Km
* Capacitance must be Consederd

بعد اجراء KVL & KCL و نشتق المعادلتين:

$$\boxed{V_s = (1 + \frac{ZY}{2})V_R + Z I_R = A V_R + B I_R}$$

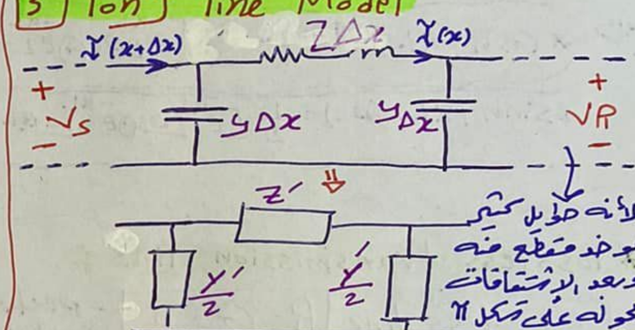
$$\boxed{I_s = Y(1 + \frac{ZY}{2})V_R + (1 + \frac{ZY}{2})I_R = C V_R + D I_R}$$

$$\begin{bmatrix} V_s \\ I_s \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_R \\ I_R \end{bmatrix}$$

$\Rightarrow \boxed{A = 1 + \frac{ZY}{2} = D}$ A.B.C.D Parameters

$\boxed{B = Z\ \Omega}$, $\boxed{C = Y(1 + \frac{ZY}{4})\ S}$ Ω^{-1}

3 long line Model



لأنه طويل كثير بوخذ مقطع منه وبعد الاشتقاقات نحوله على شكل π ونسميه

"eqnt π circut"

$$I(x) = \frac{1}{Z_c}(A_1 e^{\gamma x} - A_2 e^{-\gamma x})$$

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

$\gamma = \alpha + j\beta = \sqrt{ZY}$, $Z_c = \sqrt{\frac{Z}{Y}}$

antitenution Const (m^{-1}) or propagation cont — phase const — characterstic Impednce (Ω)

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

بعد التعويض $I_{NL} = I_{(s)}$ & $V_{(s)} = V_{NL}$ نحصل على:

$$\Rightarrow \boxed{V_s = (\cosh\gamma L)V_R + (Z_c \sinh\gamma L)I_R}$$

$$\boxed{I_s = (\frac{1}{Z_c}\sinh\gamma L)V_R + (\cosh\gamma L)I_R}$$

$\boxed{A = D = \cosh\gamma L}$ A.B.C.D parameters

$\boxed{B = Z_c \sinh\gamma L}$ Ω

$\boxed{C = \frac{\sinh\gamma L}{Z_c}}$ S

$AD - BC = 1$

Ch-4: Transmission Line parameters

* Resistance

$$\boxed{R_{dc,T} = \frac{\rho_T L}{A}} \quad A \rightarrow \frac{N\pi d^2}{4}$$

R depends on:

[1] Spiraling

[2] Current magnitude - magnatic Conductors $\boxed{I \propto R}$

[3] Temperature $\Rightarrow$ $\rho_{T_2} = \rho_{T_1}\left(\frac{T_2 + T}{T_1 + T}\right)$ T from table

[4] Frequncy ("skin effect") $\Rightarrow$ $R_{ac} = \frac{P_{Loss}}{|I|^2}$

كل ما زادت F تتوزع التيار
على اطراف الـ cond ductor وهذا يسبب
زيادة R

* Inductance

Daiamite of r, $L \propto \frac{1}{L}$ تناسب عكسي

- 1 ϕ, two wire line, not bundled

$$L_x = 2\times10^{-7} \ln \frac{D}{r'_x}, \quad r'_x = e^{-1/4} r_x = 0.7788\, r_x$$

$$L_y = 2\times10^{-7} \ln \frac{D}{r'_y}, \quad r'_y = 0.7788\, r_y$$

$$\boxed{L = L_x + L_y = 4\times10^{-7} \ln \frac{D}{\sqrt{r'_x r'_y}}}$$

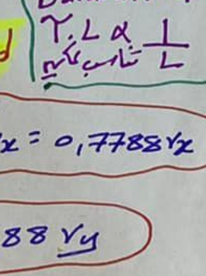
Total inductance (Loop Induct)

if $r'_x = r'_y \Rightarrow L = 4\times10^{-7} \ln \frac{D}{r'_x}$

- 3 ϕ, three wire line with equal spacing

$$\boxed{L_a = 2\times10^{-7} \cdot \ln \frac{D}{r'}} \text{ H/m per } \phi$$

كونهم الثلاث equal spacing & equal r باخذ منهم بس phase(a)



- Compsite Cond, uniqual Spacing, bundled

(1)

$$\boxed{L_x = 2\times10^{-7} \ln \frac{D_{xy}}{D_{xx}}} \quad \boxed{L_y = 2\times10^{-7} \ln \frac{D_{xy}}{D_{yy}}}$$

$$D_{xy} = \sqrt[MN]{\prod_{k=1}^{N} \prod_{m=1}^{M} D_{km}} \quad \text{(GMD)}$$

$$D_{xx} = \sqrt[N^2]{\prod_{k=1}^{N} \prod_{m=1}^{N} D_{km}} \quad \text{(GMR)}$$

$$D_{yy} = \sqrt[M^2]{\prod^{M} \prod^{M}_{m=1}} \quad \text{(GMR)}$$

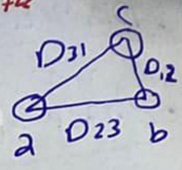
$D_{11} = D_{22} = D_{33} = e^{-1/4} r_x$

$D'_{11} = D'_{22} = e^{-1/4} r_y$

(2) unequal Spacing (phase), $L_a \neq L_b \neq L_c$

$$\boxed{L_a = 2\times10^{-7} \ln \frac{D_{eq}}{D_s}} \quad D_s \rightarrow \text{GMR from table}$$

$$\boxed{D_{eq} = \sqrt[3]{D_{12} D_{23} D_{31}}}$$



(3) Bundeld Conductors

* Adv:

(1) Reduce the electrical filed (corona)

(2) // the sieries reactance of the Line

$$\boxed{L_a = 2\times10^{-7} \ln \left(\frac{D_{eq}}{D_{SL}}\right)}, \quad D_{eq} = \sqrt[3]{D_{12} D_{23} D_{31}}$$

$D_{SL} = \sqrt{D_{sd}}$, for a two cond Bundeld

$D_{SL} = \sqrt[3]{D_{sd}^2}$, for a three cond Bundeld

$D_{SL} = 1.091 \sqrt[4]{D_{sd}^3}$, for a four cond Bundeld

* Capacitance

Diamite of r, $L \propto C$

- 1 ϕ, two wire line, not bundeld

$$\boxed{C_{xy} = \frac{\pi\epsilon}{\ln\left(\frac{D}{\sqrt{r_x r_y}}\right)}} \text{ F/m Line to Line}$$

if $r_y = r_x$ then $\Rightarrow C_{xy} = \frac{\pi\epsilon}{\ln\left(\frac{D}{r}\right)}$ F/m

- 3 ϕ, three wire line [equal phase spacing]

$$\boxed{C_{an} = \frac{2\pi\epsilon}{\ln\left(\frac{D}{r}\right)}} \text{ F/m Line to Line}$$

بس باخذ phase(a)

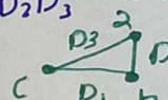
- standerd, unequal ϕ spasing, Bundleld

[1] Transposed

$$\boxed{C_{an} = \frac{2\pi\epsilon}{\ln\left(\frac{D_{eq}}{r}\right)}}, \quad D_{eq} = \sqrt[3]{D_1 D_2 D_3}$$

هون GMR مش r
نجيب r من الجدول

$C_{an} \neq C_{bn} \neq C_{cn}$



[2] Bundeld & Transposed

$$\boxed{C_{an} = \frac{2\pi\epsilon}{\ln\left(\frac{D_{eq}}{D_{SC}}\right)}}$$

D_{eq} Transposed, D_{SC} Bundeld

$D_{SC} = \sqrt{rd}$, two Bundeld

$D_{SC} = \sqrt[3]{rd^2}$, three Bundeld

$D_{SC} = \sqrt[4]{rd^2} \times 1.091$, four Bundeld

$$\boxed{Q_c = \frac{V_{xy}^2}{X_C} = V_{xy}^2 Y_{xy} = \omega C_{xy} V_{xy}^2 \text{ (Var)}}$$

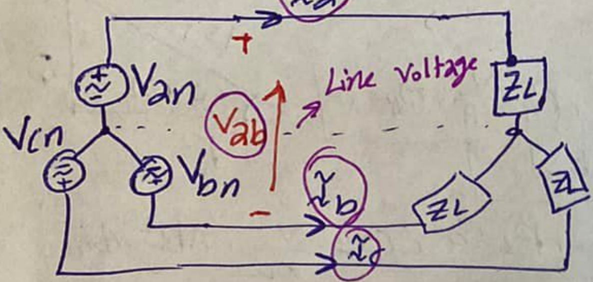
$$\boxed{I_{chg} = Y V_{an} = j\omega C_{an} V_{LN} \text{ (A)}}$$

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

$$\boxed{\begin{matrix} S \rightarrow Y \\ \text{Load} \rightarrow \Delta \end{matrix}}$$

افضل شي عند التوصيل

① Balanced Y-Y Conection



$$\text{phase } I = \text{Line } I \Rightarrow \boxed{I_L = I_p}$$

$$Y\text{-Source} \begin{cases} \Delta \\ y \end{cases} \qquad \boxed{V_\phi = \frac{V_L}{\sqrt{3}}}$$

(Y)

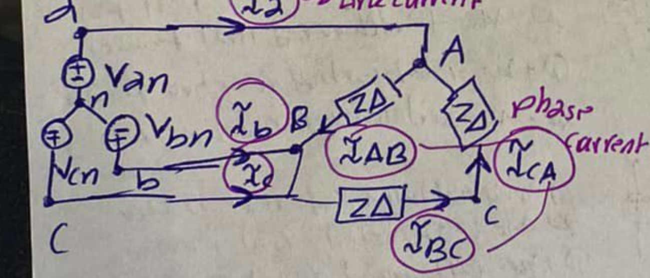
$$V_L = \sqrt{3}\,|V_p| \angle \theta + 30$$

$$V_{ab} = \sqrt{3}\,|V_{an}| \angle \theta + 30^\circ$$

$$V_{bc} = \sqrt{3}\,|V_{an}| \angle \theta + 30^\circ$$

$$V_{ca} = \sqrt{3}\,|V_{n}| \angle \theta + 30^\circ$$

② Y-Δ Conection

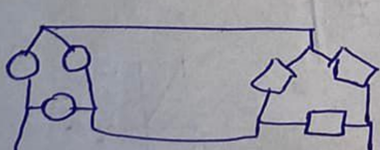


$$I_a = I_{AB} - I_{CA}$$

$$I_L = \sqrt{3}\,|I_p| \angle \theta - 30 \Rightarrow \Delta\text{-Load} \begin{cases} y \\ \Delta \end{cases}$$

③ Δ-Δ Conection

$$I_L = \sqrt{3}\,|I_p| \angle \theta - 30$$



in Δ

$$\boxed{\begin{matrix} V_\phi = V_L \\ I_\phi = \dfrac{I_L}{\sqrt{3}} \\ 3I_\phi = \sqrt{3}\,I_L \end{matrix}}$$

④ Δ-Y Conection

هون بحول لـ Y-Y او Δ-Δ

assume V_p of $\Delta \rightarrow V_L$ of Y

$$V_{ab} = \sqrt{3}\,|V_{an}| \angle \theta + 30^\circ$$

$$\boxed{V_{an} = \frac{V_{ab}}{\sqrt{3} \angle \theta + 30^\circ} \Rightarrow \frac{V_{ab} \angle -30}{\sqrt{3}}}$$

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

* Power in a Balnced 3phase:

$$P_{3\phi} = 3P_\phi = 3V_\phi I_\phi \cos\phi$$

$$Q_{3\phi} = 3Q_\phi = 3V_\phi I_\phi \sin\theta$$

$$S_{3\phi} = 3S_\phi = 3V_\phi I_\phi^* = 3|I_\phi^2| Z_\phi = \frac{3|V_\phi^2|}{Z_\phi^*}$$

$$|S_{3\phi}| = P + jQ = \sqrt{3}\, V_L I_L \angle \theta$$

- power factor unity mean no reactive power