Eko 1)

1) Power Systems are Categories into 3 Powers System Bus -

	Known	Unknown.
Load Bus : P, Q	P_i, Q_i	$\lvert V_i \rvert, \delta_i$
Voltage control : P, V	P_i, V_i	Q_i, δ_i
Slack Bus or Swing ; Ref Bus	$\lvert V_1 \rvert \delta_1$	P_1, Q_1

2) only one slack or Swing Bus exit, as it's taken as reference bus. $|V_1| = 1\,pu$ and $\delta = 0°$.

3) From SLFE, P and Q expression are

$$P_i = \sum_{n=1}^{N} |V_i V_n Y_{in}| \cos(\theta_{ik} + \delta_k - \delta_i)$$

$$Q_i = \sum_{n=1}^{N} |V_i V_n Y_{in}| \sin(\theta_{ik} + \delta_n - \delta_k)$$

4) Newton-Raphson and Gauss-Seidel are mainly used. Both method are used to solve SLFE equations which are non linear algebraic equation Start to initial value and iterative successive approximation -

Exo2 / 1

1) Set of Symetrical Components.

- Positive Sequence – noted V_d or V_1
- Negative " – noted V_i or V_2
- Zero sequence – noted V_0 or V_0.

2)

$$\begin{bmatrix} V_d \\ V_i \\ V_0 \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 1 & a & a^2 \\ 1 & a^2 & a \\ 1 & 1 & 1 \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix}$$

with

$$\begin{cases} a = 1\angle 120^\circ = -0{,}5 + j\,0{,}866 \\ a^2 = 1\angle 240^\circ = -0{,}5 - j\,0{,}866 \\ a^3 = 1 = 1\angle 0^\circ = 1 + j\,0 \end{cases}$$

$$V_0 = \frac{1}{3}\begin{bmatrix} 18\angle 0 & = 18 + j\,0 \\ +10\angle -132 & = -6{,}7 - j\,7.43 \\ +15\angle 90 & = 0 + j\,15 \end{bmatrix}$$

$\frac{1}{3}\{11{,}3 + j\,7{,}57\} = 3{,}76 + j\,2{,}52$

$$\boxed{V_0 = 4{,}53\angle 33{,}83^\circ}$$

$$V_d = \frac{1}{3}\begin{bmatrix} 18\angle 0 \times 1 = 18\angle 0^\circ & = 18 + 0j \\ 10\angle -132 \cdot 1\angle 120 = 10\angle -12 & = 9{,}78 - j\,2{,}08 \\ 15\angle 90 \cdot 1\angle 240 = 15\angle 330 & = 13 - j\,7{,}5 \end{bmatrix}$$

$V_d \quad 13{,}6 - j\,3{,}193$

$V_d = 13{,}96\angle -13{,}22$

with $V_i = 0{,}64 + j\,0{,}67$

$V_i = 0{,}9266\angle 46{,}32$

EKO 2 / (2)

3/

$$S_{3\Phi} = V_a I^* + V_b I_b^* + V_c I^* = (P_a + jQ_a) + (P_b + jQ_b) + (P_c + jQ_c)$$

$$= \left| \begin{array}{l} 18\angle 0^\circ \times 180\angle 10^\circ = 3240\angle +10 = 3191 + j562{,}6)\ P_a, Q_a \\ 10\angle -132^\circ \times 250\angle 100 = 2500\angle -32 = 2120{,}12 - j1325)\ P_b, Q_b \\ 15\angle +90 \times 200\angle -50 = 3000\angle 40 = 2298 + j1928{,}4)\ P_c, Q_c \end{array} \right.$$

$$7609\,\text{kW} + j\,1166{,}2\,\text{kVAR}$$

$S_{3\Phi} = P + jQ = 7609$ kW $+ j\,1166$ kVAR.

with $P_a = 3191$ W and $Q_a = 562{,}6$ VAR.

$P_b = \ldots$ $Q_b = \ldots$ VAR.

4) $|I_g| = 3|I_0|$

with I_0 same calculation made for V_0.

$I_0 = 204{,}7\angle 151^\circ$ Software calculation ???

$|I_g| = 614{,}1\,A \rightarrow |V_n| = 614{,}1\,A \times 10 = \underline{\underline{6{,}14\,kV}}$

$|V_n|$ Neutral Voltage relative to Ground.

$$I_n = 177{,}26 - j31{,}26 + [$$

$$- 43{,}4 - j246{,}2$$

$$+ 128{,}56 + j153{,}2$$

$$\overline{262{,}42 - j124{,}26} \Rightarrow V_N = 10 \times [\quad]$$

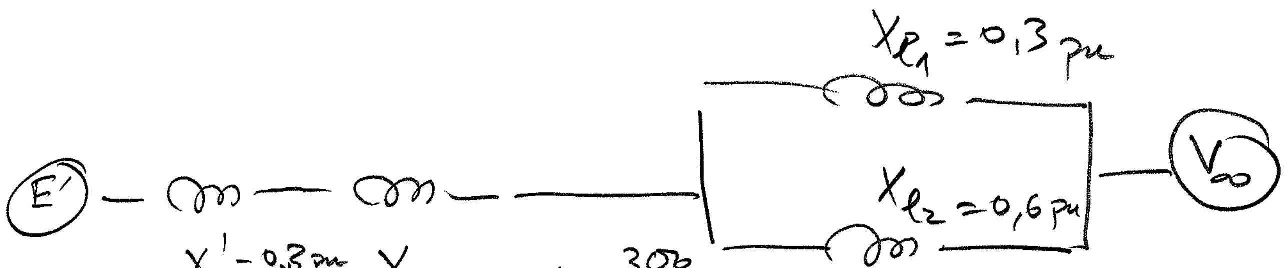
$\Rightarrow V_n = 2{,}9\,kV\angle -25{,}34^\circ$

Exo 3 / 1

1 – X_d : Synchronous direct reactance

X'_d : Synchronous direct transient reactance.

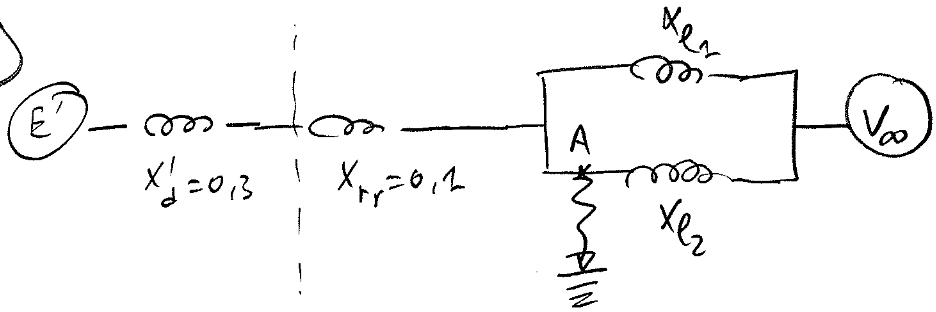
2)



$X_{tr} = 0,11 \times \frac{300}{330}$

$= 0,1$ pu

3)

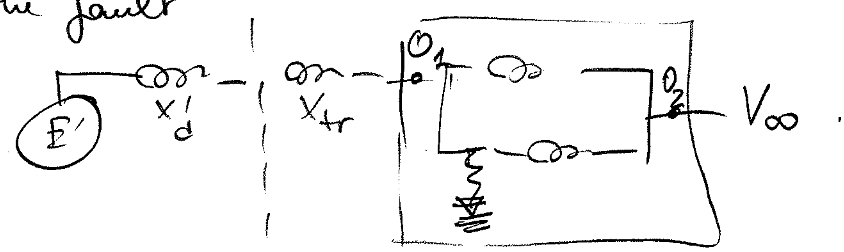


a) Just before fault

$$X_{f_1} = 0,1 + \frac{0,3 \times 0,6}{0,3 + 0,6} = 0,3 \text{ pu}.$$

including $X'_d \Rightarrow X_{f_1} = 0,6$ pu.

b) During the fault



from O_1 to O_2 the impedance is considered $\simeq 0 \Rightarrow X_{f_2} = 0$.

c) after the fault, with X_{l_2} removed

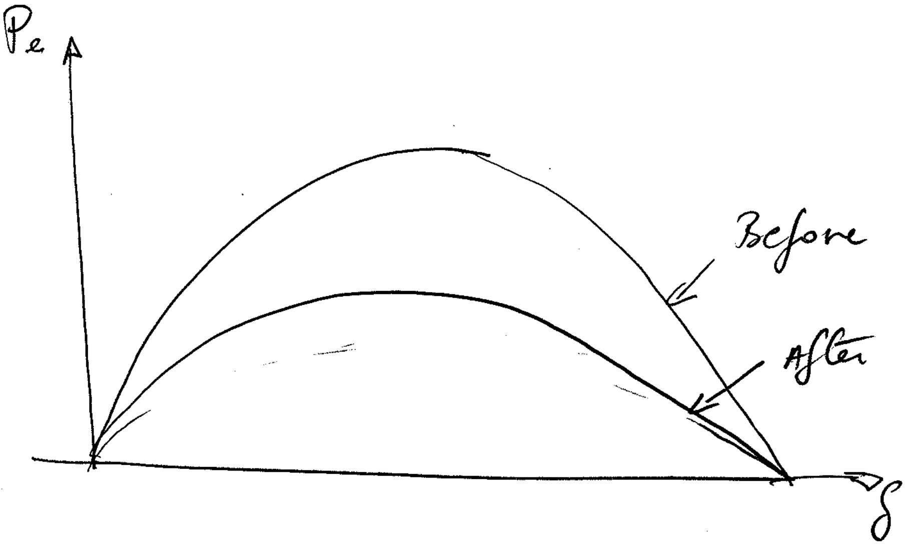
$X_{f_3} = 0,1 + 0,3 = 0,4$ pu considering X'_d

EX 03 / 2

$X_{f_3} = 0{,}4 + X'_d = 0{,}7\ pu$ $\Rightarrow$ $P_{max f_3} = \dfrac{E'V}{X_{f_3}} \sin\delta$

$= P_{max_2} \sin\delta$.

d)



Before ; $P_{max1} = \dfrac{E'V}{X_{f_2}}$

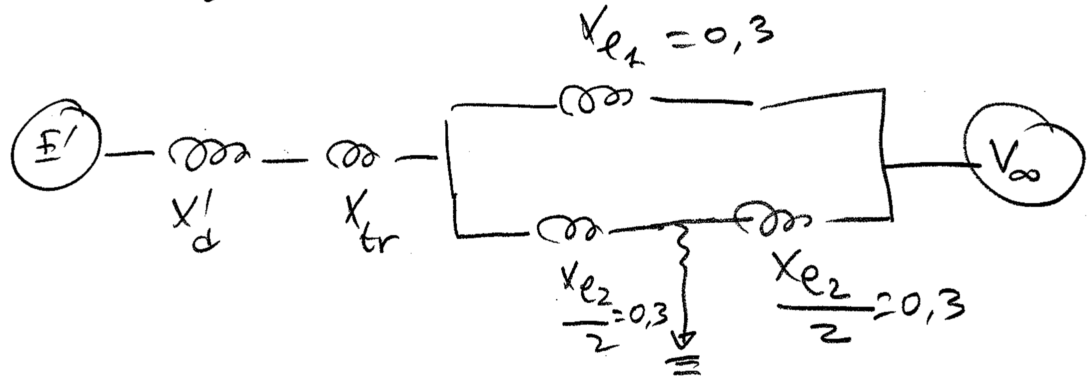
After P_{max2}, with $X_{f_3} > X_{f_1}$

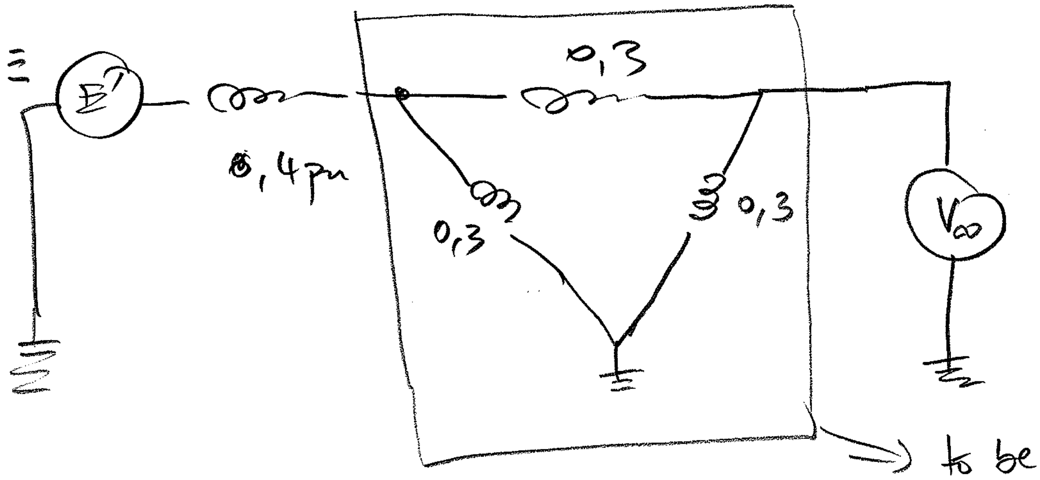
4)

fault takes place at the middle of X_{l_2}

a) $X_{e_1} = X_{f_1}$

b)

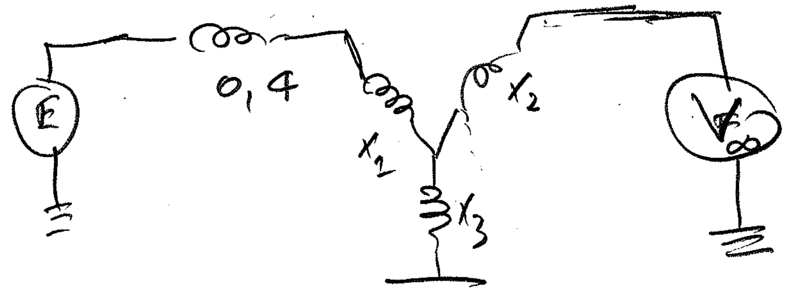




to be convert $\Delta \rightarrow Y$

EX03-4) 3

Application theorem of Kennely. $\Delta \to Y$



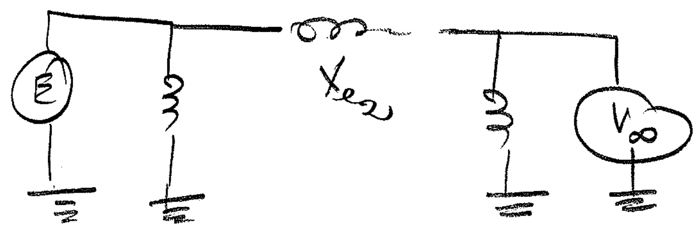
$$X_1 = \frac{0{,}3 \times 0{,}3}{0{,}3 + 0{,}3 + 0{,}3}$$

$X_1 = 0{,}1$.

$X_2 = 0{,}1$

$X_3 = 0{,}1$

$\equiv$



with

$$X_{e_2} = \frac{0{,}5 \times 0{,}1 + 0{,}1 \times 0{,}1 + 0{,}5 * 0{,}1}{0{,}1}$$

$X_{e_2} = 1{,}1$

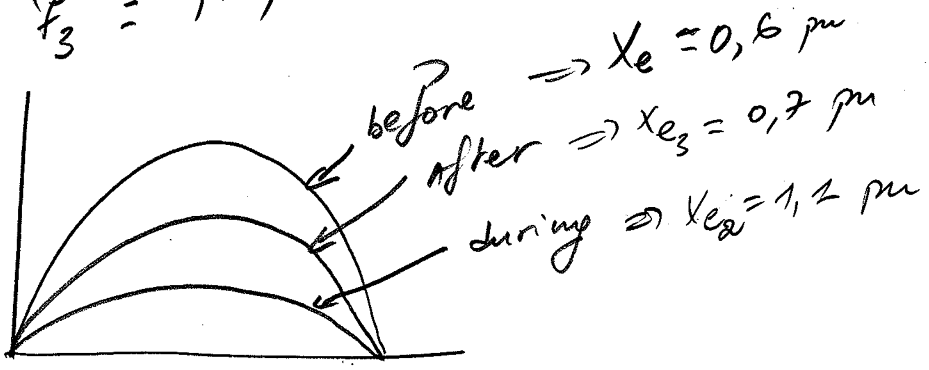
or $$X_{e_2} = \frac{(0{,}4)(0{,}3) + (0{,}3)(0{,}5) + (0{,}3)(0{,}3)}{0{,}3}$$

b) $X_{e_2} = 1{,}1$ pu.

c) after clearing the fault with X_{e_2} removed

$X_{e_3} = X_{f_3} = 0{,}7$ pu.

d)



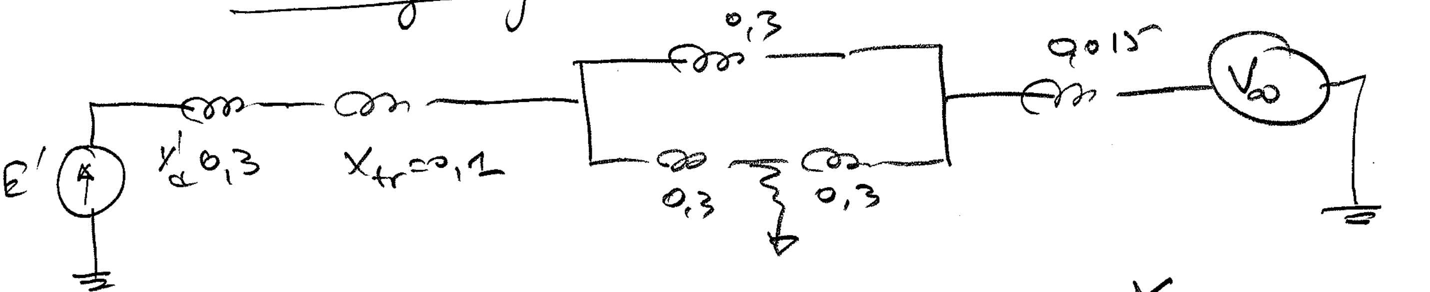
~~E~~ 04 – 1)

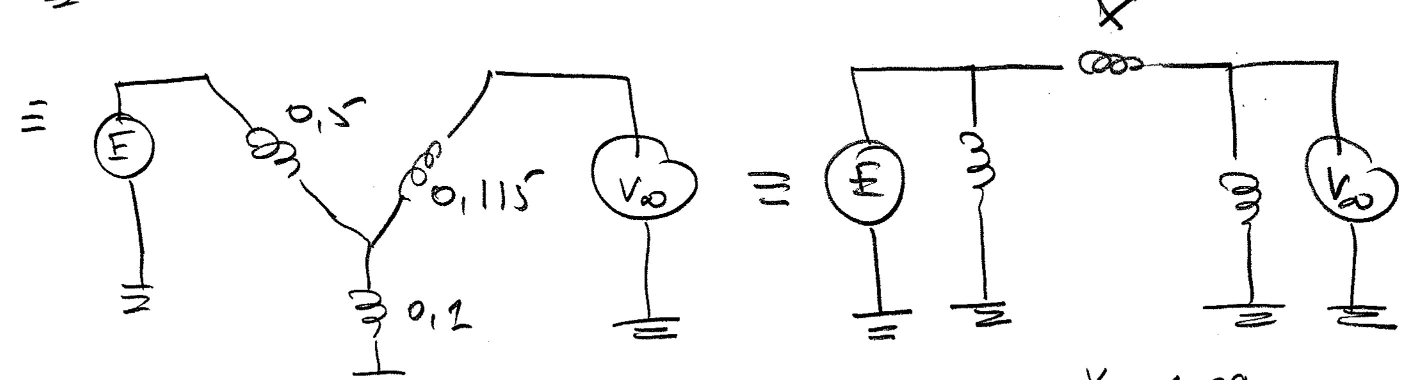
1) It's a tendency of a power system to develop restoring forces equal to or greater than the disturbing forces to maintain the state of equilibrium is known as stability -

2)
$$\frac{2H}{\omega_s}\frac{d^2\delta}{dt^2} = P_m - P_e$$

$$\frac{H}{\pi f_0}\frac{d^2\delta}{dt^2} = P_m - P_e$$

3) ~~T~~ Clearing angle





X = 1,09 pu.

3)

Before fault $\quad E' = 1{,}17 \angle 24{,}86°$

$$P_{max} \sin\delta = P_e = \frac{|E||V|}{X_{pre}} \sin\delta$$

$$P_{max} \sin\delta_0 = \frac{|1{,}17||1|}{0{,}615} \sin\delta_0 = 0{,}8 \quad \text{with} \quad P_{max} = 1{,}902$$

$$\Rightarrow \quad 1{,}902 \sin\delta_0 = 0{,}8$$

$$\Rightarrow \underline{\underline{\delta_0 = 24{,}86°}} \simeq 0{,}434 \text{ rad}$$

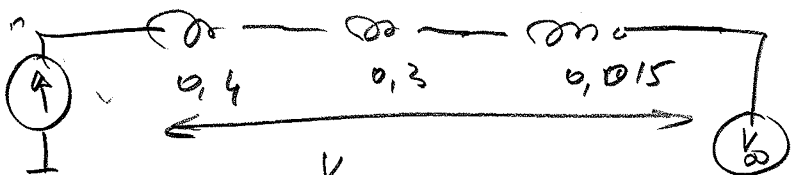
During fault

$$P_{max1} \sin\delta_1 = \frac{|E'|.|V|}{X} \sin\delta \Rightarrow$$

with $X_{during\ fault} = X_{df} = \infty$

$$P_{max1} = \frac{|1{,}17||1|}{\infty} = 0$$

After fault



$\Rightarrow$

$$X_{post} = 0{,}715 \text{ pu}$$

$$\Rightarrow P_{max2} = \frac{1{,}17 \times 1}{0{,}715} = 1{,}636 \text{ pu}.$$

$$r_1 = \frac{P_{max1}}{P_{max}} = \frac{0}{1{,}902} = 0$$

$$r_2 = \frac{P_{max2}}{P_{max}} = \frac{1{,}636}{1{,}902} = 0{,}860$$

exo4-4)

4)

when the system criticaly stable

$$P_{max_2} \sin(\pi - \delta_m) = P_{max}\, \delta_0$$

$$\Rightarrow P_{max_2} \sin(\pi - \delta_m) = 0{,}8 \Rightarrow \pi - \delta_m = \left[\sin^{-1}\left(\frac{0{,}8}{1{,}636}\right)\right]$$

$$\delta_m = \pi - \left[\sin^{-1}\left(\frac{0{,}8}{1{,}636}\right)\right]$$

$$= 180° - [\quad]$$

$$\delta_m = 150{,}7° \simeq 2{,}63 \text{ rad}$$

$$\cos\delta_{cl} = \frac{(2{,}63 - 0{,}434)[\sin 24{,}86°] - 0\,[\cos 24{,}86] + 0{,}86(\cos 150{,}70)}{0{,}860 \quad - 0}$$

$$\cos\delta_{cl} = \frac{0{,}923 \;-}{} = 0{,}201 \Rightarrow \delta_{cl} = 78{,}39°$$

$$\delta_{cl} = 1{,}37 \text{ rad}$$

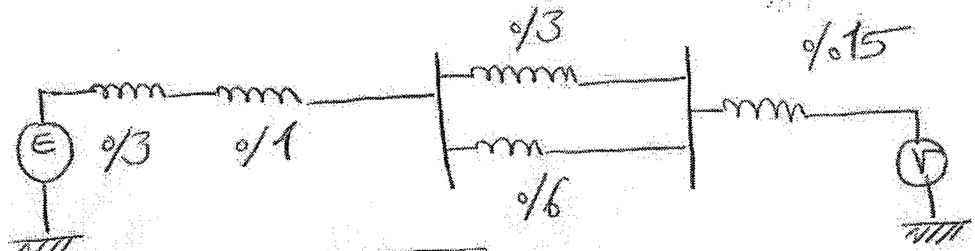
4)

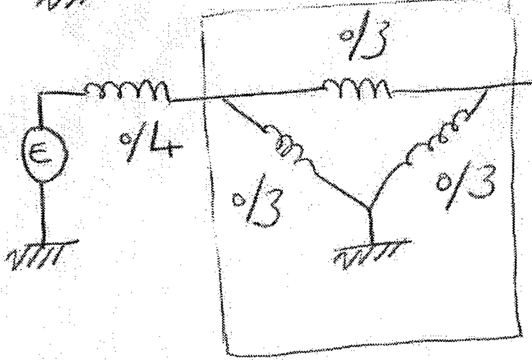
$$t_{cl} = \sqrt{\frac{2H(\delta_c - \delta_0)}{\pi f_0 P_m}}$$

$$= \sqrt{\frac{2 \times 4 \times (1{,}37 - 0{,}434)}{3{,}14 \times 50 \times 0{,}8}}$$

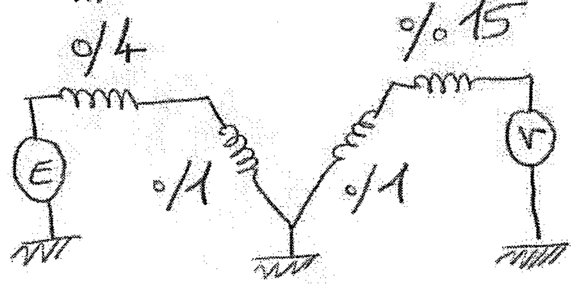
$$t_{cl} = 0{,}244 \text{ sec.}$$

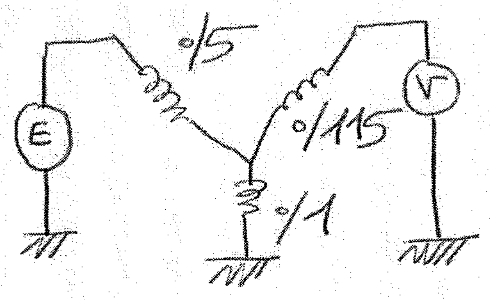
(1)



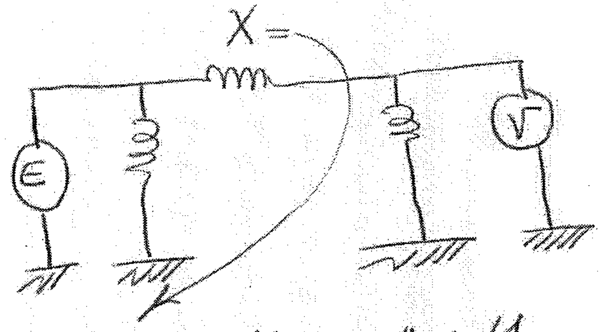


$\Delta - Y$





$Y - \Delta$



$$X = \frac{0/5 \times 0/115 + 0/1 \times 0/115 + 0/4 \times 0/1}{0/1}$$

<u>During the fault</u> | $X = 1/09$

$$S = 0/8 + j\,0/1 = V I^{*} \longrightarrow I = 0/8 - j\,0/1 = 0/8062 \angle -7{,}1276$$

$$E = V + j X' I$$

$$X' = 0/3 + 0/1 + \frac{0/3 \times 0/6}{0/3 + 0/6} + 0/15 = \underline{\underline{0/615}} \quad (\text{Before}).$$

$$E = 1 + j\,0/615\,(0/8 - j\,0/1) =$$
$$1 + 0/492j + 0/0615 = 1{,}17 \angle 24{,}8664$$

$$P_e = \frac{|E||V|}{X} \sin\delta = \frac{1{,}17 \angle 24{,}8664 \times 1 \angle 0}{1{,}09}$$
$$= 1{,}0734 \angle 24{,}8664$$

$$M = \frac{H}{180f} = \frac{4}{180 \times 50} = 4{,}44 \times 10^{-4}\ \mathrm{MJ\,S/deg}$$

(2)

$$\delta = \delta_0 = 24{,}86$$

$$P_e(0^+) = 1{,}0734 \sin(24{,}86) = -{,}12891$$

$$P_a(0^+) = P_m - P_e(0^+) = 1 + {,}2891 = 1{,}2891$$

$$\Delta\delta_1 = \Delta\delta_0 + \frac{P_a(0^+)}{M}\Delta t \cdot \frac{\Delta t}{2} = 3{,}6292.$$

$$\delta_1 = \delta_0 + \Delta\delta_1 = 24{,}86 + 3{,}6292 = 28{,}4892$$

$n = 2$

$$\delta_1 = 28{,}4892.$$

$$P_e(1) = 1{,}0734 \sin(28{,}4892) = -{,}2289$$

$$P_a(1) = P_m - P_e(1) = 1 + {,}2289 = 1{,}2289$$

$$\Delta\delta_2 = \Delta\delta_1 + \frac{P_a(1)}{M}(\Delta t)^2 = 3{,}6292 + 6{,}9195 = 10{,}5487.$$

$$\delta_2 = \delta_1 + \Delta\delta_2 = 28{,}4892 + 10{,}5489 = 39{,}0379$$

$n = 3 \qquad \delta_2 = 39{,}0379$

$$P_e(2) = 1{,}0734 \sin(39{,}0379) = 1{,}0446$$

$$P_a(2) = P_m - P_e(2) = 1 - 1{,}0446 = -{,}0446$$

$$\Delta\delta_3 = \Delta\delta_2 + \frac{P_a(2)}{M}(\Delta t)^2 = -{,}12511$$

$$\delta_3 = \delta_2 + \Delta\delta_3 = 39{,}0379 - {,}12511 = 38{,}7863$$
