مقرر نظم الطاقة/٢

٤ طاقة

University of Damascus

Faculty of Mech. & Elec. Engineering

4^{th} year Elec. power Department

Power Systems(2)

Second Semester Exam for Academic Year 2018 – 2019

Problem 1. (23 points)

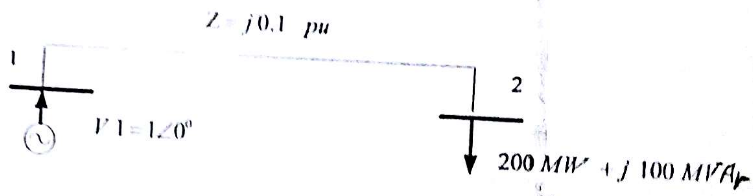
Consider the two-bus system shown. The bus powers as marked on the diagram. Line series impedance is marked in per unit on a 100 MVA base.

(a) Determine the type of the buses. Find out Ybus matrix

(b) Use the Newton-Raphson method to determine the voltage magnitude and angle at bus two for the first iteration.

(c) If the final solution is $V1 = 1\angle 0°$, $V2 = 0.8554\angle -13.522°$, find the slack bus real and reactive power, line flow, and line loss. Construct a power flow diagram showing the direction of line flow.

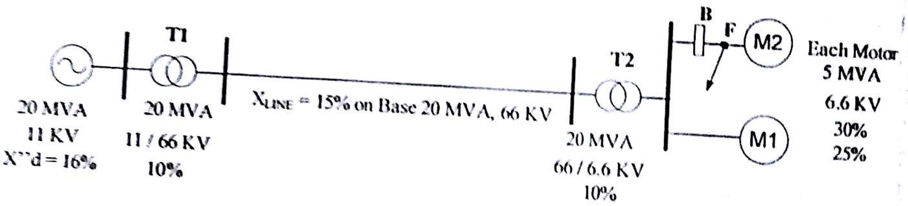
$$\left[J^{(0)}\right]^{-1} = \frac{1}{100}\begin{bmatrix} 10 & 0 \\ 0 & 10 \end{bmatrix}$$



$SB = 100MVA$ $\left(V_2^{(0)} = 1\angle 0°\right)$

Problem 2. (17 points)

For the three phase power system shown below:



The bus voltage at the motors is 6.6 kV when a three-phase fault occurs at the point F. Assume that the system is operating on no load when the fault occurs.

For the specified fault, calculate:

(a) The subtransient current in the fault,

(b) The momentary current in breaker B,

(c) The current to be interrupted by breaker B in five cycles.

(d) Draw the schematic diagram of mutually coupled circuits of the synchronous machine, write an equation for voltages in matrix form.

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Question: 3

For the three-phase power system below, the reactances are: **(26 marks)**

Generator: $X_1 = X_2 = 0.16\,pu;\ X_0 = 0.06\,pu;\ X_g(Currentlimitingreactor) = 0.30\,pu$

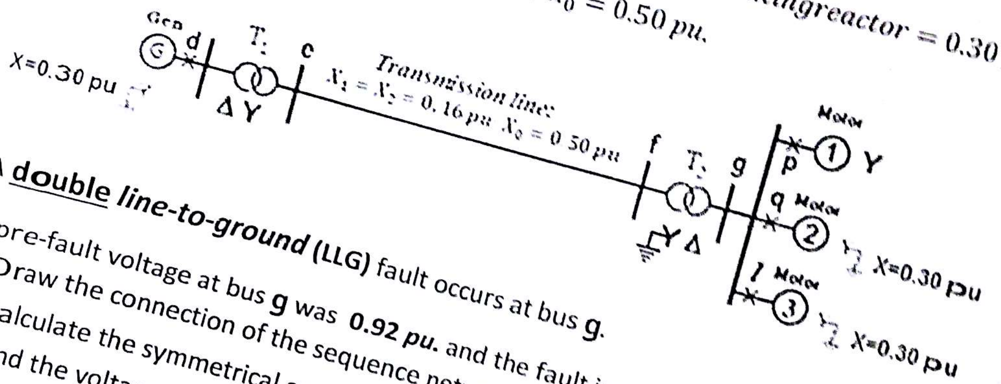
Transformers T_1, T_2: $X_1 = X_2 = X_0 = 0.08\,pu$

Motor1: $X_1 = X_2 = 0.30\,pu;\ X_0 = 0.08\,pu.$

Motor2: $X_1 = X_2 = 0.60\,pu;\ X_0 = 0.16\,pu.$

Motor3: $X_1 = X_2 = 0.60\,pu;\ X_0 = 0.16\,pu;\ Currentlimitingreactor = 0.30\,pu.$

Transmission line: $X_1 = X_2 = 0.16\,pu;\ X_0 = 0.50\,pu.$



A **double** ***line-to-ground*** **(LLG)** fault occurs at bus **g**.

if pre-fault voltage at bus **g** was **0.92 pu.** and the fault impedance $Z_f = j0.30\,pu$

1. Draw the connection of the sequence networks.
2. Calculate the symmetrical components I_{a0}, I_{a1}, I_{a2} and the fault current at bus **g**.
3. Find the voltage of the healthy phase.

Question: 4

Find the resistance of ground rod to earth (ohm), **(4 marks)**

where: ground rod length $L = 165$ cm; ground rod radius $a = 4.3$ cm;

average soil resistivity $\rho = 125\ ohm \cdot m$

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Problem 1 (23 Points)

(a)

Bus	Known	Unknown	Remarks
1	$\lvert V\rvert = 1$, $\delta = 0$	P_G, Q_G	Slack bus
2	$P_L = 200\,MW$, $Q_L = 100\,MVAr$	$\lvert V\rvert, \delta$	PQ bus

(1)

(2)

$$y_{12} = \frac{1}{j0.1} = -j10 \Rightarrow Y_{bus} = \begin{bmatrix} -j10 & j10 \\ j10 & -j10 \end{bmatrix} = \begin{bmatrix} 10\angle -1.57 & 10\angle 1.57 \\ 10\angle 1.57 & 10\angle -1.57 \end{bmatrix}$$

(b) $$P_2^{(0)} = |V_2||V_1||Y_{21}|\cos(\theta_{21} - \underbrace{\delta_2}_{0} + \underbrace{\delta_1}_{0}) + |V_2|^2|Y_{22}|\cos\theta_{22}$$ (1)

$$= (1)(1)(10)\cos(1.57) + (1)^2(10)\cos(-1.57) \Rightarrow \boxed{P_2^{(0)} = 0}$$

$$Q^{(0)} = -|V_2||V_1||Y_{21}|\sin(\theta_{21} - \delta_2 + \delta_1) - |V_2|^2|Y_{12}|\sin\theta_{22}$$ (1)

$$= -(1)(1)(10)\sin(1.57) - (1)(10)\sin(-1.57) \Rightarrow \boxed{Q_2^{(0)} = 0}$$

$$\frac{\partial P_2}{\partial \delta_2} = |V_2||V_1||Y_{21}|\sin(\theta_{21} - \delta_2 + \delta_1) = 10\ pu$$ (1)

(1)

$$\frac{\partial P_2}{\partial |V_2|} = |V_1||Y_{21}|\cos(\theta_{21} - \delta_2 + \delta_1) + 2|V_2||Y_{22}|\cos\theta_{22} = 0$$

$$\frac{\partial Q_2}{\partial \delta_2} = |V_2||V_1||Y_{21}|\cos(\theta_{21} - \delta_2 + \delta_1) = 0$$ (1)

(1)

$$\frac{\partial Q_2}{\partial |V_2|} = -|V_1||V_2||Y_{21}|\sin(\theta_{21} - \delta_2 + \delta_1) - 2|V_2||Y_{22}|\sin\theta_{22} = 10\ pu$$

$$S_2^{sch} = -\frac{200 + j100}{100} = -2 - j1\ pu$$

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$\Delta P_2^{(0)} = P_2^{sch} - P_2^{(0)} = -2 \text{ pu}$ (1)

$\Delta Q_2^{(0)} = Q_2^{sch} - Q_2^{(0)} = -1 \text{ pu}$ (1)

$$\begin{bmatrix} \Delta P_2 \\ \Delta Q_2 \end{bmatrix} = \begin{bmatrix} \frac{\partial P_1}{\partial \delta_2} & \frac{\partial P_2}{\partial |V_2|} \\ \frac{\partial Q_2}{\partial \delta_2} & \frac{\partial Q_2}{\partial |V_2|} \end{bmatrix} \begin{bmatrix} \Delta \delta_2 \\ \Delta |V_2| \end{bmatrix}$$

$$\begin{bmatrix} \Delta \delta_2^{(0)} \\ \Delta |V_2|^{(0)} \end{bmatrix} = \frac{1}{100} \begin{bmatrix} 10 & 0 \\ 0 & 10 \end{bmatrix} \begin{bmatrix} -2 \\ -1 \end{bmatrix} \Rightarrow \Delta \delta_2^{(0)} = -0.2 \quad (1)$$

$$\Delta |V_2^{(0)}| = -0.1 \quad (1)$$

$\delta_2^{(1)} = 0 - 0.2 = -0.2$ rad (1)

$|V_2|^{(0)} = 1 - 0.1 = 0.9$ pu (1)

(c) $P_1 - jQ_1 = |V_1| \angle{-\delta_1} \left(|Y_{11}||V_1| \angle{\theta_{11} + \delta_1} + |Y_{12}||V_2| \angle{\theta_{12} + \delta_2} \right)$

$V_1 = 1\angle 0^\circ$, $V_2 = 0.8554 \angle{-13.522^\circ}$ $\Rightarrow$

$P_1 - jQ_1 = 2 - j1.683 \Rightarrow P_1 = 2 \text{ Pu} = 200 \text{ MW}$ (1)

$Q_1 = 1.683 \text{ Pu} = 168.3 \text{ MVAr}$

(1)

$I_{12} = y_{12}(V_1 - V_2) = 2 - j1.683$ (1)

$I_{21} = -I_{12} = -2 + j1.683$ (1)

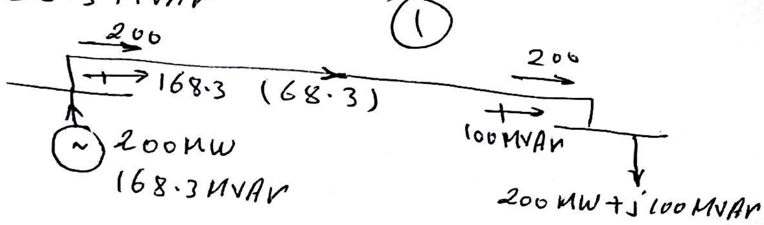
(1)

$S_{12} = V_1 I_{12}^* = 2 + j1.683 = 200 \text{ MW} + j168.3 \text{ MVAr}$

$S_{21} = V_2 I_{21}^* = -2 - j1 = -200 \text{ MW} - j100 \text{ MVAr}$ (1)

$S_{L12} = S_{12} + S_{21} = j68.3 \text{ MVAr}$

(1) (1)



Problem [illegible] (17 Points)

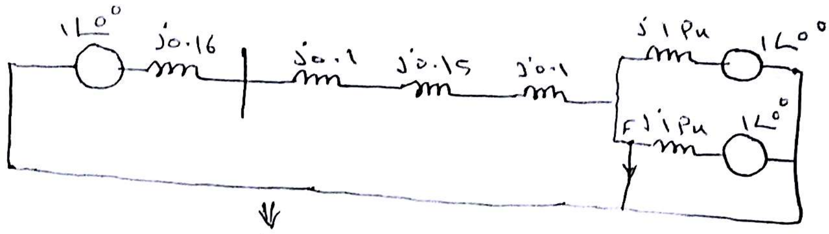
Choose a system base of 20 MVA

Generator voltage base of 11 KV. Line voltage base is 66 KV and motor voltage base is 6.6 KV.

(a) For each motor $X''_{dM} = j0.25 \times \frac{20}{5} = j1\,pu$ (1)

Line, transformers and generator reactances are already given on proper base values.

For no load condition, the circuit model of the system is (emfs are identical).



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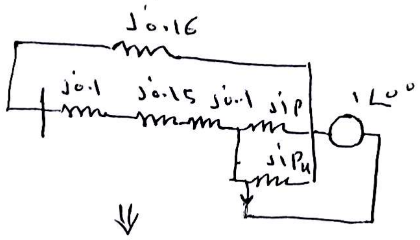
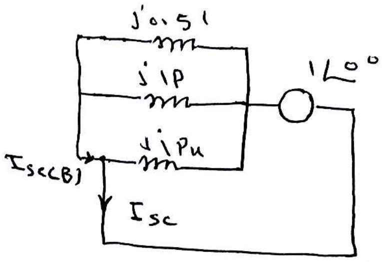


(1)

⇓



$I_{sc} = \frac{1}{[illegible]} + \frac{1}{j0.51} = [illegible]\,96$ Pu (1)

$I_{Base} = \frac{20 \times 1000}{\sqrt{3} \times 6.6} = 1.749$ KA (in motor area) (1)

So, $I_{sc} = 3.96 \times 1.749 = 6.92$ KA (1)

(b) $I_{sc(B)} = \frac{1}{j[illegible]} + \frac{1}{j0.51} = -j2.96$ Pu (1)

$I_{sc(B)} = 2.96 \times 1.749 = 5.177$ KA (1)

For finding momentary current through the breaker, we must add the DC off-set current to the symmetrical subtransient current obtained in Part (b).

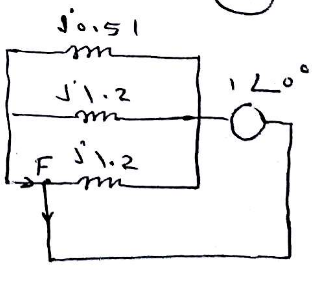
$I_{sc(B)} \times 1.6 = 5.177 \times 1.6 = 8.28$ KA. (1)

(c) X''_d is replaced by X'_d. (for motors)

$X'_{dm} = j0.3 \times \frac{20}{5} = j1.2$ Pu (1)

The reactances of the circuit now is as shown (1)

$I'_{sc(B)} = \frac{1}{j1.2} + \frac{1}{j0.51} = -j2.794$ Pu (1)



(Current (symmetrical) to be interrupted)

Allowance is made for the DC off-set value (1)

The current to be interrupted $= 1.1 \times I'_{sc(B)} = 1.1 \times 2.794 = 3.073$ Pu

$= 3.073 \times 1.749 = 5.374$ KA. (1)

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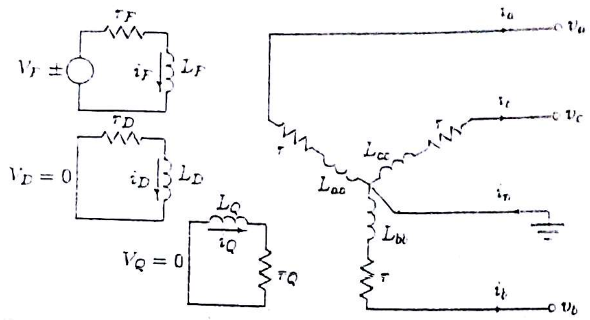
d)

In the classical method, the idealized synchronous machine is represented as a group of magnetically coupled circuits with inductances which depend on the angular position of the rotor. In addition, saturation is neglected and spatial distribution of armature mmf is assumed sinusoidal. The circuits are shown schematically in Figure 8.4.



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The stator currents are assumed to have a positive direction flowing out of the machine terminals. Since the machine is a generator, following the circuit passive sign convention, the voltage equation becomes

$$\begin{bmatrix} v_a \\ v_b \\ v_c \\ -v_F \\ 0 \\ 0 \end{bmatrix} = -\begin{bmatrix} r & 0 & 0 & 0 & 0 & 0 \\ 0 & r & 0 & 0 & 0 & 0 \\ 0 & 0 & r & 0 & 0 & 0 \\ 0 & 0 & 0 & r_F & 0 & 0 \\ 0 & 0 & 0 & 0 & r_D & 0 \\ 0 & 0 & 0 & 0 & 0 & r_Q \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \\ i_F \\ i_D \\ i_Q \end{bmatrix} - \frac{d}{dt} \begin{bmatrix} \lambda_a \\ \lambda_b \\ \lambda_c \\ \lambda_F \\ \lambda_D \\ \lambda_Q \end{bmatrix}$$

2