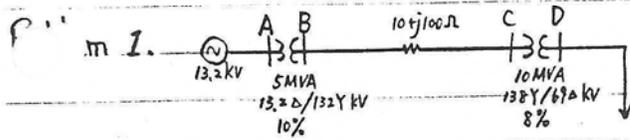


EE740

A. Keyhan



$$V_b = 13.2 \text{ kV}$$

$$S_b = 10 \text{ MVA}$$

1) Bus A: $S_b = 10 \text{ MVA}$

$$V_b = 13.2 / \sqrt{3} \text{ kV}$$

$$X_{T1} = 0.1 \times \left(\frac{13.2 / \sqrt{3}}{13.2 / \sqrt{3}} \right)^2 \left(\frac{10}{5} \right) = 0.2$$

Bus B and Bus C: $S_b = 10 \text{ MVA}$

$$V_b = 13.2 / \sqrt{3} \left(\frac{13.2}{13.2} \right) = 13.2 / \sqrt{3} \text{ kV}$$

$$Z_b = \frac{(V_b)^2}{S_b} = \frac{(13.2 / \sqrt{3} \times 10^3)^2}{10 \times 10^6 / 3} = 1742.4 \text{ } (\Omega)$$

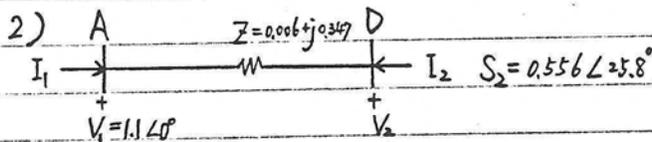
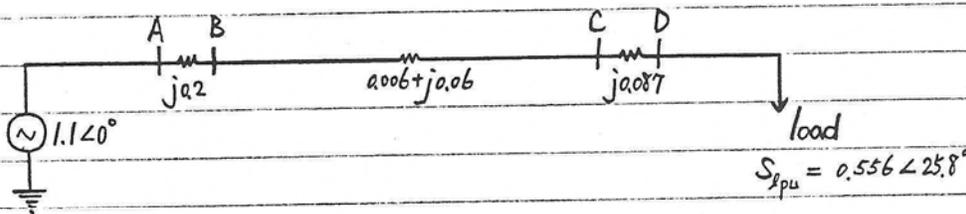
$$Z = \frac{10 + j100}{1742.2} = 0.006 + j0.06$$

Bus C: $S_b = 10 \text{ MVA}$

$$V_b = 13.2 / \sqrt{3} \times \left(\frac{6.9}{13.8} \right) = 6.6 / \sqrt{3} \text{ (kV)}$$

$$X_{T2} = 0.08 \times \left(\frac{6.6 / \sqrt{3}}{13.8 / \sqrt{3}} \right)^2 \left(\frac{10}{10} \right) = 0.087$$

$$P_L = 5 \text{ MW}, \text{ pf} = 0.9 \text{ lagging} \Rightarrow S_L = 5.56 \angle 25.8^\circ = 5 + j2.42 \Rightarrow S_{Lpu} = 0.556 \angle 25.8^\circ$$



$$Y = \frac{1}{Z} = 2.88 \angle -89^\circ = 0.05 - j2.8796$$

$$Y_{bus} = \begin{bmatrix} Y_{11} & Y_{12} \\ Y_{21} & Y_{22} \end{bmatrix} = \begin{bmatrix} Y & -Y \\ -Y & Y \end{bmatrix} = \begin{bmatrix} 2.88 \angle -89^\circ & -2.88 \angle -89^\circ \\ -2.88 \angle -89^\circ & 2.88 \angle -89^\circ \end{bmatrix} = \begin{bmatrix} 0.05 - j2.8796 & -0.05 + j2.8796 \\ -0.05 + j2.8796 & 0.05 - j2.8796 \end{bmatrix}$$

Gauss iteration method

$$\Rightarrow V_2^{(1)} = \frac{1}{Y_{22}} \left[\frac{S_2}{(V_2^{(0)})^*} - Y_{21} V_1 \right]$$

$$= \frac{1}{2.88 \angle -89^\circ} \left[\frac{-0.556 \angle -25.8^\circ}{(V_2^{(0)})^*} + (2.88 \angle -89^\circ) (1.1 \angle 0^\circ) \right]$$

$$= \frac{-0.193 \angle 63.2^\circ}{(-V_2^{(0)})^*} + 1.1$$

$$V_2^{(k+1)} = \frac{-0.193 \angle 63.2^\circ}{(V_2^{(k)})^*} + 1.1$$

iteration number	V_2
0	$1 \angle 0^\circ$
1	$1.0275 \angle -9.7^\circ$
2	$1.0601 \angle -9.7^\circ$
3	$1.0609 \angle -9.4^\circ$

$$\Rightarrow \underline{V_2 = 1.06 \angle -9.4^\circ} \quad *$$

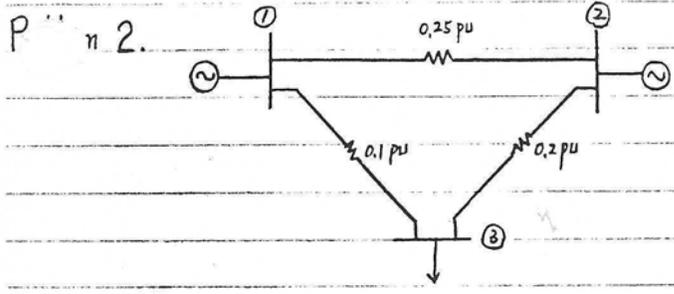
$$\begin{aligned} 3) \quad S_1 &= V_1 (Y_{11}^* V_1^* + Y_{12}^* V_2^*) \\ &= 1.1 (3.168 \angle 89^\circ + (-2.88 \angle 89^\circ)(1.06 \angle 9.4^\circ)) \\ &= 1.1 (3.168 \angle 89^\circ - 3.0528 \angle 98.4^\circ) \\ &= 0.5514 + j0.1622 \end{aligned}$$

$$\text{active power } P_1 = 0.5514 \times 10 = \underline{5.514 \text{ (MW)}} \quad *$$

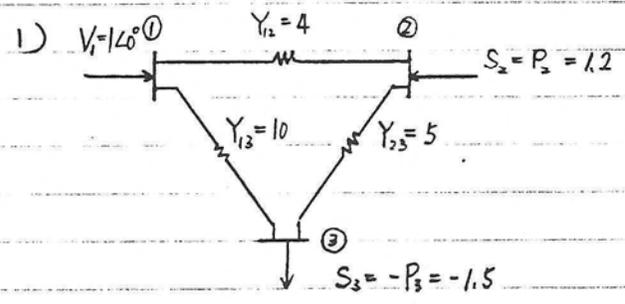
$$\text{reactive power } Q_1 = 0.1622 \times 10 = \underline{1.622 \text{ (MVAR)}} \quad *$$

$$4) \quad \text{active loss } P_{\text{loss}} = P_1 - P_2 = \underline{0.514 \text{ (MW)}} \quad *$$

$$\text{reactive loss } Q_{\text{loss}} = Q_1 - Q_2 = \underline{-0.8 \text{ (MVAR)}} \quad *$$



given $V_1 = 1 \angle 0^\circ$
 $P_{sch2} = 1.2$
 $P_{sch3} = 1.5$



$$Y_{bus} = \begin{bmatrix} Y_{11} & Y_{12} & Y_{13} \\ Y_{21} & Y_{22} & Y_{23} \\ Y_{31} & Y_{32} & Y_{33} \end{bmatrix}$$

$$= \begin{bmatrix} 14 & -4 & -10 \\ -4 & 9 & -5 \\ -10 & -5 & 15 \end{bmatrix}$$

2) Gauss-Seidel Method.

$$V_k^{(i+1)} = \frac{1}{Y_{kk}} \left[\frac{S_k^*}{V_k^{(i)}} - \sum_{n=1}^{k-1} Y_{kn} V_n^{(i+1)} - \sum_{n=k+1}^N Y_{kn} V_n^{(i)} \right]$$

$$V_2^{(i+1)} = \frac{1}{Y_{22}} \left[\frac{S_2^*}{V_2^{(i)}} - Y_{21} V_1^{(i+1)} - Y_{23} V_3^{(i)} \right]$$

$$V_3^{(i+1)} = \frac{1}{Y_{33}} \left[\frac{S_3^*}{V_3^{(i)}} - Y_{31} V_1^{(i+1)} - Y_{32} V_2^{(i+1)} \right]$$

$$S_2' = 1.02, Y_{22} = 9, Y_{21} = -4, Y_{23} = -5$$

$$S_3 = -1.05, Y_{33} = 15, Y_{31} = -10$$

$$Y_{32} = -5$$

$$V_2^{(i+1)} = \frac{0.4/3}{V_2^{(i)}} + \frac{4}{9} V_1^{(i+1)} + \frac{5}{9} V_3^{(i)}$$

$$V_3^{(i+1)} = \frac{-0.1}{V_3^{(i)}} + \frac{2}{3} V_1^{(i+1)} + \frac{1}{3} V_2^{(i+1)}$$

i	V_2	V_3
0	1	1
1	1.1333	0.9
2	1.0621	0.9333
3	1.0885	0.9224
4	1.0784	0.9180
5	1.0781	0.9171

$$\Rightarrow \underline{V_2 = 1.078 \text{ (pu)}} *$$

$$\underline{V_3 = 0.917 \text{ (pu)}} *$$

$$3) S_2 = V_2 (Y_{21}^* V_1 + Y_{22}^* V_2 + Y_{23}^* V_3)$$

$$= 1.078 (-4 \cdot 1 + 9 \cdot 1.078 + (-5) \cdot 0.917)$$

$$= 1.2041$$

$$S_3 = V_3 (Y_{31}^* V_1 + Y_{32}^* V_2 + Y_{33}^* V_3)$$

$$= 0.917 (1 \cdot (-10) + (-5) \cdot 1.078 + 15 \cdot 0.917)$$

$$= -1.4993$$

power mismatch at bus 2 :

$$\Rightarrow \Delta S_2 = S_2^{\text{cal}} - S_2^{\text{sch}} = 1.2041 - 1.2 = 0.0041 *$$

$$\Delta P_2 = P_2^{\text{cal}} - P_2^{\text{sch}} = 1.2041 - 1.2 = 0.0041 *$$

$$\Delta Q_2 = Q_2^{\text{cal}} - Q_2^{\text{sch}} = 0 - 0 = 0 *$$

power mismatch at bus 3 :

$$\Rightarrow \Delta S_3 = S_3^{\text{cal}} - S_3^{\text{sch}} = -1.4993 - (-1.5) = 0.0007 *$$

$$\Delta P_3 = P_3^{\text{cal}} - P_3^{\text{sch}} = -1.4993 - (-1.5) = 0.0007 *$$

$$\Delta Q_3 = Q_3^{\text{cal}} - Q_3^{\text{sch}} = 0 - 0 = 0 *$$

4) power supply by swing bus

$$S_1 = V_1 (Y_{11}^* V_1 + Y_{12}^* V_2 + Y_{13}^* V_3)$$

$$= 14 + (-4)(1.078) + (-10)(0.917)$$

$$= 0.518 *$$

for DC power system

$$P_1 = S_1 = 0.518 * \Rightarrow Q_1 = 0 *$$

5) power loss of transmission line

$$S_{\text{loss}} = P_{\text{loss}} = S_1 + S_2 + S_3$$

$$= 0.518 + 1.2041 - 1.4993$$

$$= 0.223 *$$

9.1 In Example 9.3 suppose that the generator's maximum reactive power generation at bus (4) is limited to 125 Mvar. Recompute the first-iteration value of the voltage at bus (4) using the Gauss-Seidel method.

The net injected power at bus (4) is $(3.18 - 0.8) + j(1.25 - 0.4954) = 2.38 + j0.7542$ pu.

$$V_4^{(1)} = \frac{1}{Y_{44}} \left[\frac{P_{4, sch} - jQ_{4, sch}}{V_4^{(0)*}} - (Y_{41}V_1 + Y_{42}V_2^{(1)} + Y_{43}V_3^{(1)}) \right] \quad (Y_{41} = 0)$$

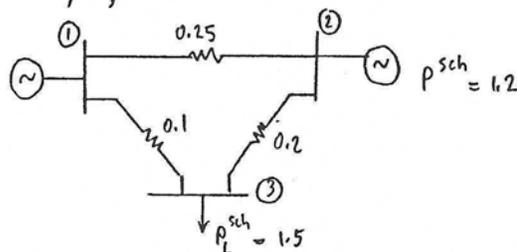
$$= \frac{1}{1.193267 - j40.863838} \left[\frac{2.38 - j0.7542}{1.02} - (-5.169561 + j25.847809)(0.973703 - j0.051706) \right. \\ \left. + (-3.023705 + j15.118528)(0.953949 - j0.066701) \right]$$

$$= 0.997117 - j0.006442$$

Using an acceleration factor of 1.6, yields

$$V_{4, acc}^{(1)} = 1.02 + 1.6(0.997117 - j0.006442 - 1.02) = 0.983387 - j0.0103073 \text{ pu} \quad \#$$

Problem 1 Use Newton-Raphson and compute the bus voltages and power mismatches at bus 1, 2, and 3



let $V_1 = 1 \angle 0^\circ$ (swing bus)

$$Y_{BUS} = \begin{bmatrix} \frac{1}{0.25} + \frac{1}{0.1} & -\frac{1}{0.25} & -\frac{1}{0.1} \\ -\frac{1}{0.25} & \frac{1}{0.25} + \frac{1}{0.2} & -\frac{1}{0.2} \\ -\frac{1}{0.1} & -\frac{1}{0.2} & \frac{1}{0.1} + \frac{1}{0.2} \end{bmatrix} = \begin{bmatrix} 14 & -4 & -10 \\ -4 & 9 & -5 \\ -10 & -5 & 15 \end{bmatrix}$$

Assign initial condition of voltage: $V_2 = 1 \angle 0^\circ$, $V_3 = 1 \angle 0^\circ$ pu.

$$J = \begin{bmatrix} \frac{\partial P_2}{\partial \delta_2} & \frac{\partial P_2}{\partial \delta_3} & |V_2| \frac{\partial P_2}{\partial |V_2|} & |V_3| \frac{\partial P_2}{\partial |V_3|} \\ \frac{\partial P_3}{\partial \delta_2} & \frac{\partial P_3}{\partial \delta_3} & |V_2| \frac{\partial P_3}{\partial |V_2|} & |V_3| \frac{\partial P_3}{\partial |V_3|} \\ \frac{\partial Q_2}{\partial \delta_2} & \frac{\partial Q_2}{\partial \delta_3} & |V_2| \frac{\partial Q_2}{\partial |V_2|} & |V_3| \frac{\partial Q_2}{\partial |V_3|} \\ \frac{\partial Q_3}{\partial \delta_2} & \frac{\partial Q_3}{\partial \delta_3} & |V_2| \frac{\partial Q_3}{\partial |V_2|} & |V_3| \frac{\partial Q_3}{\partial |V_3|} \end{bmatrix}_{4 \times 4}$$

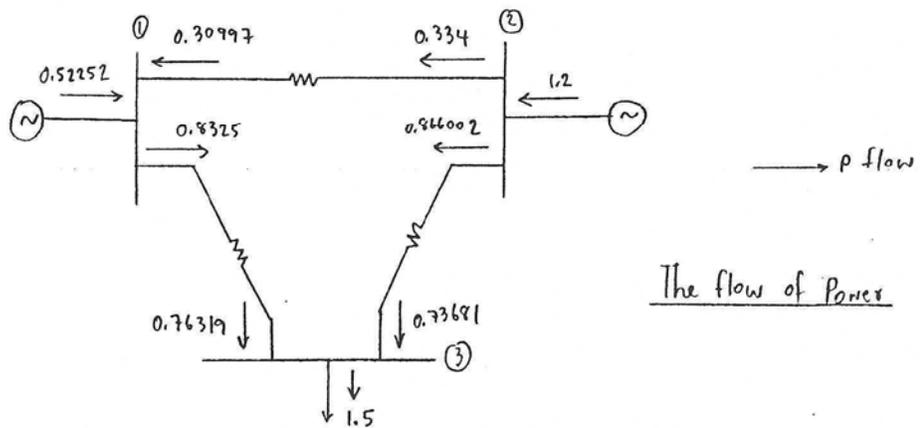
Because the transmission line model is only resistance and load complex power is also the real power, therefore $\delta_2 = \delta_3 = Q_1 = Q_2 = Q_3 = 0$, then

$$J = \begin{bmatrix} |v_2| \frac{\partial P_2}{\partial |v_2|} & |v_3| \frac{\partial P_2}{\partial |v_3|} \\ |v_2| \frac{\partial P_3}{\partial |v_2|} & |v_3| \frac{\partial P_3}{\partial |v_3|} \end{bmatrix}_{2 \times 2}$$

So,

$$\underbrace{\begin{bmatrix} |v_2| \frac{\partial P_2}{\partial |v_2|} & |v_3| \frac{\partial P_2}{\partial |v_3|} \\ |v_2| \frac{\partial P_3}{\partial |v_2|} & |v_3| \frac{\partial P_3}{\partial |v_3|} \end{bmatrix}}_{\text{Jacobian}} \underbrace{\begin{bmatrix} \frac{\Delta |v_2|}{|v_2|} \\ \frac{\Delta |v_3|}{|v_3|} \end{bmatrix}}_{\text{Corrections}} = \underbrace{\begin{bmatrix} \Delta P_2 \\ \Delta P_3 \end{bmatrix}}_{\text{Mismatches}}$$

The results of program (including the MATLAB source code) are shown in the following pages. The number of iteration is 30.



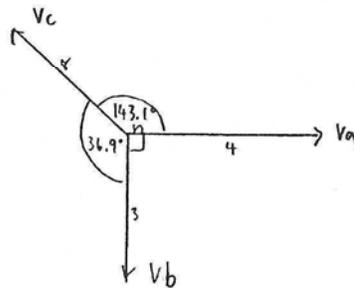
The flow of Power

$$V_{bus} = \begin{bmatrix} 1.0 \\ 1.07749415 \\ 0.916750444 \end{bmatrix}$$

$$\text{Power mismatches} = \begin{bmatrix} 0.02220446 \times 10^{-14} \\ -0.02220446 \times 10^{-14} \\ 0 \end{bmatrix}$$

#

Problem 2 consider the unbalanced three-phase system



feeding a three phase balanced load as shown.

Compute I^0 , I^+ , I^- and I_a for parts a) and b)

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```
EE740 : PROBLEM SET #5 : Problem #1 (Load Flow Studies)
% For this problem, there are 3 buses as follows:
%
% 1. Swing bus
%   Given values : MagV1 = 1.1 pu. and AngV1 = 0 rad. (reference)
%   Unknown values : P1 and Q1
% 2. Gen bus
%   Given values : P2 = 1.2 pu.
%   Unknown values : MagV2 and AngV2
% 3. Load bus
%   Given values : P3 = 1.5 pu.
%   Unknown values : MagV2 and AngV2
% The newton-raphson power-flow method is used to solve this problem.
clear
% ***** Given values *****
MagV1 = 1.0;
AngV1 = 0;
S2 = 1.2;
S3 = -1.5;
% ***** Initial values *****
MagV2 = 1.0;
AngV2 = 0;
MagV3 = 1.0;
AngV3 = 0;
N = 30;
J = zeros(2,2);
% ***** Ybus *****
Ybus = [14 -4 -10; -4 9 -5; -10 -5 15]; % 3 by 3 matrix
% ***** Power-flow calculation *****
format long;
for I = 1:N,
    P1 = (MagV1^2)*Ybus(1,1) + MagV1*MagV2*abs(Ybus(1,2))*cos(pi+AngV2-AngV1) + MagV1*MagV3*abs(Ybus(1,3))*cos(pi+AngV3-AngV1);
    Q1 = -MagV1*MagV2*abs(Ybus(1,2))*sin(pi+AngV2-AngV1) - MagV1*MagV3*abs(Ybus(1,3))*sin(pi+AngV3-AngV1);
    P2 = (MagV2^2)*Ybus(2,2) + MagV2*MagV1*abs(Ybus(2,1))*cos(pi+AngV1-AngV2) + MagV2*MagV3*abs(Ybus(2,3))*cos(pi+AngV3-AngV2);
    Q2 = -MagV2*MagV1*abs(Ybus(2,1))*sin(pi+AngV1-AngV2) - MagV2*MagV3*abs(Ybus(2,3))*sin(pi+AngV3-AngV2);
    P3 = (MagV3^2)*Ybus(3,3) + MagV3*MagV1*abs(Ybus(3,1))*cos(pi+AngV1-AngV3) + MagV3*MagV2*abs(Ybus(3,2))*cos(pi+AngV2-AngV3);
    Q3 = -MagV3*MagV1*abs(Ybus(3,1))*sin(pi+AngV1-AngV3) - MagV3*MagV2*abs(Ybus(3,2))*sin(pi+AngV2-AngV3);
    dP2 = real(S2) - P2;
    dQ2 = imag(S2) - Q2;
    dP3 = real(S3) - P3;
    dQ3 = imag(S3) - Q3;
% ***** Jacobian Matrix *****
J(1,1) = P2 + (MagV2^2)*Ybus(2,2);
J(2,1) = MagV2*MagV3*abs(Ybus(3,2))*cos(pi+AngV2-AngV3);
J(1,2) = MagV3*MagV2*abs(Ybus(2,3))*cos(pi+AngV3-AngV2);
% *****
J(2,2) = P3 + (MagV3^2)*Ybus(3,3);
% *****
Mis = [dP2;dQ3]; % Mismatch matrix
Cor = inv(J)*Mis; % Correction matrix
MagV2 = MagV2*(1 + Cor(1)); % Correct the voltage magnitude @ bus 2
MagV3 = MagV3*(1 + Cor(2)); % Correct the voltage magnitude @ bus 3
end
Vbus = [MagV1 AngV1*180/pi;
        MagV2 AngV2*180/pi;
        MagV3 AngV3*180/pi];
Ibus = [(P1-Q1*j)/MagV1;
        (P2-Q2*j)/MagV2;
        (P3-Q3*j)/MagV3];
I12 = (MagV1-MagV2)*(-Ybus(1,2));
I13 = (MagV1-MagV3)*(-Ybus(1,3));
I23 = (MagV2-MagV3)*(-Ybus(2,3));
Sloss12 = (-1/Ybus(1,2))*(abs(I12))^2;
Sloss13 = (-1/Ybus(1,3))*(abs(I13))^2;
Sloss23 = (-1/Ybus(2,3))*(abs(I23))^2;
Sloss = Sloss12 + Sloss13 + Sloss23;
dP1 = -real(S2+S3) + real(Sloss) - P1;
dQ1 = -imag(S2+S3) + imag(Sloss) - Q1;
Mismatch = [dP1+dQ1*j; Mis(1)+dQ2*j; Mis(2)+dQ3*j];
Sbus = [P1+Q1*j; P2+Q2*j; P3+Q3*j];
% total losses in the transmission lines
```

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The result of PROBLEM SET #5, Problem #1

Mismatch = 1.0e-14 *
0.02220446049250 0
-0.02220446049250 0
0 0

Sbus = 0.52251895681892 - 0.000000000000000i
1.20000000000000 - 0.000000000000000i
-1.50000000000000 - 0.000000000000000i

Sloss = 0.22251895681892 (total losses in the transmission line)

Vbus = 1.00000000000000 0
1.07749415109943 0
0.91675044387834 0

Ibus = 0.52251895681892 + 0.000000000000000i
1.11369514050315 + 0.000000000000000i
-1.63621409732207 + 0.000000000000000i