EG2100 Power System Analysis

Assignment LF

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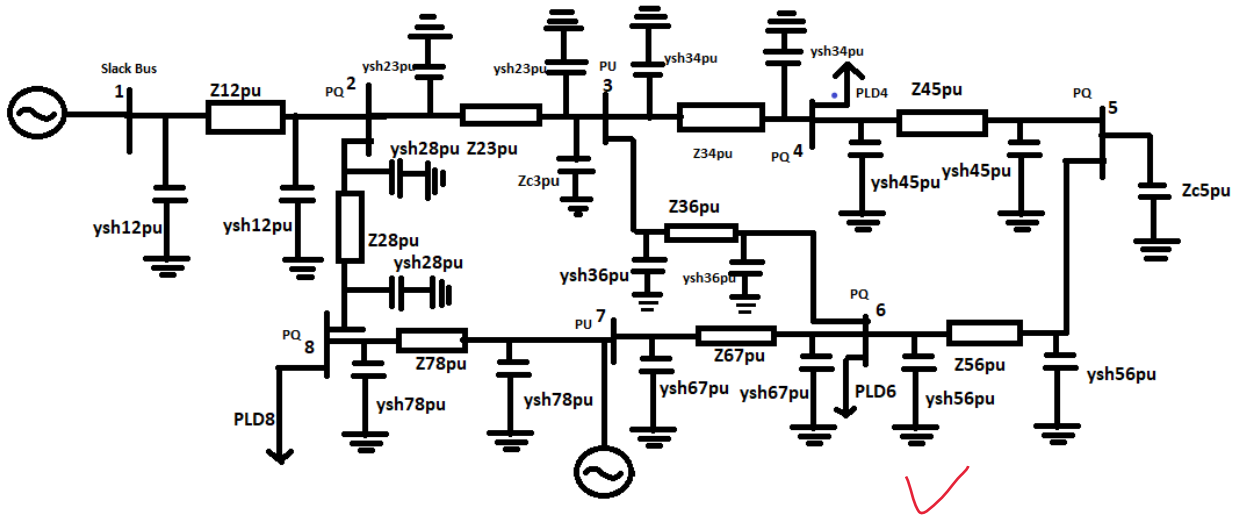
B-73

a.) Based on the given data, draw the single-line diagram of your system.



Circuit Diagram

b.) Give the type of each bus (i.e. slack, PU- or PQ-bus) in a table starting from bus 1.

Bus Number	Type
1	Slack
2	PQ
3	PU
4	PQ
5	PQ
6	PQ
7	PU
8	PQ

c.) Build the Y-bus matrix and give the value of its elements in pu.

Defining the base values in the system.
$U_{base} = 220kV, S_{base} = 100MVA(Given)$
$U_{1pu} = 220/U_{base} = 1, \theta_1 = 0°$
$U_{3pu} = 220/U_{base} = 1$
$U_{7pu} = 220/U_{base} = 1$
$Z_{base} = U_{base}^2/(\sqrt{3} * U_{base})$
Number of buses;
nbus=8

Finding per-unit Impedances

For Cable12:
$\overline{Z}_{12pu} = \frac{(0.05+i0.5)\times(86.5)}{\overline{Z}_{base}} = 0.0089 + 0.089i$
$\overline{y}_{sh12} = \frac{3.6\times10^{-6}\times86.5}{2}(\mathrm{S})$
$\overline{y}_{sh12pu} = \overline{y}_{sh12} \times Z_{base} = 0.0753i$

For Cable23:
$\overline{Z}_{23pu} = \frac{(0.05+i0.5)\times(100)}{\overline{Z}_{base}} = 0.0103 + 0.103i$
$\overline{y}_{sh23} = \frac{3.6\times10^{-6}\times100}{2}(\mathrm{S})$
$\overline{y}_{sh23pu} = \overline{y}_{sh23} \times Z_{base} = 0.08711i$

For Cable34:
$\overline{Z}_{34pu} = \frac{(0.05+i0.5)\times(100)}{\overline{Z}_{base}} = 0.0103 + 0.103i$
$\overline{y}_{sh34} = \frac{3.6\times10^{-6}\times100}{2}(\mathrm{S})$
$\overline{y}_{sh34pu} = \overline{y}_{sh34} \times Z_{base} = 0.08711i$

For Cable45:
$\overline{Z}_{45pu} = \frac{(0.05+i0.5)\times(150)}{\overline{Z}_{base}} = 0.0154 + 0.154i$
$\overline{y}_{sh45} = \frac{3.6\times10^{-6}\times150}{2}(\mathrm{S})$
$\overline{y}_{sh45pu} = \overline{y}_{sh45} \times Z_{base} = 0.1306i$

For Cable56:
$\overline{Z}_{56pu} = \frac{(0.05+i0.5)\times(150)}{\overline{Z}_{base}} = 0.0154 + 0.154i$
$\overline{y}_{sh56} = \frac{3.6\times10^{-6}\times150}{2}(\mathrm{S})$
$\overline{y}_{sh56pu} = \overline{y}_{sh56} \times Z_{base} = 0.1306i$

For Cable67:
$\overline{Z}_{67pu} = \frac{(0.05+i0.5)\times(90)}{\overline{Z}_{base}} = 0.00929 + 0.0929i$
$\overline{y}_{sh67} = \frac{3.6\times10^{-6}\times90}{2}(\mathrm{S})$
$\overline{y}_{sh67pu} = \overline{y}_{sh67} \times Z_{base} = 0.0784i$

For Cable78:
$\overline{Z}_{78pu} = \frac{(0.05+i0.5)\times(90)}{\overline{Z}_{base}} = 0.00929 + 0.0929i$
$\overline{y}_{sh78} = \frac{3.6\times10^{-6}\times90}{2}(\mathrm{S})$
$\overline{y}_{sh78pu} = \overline{y}_{sh78} \times Z_{base} = 0.0784i$

For Cable28:
$\overline{Z}_{28pu} = \frac{(0.05+i0.5)\times(136.5)}{\overline{Z}_{base}} = 0.0141 + 0.141i$
$\overline{y}_{sh28} = \frac{3.6\times10^{-6}\times136.5}{2}(\mathrm{S})$
$\overline{y}_{sh28pu} = \overline{y}_{sh28} \times Z_{base} = 0.1189i$

For Cable36:
$\overline{Z}_{36pu} = \frac{(0.05+i0.5)\times(200)}{\overline{Z}_{base}} = 0.0206 + 0.206i$
$\overline{y}_{sh36} = \frac{3.6\times10^{-6}\times200}{2}(\mathrm{S})$
$\overline{y}_{sh36pu} = \overline{y}_{sh36} \times Z_{base} = 0.1742i$

For the shunt capacitor at Bus 5:
$\overline{Z}_{c5pu} = (\frac{220^2}{-2\times i})^* \times \frac{1}{Z_{base}} = -500i$

Formation of Ybus Matrix:
Y_{bus}=

$$\begin{bmatrix} \overline{Y_{11}} & \overline{Y_{12}} & \overline{Y_{13}} & \overline{Y_{14}} & \overline{Y_{15}} & \overline{Y_{16}} & \overline{Y_{17}} & \overline{Y_{18}} \\ \overline{Y_{21}} & \overline{Y_{22}} & \overline{Y_{23}} & \overline{Y_{24}} & \overline{Y_{25}} & \overline{Y_{26}} & \overline{Y_{27}} & \overline{Y_{28}} \\ \overline{Y_{31}} & \overline{Y_{32}} & \overline{Y_{33}} & \overline{Y_{34}} & \overline{Y_{35}} & \overline{Y_{36}} & \overline{Y_{37}} & \overline{Y_{38}} \\ \overline{Y_{41}} & \overline{Y_{42}} & \overline{Y_{43}} & \overline{Y_{44}} & \overline{Y_{45}} & \overline{Y_{46}} & \overline{Y_{47}} & \overline{Y_{48}} \\ \overline{Y_{51}} & \overline{Y_{52}} & \overline{Y_{53}} & \overline{Y_{54}} & \overline{Y_{55}} & \overline{Y_{56}} & \overline{Y_{57}} & \overline{Y_{58}} \\ \overline{Y_{61}} & \overline{Y_{62}} & \overline{Y_{63}} & \overline{Y_{64}} & \overline{Y_{65}} & \overline{Y_{66}} & \overline{Y_{67}} & \overline{Y_{68}} \\ \overline{Y_{71}} & \overline{Y_{72}} & \overline{Y_{73}} & \overline{Y_{74}} & \overline{Y_{75}} & \overline{Y_{76}} & \overline{Y_{77}} & \overline{Y_{78}} \\ \overline{Y_{81}} & \overline{Y_{82}} & \overline{Y_{83}} & \overline{Y_{84}} & \overline{Y_{85}} & \overline{Y_{86}} & \overline{Y_{87}} & \overline{Y_{88}} \end{bmatrix}$$

$\overline{Y}_{11} = 1/\overline{Z}_{12pu} + \overline{y}_{sh12pu} = 1.1079 - 11.004i$
$\overline{Y}_{12} = -1/\overline{Z}_{12pu} = -1.1079 + 11.079i$
$\overline{Y}_{13} = 0$
$\overline{Y}_{14} = 0$
$\overline{Y}_{15} = 0$
$\overline{Y}_{16} = 0$
$\overline{Y}_{17} = 0$
$\overline{Y}_{18} = 0$

$\overline{Y}_{21} = \overline{Y}_{12} = -1.1079 + 11.079i$
$\overline{Y}_{22} = 1/\overline{Z}_{12pu} + \overline{y}_{sh12pu} + 1/\overline{Z}_{28pu} + \overline{y}_{sh28pu} + 1/\overline{Z}_{23pu} + \overline{y}_{sh23pu} = 2.7685 - 27.404i$
$\overline{Y}_{23} = -1/\overline{Z}_{23pu} = -0.95841 + 9.5841i;$
$\overline{Y}_{24} = 0;$
$\overline{Y}_{25} = 0;$
$\overline{Y}_{26} = 0;$
$\overline{Y}_{27} = 0;$
$\overline{Y}_{28} = -1/\overline{Z}_{28pu} = -0.70213 + 7.0213i$

$\overline{Y}_{31} = \overline{Y}_{13} = 0$
$\overline{Y}_{32} = \overline{Y}_{23} = -0.95841 + 9.5841i$
$\overline{Y}_{33} = 1/\overline{Z}_{23pu} + \overline{y}_{sh23pu} + 1/\overline{Z}_{34pu} + \overline{y}_{sh34pu} + 1/\overline{Z}_{36pu} + \overline{y}_{sh36pu} = 2.396 - 23.611i$
$\overline{Y}_{34} = -1/\overline{Z}_{34pu} = -0.9584 + 9.5841i$
$\overline{Y}_{35} = 0;$
$\overline{Y}_{36} = -1/\overline{Z}_{36pu} = -0.4792 + 4.792i$
$\overline{Y}_{37} = 0;$
$\overline{Y}_{38} = 0$

$\overline{Y}_{41} = \overline{Y}_{14} = 0$
$\overline{Y}_{42} = \overline{Y}_{24} = 0$
$\overline{Y}_{43} = \overline{Y}_{34} = -0.9584 + 9.584i$
$\overline{Y}_{44} = 1/\overline{Z}_{34pu} + \overline{y}_{sh34pu} + 1/\overline{Z}_{45pu} + \overline{y}_{sh45pu} = 1.597 - 15.755i$
$\overline{Y}_{45} = -1/\overline{Z}_{45pu} = -0.63894 + 6.3894i$
$\overline{Y}_{46} = 0$
$\overline{Y}_{47} = 0$
$\overline{Y}_{48} = 0$

$\overline{Y}_{51} = \overline{Y}_{15} = 0$
$\overline{Y}_{52} = \overline{Y}_{25} = 0$
$\overline{Y}_{53} = \overline{Y}_{35} = 0$
$\overline{Y}_{54} = \overline{Y}_{45} = -0.63894 + 6.3894i$
$\overline{Y}_{55} = 1/\overline{Z}_{45pu} + \overline{y}_{sh45pu} + 1/\overline{Z}_{56pu} + \overline{y}_{sh56pu} + 1/\overline{Z}_{c5pu} = 1.2778 - 12.515i$
$\overline{Y}_{56} = -1/\overline{Z}_{56pu} = -0.63894 + 6.3894i$
$\overline{Y}_{57} = 0;$
$\overline{Y}_{58} = 0$

$\overline{Y}_{61} = \overline{Y}_{16} = 0$
$\overline{Y}_{62} = \overline{Y}_{26} = 0$
$\overline{Y}_{63} = \overline{Y}_{36} = -0.4792 + 4.792i$
$\overline{Y}_{64} = \overline{Y}_{46} = 0$
$\overline{Y}_{65} = \overline{Y}_{56} = -0.63894 + 6.3894i$
$\overline{Y}_{66} = 1/\overline{Z}_{36pu} + \overline{y}_{sh36pu} + 1/\overline{Z}_{56pu} + \overline{y}_{sh56pu} + 1/\overline{Z}_{67pu} + \overline{y}_{sh67pu} = 2.1830 - 21.447i$
$\overline{Y}_{67} = -1/\overline{Z}_{67pu} = -1.0649 + 10.649i$
$\overline{Y}_{68} = 0$

$\overline{Y}_{71} = \overline{Y}_{17} = 0$
$\overline{Y}_{72} = \overline{Y}_{27} = 0$
$\overline{Y}_{73} = \overline{Y}_{37} = 0$
$\overline{Y}_{74} = \overline{Y}_{47} = 0$
$\overline{Y}_{75} = \overline{Y}_{57} = 0$
$\overline{Y}_{76} = \overline{Y}_{67};$
$\overline{Y}_{77} = 1/\overline{Z}_{67pu} + \overline{y}_{sh67pu} + 1/\overline{Z}_{78pu} + \overline{y}_{sh78pu} = 2.1298 - 21.141i$
$\overline{Y}_{78} = -1/\overline{Z}_{78pu} = -1.0649 + 10.649i$

$\overline{Y}_{81} = \overline{Y}_{18} = 0$
$\overline{Y}_{82} = \overline{Y}_{28} = -0.70213 + 7.0213i$
$\overline{Y}_{83} = \overline{Y}_{38} = 0$
$\overline{Y}_{84} = \overline{Y}_{48} = 0$
$\overline{Y}_{85} = \overline{Y}_{58} = 0$
$\overline{Y}_{86} = \overline{Y}_{68} = 0$
$\overline{Y}_{87} = \overline{Y}_{78} = -1.0649 + 10.649i$
$\overline{Y}_{88} = 1/\overline{Z}_{78pu} + \overline{y}_{sh78pu} + 1/\overline{Z}_{28pu} + \overline{y}_{sh28pu} = 1.7670 - 17.473i$

d.) Give the numerical values of the voltage and the phase angle of each bus in a table starting from bus 1. The voltages must be given both in pu and kV, and the phase angles in degrees.

We know that

$$P_{GD} = P_G - P_L$$

From the given data, we could calculate the following values.

$P_{GD2} = 0$
$Q_{GD2} = 0$
$P_{GD3} = 0$

$P_{GD4} = -186.5/100 = -1.865$
$Q_{GD4} = -30/100 = -0.30$
$P_{GD5} = 0$
$Q_{GD5} = 0$
$P_{GD6} = -230/100 = -2.30$
$Q_{GD6} = -10/100 = -0.10$
$P_{GD7} = 236.5/100 = 2.365$
$P_{GD8} = -210/100 = -2.10$
$Q_{GD8} = -30/100 = -0.30$

The initial values of all unknown voltages is set to 1 and unknown angles is set to 0.
We can find the Total Injected Active Power and Reactive Power as:

$$P_k = U_k \sum_{j=1}^{N} U_j(G_{kj}cos(\theta_{kj}) + B_{kj}sin(\theta_{kj})) \tag{1}$$

$$Q_k = U_k \sum_{j=1}^{N} U_j(G_{kj}sin(\theta_{kj}) - B_{kj}cos(\theta_{kj})) \tag{2}$$

Active and Reactive Power Mismatch is given by

$$\Delta P = P_k - P_{GD_k} \tag{3}$$

$$\Delta Q = Q_k - Q_{GD_k} \tag{4}$$

We used Newton-Raphson's Method in MATLAB to get the following table.

Bus Number	Voltage(in pu)	Voltage(in kV)	Phase(in degrees)
1	1	220	0
2	0.9409	207.00	-23.264
3	1	220	-38.973
4	0.9737	214.22	-49.387
5	1.0039	220.85	-48.006
6	0.9937	218.62	-46.417
7	1	220	-36.269
8	0.9427	207.40	-38.641

e.) Give value of the entries of the submatrices H, N, J and L by using equations (7.50)-(7.51) in the textbook.

As we already have the values of voltages and phases at each Bus, we can find the injected active and reactive power at each bus using equations (1) and (2).
In H_{kj} k $\neq$ slack bus j $\neq$ slack bus
In N_{kj} k $\neq$ slack bus j $\neq$ slack bus and PU-bus
In J_{kj} k $\neq$ slack bus and PU-bus j $\neq$ slack bus
In L_{kj} k $\neq$ slack bus and PU-bus j $\neq$ slack bus and PU-bus

Now we calculate the value of H,N,J and L matrices using the following relationships.

if $k \neq j$

$$H_{kj} = U_k U_j [G_{kj} sin(\theta_{kj}) - B_{kj} cos(\theta_{kj})]$$

$$N_{kj} = U_k U_j [G_{kj} cos(\theta_{kj}) + B_{kj} sin(\theta_{kj})]$$

$$J_{kj} = -U_k U_j [G_{kj} cos(\theta_{kj}) + B_{kj} sin(\theta_{kj})]$$

$$L_{kj} = U_k U_j [G_{kj} sin(\theta_{kj}) - B_{kj} cos(\theta_{kj})]$$

for k=j

$$H_{kk} = -Q_k - B_{kk} U_k^2$$

$$N_{kk} = P_k + G_{kk} U_k^2$$

$$J_{kk} = P_k - G_{kk} U_k^2$$

$$L_{kk} = Q_k - B_{kk} U_k^2$$

$$H = \begin{bmatrix} 24.261 & -8.9252 & 0 & 0 & 0 & 0 & -6.1703 \\ -8.4368 & 22.568 & -9.3474 & 0 & -4.7837 & 0 & 0 \\ 0 & -9.0101 & 15.239 & -6.2291 & 0 & 0 & 0 \\ 0 & 0 & -6.2591 & 12.613 & -6.3542 & 0 & 0 \\ 0 & -4.6603 & 0 & -6.3896 & 21.280 & -10.230 & 0 \\ 0 & 0 & 0 & 0 & -10.603 & 20.675 & -10.072 \\ -5.8401 & 0 & 0 & 0 & 0 & -9.9891 & 15.829 \end{bmatrix}$$

$$N = \begin{bmatrix} 2.4510 & 0 & 0 & 0 & 1.0509 \\ -3.3097 & 0.7689 & 0 & 0.1447 & 0 \\ 0 & -0.3504 & -0.7748 & 0 & 0 \\ 0 & -0.4739 & 1.2878 & -0.8139 & 0 \\ 0 & 0 & -0.4604 & -0.1440 & 0 \\ 0 & 0 & 0 & 0.8228 & -0.5876 \\ -2.2520 & 0 & 0 & 0 & -0.5295 \end{bmatrix}$$

$$J = \begin{bmatrix} -2.4510 & -1.5735 & 0 & 0 & 0 & 0 & -1.0509 \\ 0 & 2.6046 & -3.3795 & 0.7748 & 0 & 0 & 0 \\ 0 & 0 & 0.4739 & -1.2878 & 0.8139 & 0 & 0 \\ 0 & 1.0891 & 0 & 0.4604 & -4.4559 & 2.9062 & 0 \\ 2.2520 & 0 & 0 & 0 & 0 & 1.4184 & -3.6704 \end{bmatrix}$$

$$L = \begin{bmatrix} 24.261 & 0 & 0 & 0 & -6.1703 \\ 0 & 14.639 & -6.2290 & 0 & 0 \\ 0 & -6.2591 & 12.613 & -6.3542 & 0 \\ 0 & 0 & -6.3896 & 21.080 & 0 \\ -5.840 & 0 & 0 & 0 & 15.229 \end{bmatrix}$$

f.) Find the generated active power in MW and reactive power in MVAr of the slack bus, and also the generated reactive powers of the PU-buses in MVAr.

We calculate the generated active and reactive powers using equation(1) and (2) at Slack and PU buses.

At Bus 1(Slack Bus):

$$P_{G1} = P_1 * S_{base} = 426.80MW$$
$$Q_{G1} = Q_1 * S_{base} = 101.52MVAr$$

At Bus 3 and 7(PU Buses):

$$Q_{G3} = Q_3 * S_{base} = 104.38MVAr$$
$$Q_{G7} = Q_7 * S_{base} = 46.555MVAr$$

g.) Find the active and reactive power flows (both directions), and the active power losses in each line in a table. The active power flows and the active power losses must be given in MW and the reactive power flows in MVAr.

Active and Reactive Power Flow from Bus k to Bus j can be found by the following equation:

$$P_{kj} = g_{kj}U_k^2 - U_kU_j[g_{kj}cos(\theta_{kj}) + b_{kj}sin(\theta_{kj})] \quad (5)$$
$$Q_{kj} = U_k^2(-b_{sh-kj} - b_{kj}) - U_kU_j[g_{kj}sin(\theta_{kj}) - b_{kj}cos(\theta_{kj})] \quad (6)$$

The Power Losses in a line from Bus k to Bus j is

$$P_f = P_{kj} + P_{jk} \quad (7)$$

Using the above equations, we construct the following table:

Line	Active Power FLow(MW)	Reactive Power FLow(MVAr)	Active Power Loss(MW)
12/21	426.80/-409.46	101.51/57.677	17.340
23/32	242.20/-235.13	-51.727/106.01	7.0712
34/43	172.73/-169.59	14.958/-0.5279	3.1402
45/54	-16.905/16.999	-29.472/4.8550	0.0943
56/65	-16.999/17.055	-4.6534/-20.866	0.0555
67/76	-185.46/188.77	20.859/-3.2912	3.3152
78/87	47.722/-47.201	49.846/-59.444	0.5211
28/82	167.25/-162.79	-5.9502/29.444	4.4591
36/63	62.397/-61.593	-16.592/ -9.9932	0.8045

h.) Find the total active power losses in MW.

Total Active Power Losses is the sum of Power Losses in all lines.
We found power losses in individual lines in the previous question(last column of last table).

$$P_{Losses} = P_{12} + P_{23} + P_{34} + P_{45} + P_{56} + P_{67} + P_{78} + P_{28} + P_{36}$$
$$P_{Losses} = 36.802MW$$

MATLAB CODE

LF_B73.m

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%LF Assignment


format short g

Sbase=100; %MVA
Ubase=220; %kV
deg=180/pi;
Zbase=(Ubase^2)/Sbase;
Ibase=Sbase/(sqrt(3)*Ubase);

%known values
U1=220/Ubase; theta1=0;
U3=220/Ubase;
U7=220/Ubase;

nbus=8; %number of buses is 8

%for line-12
Z12pu=((0.05+1i*0.5)*(86.5))/Zbase;
ysh12=(1i*3.6*1E-6)*(86.5)/2;
ysh12pu=ysh12*Zbase;

%for line-23
Z23pu=((0.05+1i*0.5)*(100))/Zbase;
ysh23=(1i*3.6*1E-6)*(100)/2;
ysh23pu=ysh23*Zbase;

%for line-34
Z34pu=((0.05+1i*0.5)*(100))/Zbase;
ysh34=(1i*3.6*1E-6)*(100)/2;
ysh34pu=ysh34*Zbase;

%for line-45
Z45pu=((0.05+1i*0.5)*(150))/Zbase;
ysh45=(1i*3.6*1E-6)*(150)/2;
ysh45pu=ysh45*Zbase;

%for line-56
Z56pu=((0.05+1i*0.5)*(150))/Zbase;
ysh56=(1i*3.6*1E-6)*(150)/2;
ysh56pu=ysh56*Zbase;

%for line-67
Z67pu=((0.05+1i*0.5)*(90))/Zbase;
ysh67=(1i*3.6*1E-6)*(90)/2;
ysh67pu=ysh67*Zbase;

%for line-78
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Z78pu=((0.05+1i*0.5)*(90))/Zbase;
ysh78=(1i*3.6*1E-6)*(90)/2;
ysh78pu=ysh78*Zbase;

%for line-28
Z28pu=((0.05+1i*0.5)*(136.5))/Zbase;
ysh28=(1i*3.6*1E-6)*(136.5)/2;
ysh28pu=ysh28*Zbase;

%for line-36
Z36pu=((0.05+1i*0.5)*(200))/Zbase;
ysh36=(1i*3.6*1E-6)*(200)/2;
ysh36pu=ysh36*Zbase;

%capacitor at Node 5  %th1is 1is a constant 1impedance load
Zc5=conj((220^2)/(-0.2*1i));
Zc5pu=Zc5/Zbase;

%Format1ion of Y-Matr1ix

Y11=(1/Z12pu)+ysh12pu;
Y12= -1/Z12pu;
Y13=0;Y14=0;Y15=0;
Y16=0; Y17=0; Y18=0;

Y21=Y12;
Y22=(1/Z12pu)+ysh12pu+(1/Z28pu)+ysh28pu+(1/Z23pu)+ysh23pu;
Y23= -(1/Z23pu);
Y24=0;Y25=0;Y26=0;Y27=0;
Y28= -(1/Z28pu);

Y31=Y13; Y32=Y23;
Y33=(1/Z23pu)+ysh23pu+(1/Z34pu)+ysh34pu+(1/Z36pu)+ysh36pu;
Y34=-(1/Z34pu);
Y35=0;
Y36= -(1/Z36pu);
Y37=0;Y38=0;

Y41=Y14; Y42=Y24; Y43=Y34;
Y44=(1/Z34pu)+ysh34pu+(1/Z45pu)+ysh45pu;
Y45= -(1/Z45pu);
Y46=0;Y47=0;Y48=0;

Y51=Y15; Y52=Y25; Y53=Y35; Y54=Y45;
Y55=(1/Z45pu)+ysh45pu+(1/Z56pu)+ysh56pu+(1/Zc5pu);
Y56= -(1/Z56pu);
Y57=0;Y58=0;

Y61=Y16; Y62=Y26; Y63=Y36; Y64=Y46; Y65=Y56;
Y66=(1/Z56pu)+ysh56pu+(1/Z67pu)+ysh67pu+(1/Z36pu)+ysh36pu;
Y67= -(1/Z67pu);
Y68=0;

Y71=Y17; Y72=Y27; Y73=Y37; Y74=Y47; Y75=Y57; Y76=Y67;
Y77=(1/Z67pu)+ysh67pu+(1/Z78pu)+ysh78pu;
Y78= -(1/Z78pu);
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Y81=Y18; Y82=Y28; Y83=Y38; Y84=Y48; Y85=Y58; Y86=Y68; Y87=Y78;
Y88=(1/Z78pu)+ysh78pu+(1/Z28pu)+ysh28pu;

Ybus=[Y11 Y12 Y13 Y14 Y15 Y16 Y17 Y18;
      Y21 Y22 Y23 Y24 Y25 Y26 Y27 Y28;
      Y31 Y32 Y33 Y34 Y35 Y36 Y37 Y38;
      Y41 Y42 Y43 Y44 Y45 Y46 Y47 Y48;
      Y51 Y52 Y53 Y54 Y55 Y56 Y57 Y58;
      Y61 Y62 Y63 Y64 Y65 Y66 Y67 Y68;
      Y71 Y72 Y73 Y74 Y75 Y76 Y77 Y78;
      Y81 Y82 Y83 Y84 Y85 Y86 Y87 Y88];

G=real(Ybus); B=imag(Ybus);

%Slack bus- Bus 1
%PU bus- Bus 3,7
%PQ bus- Bus 2,4,5,6,8

PGD2=0;
QGD2=0;

PGD3=0;

PGD4=-186.5/Sbase;
QGD4=-30/Sbase;

PGD5=0;
QGD5=0;

PGD6=-230/Sbase;
QGD6=-10/Sbase;

PGD7=236.5/Sbase;

PGD8=-210/Sbase;
QGD8=-30/Sbase;

PGD=[PGD2;PGD3;PGD4;PGD5;PGD6;PGD7;PGD8]; %PGD Matr1ix for PU and PQ buses

QGD=[QGD2;QGD4;QGD5;QGD6;QGD8]; %QGD Matr1ix for PQ buses


%initial Estimates to theta and U values

% We need to find
theta2,theta3,theta4,theta5,theta6,theta7,theta8,U2,U4,U5,U6,U8

%initial Estimates
X0=[0 0 0 0 0 0 0 1 1 1 1 1];
s_z=size(X0);
nx=s_z(1,1); %g1ives us the number of unknown var1iables

options_solve=optimset('Display','off','TolX',1E-06,'TolFun',1E-06); %1E-6
1is the tolerance

PAR=[nx;nbus;U1;theta1;U3;U7]; %U1 and theta are known(slack bus)
```

```
[X_X,FVAL,EXITFLAG,OUTPUT,FJAC]=fsolve('solve_lf',X0,options_solve,G,B,PGD,QG
D,PAR);

%for the time being i have removed the exit flag condition
%Solved Var1iables X_X
%PART D
ANG=([theta1 X_X(1) X_X(2) X_X(3) X_X(4) X_X(5) X_X(6) X_X(7)]') %voltage
phase angles
VOLT=([U1 X_X(8) U3 X_X(9) X_X(10) X_X(11) U7 X_X(12)]') %voltage magnitudes

ANG_deg=ANG*deg; %in degrees
VOLT_kV=VOLT*Ubase; %in kV

%We need to find the value H N J L matrices

  for m=1:nbus
    for n=1:nbus
      PP(m,n)=VOLT(m)*VOLT(n)*(G(m,n)*cos(ANG(m)-ANG(n))+B(m,n)*sin(ANG(m)-
ANG(n)));
      QQ(m,n)=VOLT(m)*VOLT(n)*(G(m,n)*sin(ANG(m)-ANG(n))-B(m,n)*cos(ANG(m)-
ANG(n)));
    end
  end
  P=sum(PP')'
  Q=sum(QQ')'

%H will be 7x7 matrix
H=zeros(7,7);

for m=2:8
    for n=2:8
        if m~=n
            H(m-1,n-1)=VOLT(m)*VOLT(n)*((G(m,n)*sin(ANG(m)-ANG(n)))-
(B(m,n)*cos(ANG(m)-ANG(n))));
        else
            H(m-1,m-1)=-Q(m)-(B(m,m)*VOLT(m)*VOLT(m));
        end
    end
end
disp(H)

%N will be 5x7 matrix
N=zeros(7,5);

tmp=[2 4 5 6 8];

for m=2:8
    for n=1:5
        if m~=tmp(n)
            N(m-1,n)=VOLT(m)*VOLT(tmp(n))*(G(m,tmp(n))*cos(ANG(m)-
ANG(tmp(n)))+B(m,tmp(n))*sin(ANG(m)-ANG(tmp(n))));
        else
            N(m-1,n)=P(m)+(G(m,m)*VOLT(m)*VOLT(m));
        end

    end
end
```

```
disp(N)

%J will be 7x5 matrix
J=zeros(5,7);
%2 4 5 6 8
for m=1:5
    for n=2:8
        if tmp(m)~=n
            J(m,n-1)=-VOLT(tmp(m))*VOLT(n)*(G(tmp(m),n)*cos(ANG(tmp(m))-
ANG(n))+B(tmp(m),n)*sin(ANG(tmp(m))-ANG(n)));
        else
            J(m,n-1)=P(n)-(G(n,n)*VOLT(n)*VOLT(n));
        end

    end
end
disp(J)


%L will be 5x5 matrix

for m=1:5
    for n=1:5
        if m~=n

L(m,n)=VOLT(tmp(m))*VOLT(tmp(n))*(G(tmp(m),tmp(n))*sin(ANG(tmp(m))-
ANG(tmp(n)))-B(tmp(m),tmp(n))*cos(ANG(tmp(m))-ANG(tmp(n))));
        else
            L(m,n)=Q(tmp(m))-(B(tmp(m),tmp(m))*VOLT(tmp(m))*VOLT(tmp(m)));
        end
    end
end

disp(L)

%PART E Not correct values but the format is right :)

PG1=P(1)*Sbase;  %in MW  PART F
QG1=Q(1)*Sbase;  %in MVar

%bus 3 and 7 are PU buses
QG3=Q(3)*Sbase; %in MVar
QG7=Q(7)*Sbase;  %in MVar

g=-G; b=-B;

P12=((g(1,2)*(VOLT(1)^2))-(VOLT(1)*VOLT(2)*(g(1,2)*cos(ANG(1)-
ANG(2))+b(1,2)*sin(ANG(1)-ANG(2)))))*Sbase; %in MW
P21=((g(2,1)*(VOLT(2)^2))-(VOLT(2)*VOLT(1)*(g(2,1)*cos(ANG(2)-
ANG(1))+b(2,1)*sin(ANG(2)-ANG(1)))))*Sbase; %in MW
Q12=(((-imag(ysh12pu)-b(1,2))*(VOLT(1)^2))-
(VOLT(1)*VOLT(2)*(g(1,2)*sin(ANG(1)-ANG(2))-b(1,2)*cos(ANG(1)-
ANG(2)))))*Sbase; %in MVar
Q21=(((-imag(ysh12pu)-b(2,1))*(VOLT(2)^2))-
(VOLT(2)*VOLT(1)*(g(2,1)*sin(ANG(2)-ANG(1))-b(2,1)*cos(ANG(2)-
ANG(1)))))*Sbase; %in MVar
Ploss_12=P12+P21;
```

```
P23=((g(2,3)*(VOLT(2)^2))-(VOLT(2)*VOLT(3)*(g(2,3)*cos(ANG(2)-
ANG(3))+b(2,3)*sin(ANG(2)-ANG(3)))))*Sbase; %in MW
P32=((g(3,2)*(VOLT(3)^2))-(VOLT(3)*VOLT(2)*(g(3,2)*cos(ANG(3)-
ANG(2))+b(3,2)*sin(ANG(3)-ANG(2)))))*Sbase; %in MW
Q23=(((-imag(ysh23pu)-b(2,3))*(VOLT(2)^2))-
(VOLT(2)*VOLT(3)*(g(2,3)*sin(ANG(2)-ANG(3))-b(2,3)*cos(ANG(2)-
ANG(3)))))*Sbase; %in MVar
Q32=(((-imag(ysh23pu)-b(3,2))*(VOLT(3)^2))-
(VOLT(3)*VOLT(2)*(g(3,2)*sin(ANG(3)-ANG(2))-b(3,2)*cos(ANG(3)-
ANG(2)))))*Sbase; %in MVar
Ploss_23=P23+P32;

P34=((g(3,4)*(VOLT(3)^2))-(VOLT(3)*VOLT(4)*(g(3,4)*cos(ANG(3)-
ANG(4))+b(3,4)*sin(ANG(3)-ANG(4)))))*Sbase; %in MW
P43=((g(4,3)*(VOLT(4)^2))-(VOLT(4)*VOLT(3)*(g(4,3)*cos(ANG(4)-
ANG(3))+b(4,3)*sin(ANG(4)-ANG(3)))))*Sbase; %in MW
Q34=(((-imag(ysh34pu)-b(3,4))*(VOLT(3)^2))-
(VOLT(3)*VOLT(4)*(g(3,4)*sin(ANG(3)-ANG(4))-b(3,4)*cos(ANG(3)-
ANG(4)))))*Sbase; %in MVar
Q43=(((-imag(ysh34pu)-b(4,3))*(VOLT(4)^2))-
(VOLT(4)*VOLT(3)*(g(4,3)*sin(ANG(4)-ANG(3))-b(4,3)*cos(ANG(4)-
ANG(3)))))*Sbase; %in MVar
Ploss_34=P34+P43;

P45=((g(4,5)*(VOLT(4)^2))-(VOLT(4)*VOLT(5)*(g(4,5)*cos(ANG(4)-
ANG(5))+b(4,5)*sin(ANG(4)-ANG(5)))))*Sbase; %in MW
P54=((g(5,4)*(VOLT(5)^2))-(VOLT(5)*VOLT(4)*(g(5,4)*cos(ANG(5)-
ANG(4))+b(5,4)*sin(ANG(5)-ANG(4)))))*Sbase; %in MW
Q45=(((-imag(ysh45pu)-b(4,5))*(VOLT(4)^2))-
(VOLT(4)*VOLT(5)*(g(4,5)*sin(ANG(4)-ANG(5))-b(4,5)*cos(ANG(4)-
ANG(5)))))*Sbase; %in MVar
Q54=(((-imag(ysh45pu)-b(5,4))*(VOLT(5)^2))-
(VOLT(5)*VOLT(4)*(g(5,4)*sin(ANG(5)-ANG(4))-b(5,4)*cos(ANG(5)-
ANG(4)))))*Sbase; %in MVar
Ploss_45=P45+P54;

P56=((g(5,6)*(VOLT(5)^2))-(VOLT(5)*VOLT(6)*(g(5,6)*cos(ANG(5)-
ANG(6))+b(5,6)*sin(ANG(5)-ANG(6)))))*Sbase; %in MW
P65=((g(6,5)*(VOLT(6)^2))-(VOLT(6)*VOLT(5)*(g(6,5)*cos(ANG(6)-
ANG(5))+b(6,5)*sin(ANG(6)-ANG(5)))))*Sbase; %in MW
Q56=(((-imag(ysh56pu)-b(5,6))*(VOLT(5)^2))-
(VOLT(5)*VOLT(6)*(g(5,6)*sin(ANG(5)-ANG(6))-b(5,6)*cos(ANG(5)-
ANG(6)))))*Sbase; %in MVar
Q65=(((-imag(ysh56pu)-b(6,5))*(VOLT(6)^2))-
(VOLT(6)*VOLT(5)*(g(6,5)*sin(ANG(6)-ANG(5))-b(6,5)*cos(ANG(6)-
ANG(5)))))*Sbase; %in MVar
Ploss_56=P56+P65;

P67=((g(6,7)*(VOLT(6)^2))-(VOLT(6)*VOLT(7)*(g(6,7)*cos(ANG(6)-
ANG(7))+b(6,7)*sin(ANG(6)-ANG(7)))))*Sbase; %in MW
P76=((g(7,6)*(VOLT(7)^2))-(VOLT(7)*VOLT(6)*(g(7,6)*cos(ANG(7)-
ANG(6))+b(7,6)*sin(ANG(7)-ANG(6)))))*Sbase; %in MW
Q67=(((-imag(ysh67pu)-b(6,7))*(VOLT(6)^2))-
(VOLT(6)*VOLT(7)*(g(6,7)*sin(ANG(6)-ANG(7))-b(6,7)*cos(ANG(6)-
ANG(7)))))*Sbase; %in MVar
```

```
Q76=(((-imag(ysh67pu)-b(7,6))*(VOLT(7)^2))-
(VOLT(7)*VOLT(6)*(g(7,6)*sin(ANG(7)-ANG(6))-b(7,6)*cos(ANG(7)-
ANG(6)))))*Sbase; %in MVar
Ploss_67=P67+P76;

P78=((g(7,8)*(VOLT(7)^2))-(VOLT(7)*VOLT(8)*(g(7,8)*cos(ANG(7)-
ANG(8))+b(7,8)*sin(ANG(7)-ANG(8)))))*Sbase; %in MW
P87=((g(8,7)*(VOLT(8)^2))-(VOLT(8)*VOLT(7)*(g(8,7)*cos(ANG(8)-
ANG(7))+b(8,7)*sin(ANG(8)-ANG(7)))))*Sbase; %in MW
Q78=(((-imag(ysh78pu)-b(7,8))*(VOLT(7)^2))-
(VOLT(7)*VOLT(8)*(g(7,8)*sin(ANG(7)-ANG(8))-b(7,8)*cos(ANG(7)-
ANG(8)))))*Sbase; %in MVar
Q87=(((-imag(ysh78pu)-b(8,7))*(VOLT(8)^2))-
(VOLT(8)*VOLT(7)*(g(8,7)*sin(ANG(8)-ANG(7))-b(8,7)*cos(ANG(8)-
ANG(7)))))*Sbase; %in MVar
Ploss_78=P78+P87;

P36=((g(3,6)*(VOLT(3)^2))-(VOLT(3)*VOLT(6)*(g(3,6)*cos(ANG(3)-
ANG(6))+b(3,6)*sin(ANG(3)-ANG(6)))))*Sbase; %in MW
P63=((g(6,3)*(VOLT(6)^2))-(VOLT(6)*VOLT(3)*(g(6,3)*cos(ANG(6)-
ANG(3))+b(6,3)*sin(ANG(6)-ANG(3)))))*Sbase; %in MW
Q36=(((-imag(ysh36pu)-b(3,6))*(VOLT(3)^2))-
(VOLT(3)*VOLT(6)*(g(3,6)*sin(ANG(3)-ANG(6))-b(3,6)*cos(ANG(3)-
ANG(6)))))*Sbase; %in MVar
Q63=(((-imag(ysh36pu)-b(6,3))*(VOLT(6)^2))-
(VOLT(6)*VOLT(3)*(g(6,3)*sin(ANG(6)-ANG(3))-b(6,3)*cos(ANG(6)-
ANG(3)))))*Sbase; %in MVar
Ploss_36=P36+P63;

P28=((g(2,8)*(VOLT(2)^2))-(VOLT(2)*VOLT(8)*(g(2,8)*cos(ANG(2)-
ANG(8))+b(2,8)*sin(ANG(2)-ANG(8)))))*Sbase; %in MW
P82=((g(8,2)*(VOLT(8)^2))-(VOLT(8)*VOLT(2)*(g(8,2)*cos(ANG(8)-
ANG(2))+b(8,2)*sin(ANG(8)-ANG(2)))))*Sbase; %in MW
Q28=(((-imag(ysh28pu)-b(2,8))*(VOLT(2)^2))-
(VOLT(2)*VOLT(8)*(g(2,8)*sin(ANG(2)-ANG(8))-b(2,8)*cos(ANG(2)-
ANG(8)))))*Sbase; %in MVar
Q82=(((-imag(ysh28pu)-b(8,2))*(VOLT(8)^2))-
(VOLT(8)*VOLT(2)*(g(8,2)*sin(ANG(8)-ANG(2))-b(8,2)*cos(ANG(8)-
ANG(2)))))*Sbase; %in MVar
Ploss_28=P28+P82;
%PART G concluded

P_tot_losses=Ploss_12+Ploss_23+Ploss_34+Ploss_45+Ploss_56+Ploss_67+Ploss_78+P
loss_28+Ploss_36; %PART H
```

solve_lf.m

```
function [g_x] = solve_lf (X,G,B,PGD,QGD,PAR)

 format short g

  nx=PAR(1); nbus=PAR(2); U1=PAR(3); theta1=PAR(4); U3=PAR(5); U7=PAR(6);
  PGD2=PGD(1); PGD3=PGD(2); PGD4=PGD(3); PGD5=PGD(4); PGD6=PGD(5);
PGD7=PGD(6);PGD8=PGD(7);
```

```
  QGD2=QGD(1); QGD4=QGD(2); QGD5=QGD(3); QGD6=QGD(4); QGD8=QGD(5);

  theta2=X(1); theta3=X(2); theta4=X(3); theta5=X(4); theta6=X(5);
theta7=X(6); theta8=X(7);
  U2=X(8); U4=X(9); U5=X(10); U6=X(11); U8=X(12);

  ANG=[theta1 theta2 theta3 theta4 theta5 theta6 theta7 theta8];
  VOLT=[U1 U2 U3 U4 U5 U6 U7 U8];

  g_x=zeros(nx,1);

  for m=1:nbus
    for n=1:nbus
      PP(m,n)=VOLT(m)*VOLT(n)*(G(m,n)*cos(ANG(m)-ANG(n))+B(m,n)*sin(ANG(m)-
ANG(n)));
      QQ(m,n)=VOLT(m)*VOLT(n)*(G(m,n)*sin(ANG(m)-ANG(n))-B(m,n)*cos(ANG(m)-
ANG(n)));
    end
  end
  P=sum(PP')';
  Q=sum(QQ')';

  %Active Power Mismatch for PU and PQ buses

  g_x(1)=P(2)-PGD2;
  g_x(2)=P(3)-PGD3;
  g_x(3)=P(4)-PGD4;
  g_x(4)=P(5)-PGD5;
  g_x(5)=P(6)-PGD6;
  g_x(6)=P(7)-PGD7;
  g_x(7)=P(8)-PGD8;

  %Reactive Power Mismatch
  g_x(8)=Q(2)-QGD2;
  g_x(9)=Q(4)-QGD4;
  g_x(10)=Q(5)-QGD5;
  g_x(11)=Q(6)-QGD6;
  g_x(12)=Q(8)-QGD8;

end
```
