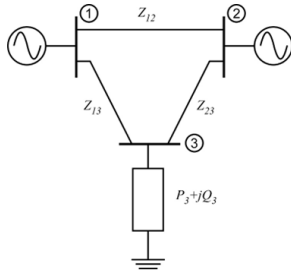# ECE 542   Homework #3

Due Date: Sunday 11:59 PM, Feb. 18, 2024

(100 points)

** Submit your (1) answer and (2) MATLAB & Power World files**

Bus data

Bus	Type	V	P_G	Q_G	P_L	Q_L
1	Slack	1.02	--	--	0.0	0.0
2	PV	1.00	0.5	--	0.0	0.0
3	PQ	--	0.0	0.0	1.2	0.5

Line data

i	j	R_{ij}	X_{ij}	B_{ij}
1	2	0.02	0.3	0.15
1	3	0.01	0.1	0.1
2	3	0.01	0.1	0.1

Knowns: Independent Unknowns:

Bus 3: $P_{3,inj}$ and $Q_{3,inj}$ V_3 and θ_3

Bus 2: $P_{2,inj}$ and V_2 θ_2

Bus 1: V_1 and θ_1 none

Figure 1. NR PF model for problems 1 ~ 3.

1. (40 **points**) Finish NR PF using MATLAB. Please show the result of each iteration.

Example)
- We need initial guesses for θ2, θ3, and V3
- Use a "flat start" in which all angles are initialized to 0 and all voltages are initialized to 1.0.
- Stopping condition $\varepsilon < 0.001$
- First iteration

$$\begin{bmatrix} -13.2859 & 9.9010 & 0.9901 \\ 9.9010 & -20.000 & -1.9604 \\ -0.9901 & 2.0000 & -19.4040 \end{bmatrix} \begin{bmatrix} \theta_2^1 - 0 \\ \theta_3^1 - 0 \\ V_3^1 - 1 \end{bmatrix} = -\begin{bmatrix} 0.5044 \\ -1.1802 \\ -0.2020 \end{bmatrix}$$

$$\text{Error} = \left\| \begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} \right\| = 1.1802$$

$$\begin{bmatrix} \theta_2^1 \\ \theta_3^1 \\ V_3^1 \end{bmatrix} = \begin{bmatrix} -0.0096 \\ -0.0621 \\ 0.9837 \end{bmatrix}$$

- Second iteration

$$\begin{bmatrix} -13.1597 & 9.7771 & 0.4684 \\ 9.6747 & -19.5280 & -0.7515 \\ -1.4845 & 3.0929 & -18.9086 \end{bmatrix} \begin{bmatrix} \theta_2^2 - (-0.0096) \\ \theta_3^2 - (-0.0621) \\ V_3^2 - 0.9837 \end{bmatrix} = -\begin{bmatrix} 0.0074 \\ -0.0232 \\ -0.0359 \end{bmatrix} \qquad \text{Error=}\left\| \begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} \right\| = 0.0359$$

$$\begin{bmatrix} \theta_2^2 \\ \theta_3^2 \\ V_3^2 \end{bmatrix} = \begin{bmatrix} -0.0101 \\ -0.0635 \\ 0.9816 \end{bmatrix}$$

- Third iteration

$$\begin{bmatrix} -13.1392 & 9.7567 & 0.4600 \\ 9.6530 & -19.4831 & -0.7213 \\ -1.4894 & 3.1079 & -18.8300 \end{bmatrix} \begin{bmatrix} \theta_2^3 - (-0.0101) \\ \theta_3^3 - (-0.0635) \\ V_3^3 - 0.9816 \end{bmatrix} = -\begin{bmatrix} 0.1717 \\ -0.5639 \\ -0.9084 \end{bmatrix} \times 10^{-4} \qquad \text{Error=}\left\| \begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} \right\| = 0.0009084$$

$$\begin{bmatrix} \theta_2^2 \\ \theta_3^2 \\ V_3^2 \end{bmatrix} = \begin{bmatrix} -0.0101 \\ -0.0635 \\ 0.9816 \end{bmatrix}$$

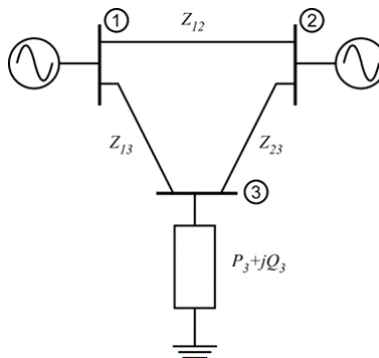2. (20 **points**) Calculate Dependent Unknowns using MATLAB.

Example)

$$P_{1,inj} = V_1 \sum_{k=1}^{3} V_k Y_{1k} \cos(-\theta_k - \varphi_{1k}) = 0.7087$$

$$Q_{1,inj} = -V_1 \sum_{k=1}^{3} V_k Y_{1k} \sin(-\theta_k - \varphi_{1k}) = 0.2806$$

$$Q_{2,inj} = -V_2 \sum_{k=1}^{3} V_k Y_{2k} \sin(\theta_2 - \theta_k - \varphi_{2k}) = -0.0446$$

3. (10 **points**) Calculate Power Flows using MATLAB and show the results on the single-line diagram.

Example)

$P_{i,j}, Q_{i,j}, I_{i,j}$ of all lines

$$I_{i,j} = \frac{V_i - V_j}{Z_{i,j}}$$

$$S_{i,j} = V \times I_{i,j}^* = P_{i,j} + jQ_{i,j}$$

4. (30 **points**) Design IEEE 9 bus system using Power World simulator, and then check the PF result with MATPOWER.

Bus No.	Bus Type	Voltage (P.U.)	Voltage (kV)	Generation		Load	
				MW	Mvar	MW	Mvar
1	Slack	1.04	16.5 kV	0	0	0	0
2	PV	1.025	18.0 kV	163	6.7	0	0
3	PV	1.025	13.8 kV	85	-10.9	0	0
4	PQ	1	230 kV	0	0	0	0
5	PQ	1	230 kV	0	0	125	50
6	PQ	1	230 kV	0	0	90	30
7	PQ	1	230 kV	0	0	0	0
8	PQ	1	230 kV	0	0	100	35
9	PQ	1	230 kV	0	0	0	0
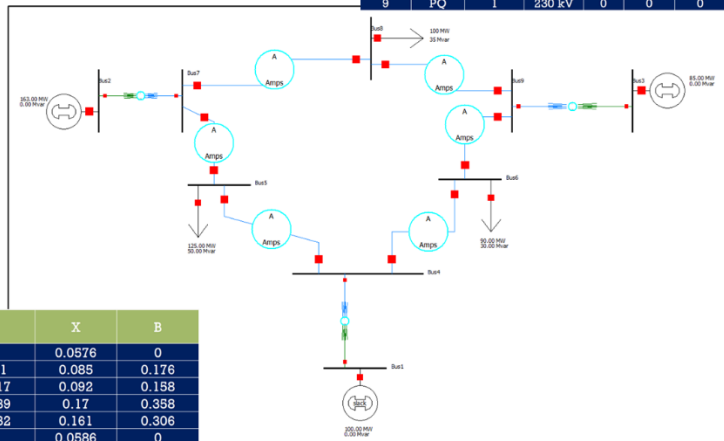
Line From	Line To	R	X	B
1	4	0	0.0576	0
4	5	0.01	0.085	0.176
4	6	0.017	0.092	0.158
6	9	0.039	0.17	0.358
5	7	0.032	0.161	0.306
9	3	0	0.0586	0
7	2	0	0.0625	0
9	8	0.0119	0.1008	0.209
7	8	0.0085	0.072	0.149

```
BUS     1 Bus1      16.5  MW   Mvar    MVA  % 1.0400  0.00  1 1
GENERATOR 1          71.64  27.11R  76.6
TO      4 Bus4    1  71.64  27.11  76.6  0  1.0000TA  0.0

BUS     2 Bus2      18.0  MW   Mvar    MVA  % 1.0250  9.28  1 1
GENERATOR 1          163.00  6.68R  163.1
TO      7 Bus7    1  163.00  6.68  163.1  0  1.0000TA  0.0

BUS     3 Bus3      13.8  MW   Mvar    MVA  % 1.0250  4.66  1 1
GENERATOR 1          85.00  -10.84R  85.7
TO      9 Bus9    1  85.00  -10.84  85.7  0  1.0000NT  0.0

BUS     4 Bus4     230.0  MW   Mvar    MVA  % 1.0258  -2.22  1 1
TO      1 Bus1    1  -71.64  -23.99  75.6  0  1.0000NT  0.0
TO      5 Bus5    1  40.94  22.97  46.9  0
TO      6 Bus6    1  30.70  1.02  30.7  0

BUS     5 Bus5     230.0  MW   Mvar    MVA  % 0.9956  -3.99  1 1
LOAD 1              125.00  50.00  134.6 DistGen  0.00  0.00  0.0
TO      4 Bus4    1  -40.68  -38.66  56.1  0
TO      7 Bus7    1  -84.32  -11.34  85.1  0

BUS     6 Bus6     230.0  MW   Mvar    MVA  % 1.0126  -3.69  1 1
LOAD 1              90.00  30.00  94.9 DistGen  0.00  0.00  0.0
TO      4 Bus4    1  -30.54  -16.53  34.7  0
TO      9 Bus9    1  -59.46  -13.47  61.0  0

BUS     7 Bus7     230.0  MW   Mvar    MVA  % 1.0258  3.72  1 1
TO      2 Bus2    1  -163.00  9.16  163.3  0  1.0000NT  0.0
TO      5 Bus5    1  86.62  -8.35  87.0  0
TO      8 Bus8    1  76.38  -0.80  76.4  0

BUS     8 Bus8     230.0  MW   Mvar    MVA  % 1.0159  0.73  1 1
LOAD 1              100.00  35.00  105.9 DistGen  0.00  0.00  0.0
TO      7 Bus7    1  -75.91  -10.70  76.7  0
TO      9 Bus9    1  -24.10  -24.30  34.2  0

BUS     9 Bus9     230.0  MW   Mvar    MVA  % 1.0323  1.97  1 1
TO      3 Bus3    1  -85.00  14.94  86.3  0  1.0000TA  0.0
TO      6 Bus6    1  60.82  -18.06  63.4  0
TO      8 Bus8    1  24.19  3.12  24.4  0
```

```
=================================================
|  Bus Data                                     |
=================================================
Bus      Voltage        Generation       Load
#   Mag(pu) Ang(deg)  P (MW)  Q (MVAr)  P (MW)  Q (MVAr)
---- ------- -------- ------- --------  ------- --------
 1  1.040   0.000*   71.64   27.05      -        -
 2  1.025   9.280    163.00  6.65       -        -
 3  1.025   4.665    85.00   -10.86     -        -
 4  1.026   -2.217     -        -       -        -
 5  0.996   -3.989     -        -      125.00   50.00
 6  1.013   -3.687     -        -       90.00   30.00
 7  1.026   3.720      -        -        -        -
 8  1.016   0.728      -        -      100.00   35.00
 9  1.032   1.967      -        -        -        -
                     -------  -------  ------- -------
            Total:   319.64   22.84    315.00  115.00

=================================================
|  Branch Data                                  |
=================================================
Brnch From  To   From Bus Injection  To Bus Injection   Loss (I^2 * Z)
#   Bus   Bus  P (MW)  Q (MVAr)  P (MW)  Q (MVAr)  P (MW)  Q (MVAr)
---- ----- ---- ------- -------- ------- -------- ------- --------
 1   1    4    71.64   27.05    -71.64   -23.92   0.000    3.12
 2   4    5    40.94   22.89    -40.68   -38.69   0.258    2.19
 3   6    4   -30.54   -16.54    30.70    1.03    0.166    0.90
 4   9    6    60.82   -18.07   -59.46   -13.46   1.354    5.90
 5   9    3   -85.00   14.96    85.00   -10.86   0.000    4.10
 6   8    9   -24.10   -24.30    24.18    3.12    0.088    0.75
 7   7    8    76.38   -0.80    -75.90   -10.70   0.475    4.03
 8   2    7    163.00   6.65   -163.00   9.18    0.000   15.83
 9   5    7   -84.32   -11.31    86.62   -8.38    2.300   11.57
                                                ------- -------
                                        Total:   4.641   48.38
```