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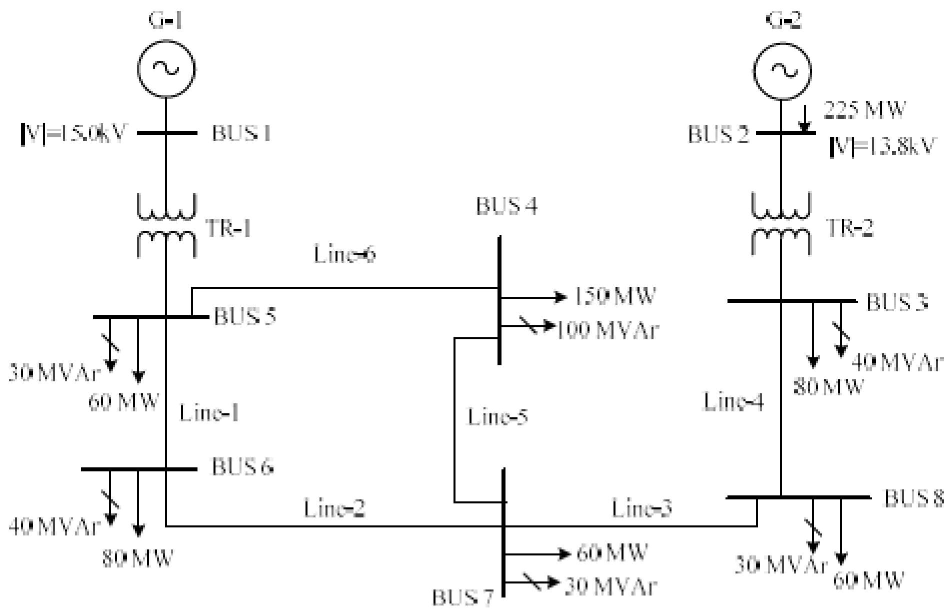
Fundamentals of Power Systems Term Project
Power System Calculations by Matpower



Generators

G-1: 300 MVA, 15.0 kV
G-2: 250 MVA, 13.8 kV

Transformers

TR-1: 300 MVA, 15.0 kV/230 kV, X=0.1 pu
TR-2: 250 MVA, 13.8 kV/230 kV, X=0.1 pu

Lines

All lines 230kV, line resistance is 0.00028 pu/km and line reactance is 0.0019 pu/km for 250 MVA and 230.0 kV base values in the zone of the lines.
Line lengths are Line-1=20 km, Line-2=60 km, Line-3=40 km, Line-4=20 km, Line-5=25 km, Line-6=60 km.

System Base Quantities

S_{BASE}=250 MVA (three-phase) and V_{BASE}=230.0 kV in the zone of Line-2

Generator, transformer, line data information, and one-line diagram of eight bus system are given above.

The first attempt to solve this type of question is just writing down the given values. F.e: S_{base}=250 MVA so

```
%% system MVA base
%already given in the question
mpc.baseMVA = 250;
```

as a code.

Matpower library is so well-made that it enables us to write down the matrices, bus types in better shape, and more tidy way.

To solve this question, I used case9 as a reference which is a given case from matpower 6.0, and altered it for the question. For each matrix, 1 row is erased since the question has 8 bus and 2 generator

Caseformat class had significant role to continue the question. According to caseformat class;

```
%   Bus Data Format
%       1   bus number (positive integer)
%       2   bus type
%               PQ bus          = 1
%               PV bus          = 2
%               reference bus   = 3
%               isolated bus    = 4
%       3   Pd, real power demand (MW)
%       4   Qd, reactive power demand (MVAr)
%       5   Gs, shunt conductance (MW demanded at V = 1.0 p.u.)
%       6   Bs, shunt susceptance (MVAr injected at V = 1.0 p.u.)
%       7   area number, (positive integer)
%       8   Vm, voltage magnitude (p.u.)
%       9   Va, voltage angle (degrees)
%   (-)     (bus name)
%       10  baseKV, base voltage (kV)
%       11  zone, loss zone (positive integer)
%   (+) 12  maxVm, maximum voltage magnitude (p.u.)
%   (+) 13  minVm, minimum voltage magnitude (p.u.)
```

Busses and other openings are given as comments in this class. After writing down the bus types according to this class the rest of the values are given in the question.

The matrix is:

```
%   bus_i   type    Pd  Qd  Gs  Bs  area    Vm  Va  baseKV  zone    Vmax
Vmin
%already given in question, just finding out the bus types
mpc.bus = [
    1   3   0   0   0   0   1   1   0   15      1   1.1 0.9;
    2   2   0   0   0   0   1   1   0   13.8    1   1.1 0.9;
    3   1   80  40  0   0   1   1   0   230     1   1.1 0.9;
    4   1   150 100 0   0   1   1   0   230     1   1.1 0.9;
    5   1   60  30  0   0   1   1   0   230     1   1.1 0.9;
    6   1   80  40  0   0   1   1   0   230     1   1.1 0.9;
    7   1   60  30  0   0   1   1   0   230     1   1.1 0.9;
    8   1   60  30  0   0   1   1   0   230     1   1.1 0.9;

];
```

Real power demand(Pd) and reactive power demand(Qd) can be observed in the system.

Shunt susceptance and shunt capacitance are not given in question so Bs = Gs = 0

```
===============================================================================
|     Bus Data                                                                |
===============================================================================
 Bus      Voltage          Generation             Load
  #   Mag(pu) Ang(deg)   P (MW)   Q (MVAr)   P (MW)   Q (MVAr)
----- ------- --------  --------  --------  --------  --------
    1  1.000    0.000*   268.07    203.99       -         -
    2  1.000   -0.268    225.00    163.16       -         -
    3  0.939   -5.767       -         -       80.00     40.00
    4  0.887   -9.372       -         -      150.00    100.00
    5  0.925   -6.660       -         -       60.00     30.00
    6  0.911   -7.734       -         -       80.00     40.00
    7  0.898   -8.688       -         -       60.00     30.00
    8  0.921   -7.091       -         -       60.00     30.00
                        --------  --------  --------  --------
               Total:    493.07    367.15    490.00    270.00
```

Figure 1. Bus Data Result

The total 493,07 MW gives the total demand, so the total Pmax for G1 and G2 should be greater. And 250+300 = 550 is greater than 493,07. The generator matrix with respect to those demand values is;

```
%% generator data
%%Changing Pmax only affects Total Gen capacity and On-line capacity
%   bus Pg   Qg   Qmax    Qmin    Vg   mBase   status  Pmax    Pmin    Pc1 Pc2
Qc1min  Qc1max  Qc2min  Qc2max  ramp_agc    ramp_10 ramp_30 ramp_q  apf
mpc.gen = [
    1   0    0    300  -300    1    100 1    250  10   0    0    0    0    0    0    0
0   0    0    0;
    2   225  0    300  -300    1    100 1    300  10   0    0    0    0    0    0    0
0   0    0    0;
];
```

Since changing Pmax only affects the total generator capacity and on-line capacity, calculating demanding value can be started by giving random numbers to the Pmax. After finding the demanding value, the correct total generator capacity and on-line capacity can be found as I did in here.

Generators only supply real power, in lines there may be reactive power too but the reactive power does not supply by generators.

Later on; the branch data matrix is written according to the given information. Transformer reactances were already given, only thing to do in here is calculating resistances and reactances with respect to line lengths. The calculations are shown below:

fbus   tbus

R and X calculations are done by line length and given unit/km for reactance and ressistance

1	5	r= 0	x=0.1(already given)
4	5	r=60*0.00028=0.0168,	x=60*0.0019=0.114
5	6	r=20**0.00028=0.0056,	x=20*0.0019=0.038
4	7	r=25*0.00028 =0.007,	x=25*0.0019=0.475
6	7	r=60*0.00028=0.0168,	x=60*0.0019=0.114

7	8	r=40*0.00028=0.0112,	x=40*0.0019=0.076
8	3	r=20**0.00028=0.0056,	x=20*0.0019=0.038
2	3	r=0	x=0.1(already given)

And after finding some explanation of the abbreviations in caseformat class which are;

```
Branch Data Format
%       1   f, from bus number
%       2   t, to bus number
%   (-)     (circuit identifier)
%       3   r, resistance (p.u.)
%       4   x, reactance (p.u.)
%       5   b, total line charging susceptance (p.u.)
%       6   rateA, MVA rating A (long term rating), set to 0 for unlimited
%       7   rateB, MVA rating B (short term rating), set to 0 for unlimited
%       8   rateC, MVA rating C (emergency rating), set to 0 for unlimited
%       9   ratio, transformer off nominal turns ratio ( = 0 for lines )
%           (taps at 'from' bus, impedance at 'to' bus,
%            i.e. if r = x = b = 0, then ratio = Vf / Vt)
%       10  angle, transformer phase shift angle (degrees), positive =>
delay
%   (-)     (Gf, shunt conductance at from bus p.u.)
%   (-)     (Bf, shunt susceptance at from bus p.u.)
%   (-)     (Gt, shunt conductance at to bus p.u.)
%   (-)     (Bt, shunt susceptance at to bus p.u.)
%       11  initial branch status, 1 - in service, 0 - out of service
%   (2) 12  minimum angle difference, angle(Vf) - angle(Vt) (degrees)
%   (2) 13  maximum angle difference, angle(Vf) - angle(Vt) (degrees)
%           (The voltage angle difference is taken to be unbounded below
%            if ANGMIN < -360 and unbounded above if ANGMAX > 360.
%            If both parameters are zero, it is unconstrained.)
```

According to the branch format, the branch data matrix is;

```
%% branch data
%   fbus    tbus    r   x   b   rateA   rateB   rateC   ratio   angle
status  angmin  angmax
mpc.branch = [
    1   5   0       0.1     0   0   0   0   0   0   1   -360    360;
    2   3   0       0.1     0   0   0   0   0   0   1   -360    360;
    4   5   0.0168  0.114   0   0   0   0   0   0   1   -360    360;
    4   7   0.007   0.0475  0   0   0   0   0   0   1   -360    360;
    5   6   0.0056  0.038   0   0   0   0   0   0   1   -360    360;
    6   7   0.0168  0.114   0   0   0   0   0   0   1   -360    360;
    7   8   0.0112  0.076   0   0   0   0   0   0   1   -360    360;
    8   3   0.0056  0.038   0   0   0   0   0   0   1   -360    360;


];
```

Since I used case 9 as a reference, generator cost data was also given in case9. But in our case, it does not need an evaluation, so the given cost data matrix for case9 is changed into comment since we do not know the costs for case8

```
%% generator cost data
%   1   startup shutdown    n   x1  y1  ... xn  yn
%   2   startup shutdown    n   c(n-1)  ... c0
%mpc.gencost = [
    %2  1500    0   3   0.11    5   150;
     %2  2000    0   3   0.085   1.2 600;
     %2  3000    0   3   0.1225  1   335;
%];
```

In mpoption class, the maximum iteration for Newton's method is given as 10

```
%pf.nr.max_it             10          maximum number of iterations for
%                                        Newton's method
```

And our tolerance is 10^{-8}

Up to know, the results are shown partly. After running the case, the whole result can be observed in the Results section

Results

To check out the matrix rows and columns, I run the case. The matrix rows and columns can be observed in figure 2

```
>> case8_1505421

ans =

  struct with fields:

    version: '2'
    baseMVA: 250
        bus: [8×13 double]
        gen: [2×21 double]
     branch: [8×13 double]
```

Figure 2. Row and collumn check

We can see the information flow of our system. According to that information, if the system has faults such as line losses, it can be fixed since the reaction of the system can be observed via Matpower results.

```
>> runpf('case8_1505421')

MATPOWER Version 6.0, 16-Dec-2016 -- AC Power Flow (Newton)

Newton's method power flow converged in 4 iterations.

Converged in 0.22 seconds
================================================================================
|     System Summary                                                           |
================================================================================

How many?                How much?              P (MW)            Q (MVAr)
---------------------    -------------------  -------------  -----------------
Buses              8     Total Gen Capacity     550.0         -600.0 to 600.0
Generators         2     On-line Capacity       550.0         -600.0 to 600.0
Committed Gens     2     Generation (actual)    493.1              367.2
Loads              6     Load                   490.0              270.0
  Fixed            6       Fixed                490.0              270.0
  Dispatchable     0       Dispatchable          -0.0 of -0.0       -0.0
Shunts             0     Shunt (inj)            -0.0                0.0
Branches           8     Losses (I^2 * Z)        3.07              97.15
Transformers       0     Branch Charging (inj)     -                0.0
Inter-ties         0     Total Inter-tie Flow     0.0               0.0
Areas              1

                          Minimum                      Maximum
                 -------------------------  --------------------------------
Voltage Magnitude   0.887 p.u. @ bus 4          1.000 p.u. @ bus 1
Voltage Angle      -9.37 deg   @ bus 4          0.00 deg   @ bus 1
P Losses (I^2*R)             -                  1.02 MW    @ line 4-5
Q Losses (I^2*X)             -                 45.39 MVAr  @ line 1-5
```

Figure 3. Result page 1

Bus Data		

Bus #	Voltage Mag(pu)	Voltage Ang(deg)	Generation P (MW)	Generation Q (MVAr)	Load P (MW)	Load Q (MVAr)
1	1.000	0.000*	268.07	203.99	-	-
2	1.000	-0.268	225.00	163.16	-	-
3	0.939	-5.767	-	-	80.00	40.00
4	0.887	-9.372	-	-	150.00	100.00
5	0.925	-6.660	-	-	60.00	30.00
6	0.911	-7.734	-	-	80.00	40.00
7	0.898	-8.688	-	-	60.00	30.00
8	0.921	-7.091	-	-	60.00	30.00
		Total:	493.07	367.15	490.00	270.00

Branch Data		

Brnch #	From Bus	To Bus	From Bus Injection P (MW)	From Bus Injection Q (MVAr)	To Bus Injection P (MW)	To Bus Injection Q (MVAr)	Loss (I^2 * Z) P (MW)	Loss (I^2 * Z) Q (MVAr)
1	1	5	268.07	203.99	-268.07	-158.60	0.000	45.39
2	2	3	225.00	163.16	-225.00	-132.26	0.000	30.90
3	4	5	-93.54	-56.99	94.57	63.94	1.024	6.95
4	4	7	-56.46	-43.01	56.64	44.23	0.179	1.22
5	5	6	113.51	64.66	-113.06	-61.63	0.447	3.03
6	6	7	33.06	21.63	-32.94	-20.77	0.126	0.86
7	7	8	-83.70	-53.46	84.25	57.17	0.548	3.72
8	8	3	-144.25	-87.17	145.00	92.26	0.750	5.09
						Total:	3.075	97.15

Figure 4. Result page 2

As shown in Figure 4, Bus Data information can be observed such as voltage magnitude as p.u and angle as a degree. In bus data information, the 1st bus has the maximum voltage magnitude and angle since it is a swing bus, but for the 4th bus, the voltage and degree can be taken as the minimum value. And for the Branch Data, the power losses can be observed for each bus. In the 1st branch from bus 1 to bus 5, we can see the greatest reactive power loss which is 45.39MVAr according to the given branch data, meanwhile, the 3rd branch which is from bus 4 to 5 has the highest active power loss which is 1.025 MW