ACTIVE AND REATIVE POWER FLOWS IN A POWER SYSTEM

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	GROUP	:04
	PRACTICAL DATE	:08/10/2024
	SUBMISSION DATE:	22/10/2024

PRELIMINARY WORK

(1) When unity power factor occurs apparent power and the active power, they are same and there is no reactive power. When considering the utility side with unity power factor transmission lossess are zero. Therefore the power transmission capacity is high and it decreases the operating cost.
Therefore, in consumer side electricity bill is reduced.

(2) Invertor based generators mostly used in solar power (solar pv) and wind power. These powers depend on the weather conditions. Because of that when generation planning the weather prediction also should be considered. Sudden change of the weather can lead to the huge supply change which makes system unstable. These generators cannot deal with sudden demand and supply changes and it will make power and frequency management complex.

(3) If sudden drop of the large power generation increases the demand of the other generators and they also couldn't fulfil the demand that may cause for all the grid will unstable and trip off.
To prevent such kind of situations load shedding can be used. that means reduce the demand. It may cause for blackout for several areas. As long term solution the auxiliary power generators can be used.

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(4) Table 01: Differencess between gauss seidel method and the Newton raphson method.

Gauss Seidel Method	Newton Raphson Method
Require less computational power	Require high computational power
Can apply linear equations only	Can apply to solve both linear and non lienear equations.
Slower rate of convergence	Fast convergent rate.

Suggesions to improve the efficiency of the Newton Raphson Method

- Use multicore processors and parallel processing
- Set close initial value.
- Use fast decoupled load flow method.

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(5) $Y_{12} = -5j$

$Y_{13} = -10j$

$Y_{14} = -6.67j$ y-admitance

$Y_{23} = -6.67j$

$Y_{24} = -10j$

$$Y = \begin{bmatrix} (y_{10}+y_{12}+y_{13}+y_{14}) & -y_{12} & -y_{13} & -y_{14} \\ -y_{12} & (y_{20}+y_{21}+y_{23}+y_{24}) & -y_{23} & -y_{24} \\ -y_{13} & -y_{23} & (y_{30}+y_{13}+y_{23}+y_{34}) & -y_{34} \\ -y_{14} & -y_{24} & -y_{34} & (y_{40}+y_{14}+y_{24}+y_{34}) \end{bmatrix}$$

$$Y = \begin{bmatrix} -21.67j & +5j & +10j & +6.67j \\ +5j & -21.67j & +6.67j & +10j \\ +10j & +6.67j & -16.67j & 0 \\ +6.67j & +10j & 0 & +16.67j \end{bmatrix}$$

power inject matrix(P) = $\begin{bmatrix} P_1 \\ P_2 \\ P_3 \\ P_4 \end{bmatrix} = \begin{pmatrix} 1 \\ 3 \\ -2 \\ -2 \end{pmatrix}$

phase angle matrix $(\theta) = \begin{pmatrix} \theta_1 \\ \theta_2 \\ \theta_3 \\ \theta_4 \end{pmatrix}$

Power injection can be calculated using,

$B = -I_m(y_{ij})$ $P = B\theta$

$$\begin{pmatrix} 1 \\ 3 \\ -2 \\ -2 \end{pmatrix} = \begin{pmatrix} +21.67j & -5j & -10j & -6.67j \\ -5j & +21.67j & -6.67j & -10j \\ -10j & -6.67j & +16.67j & 0 \\ -6.67j & -10j & 0 & +16.667j \end{pmatrix} \begin{pmatrix} \theta_1 \\ \theta_2 \\ \theta_3 \\ \theta_4 \end{pmatrix}$$

$$\begin{pmatrix} \theta_1 \\ \theta_2 \\ \theta_3 \\ \theta_4 \end{pmatrix} = \begin{pmatrix} +21.67j & -5j & -10j & -6.67j \\ -5j & +21.67j & -6.67j & -10j \\ -10j & -6.67j & +16.67j & 0 \\ -6.67j & -10j & 0 & +16.67j \end{pmatrix} \begin{bmatrix} -1 \\ 3 \\ -2 \\ -2 \end{bmatrix}$$

Assume that $\theta_1 = 0^\circ$

$$\begin{bmatrix} \theta_2 \\ \theta_3 \\ \theta_4 \end{bmatrix} = \begin{bmatrix} 21.67 & -6.67 & -10 \\ -6.67 & 16.67 & 0 \\ -10 & 0 & 16.67 \end{bmatrix}^{-1} \begin{bmatrix} 3 \\ -2 \\ -2 \end{bmatrix}$$

$$\begin{bmatrix} \theta_2 \\ \theta_3 \\ \theta_4 \end{bmatrix} = \begin{bmatrix} 0.0769 & 0.0307 & 0.0461 \\ 0.0307 & 0.0723 & 0.0184 \\ 0.0461 & 0.0184 & 0.0876 \end{bmatrix} \begin{bmatrix} 3 \\ -2 \\ -2 \end{bmatrix}$$

$$\begin{bmatrix} \theta_2 \\ \theta_3 \\ \theta_4 \end{bmatrix} = \begin{bmatrix} -0.0769 \\ -0.0892 \\ -0.0738 \end{bmatrix}$$

$$\theta_i = -|V_i| \sum_{\substack{k=1 \\ k \neq i}}^{n} |V_k||Y_{ik}| \cos(\theta_i - \theta_k) + |V_1|^2 |Y_1|$$

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$$Q_1 = -5\cos(0.0769) - 10\cos(0.0892) - 6.67\cos(0.0738) + 21.67 = 0.0726 \text{ pu}$$

$$Q_2 = -5\cos(0.0769) - 6.67\cos(0.1661) - 10\cos(0.1507) + 21.67 = 0.2229 \text{ pu}$$

$$Q_3 = -10\cos(-0.0892) - 6.67\cos(-0.01661) + 16.67 = 0.1315 \text{ pu}$$

$$Q_4 = -6.67\cos(-0.0738) - 10\cos(-0.1507) + 16.67 = 0.1315 \text{ pu}$$

Reactive power generation

$$Q_{G1} = 0.0725 + 0.5 = 0.5726 \text{ pu}$$
$$Q_{G2} = 0.2229 + 0.4 = 0.6229 \text{ pu}$$
$$Q_{G3} = 0.1315 + 1.0 = 1.1315 \text{pu}$$
$$Q_{G4} = 0.1315 + 1.0 = 1.1315 \text{pu}$$

$$P_{ik} = \frac{|V_i||V_k|}{x_{ik}} \sin(\theta_i - \theta_k)$$

$$P_{12} = \frac{1}{0.2} \sin(0 - 0.0789) = -0.3841$$

$$P_{13} = \frac{1}{0.1} \sin(0 + 0.0892) = 0.8908$$

$$P_{14} = \frac{1}{0.15} \sin(0 + 0.0738) = 0.4915$$

$$P_{23} = \frac{1}{0.15} \sin(0.0769 + 0.0692) = 1.1022$$

$$P_{24} = \frac{1}{0.1} \sin(0.0769 + 0.0738) = 1.5013$$

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$$Q_{ik} = \frac{|V_i|^2}{X_{ik}} - \frac{|V_i||V_k|}{X_{ik}} \cos(\theta_i - \theta_k)$$

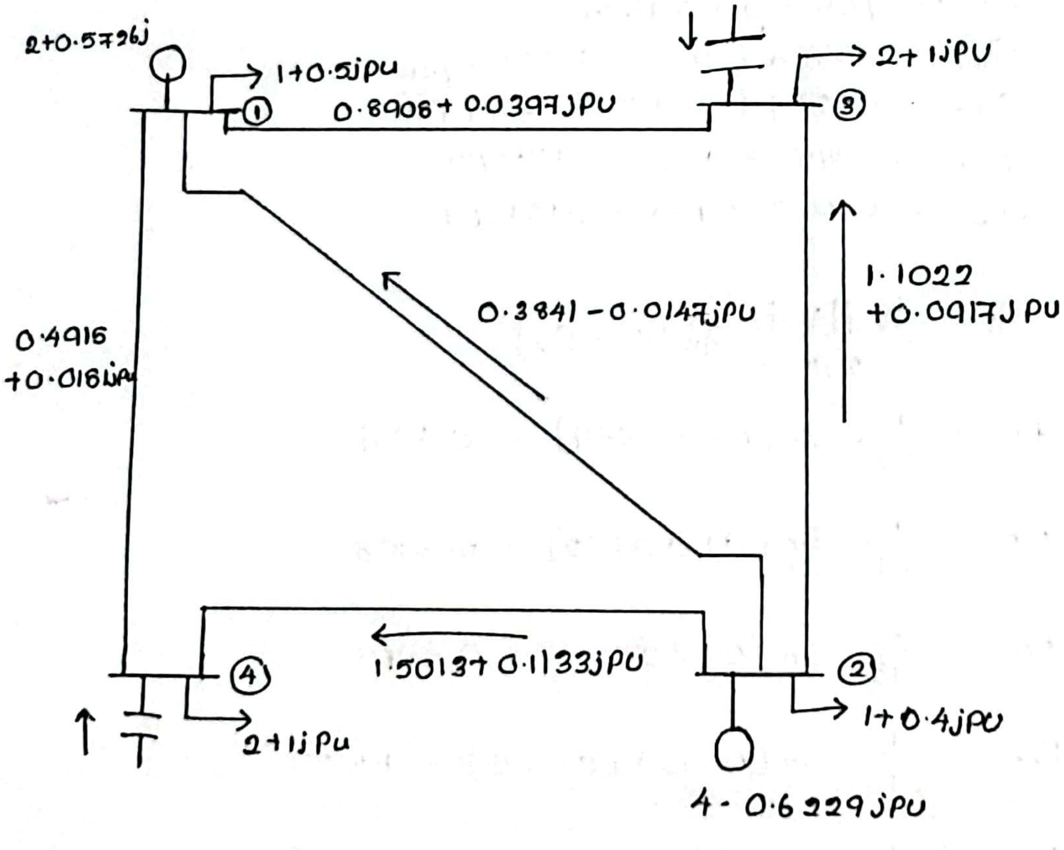
$$Q_{12} = \frac{1}{0.2} - \frac{1}{0.2} \cos(0-0.0769) = 0.0147.$$

$$Q_{13} = \frac{1}{0.1} - \frac{1}{0.1} \cos(0+0.0892) = 0.0397$$

$$Q_{14} = \frac{1}{0.15} - \frac{1}{0.15} \cos(0+0738) = 0.0161$$

$$Q_{23} = \frac{1}{0.15} - \frac{1}{0.15} \cos(0.0769+0.0892) = 0.0917.$$

$$Q_{24} = \frac{1}{0.1} - \frac{1}{0.1} \cos(0.0769+0.738) = 0.1133$$



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PRACTICAL WORK

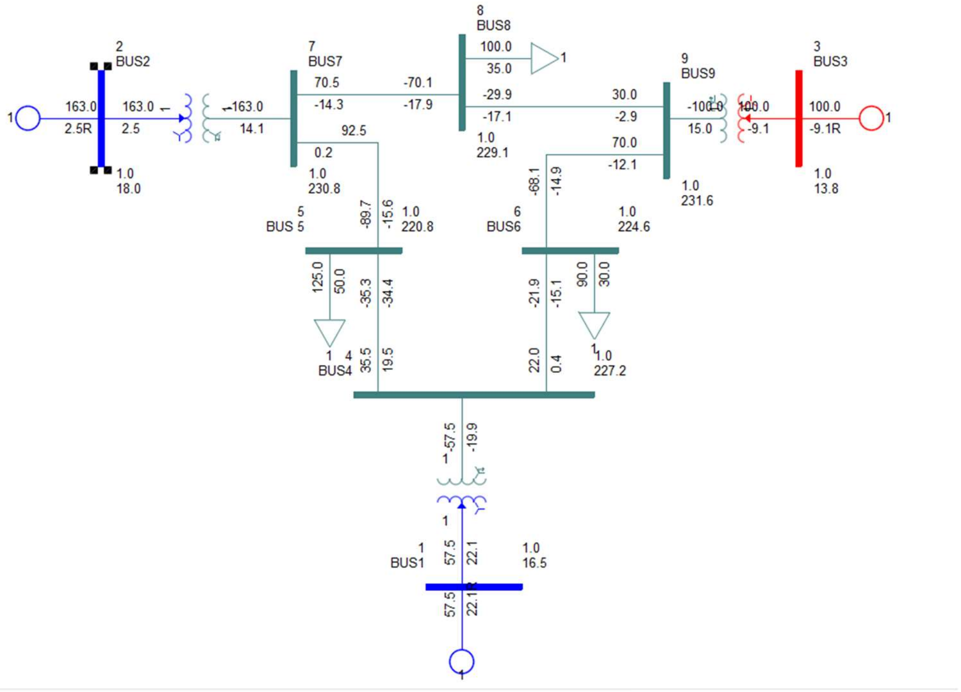

Figure 01: PSSE diagram

1.

```
 ITER       DELTAP      BUS        DELTAQ      BUS       DELTA/V/      BUS       DELTAANG      BUS
  0         1.6300(     2     )    0.3320(     7     )
                                                          0.02555(     5     )   0.19362(      2     )
  1         0.0364(     5     )    0.1759(     7     )
                                                          0.01470(     5     )   0.00726(      5     )
  2         0.0013(     5     )    0.0020(     7     )
                                                          0.00023(     5     )   0.00014(      5     )
  3         0.0000(     5     )    0.0000(     5     )

Reached tolerance in 3 iterations

Largest mismatch:       0.00 MW      0.00 Mvar       0.00 MVA at bus 5 [BUS 5       230.00]
System total absolute mismatch:                      0.00 MVA

SWING BUS SUMMARY:
  BUS#-SCT X-- NAME --X BASKV       PGEN     PMAX     PMIN      QGEN     QMAX    QMIN
     1      BUS1        16.500      57.5    100.0     10.0      22.1    300.0  -300.0
```

Figure 02: Readings when the generator 3 is switched on

Active power of the slack bus bar =57.5MW

Reactive power of the slack bus bar=22.1MVar

2.

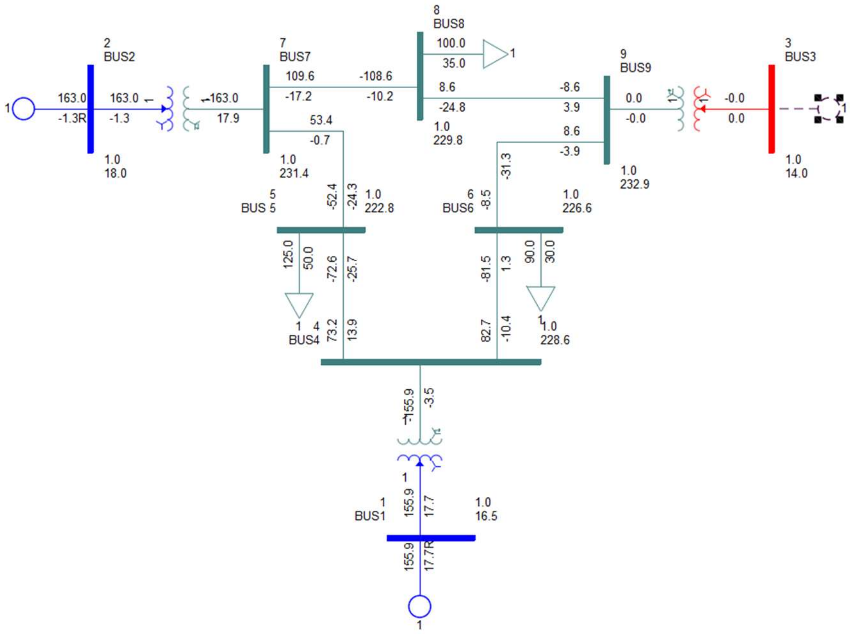

Figure 03: diagram when switched off the generator 3

```
ITER       DELTAP      BUS        DELTAQ      BUS       DELTA/V/      BUS        DELTAANG      BUS
 0         1.6300(     2    )     0.3320(     7    )
                                                         0.03258(     9    )    0.16394(      6    )
 1         0.0314(     8    )     0.1567(     7    )
                                                         0.01892(     9    )    0.00687(      2    )
 2         0.0010(     5    )     0.0022(     7    )
                                                         0.00036(     9    )    0.00020(      5    )
 3         0.0000(     4    )     0.0000(     7    )

Reached tolerance in 3 iterations

Largest mismatch:      -0.00 MW       0.00 Mvar       0.00 MVA at bus 4 [BUS4        230.00]
System total absolute mismatch:                       0.00 MVA

SWING BUS SUMMARY:
  BUS#-SCT X-- NAME --X BASKV      PGEN     PMAX     PMIN      QGEN     QMAX    QMIN
     1     BUS1        16.500     155.9*   100.0    10.0      17.7     300.0  -300.0
```

Figure 04:readings when the generator 3 is switched off

Active power of the slack bus bar =155.9MW

Reactive power of the slack bus bar = 17.7MVar

3. When the generator 3 is switched off active power is increased from 57.5MW to 155.9MW. Reactive power decreased from 22.1MVar to 17.7MVar. Changing of the reactive power value is not much larger than the active power change. When one generator is turned off remaining two busses should supply the demand of the system. Therefore, the active power of the slack bus bar has increased.

4.a) gauss-seidel method

```
ITER DELTAV/TOL X----------- AT BUS -----------X  REAL(DELTAV)  IMAG(DELTAV)
   1  941.503       3      [BUS3         13.800]   0.2008E-01   -0.9198E-01
   2  797.200       9      [BUS9         230.00]   0.1107E-01   -0.7895E-01
   3  522.590       8      [BUS8         230.00]   0.5312E-02   -0.5199E-01
   4  375.548       7      [BUS7         230.00]   0.5895E-02   -0.3709E-01
   5  607.583       2      [BUS2         18.000]   0.1732E-01   -0.5824E-01
   6  411.117       2      [BUS2         18.000]  -0.3337E-02   -0.4098E-01
   7  237.710       2      [BUS2         18.000]   0.4224E-02   -0.2339E-01
   8  101.653       2      [BUS2         18.000]  -0.2528E-02   -0.9846E-02
   9   87.482       2      [BUS2         18.000]   0.2179E-02   -0.8473E-02
  10   66.843       2      [BUS2         18.000]  -0.9853E-03   -0.6611E-02
  11   50.535       2      [BUS2         18.000]   0.7830E-03   -0.4992E-02
  12   20.730       2      [BUS2         18.000]  -0.6137E-03   -0.1980E-02
  13    8.458       2      [BUS2         18.000]   0.3139E-03   -0.7854E-03
  14    6.162       2      [BUS2         18.000]  -0.1760E-03   -0.5906E-03
  15    5.986       2      [BUS2         18.000]   0.1353E-03   -0.5831E-03
  16    2.897       2      [BUS2         18.000]  -0.9422E-04   -0.2739E-03
  17    0.874       2      [BUS2         18.000]   0.4416E-04   -0.7544E-04

Reached tolerance in 17 iterations

Largest mismatch:       0.03 MW     -0.04 Mvar       0.05 MVA at bus 7 [BUS7        230.00]
System total absolute mismatch:                      0.23 MVA

SWING BUS SUMMARY:
  BUS#-SCT X-- NAME --X BASKV       PGEN     PMAX     PMIN      QGEN     QMAX    QMIN
     1      BUS1        16.500     155.9*   100.0     10.0      17.7     300.0  -300.0
```

Figure 05:readings of gauss-seidel method

b) modified gauss-seidel method

```
ITER DELTAV/TOL X----------- AT BUS -----------X  REAL(DELTAV)  IMAG(DELTAV)
   1 1365.839       2      [BUS2         18.000]  -0.1385E-01    0.1359E+00
   2  582.453       9      [BUS9         230.00]  -0.4005E-02   -0.5811E-01
   3  354.840       9      [BUS9         230.00]  -0.9830E-02   -0.3410E-01
   4  216.987       9      [BUS9         230.00]  -0.6185E-02   -0.2080E-01
   5  147.617       9      [BUS9         230.00]  -0.5558E-02   -0.1368E-01
   6  106.521       7      [BUS7         230.00]  -0.1068E-02   -0.1060E-01
   7   88.077       2      [BUS2         18.000]  -0.2121E-03   -0.8805E-02
   8   70.025       2      [BUS2         18.000]   0.7016E-03   -0.6967E-02
   9   55.882       2      [BUS2         18.000]  -0.2956E-04   -0.5588E-02
  10   43.722       2      [BUS2         18.000]   0.2767E-03   -0.4363E-02
  11   34.343       2      [BUS2         18.000]   0.1240E-04   -0.3434E-02
  12   26.706       2      [BUS2         18.000]   0.1137E-03   -0.2668E-02
  13   20.828       2      [BUS2         18.000]   0.1717E-04   -0.2083E-02
  14   16.157       2      [BUS2         18.000]   0.4923E-04   -0.1615E-02
  15   12.559       2      [BUS2         18.000]   0.1371E-04   -0.1256E-02
  16    9.734       2      [BUS2         18.000]   0.2301E-04   -0.9731E-03
  17    7.554       2      [BUS2         18.000]   0.9179E-05   -0.7553E-03
  18    5.852       2      [BUS2         18.000]   0.1132E-04   -0.5851E-03
  19    4.537       2      [BUS2         18.000]   0.5901E-05   -0.4537E-03
  20    3.515       2      [BUS2         18.000]   0.6080E-05   -0.3514E-03
  21    2.724       2      [BUS2         18.000]   0.3636E-05   -0.2724E-03
  22    2.110       2      [BUS2         18.000]   0.3338E-05   -0.2110E-03
  23    1.635       2      [BUS2         18.000]   0.2086E-05   -0.1635E-03
  24    1.267       2      [BUS2         18.000]   0.2205E-05   -0.1266E-03
  25    0.982       2      [BUS2         18.000]   0.1073E-05   -0.9817E-04

Reached tolerance in 25 iterations

Largest mismatch:       0.08 MW      0.01 Mvar       0.08 MVA at bus 2 [BUS2        18.000]
System total absolute mismatch:                      0.22 MVA

SWING BUS SUMMARY:
  BUS#-SCT X-- NAME --X BASKV       PGEN     PMAX     PMIN      QGEN     QMAX    QMIN
     1      BUS1        16.500     155.7*   100.0     10.0      17.7     300.0  -300.0
```

Figure 06:readings of modified gauss-seidel method

5. According to the above readings the newton Raphson and gauss-seidel method has few iterations but the modified gauss seidel method has more iterations.
The rate of convergence of the gauss seidel method is slow because of its linear convergence characteristics requiring considerably greater number of iterations to obtain a solution than newton Raphson method which has quadratic converges characteristics and the modified gauss seidel method has medium position of characteristics between these two. Therefore, the Newton Raphson method is faster than the gauss seidel method and modified gauss seidel method.

In larger power systems gauss seidel and modified gauss seidel methods are not practical due to having more iteration time and having a greater number of iterations. Therefore the newton Raphson method is most efficient for large systems.