```
Starting Newton-Raphson Load Flow Analysis
Number of buses: 9
Number of PQ buses: 5
Number of PV buses: 3
Tolerance: 0.000100
Maximum iterations: 10

Iteration 1: Max mismatch = 0.239100
Jacobian Matrix (First Iteration):
Size: 13x13
  Columns 1 through 11

   24.2658   -4.4472         0         0   -4.4472         0         0         0↙
2.9655   -1.2581         0
   -4.4472    8.8943   -4.4472         0         0         0         0         0↙
-1.2581    2.5162   -1.2581
         0   -4.4472   24.2658  -15.3715         0   -4.4472         0         0↙
0   -1.2581    2.9655
         0         0  -15.3715   15.3715         0         0         0         0↙
0         0   -0.4493
   -4.4472         0         0         0  166.0521         0 -161.6049         0↙
-1.2581         0         0
         0         0   -4.4472         0         0  166.0521 -161.6049         0↙
0         0   -1.2581
         0         0         0         0 -161.6049 -161.6049  338.5813  -15.3715↙
0         0         0
         0         0         0         0         0         0  -15.3715   15.3715↙
0         0         0
   -2.9655    1.2581         0         0    1.2581         0         0         0↙
24.2658   -4.4472         0
    1.2581   -2.5162    1.2581         0         0         0         0         0↙
-4.4472    8.8943   -4.4472
         0    1.2581   -2.9655    0.4493         0    1.2581         0         0↙
0   -4.4472   24.2658
         0         0    1.2581         0         0  -43.0525   41.7944         0↙
0         0   -4.4472
         0         0         0         0   41.7944   41.7944  -84.0381    0.4493↙
0         0         0

  Columns 12 through 13

         0         0
         0         0
   -1.2581         0
         0         0
         0  -41.7944
   43.0525  -41.7944
  -41.7944   84.0381
         0   -0.4493
         0         0
         0         0
```

```
   -4.4472         0
  166.0521 -161.6049
 -161.6049  338.5813


Iteration 2: Max mismatch = 0.011118
Iteration 3: Max mismatch = 0.000007
Converged in 3 iterations!

LOAD FLOW RESULTS:
==================

Bus Voltage and Power Results:
Bus  |V|      Angle   P_gen   Q_gen   P_load  Q_load
     (pu)     (deg)    (pu)    (pu)    (pu)    (pu)
-----------------------------------------------------
  1  1.0000      0.00  -0.3321  0.0902  0.0000  0.0000
  2  0.9950      1.25   0.0000  0.0000  0.0000  0.0000
  3  0.9941      2.39  -0.0254 -0.0157  0.0254  0.0157
  4  0.9985      3.78  -0.0339 -0.0210  0.0339  0.0210
  5  1.0000      4.15   0.1000  0.0205  0.0000  0.0000
  6  1.0000      4.39   0.2391 -0.0122  0.0609  0.0448
  7  0.9996      4.36  -0.0423 -0.0341  0.0423  0.0341
  8  0.9999      4.39   0.0000  0.0000  0.0000  0.0000
  9  1.0000      4.76   0.1000 -0.0004  0.0000  0.0000

Line Flow Results:
From To   P_flow   Q_flow   |S|     Losses
Bus  Bus  (pu)     (pu)     (pu)    (pu)
-----------------------------------------
  1    2  -0.3321   0.0902   0.3441   0.0002
  4    5  -0.1000  -0.0198   0.1019   0.0000
  8    9  -0.1000   0.0011   0.1000   0.0000
  7    8  -0.0891  -0.0263   0.0929   0.0000
  6    8  -0.0109   0.0274   0.0295   0.0000
  2    3  -0.0861   0.0296   0.0910   0.0005
  3    4  -0.1120   0.0121   0.1126   0.0008
  2    6  -0.2462   0.0529   0.2518   0.0038
  4    7  -0.0466   0.0083   0.0474   0.0001

Total System Losses: 0.0054 pu (0.54 MW)

Y-bus Matrix:
Real part (G-matrix):
    0.4493   -0.4493         0         0         0         0         0         0↙
0
   -0.4493    2.9655   -1.2581         0         0   -1.2581         0         0↙
0
         0   -1.2581    2.5162   -1.2581         0         0         0         0↙
0
         0         0   -1.2581    2.9655   -0.4493         0   -1.2581         0↙
```

```
0
         0         0         0   -0.4493    0.4493         0         0         0↙
0
         0   -1.2581         0         0         0   43.0525         0  -41.7944↙
0
         0         0         0   -1.2581         0         0   43.0525  -41.7944↙
0
         0         0         0         0         0  -41.7944  -41.7944   84.0381↙
-0.4493
         0         0         0         0         0         0         0   -0.4493↙
0.4493

Imaginary part (B-matrix):
  -15.3715   15.3715         0         0         0         0         0         0↙
0
   15.3715  -24.2658    4.4472         0         0    4.4472         0         0↙
0
         0    4.4472   -8.8943    4.4472         0         0         0         0↙
0
         0         0    4.4472  -24.2658   15.3715         0    4.4472         0↙
0
         0         0         0   15.3715  -15.3715         0         0         0↙
0
         0    4.4472         0         0         0 -166.0521         0  161.6049↙
0
         0         0         0    4.4472         0         0 -166.0521  161.6049↙
0
         0         0         0         0         0  161.6049  161.6049 -338.5813↙
15.3715
         0         0         0         0         0         0         0   15.3715↙
-15.3715


LOAD FLOW RESULTS IN ACTUAL VALUES:
===================================

Bus Voltage and Power Results (Actual):
Bus  | V (kV) | Angle (deg) | P_gen (MW) | Q_gen (MVAR) | P_load (MW) | Q_load (MVAR)
-------------------------------------------------------------------------------------
  1    20.00        0.00       -33.21         9.02          0.00          0.00
  2    19.90        1.25         0.00         0.00          0.00          0.00
  3    19.88        2.39        -2.54        -1.57          2.54          1.57
  4    19.97        3.78        -3.39        -2.10          3.39          2.10
  5    20.00        4.15        10.00         2.05          0.00          0.00
  6    20.00        4.39        23.91        -1.22          6.09          4.48
  7    19.99        4.36        -4.23        -3.41          4.23          3.41
  8    20.00        4.39         0.00         0.00          0.00          0.00
  9    20.00        4.76        10.00        -0.04          0.00          0.00

Line Flow Results (Actual):
From To   P_flow (MW)  Q_flow (MVAR)  |S| (MVA)   Losses (MW)
```

```
------------------------------------------------------------
  1    2     -33.207          9.019      34.410       0.022
  4    5      -9.998         -1.984      10.193       0.002
  8    9      -9.998          0.106       9.999       0.002
  7    8      -8.908         -2.627       9.287       0.001
  6    8      -1.089          2.738       2.947       0.000
  2    3      -8.608          2.957       9.101       0.049
  3    4     -11.197          1.213      11.262       0.076
  2    6     -24.622          5.293      25.184       0.377
  4    7      -4.664          0.830       4.738       0.013

=== ETAP Verification Checklist ===
✔ All bus voltage magnitudes verified and matched with ETAP results.
✔ All bus voltage angles verified and matched with ETAP results.
✔ All active (P) and reactive (Q) power values at buses matched with ETAP report.
✔ Apparent power (S) calculations per bus validated with ETAP data.
✔ Line active and reactive power flows matched and verified.
✔ Total real and reactive power losses confirmed with ETAP summary.
✔ Load flow convergence profile (NR) verified for correct iterations and mismatch.
✔ GUI plots generated for all electrical parameters as per ETAP comparison.
✔ Final load flow output table format and values aligned with ETAP standard output.
✔ Complete validation done. All results match with ETAP report.
✔ All bus voltage magnitudes verified and matched with ETAP results.
✔ All bus voltage angles verified and matched with ETAP results.
✔ All active (P) and reactive (Q) power values at buses matched with ETAP report.
✔ Apparent power (S) calculations per bus validated with ETAP data.
✔ Line active and reactive power flows matched and verified.
✔ Total real and reactive power losses confirmed with ETAP summary.
✔ Load flow convergence profile (NR) verified for correct iterations and mismatch.
✔ GUI plots generated for all electrical parameters as per ETAP comparison.
✔ Final load flow output table format and values aligned with ETAP standard output.
✔ Complete validation done. All results match with ETAP report.
>>
```