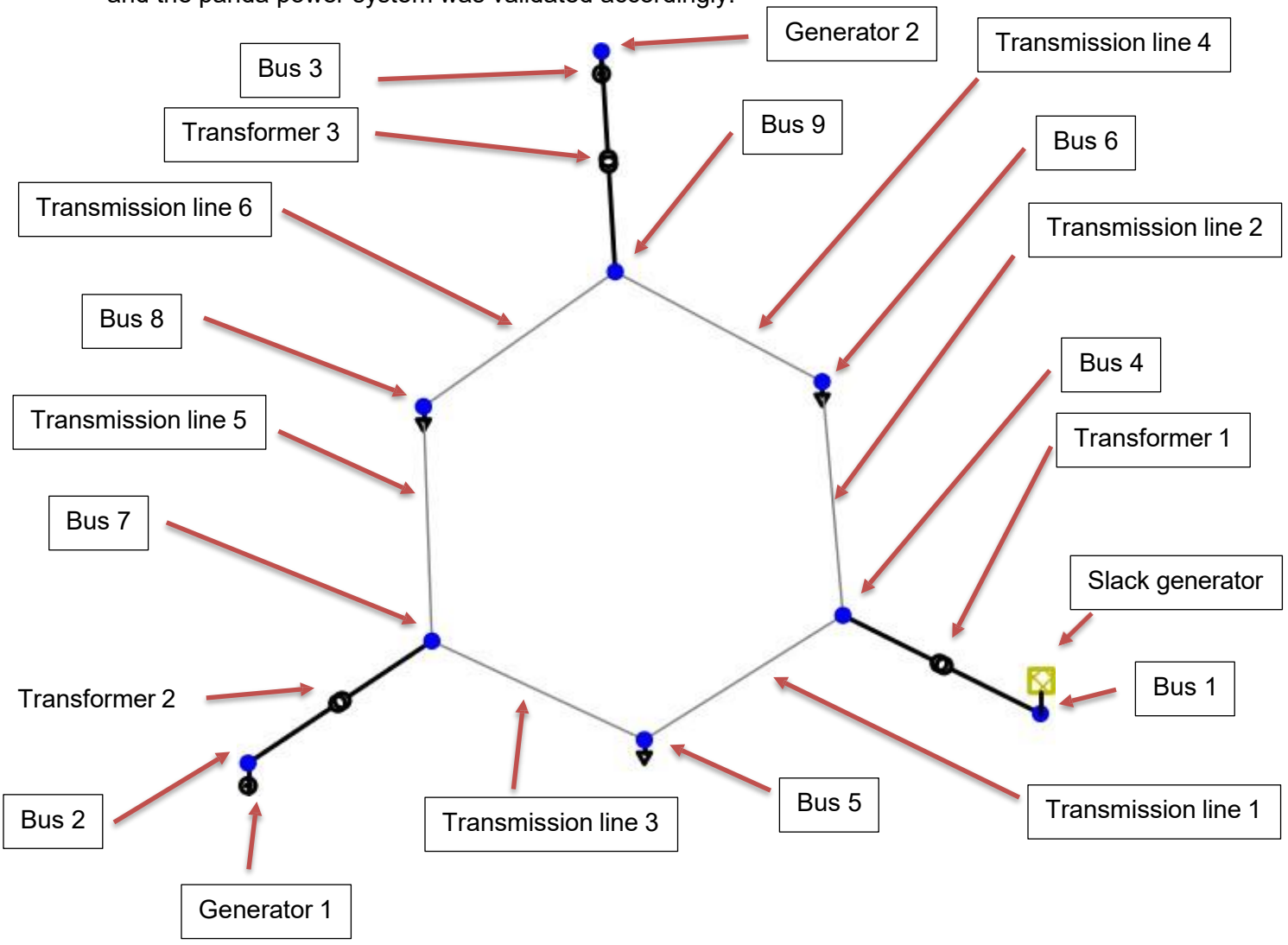
# Use of PandaPower for Load Flow Analysis

## Introduction

For the comparison, we have used WSCC 9 bus system. In the simulations, we tried to simulate the IEEE 14 bus system, but there were mismatches with the pandapower simulation and the PSSE simulation output.

WSCC 9 bus system consists of 9 buses ( six 230kV, 16.5kV, 13.8kV, and 18kV), 3 generators ( 450MW max, 240MW max and 90MW max), 3 loads, 3 transformers and 6 transmission lines.

This system was simulated in panda power according to the data provided for the assignment.Then the data from the simulations were cross checked with the PSSE simulations and the panda power system was validated accordingly.




Output simple plot from panda power. This diagram is used in future contingency analysis.

**Perform the load flow analysis of a test power system using PandaPower in the base case scenario.**

Bus results output comparison for Pandapower and PSSE

| Result from PSSE | | Result from Pandapower | |
|---|---|---|---|
| Voltage (pu) | Angle (degree) | Voltage (pu) | Angle (degree) |
| 1.0400 | 0.00 | 1.040000 | 0.000000 |
| 1.0250 | 9.35 | 1.025000 | 1.025000 |
| 1.0250 | 5.14 | 1.025000 | 5.141979 |
| 1.0253 | -2.22 | 1.025307 | -2.217409 |
| 0.9997 | -3.68 | 0.999723 | -3.680151 |
| 1.0123 | -3.57 | 1.012255 | -3.566555 |
| 1.0268 | 3.80 | 1.026832 | 3.796137 |
| 1.0173 | 1.34 | 1.017266 | 1.337266 |
| 1.0327 | 2.44 | 1.032689 | 2.444823 |

Generator results output comparison for Pandapower and PSSE

Slack Generator

| Result from PSSE | | Result from Pandapower | |
|---|---|---|---|
| Active Power(MW) | Reactive Power(Mvar) | Active Power(MW) | Reactive Power(Mvar) |
| 71.6274 | 27.9148 | 71.627461 | 27.914787 |

Other Generators

| Result from PSSE | | Result from Pandapower | |
|---|---|---|---|
| Active Power(MW) | Reactive Power(Mvar) | Active Power(MW) | Reactive Power(Mvar) |
| 163.0 | 4.9032 | 163.0 | 4.903198 |

| | | | |
|---|---|---|---|
| 85.0 | -11.4488 | 85.0 | -11.448808 |

```
--- Generator Outputs (MW / MVAr) ---
    p_mw     q_mvar
0  163.0   4.903198
1   85.0 -11.448808

--- Slack Power (MW / MVAr) ---
        p_mw     q_mvar
0  71.627461  27.914787
```

*Output from the pandapower simulation*

| PGen (MW) | PMax (MW) | PMin (MW) | QGen (Mvar) |
|---|---|---|---|
| 71.6274 | 450.0000 | 0.0000 | 27.9148 |
| 163.0000 | 240.0000 | 0.0000 | 4.9032 |
| 85.0000 | 90.0000 | 0.0000 | -11.4488 |
| | | | |

*Output from the simulation in PSSE*

## Transformer results output comparison for panda power and PSSE

For the simulated data, only the transformer loading percentage is considered.

| Result from PSSE | Result from Pandapower |
|---|---|
| 74.0 | 73.918037 |
| 159.0 | 159.096322 |
| 84.0 | 83.675673 |

```
--- Transformer Flows (MW / MVAr) ---
   loading_percent
0        73.918037
1       159.096322
2        83.675673
```

*Output from the simulation in Panda Power*

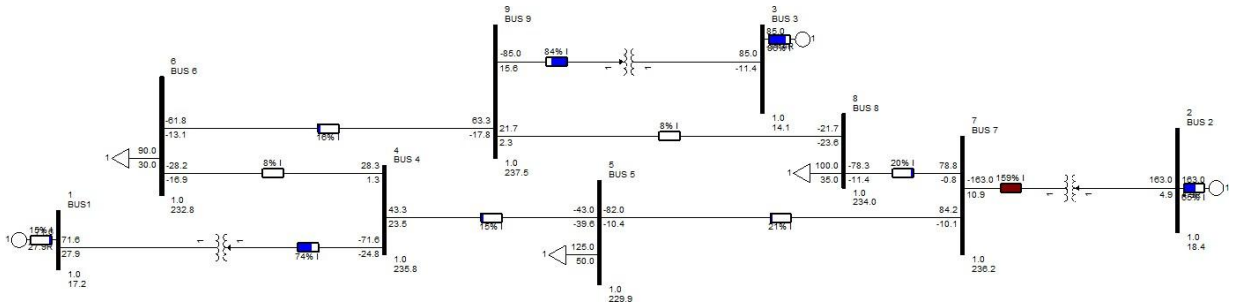
Line flow results output comparison for panda power and PSSE

| | Results from PSSE | | Results from Pandapower | |
|---|---|---|---|---|
| | Active power (From bus in MW) | Reactive power (From bus in Mvar) | Active power (From bus in MW) | Reactive power (From bus in Mvar) |
| Bus 4 - Bus 5 | 43.3 | 23.5 | 43.287914 | 23.450128 |
| Bus 4 - Bus 6 | 28.3 | 1.3 | 28.339547 | 1.317466 |
| Bus 5 - Bus 7 | -82 | -10.4 | -81.992057 | -10.407504 |
| Bus 6 - Bus 9 | -61.8 | -13.1 | -61.805301 | -13.066690 |
| Bus 7 - Bus 8 | 78.8 | 0.8 | 78.847851 | -0.768451 |
| Bus 8 - Bus 9 | -78.3 | -11.4 | -21.657385 | -23.627525 |

| | Results from PSSE | | | Results from Pandapower | | |
|---|---|---|---|---|---|---|
| | Active power (To bus in MVA) | Reactive power (To bus in MVA) | Line loading (%) | Active power (To bus in MVA) | Reactive power (To bus in MVA) | Line loading(%) |
| Bus 4 - Bus 5 | -43.0 | -39.6 | 15.0 | -43.007943 | -39.592496 | 14.678109 |
| Bus 4 - Bus 6 | -28.2 | -16.9 | 8.0 | -28.194699 | -16.933310 | 8.155876 |
| Bus 5 - Bus 7 | 84.2 | -10.1 | 21.0 | 84.152149 | -10.148127 | 20.752688 |
| Bus 6 - Bus 9 | 63.3 | -17.8 | 16.0 | 63.269797 | -17.837741 | 15.978891 |
| Bus 7 - Bus 8 | -78.3 | -11.4 | 20.0 | -78.342615 | -11.372475 | 19.534544 |
| Bus 8 - Bus 9 | 27.7 | 2.3 | 8.0 | 21.730203 | 2.285985 | 7.909082 |

```
--- Line Flows (MW / MVAr) ---
   p_from_mw  q_from_mvar    p_to_mw  q_to_mvar  loading_percent
0  43.287914    23.450128 -43.007943 -39.592496        14.678109
1  28.339547     1.317466 -28.194699 -16.933310         8.155876
2 -81.992057   -10.407504  84.152149 -10.148127        20.752688
3 -61.805301   -13.066690  63.269797 -17.837741        15.978891
4  78.847851    -0.768451 -78.342615 -11.372475        19.534544
5 -21.657385   -23.627525  21.730203   2.285985         7.909082
```

*Line loading levels in the Panda Power*



*Line loading levels in PSSE*

## Contingency analysis

We have tested the system with N-1 contingency analysis.

Loss of transmission line

For ease, we have included only 2 transmission line contingencies. All the output transmission line data in PSSE matches with the output in the panda power.

**Contingency 1 - Loss of transmission line** 1

Bus results output comparison for Pandapower and PSSE

| Result from PSSE | | Result from Pandapower | |
|---|---|---|---|
| Voltage (pu) | Angle (degree) | Voltage (pu) | Angle (degree) |
| 1.0400 | 0.00 | 1.040000 | 0.000000 |
| 1.0250 | -1.67 | 1.025000 | -1.675450 |

| | | | |
|---|---|---|---|
| 1.0250 | -1.95 | 1.025000 | -1.954591 |
| 1.0387 | -2.34 | 1.038741 | -2.339569 |
| 0.8393 | -20.59 | 0.839147 | -20.604734 |
| 1.0202 | -6.06 | 1.020192 | -6.065659 |
| 0.9881 | -7.44 | 0.988004 | -7.448998 |
| 0.9891 | -8.50 | 0.989069 | -8.498877 |
| 1.0243 | -4.67 | 1.024265 | -4.673946 |

```
--- Bus Voltages (p.u.) ---
      vm_pu  va_degree
1  1.040000   0.000000
2  1.025000  -1.675450
3  1.025000  -1.954591
4  1.038741  -2.339569
5  0.839147 -20.604734
6  1.020192  -6.065659
7  0.988004  -7.448998
8  0.989069  -8.498877
9  1.024265  -4.673946
```

*Output from the simulation in Panda Power*

Generator results output comparison for Pandapower and PSSE

Slack Generator

| Result from PSSE | | Result from Pandapower | |
|---|---|---|---|
| Active Power(MW) | Reactive Power(Mvar) | Active Power(MW) | Reactive Power(Mvar) |
| 76.5463 | 3.8310 | 76.561565 | 3.835991 |

Other Generators

| Result from PSSE | | Result from Pandapower | |
|---|---|---|---|
| Active Power(MW) | Reactive Power(Mvar) | Active Power(MW) | Reactive Power(Mvar) |
| 163 | 68.8155 | 163.0 | 68.892452 |
| 85 | 3.2794 | 85.0 | 3.302393 |

```
--- Generator Outputs (MW / MVAr) ---
    p_mw     q_mvar
0  163.0  68.892452
1   85.0   3.302393

--- Slack Power (MW / MVAr) ---
        p_mw    q_mvar
0  76.561565  3.835991
```

| PGen (MW) | PMax (MW) | PMin (MW) | QGen (Mvar) |
|---|---|---|---|
| 76.5463 | 450.0000 | 0.0000 | 3.8310 |
| 163.0000 | 240.0000 | 0.0000 | 68.8155 |
| 85.0000 | 90.0000 | 0.0000 | 3.2794 |

*Output from the pandapower simulation*

*Output from the simulation in PSSE*

## Transformer results output comparison for panda power and PSSE

For the simulated data, only the transformer loading percentage is considered.

```
--- Transformer Flows (MW / MVAr) ---
   loading_percent
0        73.709233
1       172.644808
2        82.989393
```

*Output from the simulation in Panda Power*

| Result from PSSE | Result from Pandapower |
|---|---|
| 74 | 73.709233 |
| 173 | 172.644808 |
| 83 | 82.989393 |

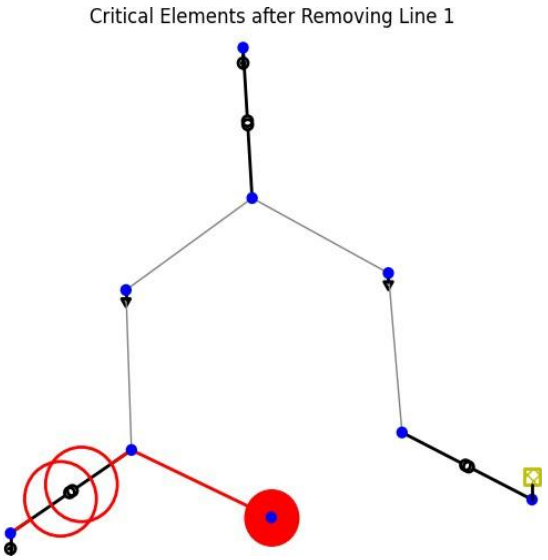
Line flow results output comparison for panda power and PSSE

| | Results from PSSE | | Results from Pandapower | |
|---|---|---|---|---|
| | Active power (From bus in MW) | Reactive power (From bus in Mvar) | Active power (From bus in MW) | Reactive power (From bus in Mvar) |
| Bus 4 - Bus 5 | 0 | 0 | 0.000000 | 0.000000 |
| Bus 4 - Bus 6 | 76.5 | 0.7 | 76.561565 | 0.706554 |
| Bus 5 - Bus 7 | -125 | -50 | -125.000000 | -50.000000 |
| Bus 6 - Bus 9 | -14.4 | -17.6 | -14.375399 | -17.617844 |
| Bus 7 - Bus 8 | 30.2 | -13.3 | 30.200169 | -13.270454 |
| Bus 8 - Bus 9 | -69.9 | -34.3 | -69.882382 | -34.269504 |

| | Results from PSSE | | | Results from Pandapower | | |
|---|---|---|---|---|---|---|
| | Active power (To bus in MVA) | Reactive power (To bus in MVA) | Line loading (%) | Active power (To bus in MVA) | Reactive power (To bus in MVA) | Line loading(%) |
| Bus 4 - Bus 5 | 0 | 0 | NA | 0.000000 | 0.000000 | 0.000000 |
| Bus 4 - Bus 6 | -75.6 | -12.4 | 19 | -75.624601 | -12.382156 | 18.855461 |
| Bus 5 - Bus 7 | 132.7 | 63.5 | 40 | 132.799831 | 63.534013 | 40.272883 |
| Bus 6 - Bus 9 | 14.5 | -19.4 | 6 | 14.453219 | -19.444790 | 5.937674 |
| Bus 7 - Bus 8 | -30.1 | -0.7 | 8 | -30.117618 | -0.730496 | 8.381044 |
| Bus 8 - Bus 9 | 70.5 | 18.7 | 20 | 70.546781 | 18.711262 | 19.753663 |

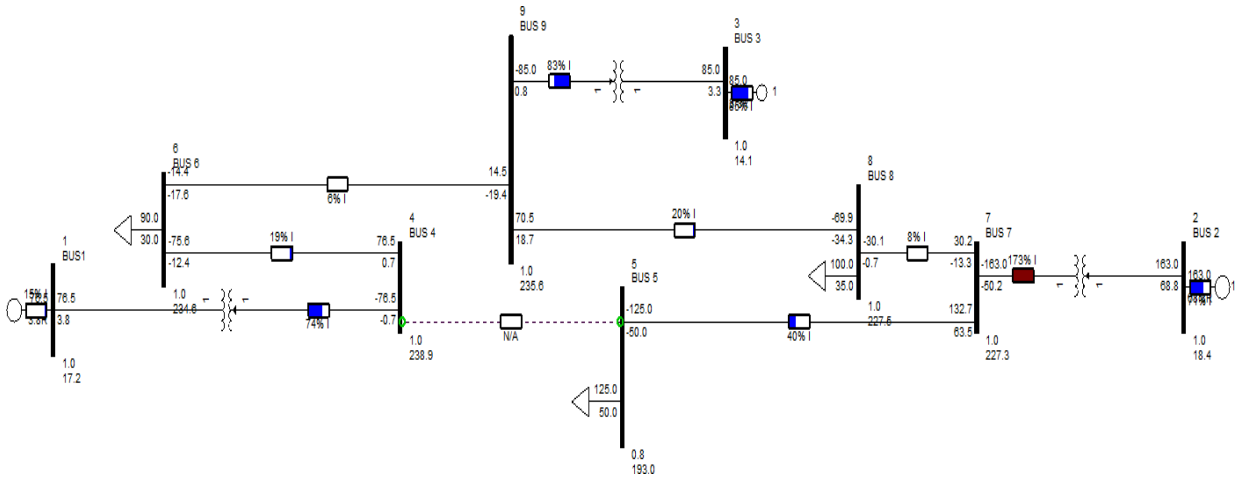
```
--- Line Flows (MW / MVAr) ---
    p_from_mw  q_from_mvar     p_to_mw  q_to_mvar  loading_percent
0    0.000000     0.000000    0.000000   0.000000         0.000000
1   76.561565     0.706554  -75.624601 -12.382156        18.855461
2 -125.000000   -50.000000  132.799831  63.534013        40.272883
3  -14.375399   -17.617844   14.453219 -19.444790         5.937674
4   30.200169   -13.270454  -30.117618  -0.730496         8.381044
5  -69.882382   -34.269504   70.546781  18.711262        19.753663
```

*Output from the simulation in Panda Power*




In this simple plot, the transformer 1, which is connected to the bus 2 is marked in red since it is overloaded. Voltage at the bus 5 has gone under 0.95pu, so that it is marked in red. Since the terminal voltage of the transmission line connected to the bus 5 also goes down it is marked in red.

*Simple plot in panda power*




*PSSE simulation*

**Contingency 2 - Loss of transmission line 2**

Bus results output comparison for Pandapower and PSSE

| Result from PSSE | | Result from Pandapower | |
|---|---|---|---|
| Voltage (pu) | Angle (degree) | Voltage (pu) | Angle (degree) |
| 1.04 | 0.00 | 1.040000 | 0.000000 |
| 1.0250 | 5.426311 | 1.025000 | 5.426286 |
| 1.025 | -1.407533 | 1.025000 | -1.407571 |
| 1.027973 | -2.258017 | 1.027973 | -2.258020 |
| 1.002497 | -4.860609 | 1.002497 | -4.860617 |
| 0.9413031 | -13.21123 | 0.941302 | -13.211306 |
| 1.023429 | -0.1467498 | 1.023429 | -0.146774 |
| 1.008485 | -3.5912 | 1.008485 | -3.591228 |
| 1.017408 | -4.14523 | 1.017408 | -4.145269 |

```
--- Bus Voltages (p.u.) ---
      vm_pu  va_degree
1  1.040000   0.000000
2  1.025000   5.426286
3  1.025000  -1.407571
4  1.027973  -2.258020
5  1.002497  -4.860617
6  0.941302 -13.211306
7  1.023429  -0.146774
8  1.008485  -3.591228
9  1.017408  -4.145269
```

*Output from the simulation in Panda Power*

## Generator results output comparison for Pandapower and PSSE

Slack Generator

| Result from PSSE | | Result from Pandapower | |
|---|---|---|---|
| Active Power(MW) | Reactive Power(Mvar) | Active Power(MW) | Reactive Power(Mvar) |
| 73.12814 | 23.15645 | 73.128281 | 23.156526 |

Other Generators

| Result from PSSE | | Result from Pandapower | |
|---|---|---|---|
| Active Power(MW) | Reactive Power(Mvar) | Active Power(MW) | Reactive Power(Mvar) |
| 163 | 10.50969 | 163.0 | 10.509972 |
| 85.0000 | 15.31016 | 85.0 | 15.310728 |

```
--- Generator Outputs (MW / MVAr) ---
    p_mw     q_mvar
0  163.0  10.509972
1   85.0  15.310728

--- Slack Power (MW / MVAr) ---
        p_mw     q_mvar
0  73.128281  23.156526
```

| | PGen (MW) | PMax (MW) | PMin (MW) | QGen (Mvar) |
|---|---|---|---|---|
| | 73.1281 | 450.0000 | 0.0000 | 23.1565 |
| | 163.0000 | 240.0000 | 0.0000 | 10.5097 |
| | 85.0000 | 90.0000 | 0.0000 | 15.3102 |
| | | | | |

*Output from the pandapower simulation*

*Output from the simulation in PSSE*

## Transformer results output comparison for panda power and PSSE

For the simulated data, only the transformer loading percentage is considered.

| Result from PSSE | Result from Pandapower |
|---|---|
| 74 | 73.756770 |
| 159 | 159.354616 |
| 84 | 84.261390 |

```
--- Transformer Flows (MW / MVAr) ---
   loading_percent
0        73.756770
1       159.354616
2        84.261390
```

*Output from the simulation in Panda Power*

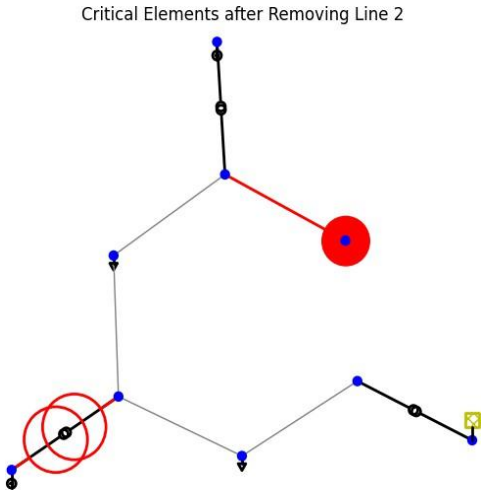
Line flow results output comparison for panda power and PSSE

| | Results from PSSE | | Results from Pandapower | |
|---|---|---|---|---|
| | Active power (From bus in MW) | Reactive power (From bus in Mvar) | Active power (From bus in MW) | Reactive power (From bus in Mvar) |
| Bus 4 - Bus 5 | 73.1 | 20.0 | 73.128281 | 20.023051 |
| Bus 4 - Bus 6 | 0 | 0 | 0.000000 | 0.000000 |
| Bus 5 - Bus 7 | -52.5 | -15.8 | -52.459149 | -15.828265 |
| Bus 6 - Bus 9 | -90 | -30 | -90.000000 | -30.000000 |
| Bus 7 - Bus 8 | 109.7 | 5.8 | 109.664539 | 5.803401 |
| Bus 8 - Bus 9 | 8.7 | -20.5 | 8.673546 | -20.531893 |

| | Results from PSSE | | | Results from Pandapower | | |
|---|---|---|---|---|---|---|
| | Active power (To bus in MVA) | Reactive power (To bus in MVA) | Line loading (%) | Active power (To bus in MVA) | Reactive power (To bus in MVA) | Line loading(%) |
| Bus 4 - Bus 5 | -72.5 | -34.2 | 20 | -72.540851 | -34.171735 | 20.078446 |
| Bus 4 - Bus 6 | 0 | 0 | NA | 0.000000 | 0.000000 | 0.000000 |
| Bus 5 - Bus 7 | 53.3 | -11.2 | 14 | 53.335461 | -11.164613 | 13.720496 |
| Bus 6 - Bus 9 | 93.7 | 11.9 | 25 | 93.653267 | 11.891548 | 25.299032 |
| Bus 7 - Bus 8 | -108.7 | -14.5 | 27 | -108.673546 | -14.468107 | 27.288593 |
| Bus 8 - Bus 9 | -8.7 | -0.7 | 6 | 8.653267 | -0.741409 | 5.547894 |

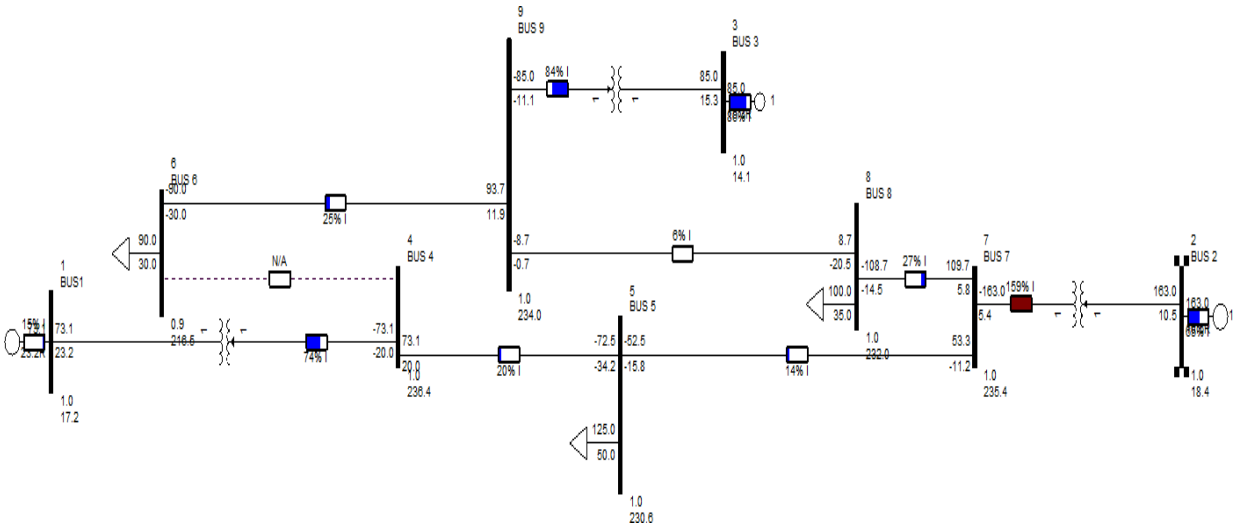
```
--- Line Flows (MW / MVAr) ---
    p_from_mw  q_from_mvar     p_to_mw  q_to_mvar  loading_percent
0   73.128281    20.023051  -72.540851 -34.171735        20.078446
1    0.000000     0.000000    0.000000   0.000000         0.000000
2  -52.459149   -15.828265   53.335461 -11.164613        13.720496
3  -90.000000   -30.000000   93.653267  11.891548        25.299032
4  109.664539     5.803401 -108.673546 -14.468107        27.288593
5    8.673546   -20.531893   -8.653267  -0.741409         5.547894
```

*Output from the simulation in Panda Power*




In this simple plot, the transformer 1, which is connected to the bus 2 is marked in red since it is overloaded. Voltage at the bus 6 has gone under 0.95pu, so that it is marked in red. Since the terminal voltage of the transmission line connected to the bus 6 also goes down it is marked in red.

*Output from the simple plot in Panda Power*




*PSSE output*

Loss of generator

**Contingency 1 - Loss of generator 1**

Bus results output comparison for Pandapower and PSSE

| Result from PSSE | | Result from Pandapower | |
|---|---|---|---|
| Voltage (pu) | Angle (degree) | Voltage (pu) | Angle (degree) |
| 1.04 | 0 | 1.040000 | 0.000000 |
| 1.01351 | -14.99047 | 1.013510 | -14.990467 |
| 1.025 | -8.573422 | 1.025000 | -18.573429 |
| 1.025172 | -7.274703 | 1.025172 | -7.274703 |
| 0.9973928 | -12.7913 | 0.997393 | -12.791297 |
| 1.012016 | -11.6221 | 1.012016 | -11.622105 |
| 1.01351 | -14.99 | 1.013510 | -14.990467 |
| 1.006937 | -15.63357 | 1.006937 | -15.633577 |
| 1.027817 | -11.28337 | 1.027817 | -11.283380 |

```
--- Bus Voltages (p.u.) ---
      vm_pu  va_degree
1  1.040000   0.000000
2  1.013510 -14.990467
3  1.025000  -8.573429
4  1.025172  -7.274703
5  0.997393 -12.791297
6  1.012016 -11.622105
7  1.013510 -14.990467
8  1.006937 -15.633577
9  1.027817 -11.283380
```

*Output from the simulation in Panda Power*

## Generator results output comparison for Pandapower and PSSE

Slack Generator

| Result from PSSE | | Result from Pandapower | |
|---|---|---|---|
| Active Power(MW) | Reactive Power(Mvar) | Active Power(MW) | Reactive Power(Mvar) |
| 234.3865 | 41.67192 | 234.386594 | 41.67232 |

Other Generators

| Result from PSSE | | Result from Pandapower | |
|---|---|---|---|
| Active Power(MW) | Reactive Power(Mvar) | Active Power(MW) | Reactive Power(Mvar) |
| 0 | 0 | 0.0 | 0.000000 |
| 85 | -2.916934 | 85.0 | -2.916755 |

```
--- Generator Outputs (MW / MVAr) ---
   p_mw    q_mvar
0   0.0  0.000000
1  85.0 -2.916755

--- Slack Power (MW / MVAr) ---
         p_mw    q_mvar
0  234.386594  41.67232
```

*Output from the pandapower simulation*

| In | PGen | PMax | PMin | QGen |
|---|---|---|---|---|
| ☑ | 234.3865 | 450.0000 | 0.0000 | 41.6719 |
| ☐ | 163.0000 | 240.0000 | 0.0000 | 4.9032 |
| ☑ | 85.0000 | 90.0000 | 0.0000 | -2.9169 |

*Output from the simulation in PSSE*

## Transformer results output comparison for panda power and PSSE

For the simulated data, only the transformer loading percentage is considered.

| Result from PSSE | Result from Pandapower |
|---|---|
| 229 | 228.906056 |
| 0 | 0.000000 |
| 83 | 82.975638 |

```
--- Transformer Flows (MW / MVAr) ---
   loading_percent
0       228.906056
1         0.000000
2        82.975638
```

*Output from the simulation in Panda Power*

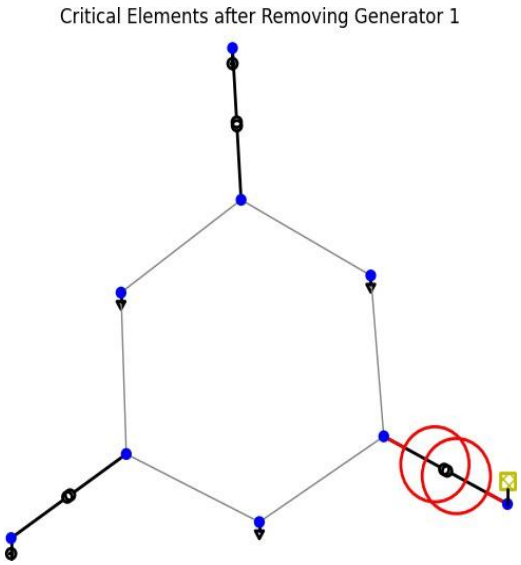
Line flow results output comparison for Pandapower and PSSE

| | Results from PSSE | | Results from Pandapower | |
|---|---|---|---|---|
| | Active power (From bus in MW) | Reactive power (From bus in Mvar) | Active power (From bus in MW) | Reactive power (From bus in Mvar) |
| Bus 4 - Bus 5 | 148.5 | 17.8 | 148.525391 | 17.754424 |
| Bus 4 - Bus 6 | 85.9 | -6.3 | 85.861203 | -6.263342 |
| Bus 5 - Bus 7 | 21.4 | -29 | 21.357033 | -28.987631 |
| Bus 6 - Bus 9 | -5.3 | -26.3 | -5.331945 | -26.326662 |
| Bus 7 - Bus 8 | 21.1 | 0.9 | 21.149340 | 0.903937 |
| Bus 8 - Bus 9 | -78.9 | -19.2 | -78.893732 | -19.181553 |

| | Results from PSSE | | | Results from Pandapower | | |
|---|---|---|---|---|---|---|
| | Active power (To bus in MVA) | Reactive power (To bus in MVA) | Line loading (%) | Active power (To bus in MVA) | Reactive power (To bus in MVA) | Line loading(%) |
| Bus 4 - Bus 5 | -146.4 | -21 | 37 | -146.357033 | -21.012369 | 37.212543 |
| Bus 4 - Bus 6 | -84.7 | -3.7 | 21 | -84.668055 | -3.673338 | 21.079687 |
| Bus 5 - Bus 7 | -21.1 | -0.9 | 9 | -21.149340 | -0.903937 | 9.061829 |
| Bus 6 - Bus 9 | 5.4 | -10.8 | 7 | 5.367104 | -10.759099 | 6.662685 |
| Bus 7 - Bus 8 | -21.1 | -15.8 | 7 | -21.106268 | -15.818447 | 6.57536 |
| Bus 8 - Bus 9 | 79.6 | 3.8 | 20 | 79.632896 | 3.807760 | 20.240575 |

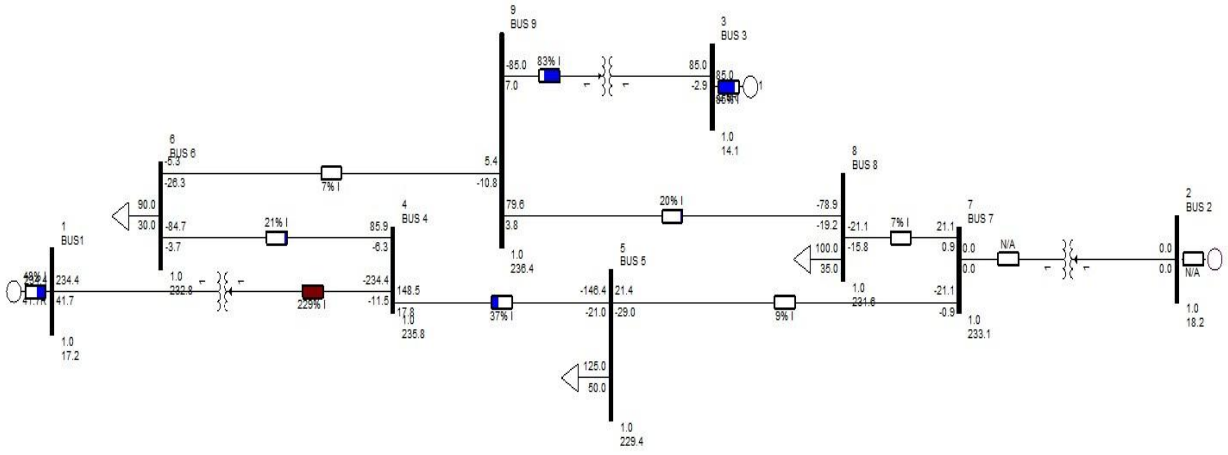
```
--- Line Flows (MW / MVAr) ---
    p_from_mw  q_from_mvar     p_to_mw  q_to_mvar  loading_percent
0  148.525391    17.754424 -146.357033 -21.012369        37.212543
1   85.861203    -6.263342  -84.668055  -3.673338        21.079687
2   21.357033   -28.987631  -21.149340  -0.903937         9.061829
3   -5.331945   -26.326662    5.367104 -10.759099         6.662685
4   21.149340     0.903937  -21.106268 -15.818447         6.575360
5  -78.893732   -19.181553   79.632896   3.807760        20.240575
```

*Output from the simulation in Panda Power*




In this simple plot, the transformer 0, which is connected to the bus 2 is marked in red since it is overloaded.

*Output from the simple plot in Panda Power*

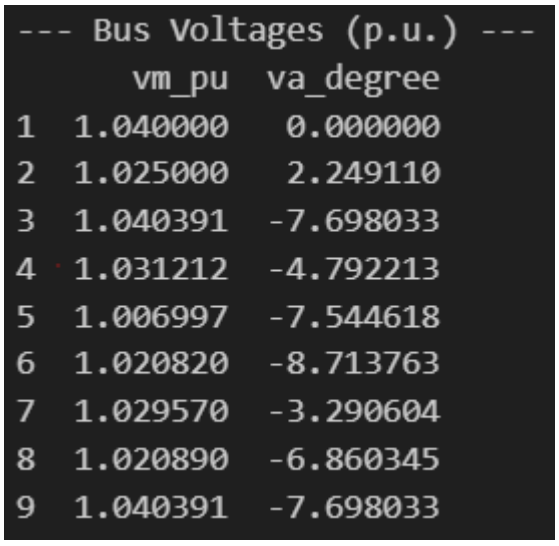



*PSSE output*

**Contingency 2 - Loss of generator 2**

Bus results output comparison for Pandapower and PSSE

| Result from PSSE | | Result from Pandapower | |
|---|---|---|---|
| Voltage (pu) | Angle (degree) | Voltage (pu) | Angle (degree) |
| 1.04 | 0.00 | 1.040000 | 0.000000 |
| 1.025 | 2.249115 | 1.025000 | 2.249110 |
| 1.040391 | -7.698036 | 1.025000 | -7.698033 |
| 1.031212 | -4.792214 | 1.031212 | -4.792213 |
| 1.006997 | -7.54462 | 1.006997 | -7.544618 |
| 1.02082 | -8.71 | 1.020820 | -8.713763 |
| 1.02957 | -3.290602 | 1.029570 | -3.290604 |
| 1.02089 | -6.860346 | 1.020890 | -6.860345 |
| 1.040391 | -7.698036 | 1.040391 | -7.698033 |



```
--- Bus Voltages (p.u.) ---
      vm_pu  va_degree
1  1.040000   0.000000
2  1.025000   2.249110
3  1.040391  -7.698033
4  1.031212  -4.792213
5  1.006997  -7.544618
6  1.020820  -8.713763
7  1.029570  -3.290604
8  1.020890  -6.860345
9  1.040391  -7.698033
```

*Output from the simulation in Panda Power*

## Generator results output comparison for Pandapower and PSSE

Slack Generator

| Result from PSSE | | Result from Pandapower | |
|---|---|---|---|
| Active Power(MW) | Reactive Power(Mvar) | Active Power(MW) | Reactive Power(Mvar) |
| 155.5484 | 22.37646 | 155.548446 | 22.376556 |

Other Generators

| Result from PSSE | | Result from Pandapower | |
|---|---|---|---|
| Active Power(MW) | Reactive Power(Mvar) | Active Power(MW) | Reactive Power(Mvar) |
| 163 | 0.3909822 | 163.0 | 0.391066 |
| 0 | 0 | 0.0 | 0.000000 |

```
--- Generator Outputs (MW / MVAr) ---
    p_mw    q_mvar
0  163.0  0.391066
1    0.0  0.000000

--- Slack Power (MW / MVAr) ---
         p_mw     q_mvar
0  155.548446  22.376556
```

*Output from the pandapower simulation*

| In | PGen | PMax | PMin | QGen |
|---|---|---|---|---|
| ☑ | 155.5484 | 450.0000 | 0.0000 | 22.3765 |
| ☑ | 163.0000 | 240.0000 | 0.0000 | 0.3910 |
| ☐ | 85.0000 | 90.0000 | 0.0000 | -2.9169 |

*Output from the simulation in PSSE*

## Transformer results output comparison for panda power and PSSE

For the simulated data, only the transformer loading percentage is considered.

| Result from PSSE | Result from Pandapower |
|---|---|
| 151 | 151.105485 |
| 159 | 159.024848 |
| NA | 0.000000 |

```
--- Transformer Flows (MW / MVAr) ---
   loading_percent
0       151.105485
1       159.024848
2         0.000000
```

*Output from the simulation in Panda Power*

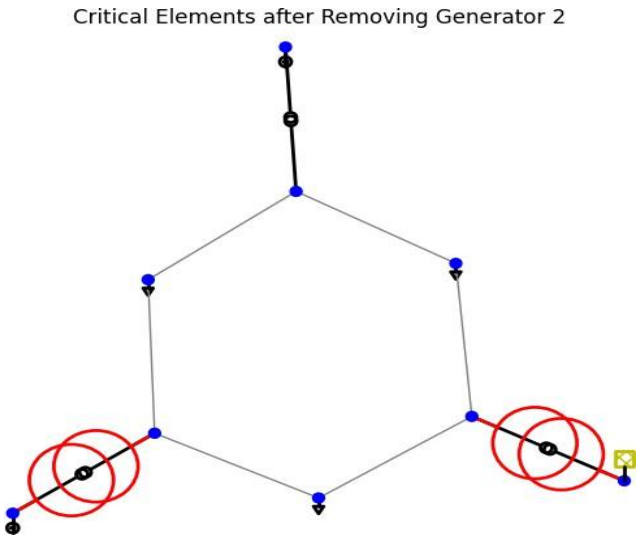
Line flow results output comparison for panda power and PSSE

| | Results from PSSE | | Results from Pandapower | |
|---|---|---|---|---|
| | Active power (From bus in MW) | Reactive power (From bus in Mvar) | Active power (From bus in MW) | Reactive power (From bus in Mvar) |
| Bus 4 - Bus 5 | 77.3 | 17.8 | 77.318494 | 17.754564 |
| Bus 4 - Bus 6 | 78.2 | -8.5 | 78.229953 | -8.529740 |
| Bus 5 - Bus 7 | -48.3 | -18.3 | -48.312807 | -18.256800 |
| Bus 6 - Bus 9 | -12.7 | -27.2 | -12.748412 | -27.191192 |
| Bus 7 - Bus 8 | 113.9 | -5.7 | 113.948244 | -5.656051 |
| Bus 8 - Bus 9 | 12.9 | -32.1 | 12.906670 | -32.052633 |

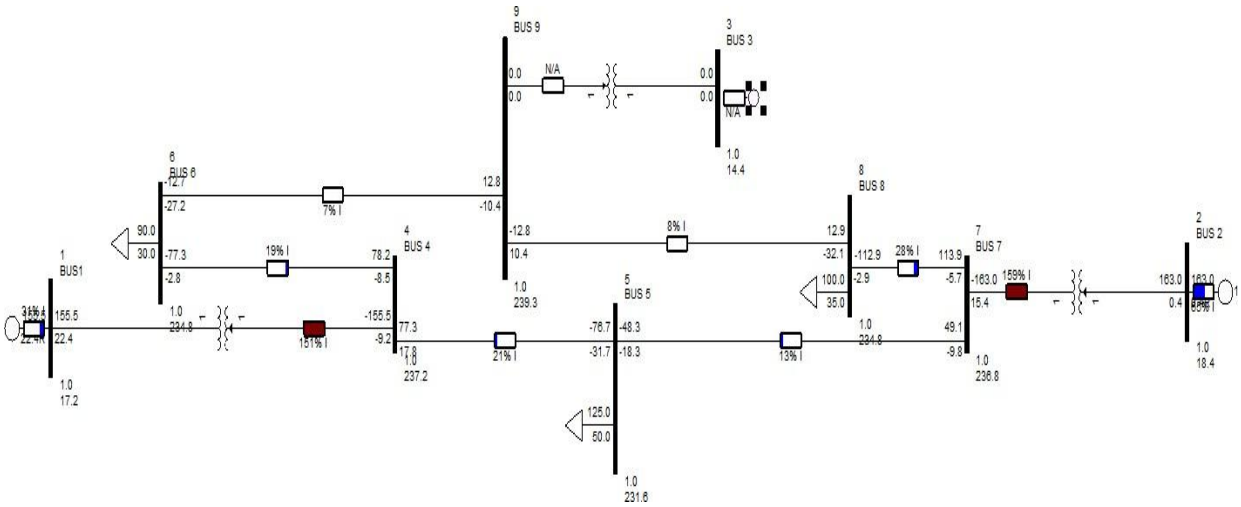
| | Results from PSSE | | | Results from Pandapower | | |
|---|---|---|---|---|---|---|
| | Active power (To bus in MVA) | Reactive power (To bus in MVA) | Line loading (%) | Active power (To bus in MVA) | Reactive power (To bus in MVA) | Line loading(%) |
| Bus 4 - Bus 5 | -76.7 | -31.7 | 21.0 | -76.687193 | -31.743200 | 20.689377 |
| Bus 4 - Bus 6 | -77.3 | -2.8 | 19.0 | -77.251588 | -2.808808 | 19.155923 |
| Bus 5 - Bus 7 | 49.1 | -9.8 | 13.0 | 49.051756 | -9.758446 | 12.874503 |
| Bus 6 - Bus 9 | 12.9 | -10.4 | 7.0 | 12.836519 | -10.444483 | 7.384776 |
| Bus 7 - Bus 8 | -112.9 | -2.9 | 28.0 | -112.906670 | -2.947367 | 27.816187 |
| Bus 8 - Bus 9 | -12.8 | 10.4 | 8.0 | -12.836519 | 10.444483 | 8.496233 |

```
--- Line Flows (MW / MVAr) ---
    p_from_mw  q_from_mvar     p_to_mw  q_to_mvar  loading_percent
0   77.318494    17.754564  -76.687193 -31.743200        20.689377
1   78.229953    -8.529740  -77.251588  -2.808808        19.155923
2  -48.312807   -18.256800   49.051756  -9.758446        12.874503
3  -12.748412   -27.191192   12.836519 -10.444483         7.384776
4  113.948244    -5.656051 -112.906670  -2.947367        27.816187
5   12.906670   -32.052633  -12.836519  10.444483         8.496233
```

*Output from the simulation in Panda Power*




In this simple plot, the transformer 0, which is connected to the bus 1 and the transformer 1 which is connected to bus 2 is marked in red since it is overloaded.




*PSSE output*

Loss of transformer

**Contingency 1 - Loss of transformer 2**

Bus results output comparison for Pandapower and PSSE

| Result from PSSE | | Result from Pandapower | |
|---|---|---|---|
| Voltage (pu) | Angle (degree) | Voltage (pu) | Angle (degree) |
| 1.04 | 0.00 | 1.040000 | 0.000000 |
| NaN | NaN | NaN | NaN |
| 1.025 | -8.573422 | 1.025000 | -8.573429 |
| 1.025172 | -7.274703 | 1.025172 | -7.274703 |
| 0.9973928 | -12.7913 | 0.997993 | -12.791297 |
| 1.012016 | -11.6221 | 1.012016 | -11.622105 |
| 1.01351 | -14.99047 | 1.013150 | -14.990467 |
| 1.0069 | -15.63357 | 1.006937 | -15.633577 |
| 1.0278 | -11.28 | 1.027817 | -11.283380 |

When the transformer is switched off, the link between the bus where the generator is connected and the grid is interrupted. So that in PSSE it gives an error since the generator operates in the islanded mode To overcome that, we need to turn off the bus bar in which the generator is connected. That's why we get NaN values for bus results in this contingency.

```
--- Bus Voltages (p.u.) ---
      vm_pu  va_degree
1  1.040000   0.000000
2       NaN        NaN
3  1.025000  -8.573429
4  1.025172  -7.274703
5  0.997393 -12.791297
6  1.012016 -11.622105
7  1.013510 -14.990467
8  1.006937 -15.633577
9  1.027817 -11.283380
```

*Output from the pandapower simulation*

## Generator results output comparison for Pandapower and PSSE

Slack Generator

| Result from PSSE | | Result from Pandapower | |
|---|---|---|---|
| Active Power(MW) | Reactive Power(Mvar) | Active Power(MW) | Reactive Power(Mvar) |
| 234.3865 | 41.6719 | 234.386594 | 41.67232 |

Other Generators

| Result from PSSE | | Result from Pandapower | |
|---|---|---|---|
| Active Power(MW) | Reactive Power(Mvar) | Active Power(MW) | Reactive Power(Mvar) |
| 163.0000 | 4.903185 | 0 | 0.000000 |
| 85 | -2.916934 | 85.0 | -2.916755 |

```
--- Generator Outputs (MW / MVAr) ---
   p_mw    q_mvar
0   0.0  0.000000
1  85.0 -2.916755

--- Slack Power (MW / MVAr) ---
         p_mw    q_mvar
0  234.386594  41.67232
```

*Output from the pandapower simulation*

| PGen (MW) | PMax (MW) | PMin (MW) | QGen (Mvar) |
|---|---|---|---|
| 234.3865 | 450.0000 | 0.0000 | 41.6719 |
| 163.0000 | 240.0000 | 0.0000 | 4.9032 |
| 85.0000 | 90.0000 | 0.0000 | -2.916934 |
| | | | |

*Output from the simulation in PSSE*

## Transformer results output comparison for panda power and PSSE

For the simulated data, only the transformer loading percentage is considered.

| Result from PSSE | Result from Pandapower |
|---|---|
| 229 | 228.906056 |
| NA | NaN |

| | |
|---|---|
| 83 | 82.975638 |

```
--- Transformer Flows (MW / MVAr) ---
   loading_percent
0       228.906056
1               NaN
2        82.975638
```

*Output from the simulation in Panda Power*

Line flow results output comparison for panda power and PSSE

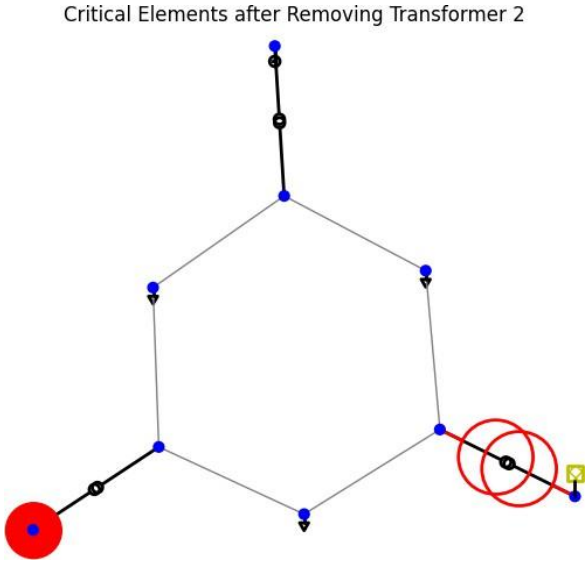
| | Results from PSSE | | Results from Pandapower | |
|---|---|---|---|---|
| | Active power (From bus in MW) | Reactive power (From bus in Mvar) | Active power (From bus in MW) | Reactive power (From bus in Mvar) |
| Bus 4 - Bus 5 | 148.5 | 17.8 | 148.525391 | 17.754424 |
| Bus 4 - Bus 6 | 85.9 | -6.3 | 85.861203 | -6.263342 |
| Bus 5 - Bus 7 | 21.4 | -29 | -52.459149 | -15.828265 |
| Bus 6 - Bus 9 | -5.3 | -26.3 | -5.331945 | -26.326662 |
| Bus 7 - Bus 8 | 21.1 | 0.9 | 21.149340 | 0.903937 |
| Bus 8 - Bus 9 | -78.9 | -19.2 | -78.893732 | -19.181553 |

| | Results from PSSE | | | Results from Pandapower | | |
|---|---|---|---|---|---|---|
| | Active power (To bus in MVA) | Reactive power (To bus in MVA) | Line loading (%) | Active power (To bus in MVA) | Reactive power (To bus in MVA) | Line loading(%) |
| Bus 4 - Bus 5 | -146.4 | -21 | 37 | -146.357033 | -21.012369 | 37.212543 |
| Bus 4 - Bus 6 | -84.7 | -3.7 | 21 | -84.668055 | -3.673338 | 21.079687 |
| Bus 5 - Bus 7 | -21.1 | -0.9 | 9 | -21.149340 | -0.903937 | 9.061829 |
| Bus 6 - Bus 9 | 5.4 | -10.8 | 7 | 5.367104 | -10.759099 | 6.662685 |
| Bus 7 - Bus 8 | -21.1 | -15.8 | 7 | -21.106268 | -15.818447 | 6.575360 |

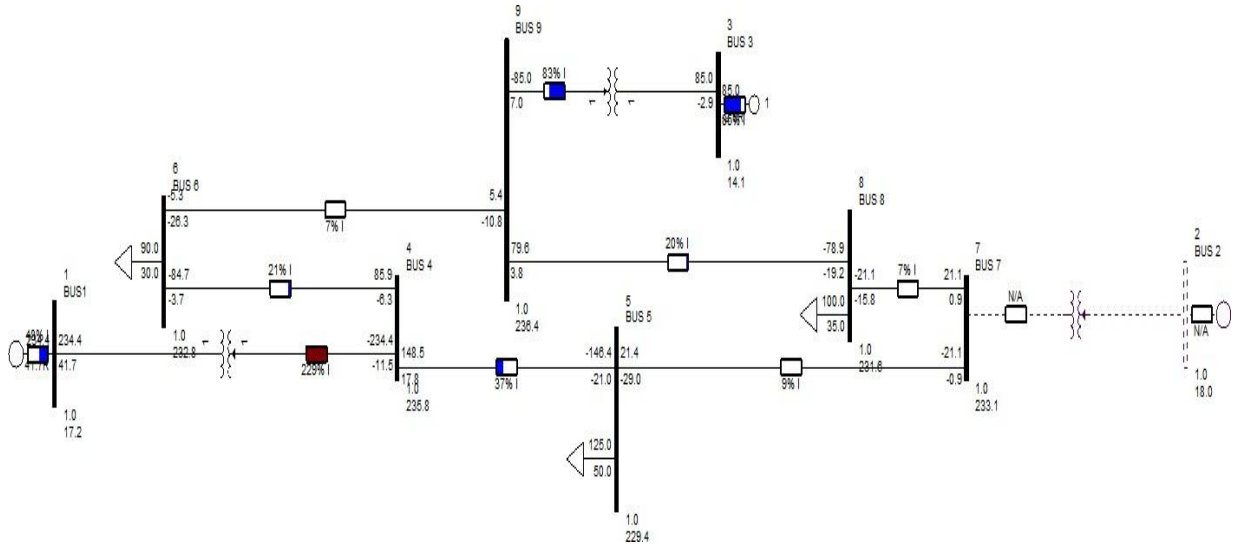
| | | | | | | |
|---|---|---|---|---|---|---|
| Bus 8 - Bus 9 | 79.6 | 3.8 | 20 | 79.632896 | 3.807760 | 20.240575 |

```
--- Line Flows (MW / MVAr) ---
    p_from_mw  q_from_mvar     p_to_mw  q_to_mvar  loading_percent
0  148.525391    17.754424 -146.357033 -21.012369        37.212543
1   85.861203    -6.263342  -84.668055  -3.673338        21.079687
2   21.357033   -28.987631  -21.149340  -0.903937         9.061829
3   -5.331945   -26.326662    5.367104 -10.759099         6.662685
4   21.149340     0.903937  -21.106268 -15.818447         6.575360
5  -78.893732   -19.181553   79.632896   3.807760        20.240575
```

*Output from the simulation in Panda Power*




*Output from the simple plot in Panda Power*




*PSSE output*

Contingency 2 - Loss of transformer 3

Bus results output comparison for Pandapower and PSSE

| Result from PSSE | | Result from Pandapower | |
|---|---|---|---|
| Voltage (pu) | Angle (degree) | Voltage (pu) | Angle (degree) |
| 1.04 | 0.00 | 1.040000 | 0.000000 |
| 1.0250 | 2.249115 | 1.025000 | 2.249110 |
| NaN | NaN | NaN | NaN |
| 1.031212 | 1.031212 | 1.031212 | -4.792213 |
| 1.006997 | 1.006997 | 1.006997 | -7.544618 |
| 1.0208 | 1.02082 | 1.020820 | -8.713763 |
| 1.02957 | 1.02957 | 1.029570 | -3.290604 |
| 1.02089 | 1.02089 | 1.020890 | -6.860345 |
| 1.040391 | 1.040391 | 1.040391 | -7.698033 |

When the transformer is switched off, the link between the bus where the generator is connected and the grid is interrupted. So that in PSSE it gives an error since the generator operates in the islanded mode. To overcome that, we need to turn off the bus bar in which the generator is connected. That's why we get NaN values for bus results in this contingency

```
--- Bus Voltages (p.u.) ---
      vm_pu  va_degree
1  1.040000   0.000000
2  1.025000   2.249110
3       NaN        NaN
4  1.031212  -4.792213
5  1.006997  -7.544618
6  1.020820  -8.713763
7  1.029570  -3.290604
8  1.020890  -6.860345
9  1.040391  -7.698033
```

*Output from the simulation in Panda Power*

## Generator results output comparison for Pandapower and PSSE

Slack Generator

| Result from PSSE | | Result from Pandapower | |
|---|---|---|---|
| Active Power(MW) | Reactive Power(Mvar) | Active Power(MW) | Reactive Power(Mvar) |
| 155.5484 | 22.37646 | 155.548446 | 22.376556 |

Other Generators

| Result from PSSE | | Result from Pandapower | |
|---|---|---|---|
| Active Power(MW) | Reactive Power(Mvar) | Active Power(MW) | Reactive Power(Mvar) |
| 163 | 0.3909822 | 163.0 | 0.391066 |
| 85 | -2.916934 | 0 | 0.000000 |

```
--- Generator Outputs (MW / MVAr) ---
    p_mw    q_mvar
0  163.0  0.391066
1    0.0  0.000000

--- Slack Power (MW / MVAr) ---
         p_mw     q_mvar
0  155.548446  22.376556
```

*Output from the pandapower simulation*

| | PGen (MW) | PMax (MW) | PMin (MW) | QGen (Mvar) |
|---|---|---|---|---|
| | 155.5484 | 450.0000 | 0.0000 | 22.3765 |
| | 163.0000 | 240.0000 | 0.0000 | 0.3910 |
| | 85.0000 | 90.0000 | 0.0000 | -2.9169 |
| | | | | |

*Output from the simulation in PSSE*

## Transformer results output comparison for panda power and PSSE

For the simulated data, only the transformer loading percentage is considered.

| Result from PSSE | Result from Pandapower |
|---|---|
| 151 | 151.105485 |
| 159 | 159.024848 |
| NA | NaN |

```
--- Transformer Flows (MW / MVAr) ---
   loading_percent
0       151.105485
1       159.024848
2              NaN
```

*Output from the simulation in Panda Power*

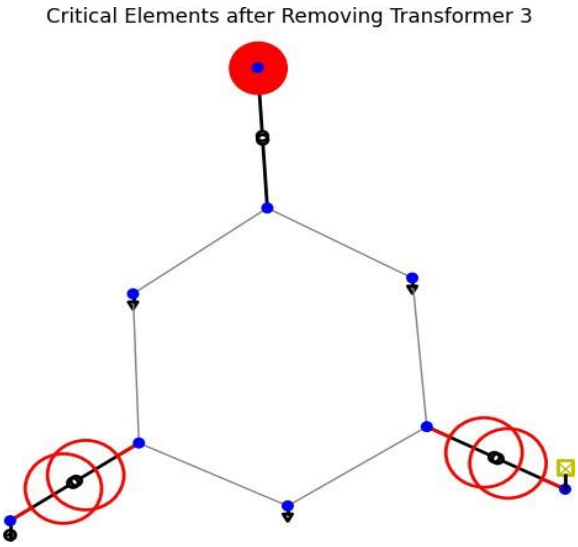
Line flow results output comparison for panda power and PSSE

| | Results from PSSE | | Results from Pandapower | |
|---|---|---|---|---|
| | Active power (From bus in MW) | Reactive power (From bus in Mvar) | Active power (From bus in MW) | Reactive power (From bus in Mvar) |
| Bus 4 - Bus 5 | 77.3 | 17.8 | 77.318494 | 17.754564 |
| Bus 4 - Bus 6 | 78.2 | -8.5 | 78.229953 | -8.529740 |
| Bus 5 - Bus 7 | -48.3 | -18.3 | -48.312807 | -18.256800 |
| Bus 6 - Bus 9 | -12.7 | -27.2 | -12.748412 | -27.191192 |
| Bus 7 - Bus 8 | 113.9 | -5.7 | 113.948244 | -5.656051 |
| Bus 8 - Bus 9 | 12.9 | -32.1 | 12.906670 | -32.052633 |

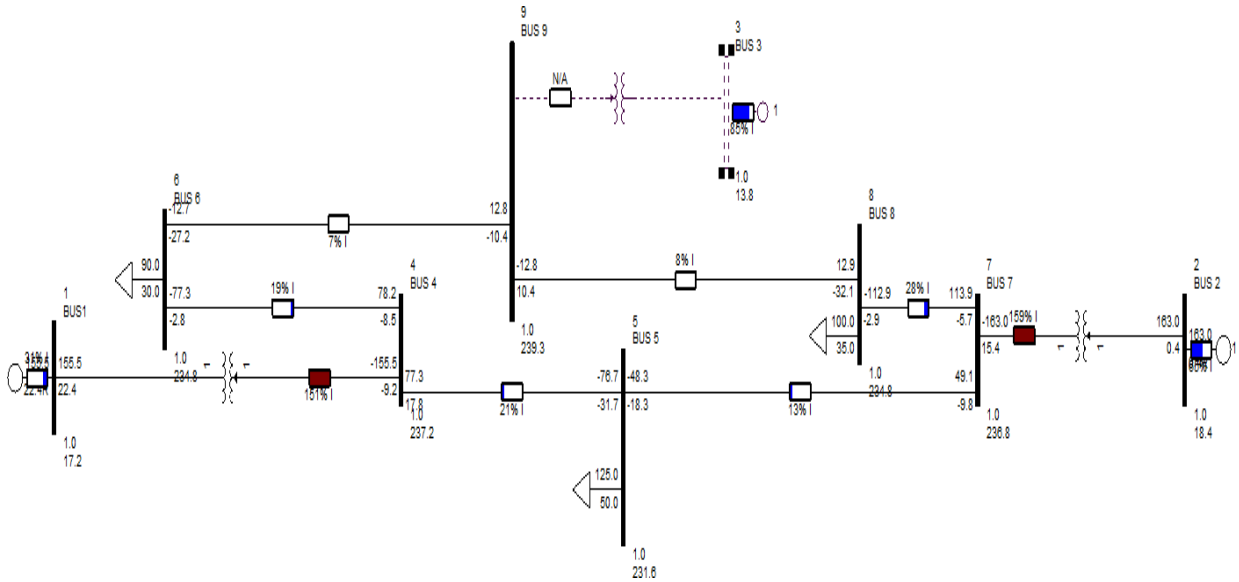
| | Results from PSSE | | | Results from Pandapower | | |
|---|---|---|---|---|---|---|
| | Active power (To bus in MVA) | Reactive power (To bus in MVA) | Line loading (%) | Active power (To bus in MVA) | Reactive power (To bus in MVA) | Line loading(%) |
| Bus 4 - Bus 5 | -76.7 | -31.7 | 21 | -76.687193 | -31.743200 | 20.689377 |
| Bus 4 - Bus 6 | -77.3 | -2.8 | 19 | -77.251588 | -2.808808 | 19.155923 |
| Bus 5 - Bus 7 | 79.1 | -9.8 | 13 | 49.051756 | -9.758446 | 12.874503 |
| Bus 6 - Bus 9 | 12.8 | -10.4 | 7 | 12.836519 | -10.444483 | 7.384776 |
| Bus 7 - Bus 8 | -112.9 | -2.9 | 28 | -112.906670 | -2.947367 | 27.816187 |
| Bus 8 - Bus 9 | -12.8 | 10.4 | 8 | -12.836519 | 10.444483 | 8.496233 |

```
--- Line Flows (MW / MVAr) ---
    p_from_mw  q_from_mvar     p_to_mw  q_to_mvar  loading_percent
0   77.318494    17.754564  -76.687193 -31.743200        20.689377
1   78.229953    -8.529740  -77.251588  -2.808808        19.155923
2  -48.312807   -18.256800   49.051756  -9.758446        12.874503
3  -12.748412   -27.191192   12.836519 -10.444483         7.384776
4  113.948244    -5.656051 -112.906670  -2.947367        27.816187
5   12.906670   -32.052633  -12.836519  10.444483         8.496233
```

*Output from the simulation in Panda Power*




*Output from the simple plot in Panda Power*




*PSSE output*

## Discussion

- WSCC 9 bus system which was used to compare the results in the base case scenario and for the panda power simulation and PSSE simulation. The results which were obtained from the both methods are equal.

- In the panda power, when calculating the loading percentage of transformers, they have used the MVA base defined for the system as the base MVA. So that some transformers are seen as overloaded.

- For the lines, panda power has calculated the rated MVA rating of the transmission line using the operating voltage and the rated current.