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POWER SYSTEMS · AI · RESEARCH

# Technical Note 006: Coupling PSCAD and Pandapower for Loadflow Initialisation

N-006

*This is preliminary research and has not been validated or peer-reviewed. It could therefore be totally wrong.*

# Key Concepts

- One of the common headaches on large PSCAD models is how to initialise the network for specific loadflow cases. This usually needs a second model to be created in DIgSILENT or PSS/E and then used to calculate the various machine angles and terminal voltages.

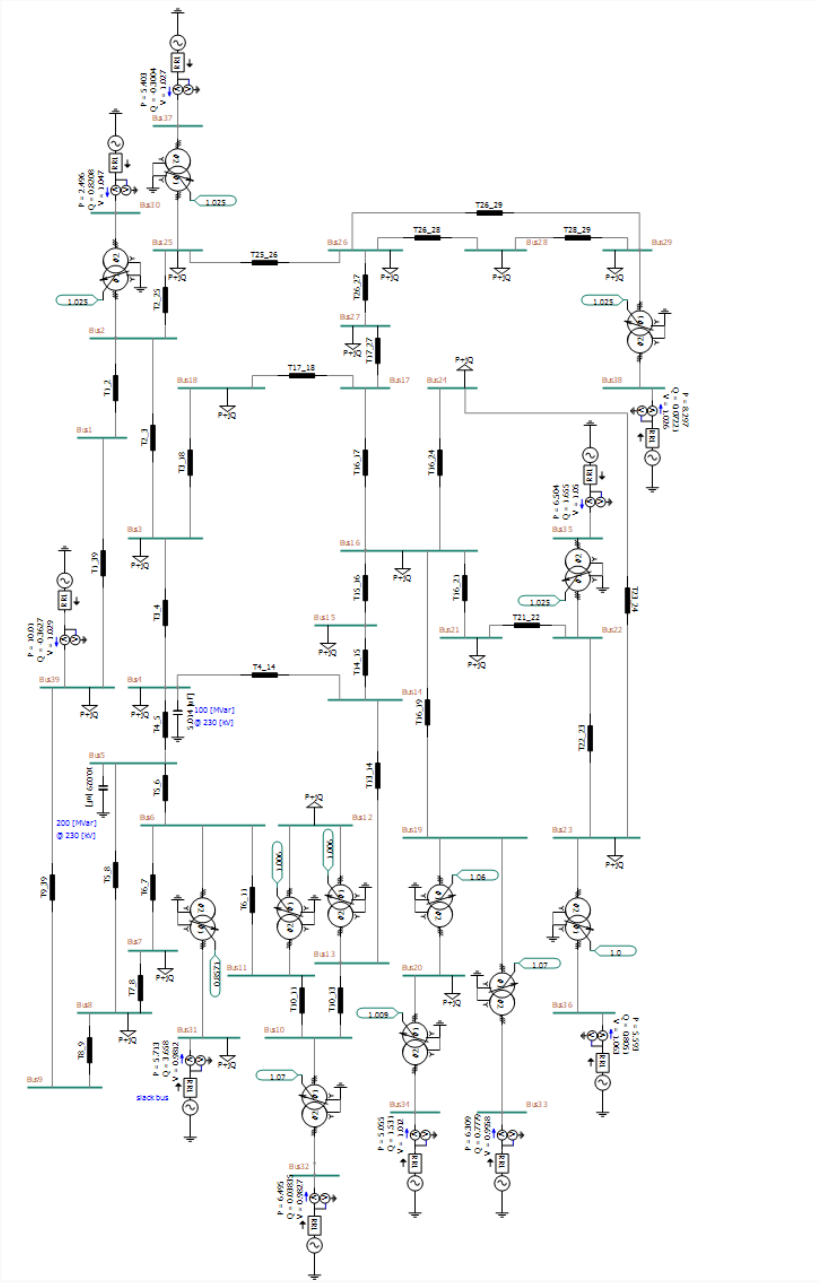
- Pandapower can be coupled with PSCAD to resolve this headache, by using an AI to connect to PSCAD and build its own Pandapower model and cross check against each other.

- Using an MCP server, it is possible for the AI to create a simplified 1-to-1 model of the PSCAD network in pandapower and solve any loadflow scenario using an established Newton-Raphson iteration model.

- Once the network is solved, the AI can then pass the initialisation values for each loadflow case to PSCAD through the MCP layer.

# IEEE 39-Bus

- The IEEE 39-Bus model is a well-known industry benchmark, and has been setup by MHI already in PSCAD, as can be seen below.
- The standard PSCAD model includes all the generators as simple Voltage sources rather than as synchronous machines - as that would get a bit challenging, but the same principle with the source terminal voltage and angles.
- The model is large enough to be interesting, but not so large as to get lost in the detail.



# Testing

- 4 test cases were setup in Pandapower with different loading scenarios, and the correlation between the two models was then checked.

- A simple base case scenario (S1) and then two load variations keeping the network balance the same (S2 and S3) and then finally a case with 450 MW of generation shifted from the East to the North East (load unchanged).

| Case | Definition | Load MW | Gen MW | Losses MW | Vmin / Vmax pu |
|---|---|---|---|---|---|
| S1 Base | Model's own dispatch, 100% load. Sanity check that pandapower reproduces the PSCAD file's existing init values. | 6150 | 6178 | 28.9 | 0.982 / 1.075 |
| S2 Light | All loads scaled to 60% (P and Q), all generator P scaled to 60%. | 3690 | 3702 | 11.8 | 0.982 / 1.106 |
| S3 Peak | All loads scaled to 110%, all generator P scaled to 110%. | 6764 | 6799 | 34.9 | 0.982 / 1.066 |
| S4 Dispatch shift | 100% load, 450 MW moved from the east to the north-east. G6 and G7 back off, G8 and G9 pick up. | 6150 | 6195 | 45.3 | 0.982 / 1.074 |

# Results – S1 (Base Case)

| Gen | Bus | P pp MW | P emt MW | dP MW | Q pp MVAr | Q emt MVAr | dQ MVAr | V pp pu | V emt pu | dV pu | ang pp deg | ang emt deg | dang deg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| G1 | 39 | 987.1 | 990.6 | +3.5 | -38.5 | -35.8 | +2.7 | 1.0300 | 1.0296 | -0.0004 | -10.06 | -10.06 | +0.000 |
| G2 | 31 | 571.3 | 572.8 | +1.5 | 361.7 | 365.8 | +4.1 | 0.9820 | 0.9814 | -0.0006 | -1.38 | -1.36 | +0.024 |
| G3 | 32 | 650.0 | 650.9 | +0.9 | -1.7 | 3.3 | +5.0 | 0.9831 | 0.9824 | -0.0007 | 2.01 | 2.04 | +0.030 |
| G4 | 33 | 632.0 | 633.3 | +1.3 | 77.2 | 81.2 | +4.1 | 0.9972 | 0.9966 | -0.0006 | 3.20 | 3.22 | +0.025 |
| G5 | 34 | 508.0 | 509.5 | +1.5 | 148.8 | 152.5 | +3.8 | 1.0123 | 1.0118 | -0.0005 | 1.86 | 1.88 | +0.024 |
| G6 | 35 | 650.0 | 651.4 | +1.4 | 157.9 | 161.9 | +4.0 | 1.0493 | 1.0488 | -0.0005 | 5.05 | 5.08 | +0.026 |
| G7 | 36 | 560.0 | 560.9 | +0.9 | 79.1 | 82.6 | +3.5 | 1.0635 | 1.0631 | -0.0004 | 7.75 | 7.78 | +0.031 |
| G8 | 37 | 540.0 | 541.1 | +1.1 | -31.5 | -28.2 | +3.3 | 1.0278 | 1.0275 | -0.0003 | 2.25 | 2.28 | +0.028 |
| G9 | 38 | 830.0 | 832.3 | +2.3 | 5.3 | 8.7 | +3.4 | 1.0265 | 1.0260 | -0.0005 | 7.57 | 7.58 | +0.014 |
| G10 | 30 | 250.0 | 251.9 | +1.9 | 75.7 | 79.3 | +3.6 | 1.0475 | 1.0471 | -0.0004 | -3.50 | -3.48 | +0.023 |
| **Total** | | **6178.4** | **6194.7** | **+16.3** | **833.9** | **871.4** | **+37.4** | | | | | | |

# Results – S2 (Light Load, 60%)

| Gen | Bus | P pp MW | P emt MW | dP MW | Q pp MVAr | Q emt MVAr | dQ MVAr | V pp pu | V emt pu | dV pu | ang pp deg | ang emt deg | dang deg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| G1 | 39 | 586.7 | 588.7 | +2.0 | -226.7 | -224.8 | +1.9 | 1.0300 | 1.0299 | -0.0001 | -10.06 | -10.06 | +0.000 |
| G2 | 31 | 342.8 | 343.7 | +0.9 | 204.4 | 207.9 | +3.5 | 0.9820 | 0.9816 | -0.0004 | -5.06 | -5.05 | +0.014 |
| G3 | 32 | 390.0 | 390.6 | +0.6 | -148.2 | -143.9 | +4.3 | 0.9831 | 0.9826 | -0.0005 | -3.06 | -3.04 | +0.018 |
| G4 | 33 | 379.2 | 380.0 | +0.8 | -30.6 | -27.1 | +3.5 | 0.9972 | 0.9968 | -0.0004 | -2.26 | -2.24 | +0.015 |
| G5 | 34 | 304.8 | 305.7 | +0.9 | 67.4 | 70.6 | +3.3 | 1.0123 | 1.0119 | -0.0004 | -3.04 | -3.03 | +0.015 |
| G6 | 35 | 390.0 | 390.9 | +0.9 | 20.8 | 24.1 | +3.3 | 1.0493 | 1.0490 | -0.0003 | -1.23 | -1.22 | +0.015 |
| G7 | 36 | 336.0 | 336.6 | +0.6 | -17.0 | -14.0 | +2.9 | 1.0635 | 1.0633 | -0.0002 | 0.35 | 0.37 | +0.018 |
| G8 | 37 | 324.0 | 324.7 | +0.7 | -101.7 | -99.0 | +2.7 | 1.0278 | 1.0276 | -0.0002 | -2.75 | -2.73 | +0.016 |
| G9 | 38 | 498.0 | 499.5 | +1.5 | -119.4 | -116.9 | +2.6 | 1.0265 | 1.0263 | -0.0002 | 0.32 | 0.33 | +0.006 |
| G10 | 30 | 150.0 | 151.1 | +1.1 | -14.4 | -11.5 | +3.0 | 1.0475 | 1.0472 | -0.0003 | -6.20 | -6.18 | +0.014 |
| **Total** | | **3701.5** | **3711.4** | **+9.9** | **-365.5** | **-334.4** | **+31.1** | | | | | | |

# Results – S3 (Peak Load, 110%)

| Gen | Bus | P pp MW | P emt MW | dP MW | Q pp MVAr | Q emt MVAr | dQ MVAr | V pp pu | V emt pu | dV pu | ang pp deg | ang emt deg | dang deg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| G1 | 39 | 1088.9 | 1092.9 | +3.9 | 11.9 | 14.8 | +2.9 | 1.0300 | 1.0295 | -0.0005 | -10.06 | -10.06 | +0.000 |
| G2 | 31 | 628.4 | 630.1 | +1.6 | 408.4 | 412.7 | +4.4 | 0.9820 | 0.9813 | -0.0007 | -0.44 | -0.41 | +0.028 |
| G3 | 32 | 715.0 | 715.9 | +0.9 | 42.7 | 48.0 | +5.3 | 0.9831 | 0.9823 | -0.0008 | 3.32 | 3.35 | +0.034 |
| G4 | 33 | 695.2 | 696.6 | +1.4 | 110.5 | 114.8 | +4.3 | 0.9972 | 0.9966 | -0.0006 | 4.59 | 4.62 | +0.029 |
| G5 | 34 | 558.8 | 560.5 | +1.7 | 173.3 | 177.2 | +4.0 | 1.0123 | 1.0118 | -0.0005 | 3.11 | 3.13 | +0.027 |
| G6 | 35 | 715.0 | 716.5 | +1.5 | 200.5 | 204.7 | +4.2 | 1.0493 | 1.0487 | -0.0006 | 6.68 | 6.71 | +0.030 |
| G7 | 36 | 616.0 | 617.0 | +1.0 | 109.2 | 113.0 | +3.7 | 1.0635 | 1.0631 | -0.0004 | 9.67 | 9.71 | +0.035 |
| G8 | 37 | 594.0 | 595.2 | +1.2 | -9.2 | -5.7 | +3.5 | 1.0278 | 1.0274 | -0.0004 | 3.51 | 3.54 | +0.032 |
| G9 | 38 | 913.0 | 915.5 | +2.5 | 45.1 | 48.7 | +3.7 | 1.0265 | 1.0260 | -0.0005 | 9.44 | 9.45 | +0.017 |
| G10 | 30 | 275.0 | 277.1 | +2.1 | 102.3 | 106.1 | +3.8 | 1.0475 | 1.0470 | -0.0005 | -2.83 | -2.80 | +0.026 |
| **Total** | | **6799.4** | **6817.4** | **+18.0** | **1194.6** | **1234.3** | **+39.7** | | | | | | |

# Results – S4 (Dispatch Shift, 450 MW E→NE)

| Gen | Bus | P pp MW | P emt MW | dP MW | Q pp MVAr | Q emt MVAr | dQ MVAr | V pp pu | V emt pu | dV pu | ang pp deg | ang emt deg | dang deg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| G1 | 39 | 1003.5 | 1007.0 | +3.4 | -22.3 | -19.5 | +2.8 | 1.0300 | 1.0296 | -0.0004 | -10.06 | -10.06 | +0.000 |
| G2 | 31 | 571.3 | 572.7 | +1.4 | 366.2 | 370.3 | +4.1 | 0.9820 | 0.9814 | -0.0006 | -2.71 | -2.69 | +0.024 |
| G3 | 32 | 650.0 | 650.8 | +0.8 | 2.5 | 7.5 | +5.0 | 0.9831 | 0.9824 | -0.0007 | 0.47 | 0.50 | +0.030 |
| G4 | 33 | 632.0 | 633.3 | +1.3 | 77.7 | 81.7 | +4.0 | 0.9972 | 0.9966 | -0.0006 | -0.26 | -0.24 | +0.025 |
| G5 | 34 | 508.0 | 509.5 | +1.5 | 149.0 | 152.7 | +3.8 | 1.0123 | 1.0118 | -0.0005 | -1.61 | -1.58 | +0.024 |
| G6 | 35 | 400.0 | 401.7 | +1.7 | 118.0 | 121.9 | +3.9 | 1.0493 | 1.0488 | -0.0005 | -4.14 | -4.12 | +0.023 |
| G7 | 36 | 360.0 | 361.2 | +1.2 | 42.6 | 46.0 | +3.4 | 1.0635 | 1.0632 | -0.0003 | -2.44 | -2.41 | +0.028 |
| G8 | 37 | 740.0 | 740.6 | +0.6 | -2.7 | 0.6 | +3.4 | 1.0278 | 1.0274 | -0.0004 | 6.71 | 6.74 | +0.031 |
| G9 | 38 | 1080.0 | 1082.4 | +2.4 | 101.0 | 104.6 | +3.6 | 1.0265 | 1.0259 | -0.0006 | 16.08 | 16.09 | +0.010 |
| G10 | 30 | 250.0 | 251.8 | +1.8 | 121.4 | 125.0 | +3.6 | 1.0475 | 1.0471 | -0.0004 | -2.67 | -2.65 | +0.024 |
| **Total** | | **6194.8** | **6211.2** | **+16.4** | **953.4** | **991.0** | **+37.5** | | | | | | |

# Observations

- There was a small systematic bias identified in every case. The EMT P and Q are higher at all ten machines, every terminal voltage is a fraction lower, and angles lead by 0.01–0.035°.
- EMT generates 10–18 MW / 31–40 MVAr more than pandapower, scaling with load. G1 (slack) takes the P mismatch; dQ spreads across the PV machines, G3 largest.
- This is thought to be representation difference (line charging, transformer model, or fixed-P sources not holding their Pinit) rather than an initialisation error.

| Case | Where the mismatch sits | ΣdP MW | ΣdQ MVAr | max dV pu | max dθ deg |
|---|---|---|---|---|---|
| S1 Base | G1 slack dP +3.5 MW; G3 largest dQ +5.0 MVAr | +16.3 | +37.4 | 0.0007 | 0.031 |
| S2 Light | G1 slack dP +2.0 MW; G3 largest dQ +4.3 MVAr | +9.9 | +31.1 | 0.0005 | 0.018 |
| S3 Peak | G1 slack dP +3.9 MW; G3 largest dQ +5.3 MVAr | +18.0 | +39.7 | 0.0008 | 0.035 |
| S4 Shift | G1 slack dP +3.4 MW; G3 largest dQ +5.0 MVAr | +16.4 | +37.5 | 0.0007 | 0.031 |

# Summary

- Coupling Pandapower to PSCAD started off as a bit of fun, but has rapidly become a key use case and a great time saver when working on real problems and scenarios.

- The dual configured PSCAD-Pandapower model lets me run both models simultaneously and configure the PSCAD model for pretty much any case I want without having to do a lot of manual labour and iteration.

- There is the added bonus, that as Pandapower is native python there was no need to build another MCP server or setup any tools or skillsets for it.

- As a small 'fun' experiment I might get the AI to see if it can replace all the voltage sources with a sub-module of a synchronous machine and then rewire and test again!