POLITECNICO DI TORINO

Master of science program in Energy and Nuclear Engineering

Energy Networks

ELECTRICITY WONDERLAND

Team

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1. Abstract

The steady-state representation of the transmission system is modeled based on the complete data set provided. After completing the modeling of the underlying grid, we perform a series of studies.

First, we study whether the network satisfies the constraints we set in terms of voltage distribution and line flow limits under normal operating conditions (without any faults).

Next, we study the load growth at a specific value per year over the next five years, filtering out the maximum annual growth value that is acceptable in terms of adequacy.

Finally, we study a fixed load growth of 10% in the next few years. Thus, the existing electrical network is economically adjusted to accommodate the new load demand.

2. T0: steady-state representation of the transmission system, using a full AC power flow model and the datasets provided.

The electricity wonderland grid is composed of 49 buses, 39 generators (among which 14 generators are tie-lines equivalent models), 114 lines (among which 30 lines are tie-lines) and 27 loads. All bus nominal voltage is 380 kV.

Import all the basic grid data provided in the mission file (including buses, generators, loads and branches) into the “Powerworld” to generate an "electric wonderland" model. A single-line graph of the power grid can be generated from the latitude and longitude coordinates of each bus line, as shown in Figure 1.

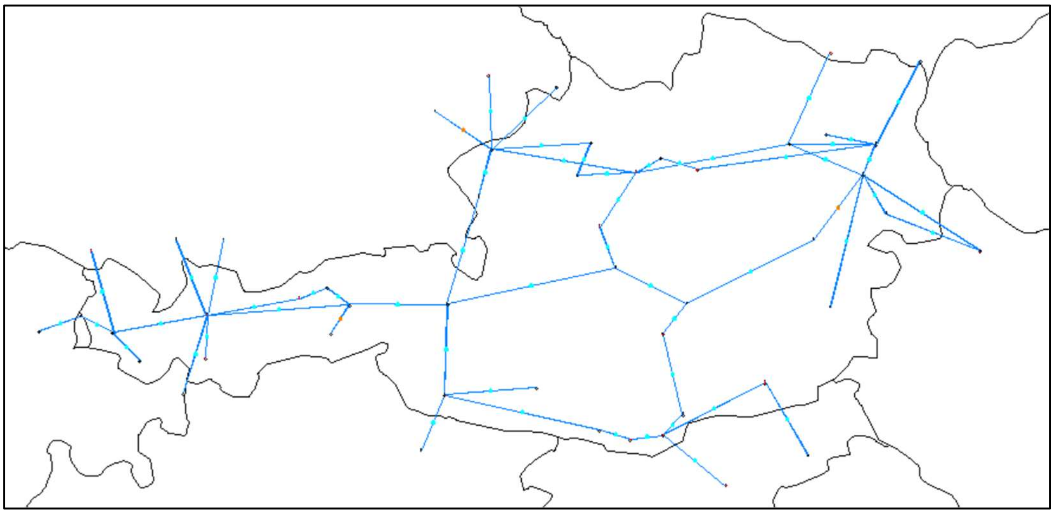

Figure1. The one-line diagram of electricity wonderland

3. T1: assessment of the present situation of the network.

In order to perform the EW assessment, the network is submitted under evaluation by using the contouring tool for buses (nodes) and branches (lines), it highlights how the "stresses" are distributed along the network working in normal conditions. In the case of buses, the variable under analysis is the voltage per unit magnitude, which places on evidence the voltage offset with respect to the nominal one (220 kV), as a rule of thumb the upper and lower limits of the rated value is set as +/- 8%.

In figure 2 is shown the voltage profile of the EW network, it is like nothing which are the nodes on overvoltage with red zones (CZ-32, CZ-31, D-188) and undervoltage with blue zones (D_leupol, H-13). It is remarkable to mention that the nodes with higher offset are the ones at the borders with the neighboring countries and the ones inside the electricity wonderland zone are most likely to round the rated voltage. In this sense the power configuration has no unacceptable voltage levels working on normal conditions, besides three nodes rounding the under-limit threshold (A-13, A-14, A-15).

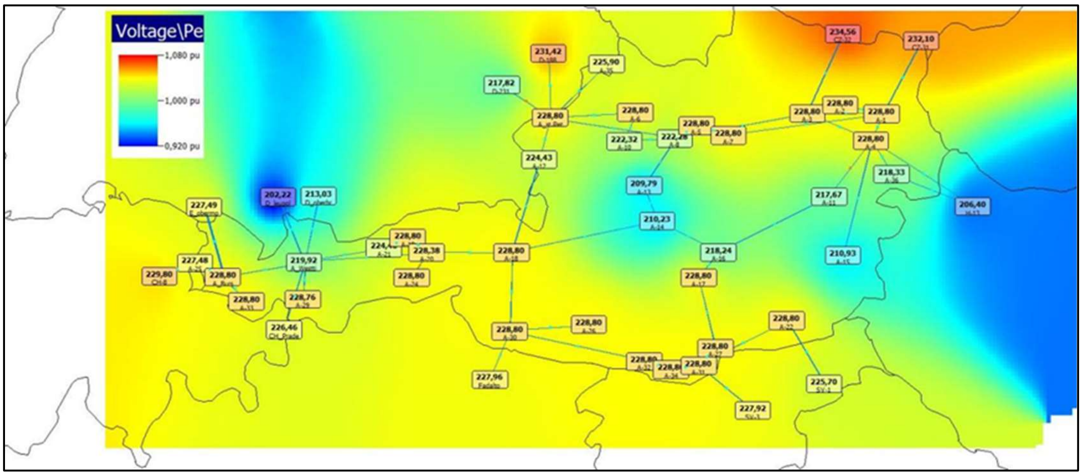

Figure 2. Voltage distribution of EW network.

Likewise, in case of the branches the variable under investigation is the percentage limit of apparent power (%MVALIM), the upper limit of transmission capacities is set to 96,6% and the contouring evaluation is performed. In figure 3 can be seen the potential distribution along the transmission lines, the ones highlighted with red are those close to the maximum limit. It is remarkable how three of them are almost reaching the upper limit, two inside the EW zone and the last one out of the perimeter of control.

Therefore, the assessment of the network working under normal conditions was validated in which concerns for voltage and apparent power distribution along it. For detailed values of each node and branch can be found on the PowerWorld file attached.

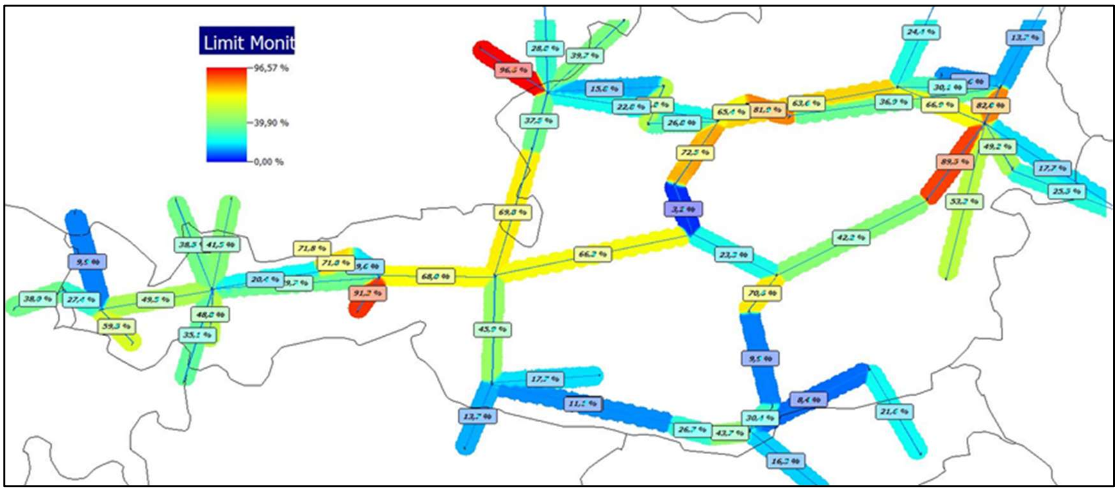

Figure 3. %MVALIM distribution of EW network.

Furthermore, in Figure 4 is shown the “stress” distribution along the network for the 49 buses and 114 transmission lines, it is a graphical representation of the system pointing out the percentage of buses and branches that are under/over the limit. In the case of Voltage PU magnitude, the buses reaching the under and over voltage are 2.04% and 6.12% respectively, the rest of them are mostly in the acceptable region. Likewise for the case of branches just the 9% of them are almost reaching the maximum acceptable limit (%MVALIM).

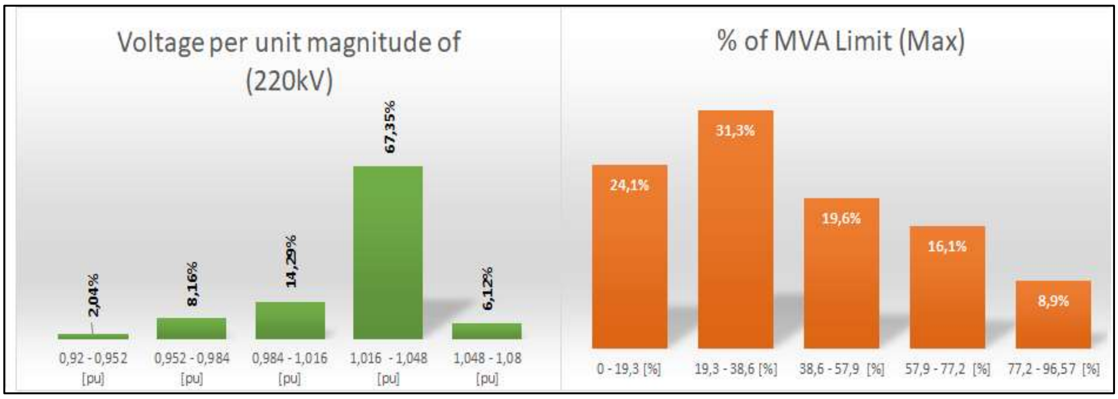

Figure 4. “Stress” distribution of branches and buses.

4. T3: network assessment with load increment during the following 5 years.

In this task, we are going to linearly scale the load at buses in “electricity wonderland” by X% lasting 5 years. Because the load will increase proportionally to the present value at each bus in this task, the “scale” module in “PowerWorld” can be conveniently used to estimate the maximum acceptable value of x in terms of adequacy.

We start increasing the bus loads of area A (electricity wonderland) from 0.2% annually, which the total increasing ratio after 5 years is up to 1%, to 0.3% annually (1.5% after 5 years), and finally to 0.4% (2% after 5 years). Finally, by the “model explorer dialog” module, the data of all the buses and lines can be checked with a constraint applied here for buses and lines were “+/-8% of the rated voltage value” and “100% of the power transmission capacities” respectively.

The table below shows some related data of some scaling trying mentioned above.

Table 1. data from the scaling simulation

Ratio (annually)	original	0.2%	0.3%	0.4
Load MW	6793.38	6861.59	6895.89	6930.34
Load Mvar	2232.86	2255.28	2266.55	2277.88
Overvoltage Num	0	0	0	0
Undervoltage Num	1 (D_leupol)	1 (D_leupol)	1 (D_leupol)	1 (D_leupol)
Over capacity Num	0	0	0	2

From the initially simulation, we could point out that when the scaling ratio is up to 0.4%annually, there were two transmission line is over the capacity, so we decreased backwards the ratio step by step until this limiting condition was no longer being violated, and finally found that a 0.34% increase in overall demand was the limit for the power system to accommodate without violating any normal operating condition limits, except the BUS D_leupol, which was overvoltage even in original situation and was outside of our Control Area. Regarding the data of increase ratio at 0.34% (1.7% after 5 years), the highest loaded lines within the system are from A-20 to A-24 buses, at 99.8% loading. Although the voltage level of buses over the system was acceptable there are some buses has a potential to break the up or under limit threshold, such as CZ-32, CZ-31, D-188, H-13 and A-13 and, considering we set a relatively loosen limit threshold at +/-8%, these buses could be concerned.

It can be suggested that some shunt capacitors should be installed on some buses and therefore, increasing their voltage and keeping at a relatively safety range, the system would also be able to hold a slightly higher overall load without over the transmission capacity.

Overall, all these data above and suggestions are based on the simulation by Powerworld. Both active power and reactive power loads were increasing linearly at the same step. But in the real world the situation would be more complicated and difficult.

5. T5: reinforcement the network after a 10% load increase.

In this task, we are going to have a load increase in “electricity wonderland” by 10%. Same as the task 3, the load will increase proportionally to the present value at each bus in this task. After the load of the local area was increased by 10%, the total load changed as follows showed in table 2, and there were 8 violations branches. We can extract the data of these 8 lines and make it into table 3.

Table 2. data from the 10% increased simulation

	Load MW	Load Mvar
original	6793.38	2232.86
10% adjustment	7472.72	2456.15

Table 3. data from the 10% increased simulation

From Number	From Name	To Number	To Name	Circuit	Limiting Flow Used	Limit Used	% of Limit Used
1013	A-18	1007	A-12	1	352.4	330	106.8
1013	A-18	1007	A-12	2	352.4	330	106.8
1009	A-14	1013	A-18	1	337.2	330	102.2
1009	A-14	1013	A-18	2	337.2	330	102.2
1015	A-20	1013	A-18	1	919.2	800	114.9
1015	A-20	1013	A-18	2	919.2	800	114.9
1015	A-20	1019	A-24	1	1151.3	800	143.9

From Table 3, The main area where violations branches appear is around bus A-18, so it is expected that additional lines will be added around this area to reinforce the network.

After various attempts, it was found that adding a transmission line from bus A-24 to bus A-14 can solving above mentioned violations and there are no new violations generated. We select wires with Line X is 0.05042 and limit is 800 MVA for this line. Finally, the load on this line is calculated as 758.2 MW, 130.6 MAR and 769.4 MVA. The reinforcement contouring diagram is shown in Figure 5.

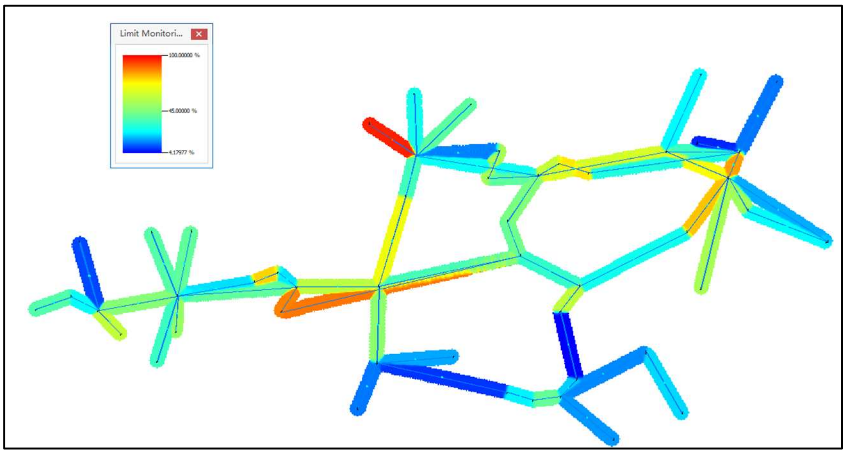

Figure 5. $\%MVA_{LIM}$ distribution of reinforcement network.

6. Conclusion

In the project exercise, we simulate the role of an electricity infrastructure operator to detect and regulate or provide technical solutions in case of system failures or irregularities and load increases, to ensure a safe and stable supply of electricity to customers. With the help of specialized software, we can effectively model and simulate power networks to produce reliable simulation data results. With the simulation results, we can effectively predict the foreseeable risks in the real network and avoid them.