POLITENICO DI TORINO

MSc in Energy and Nuclear Engineering – Renewable Energy Systems

ENERGY NETWORKS COURSE
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Group project A2

MANAGING THE DISTRIBUTION SYSTEM OF HAPPY PROSUMER COMMUNITY

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Introduction

The goal of the project is to study a realistic electricity prosumer community, in order to promote the implementation of the production of renewable energy into the grid.
The installation site chosen includes the city of Florence, the capital city of Tuscany region, for a total installation area of 30 m^2, accounting of around 380.000 inhabitants.
The figure 1 shows the area of interest concerning the city of Florence from the river Arno in the south part to the northern mountains.

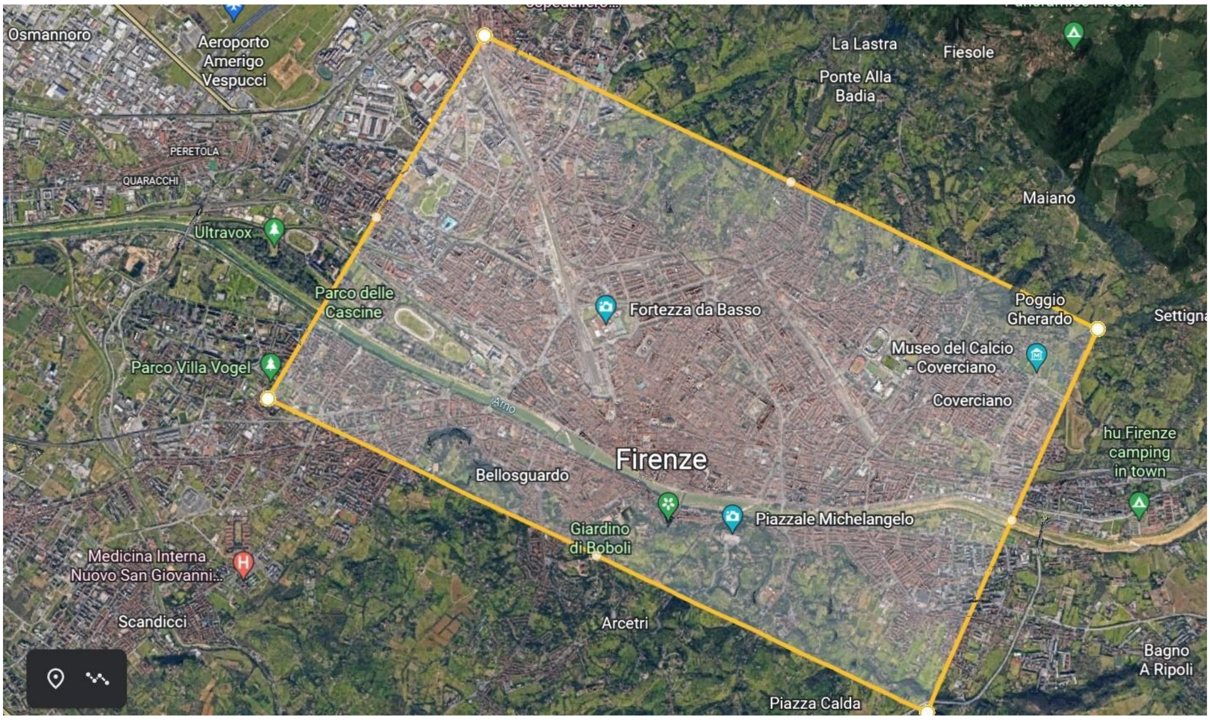


Figure 1 - Installation area at the city of Florence

For the purpose of the project, the residents are free to develop their own scheme of electricity supply: PV panel, micro-wind turbine or micro-hydro turbines are valid example of installation.

The solar resource is abundant on the region as shown in figure 2.

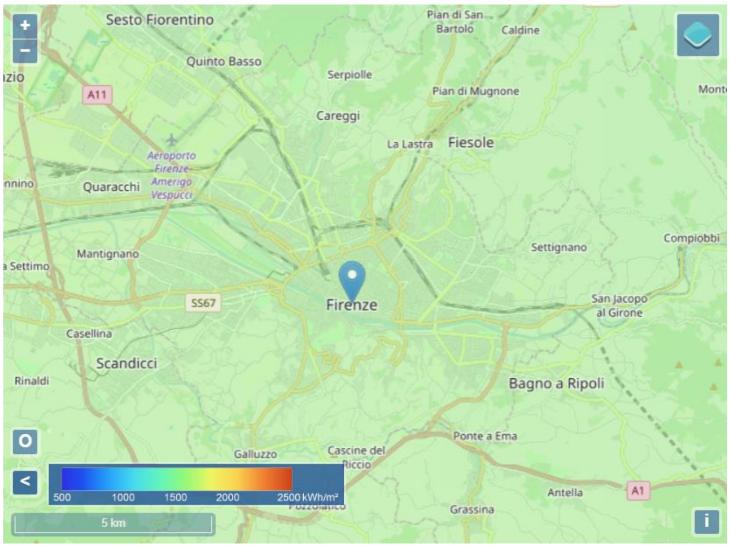


Figure 2 – Solar resource around Florence

Considering the river Arno, are being realized three micro-hydro plants in the southern locations of San Niccolò, Parco delle Cascine and Isolotto: the projects will employ the already existing structures of weirs. The figure 3 shows the beginning of works at Isolotto weir.

Figure 3 - Beginning of works at Isolotto micro-hydro plant

The wind resource is consistent: wind turbines have already been installed on the tips of mountains in the hilly region northern to the city. Monte del Galletto and Secchieta are the two closest wind farms to Florence. In the city we can consider micro-wind turbines.

T0

The model requested is performed by the programme PowerWorld Simulator, in order to simulate a distribution network with realistic tasks and characteristics.
The distribution network considers 28 buses at 20 kV and 1 bus at 150 kV HV/MV transformer, 27 distribution lines and 26 loads. All medium voltage buses have a nominal voltage 20 kV. The figure 4 shows the steady-state representation of the distribution system using a full AC power flow model and the dataset provided. The base VMA is set to 1 MW.

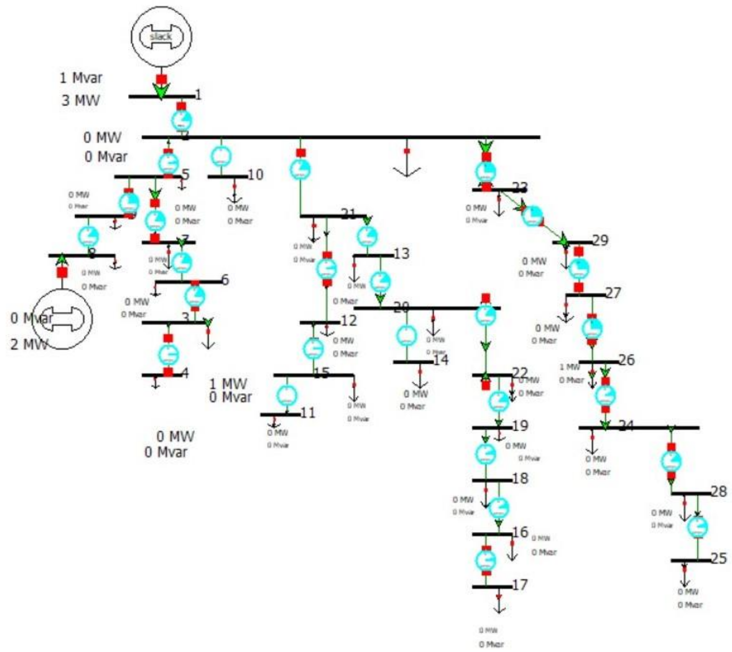
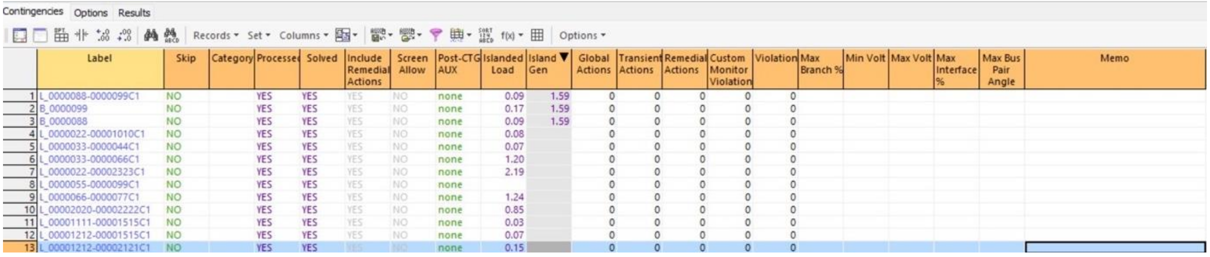


Figure 4 - Steady-state distribution system by PowerWorld Simulator

T1

In the first task it is asked to study the adequacy of our network in normal operating conditions, so without any faults. In order to assess this task, a contingency analysis on PowerWorld is performed: the contingency analysis is a powerful tool that allows us to disconnect automatically the components of the network one by one, however it is a standard procedure and returns some simple indicators.
In this case, the fault analyzed are the disconnection of all the buses and of all the lines one by one. For all these contingencies, no violations have been detected, however some useful insights about islanded load and generation can be seen in the figure 5 below:


Contingencies | Options | Results
Records ▾ Set ▾ Columns ▾ f(x) ▾ Options ▾

	Label	Skip	Category	Processed	Solved	Include Remedial Actions	Screen Allow	Post-CTG AUX	Islanded Load	Island Gen	Global Actions	Transient Actions	Remedial Actions	Custom Monitor Violation	Violation	Max Branch %	Min Volt	Max Volt	Max Interface %	Max Bus Pair Angle	Memo
1	L_0000088-0000099C1	NO		YES	YES	YES	NO	none	0.09	1.59	0	0	0	0	0						
2	B_0000099	NO		YES	YES	YES	NO	none	0.17	1.59	0	0	0	0	0						
3	B_0000088	NO		YES	YES	YES	NO	none	0.09	1.59	0	0	0	0	0						
4	L_0000022-00001010C1	NO		YES	YES	YES	NO	none	0.08		0	0	0	0	0						
5	L_0000033-0000044C1	NO		YES	YES	YES	NO	none	0.07		0	0	0	0	0						
6	L_0000033-0000066C1	NO		YES	YES	YES	NO	none	1.20		0	0	0	0	0						
7	L_0000022-00002323C1	NO		YES	YES	YES	NO	none	2.19		0	0	0	0	0						
8	L_0000055-0000099C1	NO		YES	YES	YES	NO	none			0	0	0	0	0						
9	L_0000066-0000077C1	NO		YES	YES	YES	NO	none	1.24		0	0	0	0	0						
10	L_00002020-00002222C1	NO		YES	YES	YES	NO	none	0.85		0	0	0	0	0						
11	L_00001111-00001515C1	NO		YES	YES	YES	NO	none	0.03		0	0	0	0	0						
12	L_00001212-00001515C1	NO		YES	YES	YES	NO	none	0.07		0	0	0	0	0						
13	L_00001212-00002121C1	NO		YES	YES	YES	NO	none	0.15		0	0	0	0	0						

Figure 5 - Contingency analysis results

From figure 5 it is possible to see that buses number 8 and 9 and the line that connects them are subjected to islanded load, and, most importantly to islanded generation, therefore it is possible to say that this portion of the network is operating as an island.
The term "islanding" refers to operating portions of the system with the only supply from distributed generation. The islanding can be intentional or non-intentional: intentional islanding refers to the independent operation of portions of the network in normal conditions, this is agreed by the DSO and the active user, while non-intentional islanding refers to island formation after an outage and it has to be eliminated, generally it is not permitted.
We are in the second case, since the island is formed when the connection of this portion of the network to the generator connected to bus 1 is cut, so when a contingency occurs. Now this portion is only fed by the generator connected to bus 8.

In order to assess the voltage profile, the voltage at each bus has been analyzed, it is plotted in per unit in the figure below:

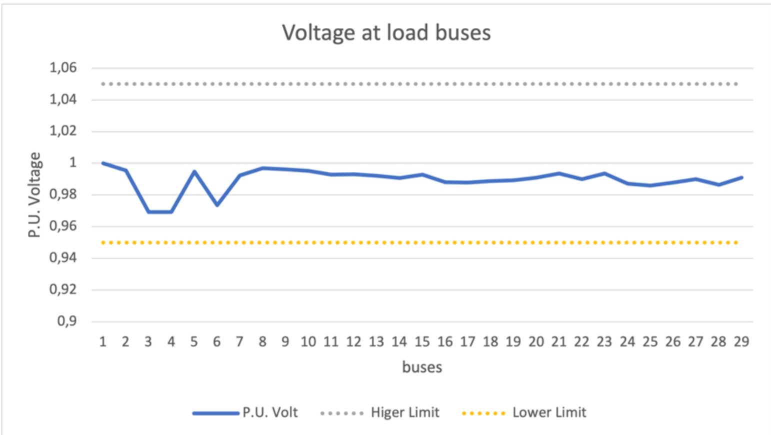


Figure 6 - Voltage at each bus

Overall the voltages are near to their rated value, in particular all the voltages are in the admissible range of +5%/-5% of the pu value. No voltage exceeds the rated value of 1 pu, however at buses 3, 4 and 7 the voltages are around 0.97 pu, this value is visibly lower than the voltages at the other buses.

T2

In the second task it is asked to find the bus with the lowest voltage and to install on it a capacitor, aiming at boosting this voltage in order for it to reach 0.98 pu. In this network the lowest voltage is at bus 3, with a value of 0.97178 pu, so at this bus we have tried to install capacitors with different capacitances, aiming at finding the lowest capacitance that can guarantee the required voltage.
Starting from a capacitance of 0.1 Mvar, we have gradually increased this value up to 0.4 Mvar. Since now the value of the voltage at this bus is 0.97929 pu, we have decided to increase the capacitance a little bit more, reaching the values:

Capacitance = 0.45 Mvar
Voltage at bus 3 = 0.98055 pu

The procedure can be visualized in the figure below:

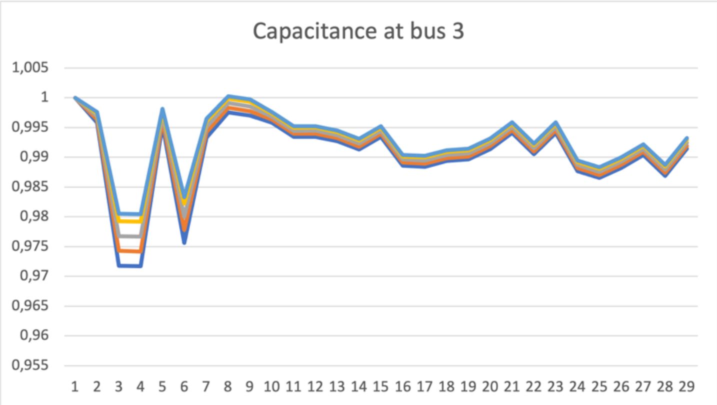


Figure 7 - Capacitance at bus 3

It is possible to notice that the capacitance, although it is inserted at bus 3, has an effect also on the other lowest voltages in the network: in fact, it also boosts voltages at bus 4 and 7 while it leaves almost unchanged the higher voltages at the other buses.
Fixing the capacitance at 0.45 Mvar, we have tried to move the capacitor among the same line, in particular at bus 4 and 7, the results are shown in the figure below:

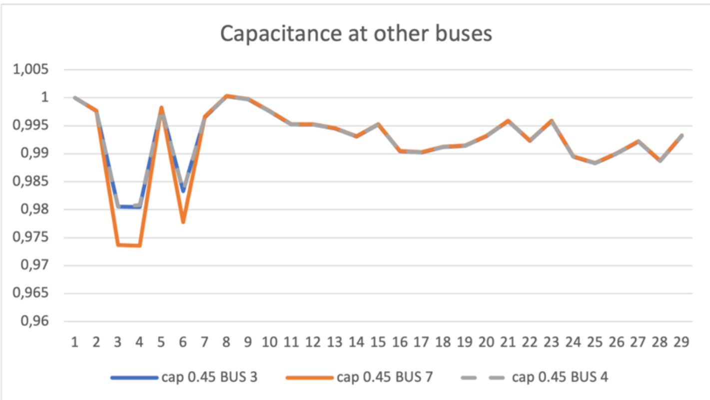


Figure 8 - Capacitance at other buses

It is possible to see that by moving the capacitance downstream at bus 4, the voltages are practically unchanged with respect to the previous case, so this capacitance has a beneficial effect also on upstream buses like bus 7. On the contrary, by moving the same capacitance upstream at bus 7 we can see that the voltage at this bus is a little bit boosted, but the capacitance seems to have no effect to the downstream buses (buses 3 and 4).

T6

In this task, we assume a charging load that triple the current load at each bus due to the utilization of electrical vehicles that increase the load. We have tripled the value of active and reactive power in the Excel file. We study the network on PowerWorld to see if the constraints were satisfied. The first problem is the decrease in the voltage in the bus 3 and 4, that goes below the limit, so we install a capacitor in bus 3 to boost the value of the voltage, in order to reach 0.95 pu. In figure 9 and 10 we can see the two different configurations of the network before and after the improvement.

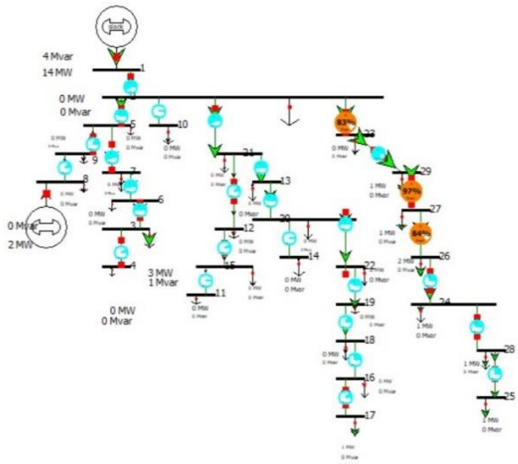


Figure 9 – Configuration of electrical vehicles

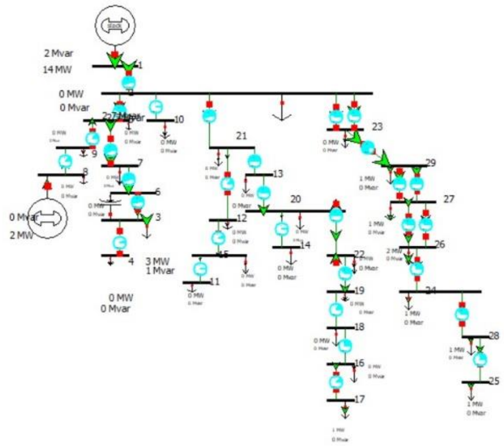


Figure 10- Configuration after improvement

We tried different value of capacitances, in figure 11 and 12 we can see that the value that allows us to go above the lower limit is 3 Mvar.

The second approach that we use to solve the problem of the overload in bus 23,29,27 is to split the loads, drawing two lines, so we create a new transmission line in parallel with the same parameters.

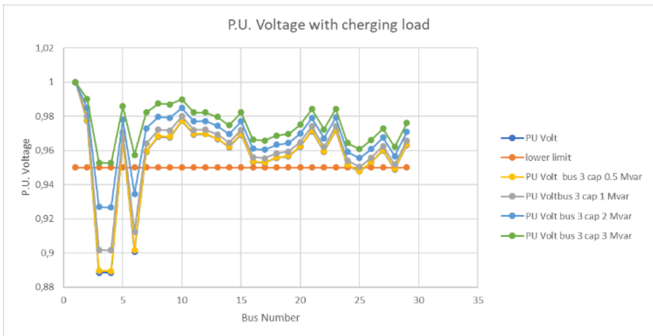


Figure 11 – PU Voltage at bus 3 with different value of capacitance

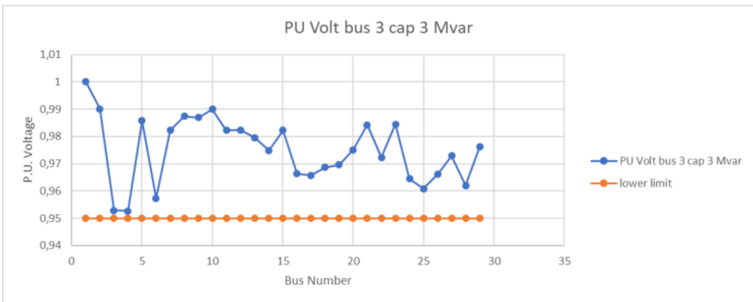


Figure 12 – PU voltage at bus 3 with capacitance 3 Mvar

Conclusion

The scope of the project is to implement a smart grid able to connect energy from renewable sources into a big city.
We have used the program PowerWorld.
In task 0 we have designed the tree-shaped network in the simulation program.
In task 1 we have performed the contingency analysis to assess the reliability of our network in normal operating conditions, the network has proven to be reliable, because no faults have been detected apart from islanding operation.
In task 2 we perform the regulation of voltages by installing a capacitance in the buses with the lower value of voltages, this strategy has proven to be successful because voltage raised.
In task 6 we consider a real case of the network where we add the charging of electrical vehicles to the grid. This modification causes an increase of the load request equal to three times the base case. This leads to two problems: voltage too low at buses 3,4 and the overload of lines 23,27,29. To solve these problems we increase the voltage by adding a capacitance at bus 3 and by splitting the transmission load at the overloaded lines.

References and links

- https://re.jrc.ec.europa.eu/pvg_tools/en/
- https://www.toscana-notizie.it/-/briglie-sull-arno-progetto-da-80-milioni-per-creare-12-centrali-idroelettriche
- https://www.toscana-notizie.it/documents/735693/1398867/Presentazione%20progetto%20briglie.pdf/f4400f99-beba-0fa5-8a6d-588f46c5f1c5
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- PowerWorld » The visual approach to electric power systems