The effect of small power plants on the distribution of mains voltage and power losses

Daniel Pál
Department of Electric Power Engineering
FEI TU of Košice
Košice, Slovak Republic
daniel.pal@tuke.sk

Péter Kádár
Department of Power Engineering
University of Óbuda
Budapest, Hungary
kadar.peter@kvk.uni-obuda.hu

György Morva
Department of Power Engineering
University of Óbuda
Budapest, Hungary
morva.gyorgy@kvk.uni-obuda.hu

Ľubomír Beňa
Department of Electric Power Engineering
FEI TU of Košice
Košice, Slovak Republic
lubomir.bena@tuke.sk

***Abstract* — This publication examines the impact of small power plants on the grid. Today, due to the popularity of renewable energy sources, more and more small power plants are being connected to the grid, which are affecting grid parameters. The publication examines how the amount of voltage in the node's changes from the number of small power plants connected to the network and presents the effects on wattage power loss in the network.**

Keywords* — *decentralized energy system, power losses, voltage distribution

I. INTRODUCTION

Renewable energy sources (RES) are playing an increasingly important role in energy production. The size of non-renewable sources is limited, so humans has had to look for new sources. The European Union would provide 20 % of its energy from renewable sources by 2020, which it would increase to 32 % by 2030 [1], [2].

Fig. 1 shows the change trends in Hungary's installed capacity since 2010. Performance has almost tripled in 10 years. This is mainly due to solar energy and solar cells, while the amount of other energy sources has increased only slightly or not at all.

The installed capacity of solar energy increased in the country to such an extent that the peak of solar energy production in Hungary was exceeded on 16 April. It was able to provide 22 % of domestic production for a time and 8,3 % of domestic production for the whole day [3].

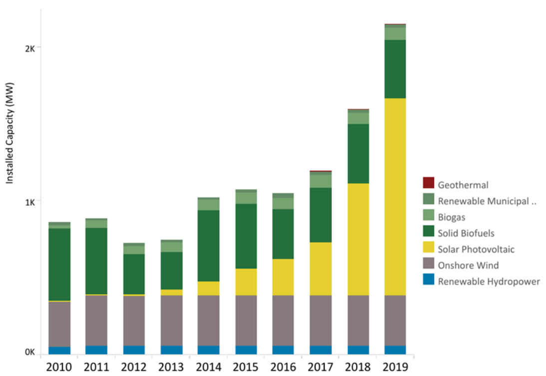

Fig. 1. Installed capacity trends in Hungary [4]

This work was supported by the Scientific Grant Agency of the Ministry of Education of Slovak Republic and the Slovak Academy of Sciences by the projects VEGA No. 1/0372/18 and by the Slovak Research and Development Agency under the contract No. APVV-19- 0576.

II. CENTRALIZED, DECENTRALIZED ENERGY SYSTEMS

The traditional energy system is centralized. Energy is produced in large power plants, which reach consumers through different voltage lines. Transformation between these lines generate losses that need to be minimized for energy efficiency. In centralized system, there is a significant transport distance between consumers and electricity producers [5], [6]. This system has advantages but also disadvantages. Its advantages include the fact that the direction of energy flow is always known - from power plants to consumers. The disadvantage is that in the event of a failure, even an entire area can be left without energy.

The decentralized energy system has come to the fore with the spread of renewable energy sources. There are still large power plants in this system that were also in the centralized energy system, but many smaller power plants are built into the grid [7]. As a result, the failure of some power plants will not have as much impact on the entire energy system. Fig. 2 shows the difference between the centralized and decentralized energy system.

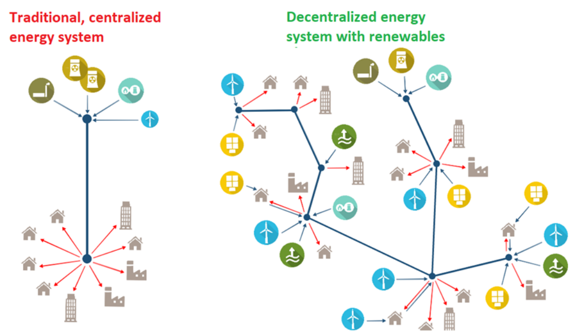

Fig. 2. Difference between the centralized and decentralized energy system [8]

III. SIMULATED NETWORK

The test network topology is illustrated in Fig. 3. There are 2 feed points in the network (TR_1, TR_2). Thanks to the remote-controlled switches (RCS), which is in the position open, all consumer can only receive electricity only from one direction. This is the biggest disadvantages of this network structure. If any problems occur on the branch 1, from nodes 2 to 11 will be left without power if RCS remain in the OPEN position. If

RCS will be in the position CLOSE, these nodes will not be left without power.

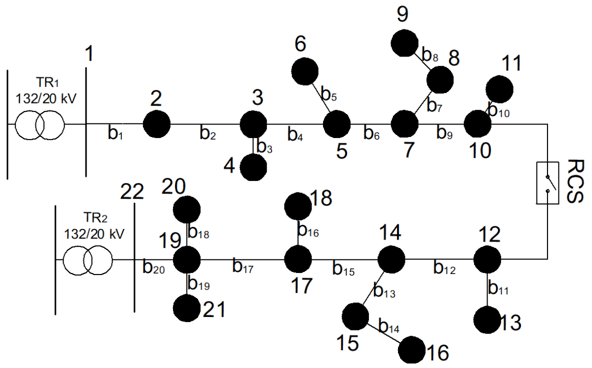

Fig. 3. Topology of the examined network

Branch parameters are shown in Table I.

TABLE I. BRANCH PARAMETERS

Branch	Resis-tance [Ω]	Inductive reactance [Ω]	Branch	Resis-tance [Ω]	Inductive reactance [Ω]
1	0,9	0,9	11	1,2	1,2
2	1,2	1,2	12	1,2	1,2
3	0,9	0,9	13	1,5	1,5
4	1,5	1,5	14	1,2	1,2
5	0,9	0,9	15	0,9	0,9
6	1,5	1,5	16	1,5	1,5
7	0,9	0,9	17	1,8	1,8
8	0,9	0,9	18	1,5	1,5
9	1,2	1,2	19	1,5	1,5
10	0,9	0,9	20	1,2	1,2

Nodes consumption data were as follows:

- Nodes 1 to 11 consume 700 kW from the grid.
- All nodes between 12 and 22 consume 900 kW from the grid.

IV. RESULTS

A. *Only 1 small power plant is connected to the grid*

The first step in the simulation was to simulate the current state. We examined the voltages at the nodes without small power plants. This current state is indicated by point current state in the Fig. 4 and Fig. 5.

After that, we started to connect 500 kW small power plant to the grid. We connected to the Node 1 and after that started the simulation. After the simulation small power plant was connected to the Node 2, but we removed the previous added small power plant from the grid. In this way, we continued the simulation until we reached the last node.

a) Investigation of power losses

The current wattage loss without small power plants is 0,4637 MW. When the new power plant is connected close to the feed point, the loss decreased only minimally. From 0,4637 MW to 0,4191 MW. The best value is then, when new plant is connected to the end of the grid, to the Node 11. So the farther we connect the power plant from the feed point, we will achieve a better result.

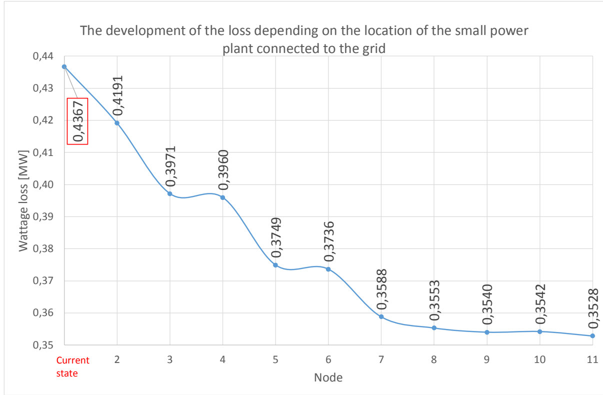

Fig. 4. The development of the wattage loss depending on the location of the small power plant connected to the grid between nodes 2 – 11

A similar power losses reduction is observed in the second part of the grid, when consumers was connected to the transformer 2 (TR_2). Thanks to the network parameters, the value of the wattage losses was higher, 0,5471 MW. In this case the values of the branch were different, and the consumption was higher as before. The best value in this simulation was then, when the new plant was connected to the Node 15.

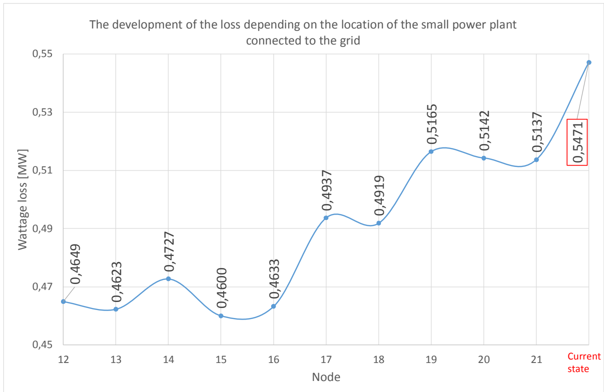

Fig. 5. The development of the wattage loss depending on the location of the small power plant connected to the grid between nodes 12 – 21

b) Voltage distribution

The voltage distribution between nodes 1 and 11 is illustrated in Fig. 6 and the voltage distribution between nodes 12 and 21 is illustrated in Fig. 7. It can be observed that the voltage decreases continuously from the feed point to the end. It can also be observed that if the power plant is installed, it also increases the voltage there.

For ease of transparency, only 3 cases are shown in the images. The first case in both figures shows the current situation when no new power plant is connected. In the Fig. 6, the new power plant is connected to the Node 6 and in the case 3 is connected to the Node 11. In the Fig. 7, the new power plant is connected to the Node 13 and to the Node 15. In both cases, it can be seen that the connected power plant increased the voltage at node point.

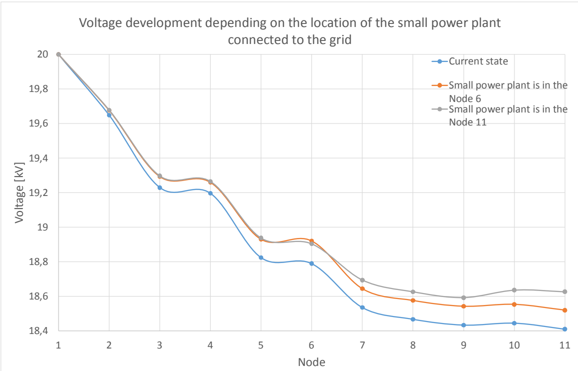

Fig. 6. Voltage development depending on the location of the small power plant connected to the grid between nodes 1 – 11

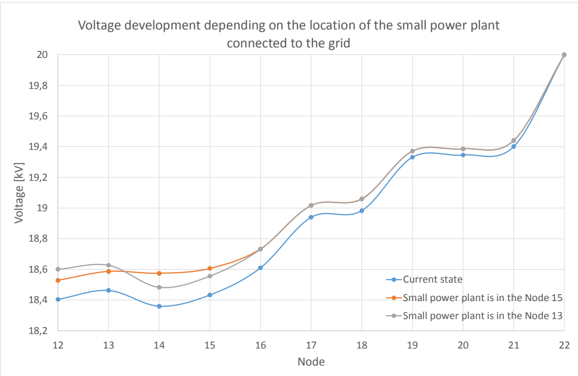

Fig. 7. Voltage development depending on the location of the small power plant connected to the grid between nodes 12 – 22

B. Small power plants are connected to the grid

The first step in this case is unchanged, the current state must be calculated. The current state is indicated by point 0 in the following figures.

After that, we started to connect 500 kW small power plants to the grid. We always started in the node, which was the closest to the remote-controlled switches and moved in the direction of the feed point. The reason for this was to increase the voltage at the end of the network. If all small power plants had been connected to Node 2, a failure on branch 2 would have affected the entire network. During the simulation we followed the following process:

- First power plant was placed at the node closest to the remote-controlled switch. This is characterized by point 1 in the Fig. 8, because 1 power plant has been added to the grid.
- After that, we placed a power plant to the next node, but the previous power plant also remained. This is represented by point 2 in the Fig. 8.
- In this way, we continued the simulation until we reached the last node as well.

a) Voltage distribution

The voltage distribution between nodes 1 and 11 is illustrated in Fig. 8. Currently, the voltage drops drastically from the feed point to the end of the network. At present, the voltage at Node 1 is 20 kV, but at Node 11 it is only 18,4 kV. The difference is 1,6 kV. When 500 kW power plant was connected in Node 11, the voltage at Node 11 increased to 18,6 kV. Added power plant was affected voltage in the rest of the grid, not only in point 11. When the power plants were added at all 10 nodes, a total power 5 MW was achieved. This resulted in a voltage drop between nodes 1 and 11 from the original 1,6 kV to 0,4 kV.

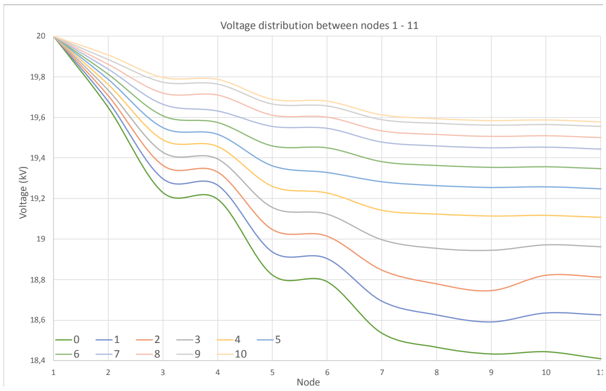

Fig. 8. Voltage distribution between nodes 1 – 11

A similar voltage distribution is observed in the other part of the grid when consumers was connected to the transformer 2. Here, due to the topology of the network and the parameters of the wires, a different voltage distribution can be observed. The current situation is also characterized by line 0, which caused the worst results. Here, the voltage is reduced to approximately 18,35 kV. As more and more small power plants gradually turned on, the voltage increased more and more. In the worst node the voltage increased to 19,35 kV from the initial 18,35 kV, which is 1 kV higher.

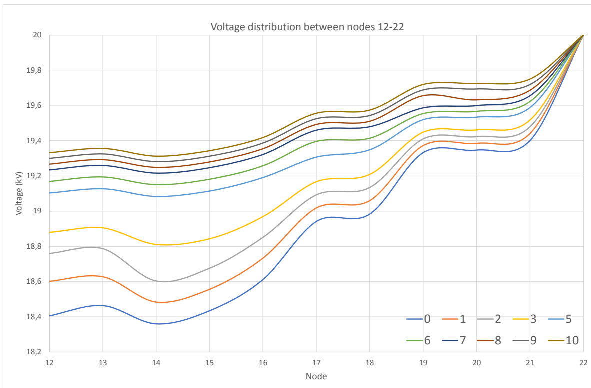

Fig. 9. Voltage distribution between nodes 12 – 22

The legends in the Fig. 8 and Fig. 9 shows how many small power plants are connected to the grid. 0 indicates that small power plant is none connected to the grid, it only represents the current situation. 1 show when 1 new is connected and 2 is when 2 new is connected. Each number covers how many power plants are connected. The maximum value in both images is 10 when 10 small power plants are connected.

b) Investigation of power losses

As the voltage increased, the power losses were decreased. In the current state, this value was 436 kW. When only one power plant was added to the grid, it dropped to around 350 kW. This is shown in the Fig. 10. As more and more power plants turned on, the value of the wattage losses further decreased, up to 32 kW which was the best value. Between the worst and best value, this would result in 400 kW of power savings.

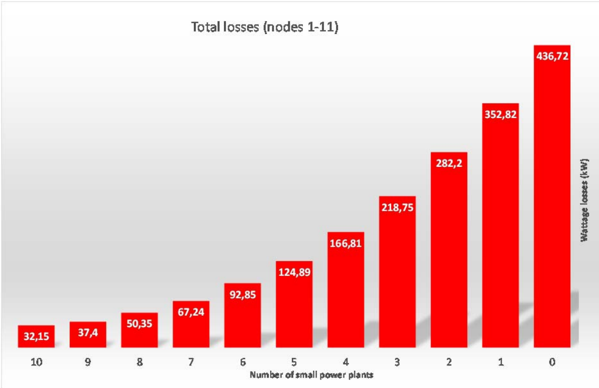

Fig. 10. Development of total loss between nodes 1 and 11 depending on the number of small power plants connected to the network

A similar power losses reduction is observed in the second part of the grid, when consumers was connected to the transformer 2. Shown in Fig. 11. Thanks to the network parameters, the value of the initial network loss reached 547 kW, which is 100 kW more than in the previous case. The reason for this, as mentioned, was the branch parameters. In the best case, the value has been reduced to 100 kW, which also leads to energy savings of 400 kW if there are 500 kW of power plants connected to the grid in all nodes.

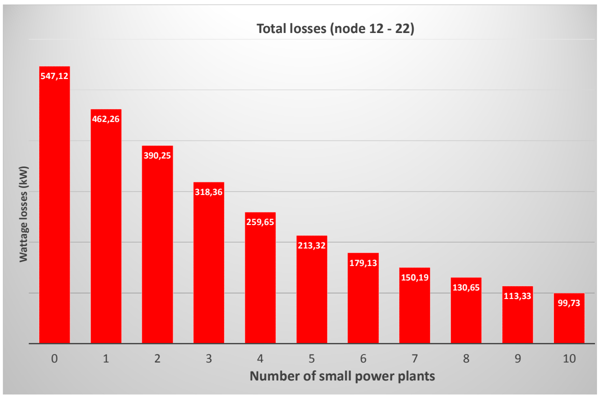

Fig. 11. Development of total loss between nodes 12 and 22 depending on the number of small power plants connected to the network

V. Conclusion

The aim of the publication was to draw attention to the possible impact of renewable energy sources on mains voltage and loss. It was seen that small power plants (usually renewables) were able to significantly increase the voltage, even above the allowable value, what to look out for. However, this has not been investigated in this publication. In this article we examined the effect of small power plant on the network when only 1 small power plant was connected to the grid, but also examined, when more small power plants are connected to the grid.

The reason for the reduction in wattage power losses was that the energy did not have to be transported from a remote point in the grid but was produced close to consumption. Based on the above, in the case study, small power plants improved the quality of supply.

Acknowledgment

This work was supported by the Scientific Grant Agency of the Ministry of Education of Slovak Republic and the Slovak Academy of Sciences by the projects VEGA No. 1/0372/18 and by the Slovak Research and Development Agency under the contract No. APVV-19-0576.

References

[1] 2020 climate & energy. [online]. Available at: https://ec.europa.eu/clima/policies/strategies/2020_en. Accessed on September 17, 2020.

[2] DIRECTIVE (EU) 2018/2001 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2018 on the promotion of the use of energy from renewable sources [online]. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L2001&from=SK

[3] Újabb rekordok születhetnek a folyamatos napos időben [online]. Available at: https://www.mavir.hu/web/mavir/kozlemenyek. Accessed on September 17, 2020.

[4] Solar energy [online]. Available at: https://www.irena.org/solar. Accessed on September 17, 2020.

[5] François Bouffard, Daniel S. Kirschen: "Centralised and distributed electricity systems" in Energy Policy, Volume 36, Issue 12, 2008. pp 4504-4508, ISSN 0301-4215. https://doi.org/10.1016/j.enpol.2008.09.060

[6] Lost In Transmission: How Much Electricity Disappears Between A Power Plant And Your Plug? [online]. [16.9.2020]. Available at: http://insideenergy.org/2015/11/06/lost-in-transmission-how-much-electricity-disappears-between-a-power-plant-and-your-plug/

[7] Dulau, Lucian Ioan, Abrudean, Mihail, Bica, Dorin : "Effects of Distributed Generation on Electric Power Systems:. Procedia Technology. Volume 12, 2014.pp 681-686. https://doi.org/10.1016/j.protcy.2013.12.549.

[8] Paks II nélkül a világ – Mi kiszámoltuk, és közzé is tesszük [online]. Available at: https://230.atlatszo.hu/2015/01/20/paks-ii-nelkul-a-vilag-kiszamoltuk-es-kozze-is-tesszuk/. Accessed on September 17, 2020.