The Impact of the Smart Grid on the Distribution

Michal Ivančák, Juraj Kurimský
Department of Electric Power Engineering
Technical University of Košice, FEI
Košice, Slovak Republic
michal.ivancak@tuke.sk, juraj.kurimsky@tuke.sk

Abstract — **Intelligent networks or smart grid are the most frequently mentioned theme in this time. We can say that research in this area is expected. First part of this paper describes modelling electrical network through software like Neplan that replaces mathematical computation, facilitates and speeds up this process. The data are used from real distribution system from the average village in Slovakia. In this paper is simulated effect of PV panels and e-car charger on the small part of the distribution system.**

Keywords: smart grid, modelling of network, e-car charging, RES

I. Introduction

Smart grids are a topic that is often referred to in these years, not only in the scientific circles but also in common users of electricity. The constant development of new technologies as well as the increased informatization brings many new questions about how electricity distribution will work in the future. Significant facts that are already visible today are higher electricity consumption per capita, more and more electronics within the household as well as the arrival and increasing number of electric cars not only in the EU but also in Slovakia.

The impact of smart grids can be divided into 3 parts - the impact on the transmission system, the impact on the distribution system and, last but not least, the impact on the customer. As part of the Smart Grid's impact on the transmission system, the effects on system and support service volumes, voltage stability, short-circuit ratios, static and dynamic stability are being analyzed. In the last part are analyzed mainly impacts on electric energy quality for end customers.

Several methods can be used to achieve a fairly accurate analysis. One of them is the use of software programs where, thanks to the adaptive graphical interface and data from real measurements, we can model an existing power network and test its performance in critical conditions on such a network. At the same time, such software has a number of mathematical models to calculate short-circuit conditions, network optimization, and load calculations.

Another option is to test conditions in a smart grid lab that no longer only works with mathematical models. Depending on the size and capabilities of the laboratory, it is then possible to do such testing and to determine the behavior of the network model again under different conditions. Such a form of smart grid designation is also called microgrid.

II. Smart grid systems

A. The main features of smart grid

One of the main concepts closely related to SG is Distributed Production (DG). Distributed production is or even decentralized production is the production of electrical energy from a large number of small energy sources. Most of the electricity is currently produced in large central power plants, whether coal-fired power plants, nuclear power plants, or hydroelectric power plants. Consequently, the energy produced in such power plants is transmitted over long-distance power lines to the point of consumption. Most of these power plants are built on remote locations due to the economic, security or geological conditions. DG is significantly reducing the losses that arise from the transmission and distribution of electricity. The dispersion of these sources, low maintenance, small dirt areas and high efficiency are the main features of DG. By building such microgrids, ultimately, it can reduce emissions, reduce public threats. The most commonly used sources of this type are photovoltaic panels, wind turbines and cogeneration units **Chyba! Nenašiel sa žiaden zdroj odkazov.**, [2].

The most commonly used sources are photovoltaic panels. Due to their size they are placed on the roofs of family houses but also on the roof of industrial buildings. Building on fields is no longer supported by legislation. Polycrystalline panels are most commonly used in various sizes. The potential of a photovoltaic power plant is most often connected to a grid or as an island operation, sometimes with battery accumulation. An inverter is also an integral part of such a system. Such a system for family houses envisages a return on investment of about 6-8 years [5],[6].

Wind turbines in the Slovak Republic do not have very suitable conditions. For their use an average wind speed above 5 m/s is required. Therefore, their use, but lesser performance, is usually combined with PV panels.

Cogeneration units – i.e. combined production of electricity and heat by burning natural gas are mainly used in industrial buildings or in larger residential complexes. For renewable energy sources, RES predicts wind and sun prediction. Therefore, the MG is looking for suitable combinations for reliable power supply [7].

B. Legislative changes in the energy sector

As in the last European Directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014 on the deployment of alternative fuels infrastructure, Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and Directive 2010/31/EU of the European

Parliament and of the Council of 19 May 2010 on the energy performance of buildings. There the idea is suggested, that new buildings need to take into the account:

- Cogeneration
- Heat pumps
- Block or district heating or cooling, particularly where it is partially or entirely supplied from renewable energy sources
- Decentralised energy supply systems on energy from RES

Article 9 of the Directive is focused on Nearly zero-energy buildings committed to build only houses with nearly zero energy by 31. December 2020. To fulfil this criterion is needed to install to all buildings photovoltaic power plant, and there are suggestions to build on all new houses electro mobile charger [3]**Chyba! Nenašiel sa žiaden zdroj odkazov.**.

III. Modeling in simlation software

Electricity modeling is a quite often used tool for theoretical verification as a practice preparation. Optionally, simulations to test critical network situations whose parameters are based on measurements on existing devices.

In the following lines there is a simulated behavior of the electric network, in the village in eastern Slovakia. It is a part of this village, namely a single street that is powered from one transformer branch. In this model, photovoltaic panels were designed for each house and an electric vehicle charger. The following table shows the number of elements used in the model.

Table 1. Elements used in project

Line	63
Nodes	51
Loads	37
Charging for Electric Vehicles	37
Photovoltaic	37
Transformer	1

A. Loads

The loads represented in the simulations are family houses in the village. One street from this village was tested to verify stability. The values of these loads were used from the data provided directly from the distribution service provider. The values in the table below are in the state before the PV panels are connected.

Table 2. Network parameters

P Loss	**Q Loss**	**P Imp**	**Q Imp**	**P Gen**	**Q Gen**	**P Load**	**Q Load**
kW	**kVar**	**kW**	**kVar**	**kW**	**kVar**	**kW**	**kVar**
4.03	9.42	139.8	54.05	139.8	54.05	135.8	44.63

B. PV panels

All-Black CS6K-300M monocrystalline panels were used as renewable electricity sources for each sampling. Eleven pieces were used to create an optimal 3.3 kW output. The value of this performance was determined because of the amount of the subsidy for renewable electricity sources in Slovakia. In the software was used a dispersion generator with a preset type photovoltaic, which simulates the production of the PV panel and the inverter simultaneously.

The parameters of the panel used can be seen in table no. 3, under this text.

Table 3. PV panel - parametres

Nominal Max. Power (Pmax)	300 W
Opt. Operating Voltage (Vmp)	32.5 V
Opt. Operating Current (Imp)	9.24 A
Open Circuit Voltage (Voc)	39.7 V
Short Circuit Current (Isc)	9.83 A
Module Efficiency	18.33%
Operating Temperature	-40°C ~ +85°C
Max. System Voltage	1000 V
Module Fire Performance	TYPE 1 (UL 1703) or CLASS C (IEC 61730)
Max. Series Fuse Rating	15 A
Application Classification	Class A
Power Tolerance	0 ~ + 5 W

C. Electric car charger

The model also includes an electric car charger for every household. This is due to the changing European legislation mentioned in Chapter 2. The same 11 kW charger has been designed for each house.

There are some basic charging scenarios/profiles when charging an electric car. All these scenarios are based on people's working hours:

Profile #1: People going to work with a possibility to charge their car at work.

Profile #2: People going to work with no possibility to charge their car at work.

Profile #3: People going to work with a possibility to charge their car at work but with a longer ride

Profile #4: People staying at home.

Profile #5: People working on a night shift.

It is important to note that in the future, when an electric vehicle is connected to the network, it will be considered as a battery that will assist the distribution network in its operation.

IV. Network analysis

In this model, several analyzes have been made to assess the impact of renewable resources on this small system. Based on these analyzes, it is then possible to evaluate the design itself and the network functionality itself.

Three scenarios were created as part of the network analysis.

Scenario 1: Turning PV panels on step by step

Scenario 2: Starting electric cars chargers without PV panels

Scenario 3: Starting e-cars chargers in full PV panel operation.

For these scenarios was made Table 4, 5, 6 and Figure 1. to Figure 6. After every table there is a comparison of losses (active and reactive) according to number of connected devices and also comparison of generated active and reactive power.

In table 4. is scenario 1 where was PV panels turning on step by step. In Figure 1. we can see that losses are going down because of energy that PV panels made. In Figure 2. we can see that the energy supplied to the network decreases as the number of connected PV panels increases. Based on these findings, we can say that by increasing renewable energy sources, the energy intensity of a given part of the village is reduced and the network losses are reduced. Based on these findings, we can say that by increasing renewable energy sources, the energy intensity of a given part of the village is reduced and also the network losses are reduced. However, in the event of a load decrease, there could be conditions where there would be a surplus of energy in the network and the electricity flow would change.

Table 4. Simulated values during scenario 1

PV	P Loss	Q Loss	P Imp	Q Imp	P Gen	Q Gen	P Load	Q Load
(-)	kW	kVar	kW	kVar	kW	kVar	kW	kVar
0	3.25	7.78	124.2	54.1	124.22	54.05	130.87	43.02
2	2.97	7.19	117.3	55.6	117.34	55.63	130.87	43.01
6	2.67	6.34	103.8	59.1	103.84	59.12	130.87	43.01
10	2.48	5.68	90.45	62.8	90.45	62.8	130.87	43.02
14	2.22	5.05	77	66.5	77	66.5	130.87	43.02
18	1.95	4.49	63.52	70.3	63.52	70.28	130.87	43.02
22	1.68	4.03	50.06	74.2	50.06	74.16	130.87	43.02
26	1.51	3.75	36.68	78.2	36.68	78.22	130.87	43.02
32	1.49	3.71	23.47	82.5	23.47	82.52	130.87	43.02
37	1.52	3.8	10.29	87	10.29	86.95	130.87	43.02

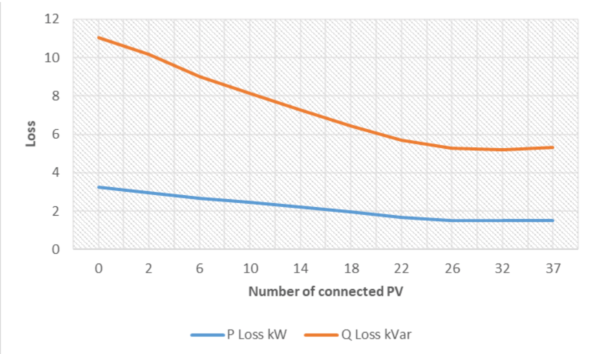

Figure 1. Losses of active power and reactive power in the network when running scenario 1

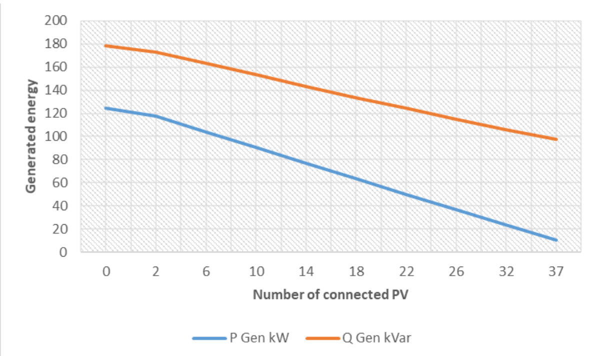

Figure 2. Generated energy in the network when running scenario 1

In the scenario two, chargers for electric vehicles were switched on while the PV panels were turned off. When the 17th charger was switched on, there was an increased load on the network and overloading the lines. In Figure 3. we can see that the losses started to grow sharply. Even after connecting all the devices, the network remained running even in extreme traffic.

In Figure 4. , the energy supplied to the network began to rise more sharply as the network became more congested. The chargers were switched on gradually from the location to the transformer closest to the outermost charger. In the case of the opposite direction of switching, network overload could occur earlier, especially at the edge of the network.

Table 5. Simulated values during scenario 2

	P Loss	Q Loss	P Imp	Q Imp	P Gen	Q Gen	P Load	Q Load
	kW	kVar	kW	kVar	kW	kVar	kW	kVar
0	4.03	9.42	139.81	54.05	140	54.05	135.79	44.63
4	5.08	14.21	184.86	73.3	185	73.3	179.79	59.09
8	7.36	21.41	231.15	94.97	231	94.97	223.79	73.56
12	11.17	31.45	278.95	119.5	279	119.47	267.79	88.02
16	14.1	41.88	325.89	144.4	326	144.36	311.79	102.48
17	15.18	45.07	337.97	151.2	338	151.17	322.79	106.1
21	21.09	60.55	387.88	181.1	388	181.11	366.79	120.57
25	35.49	93.22	468.28	235.5	468	235.48	432.79	142.26
30	47.67	120.43	524.46	277.2	524	277.16	476.79	156.73
34	66.02	161.26	597.8	336.1	598	336.06	531.79	174.81
38	75.57	181.4	629.36	363.4	629	363.44	553.79	182.04

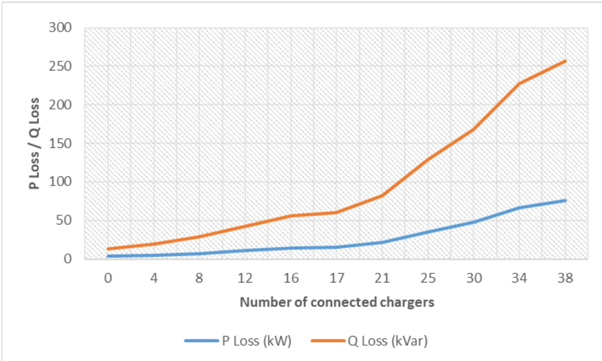

Figure 3. Losses of active power and reactive power in the network when running scenario 2

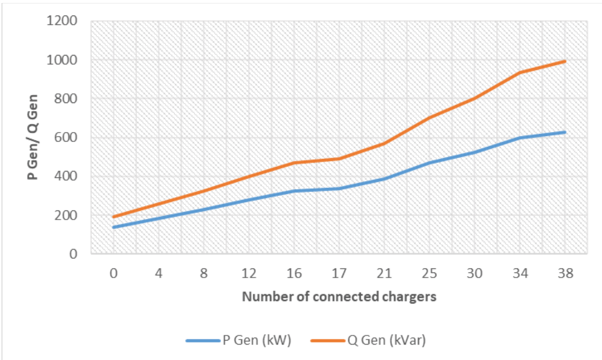

Figure 4. Generated energy in the network when running scenario 2

In scenario 3, the chargers switched on again step by step, but with the PV panels in fully operation. Network overload occurred only when the 19th charger was turned on. When comparing graphs or tables, it is possible to observe reduced performances that have been beneficial to the operation of the network and partial reduction in energy load.

PV panels installed on the home of individual offsets have a positive impact on the operation of the distribution system. First and foremost, they reduce household consumption, while reducing losses as energy is directly consumed at the site of production. The use of PV panels, thanks to subsidies, will be increasingly a solution to save household electricity.

Table 6. Simulated values during scenario 3

	P Loss	Q Loss	P Imp	Q Imp	P Gen	Q Gen	P Load	Q Load
	(kW)	(kVar)	kW	kVar	(kW)	(kVar)	kW	kVar
0	1.62	4	15.31	88.76	15.3	88.76	135.79	44.63
4	2.02	5.81	59.71	105	59.7	105.04	179.79	59.09
8	2.89	9.17	104.58	122.9	105	122.86	223.79	73.56
12	4.42	14.32	150.1	142.5	150	142.47	267.79	88.02
16	6.92	21.68	196.61	164.3	197	164.3	311.79	102.49
19	9.43	28.72	232.11	182.2	232	182.18	344.79	113.33
20	10.46	31.44	244.14	188.5	244	188.52	355.79	116.95
24	15.41	43.77	289.79	216.4	290	216.4	399.79	131.41
28	22.18	59.97	340.57	247.1	341	247.07	443.79	145.88
32	31.72	81.05	394.1	282.6	394	282.61	487.79	160.34
36	43.77	107.04	450.16	323.1	450	323.06	531.79	174.8
38	50.98	122.25	479.37	345.5	479	345.5	553.79	182.04

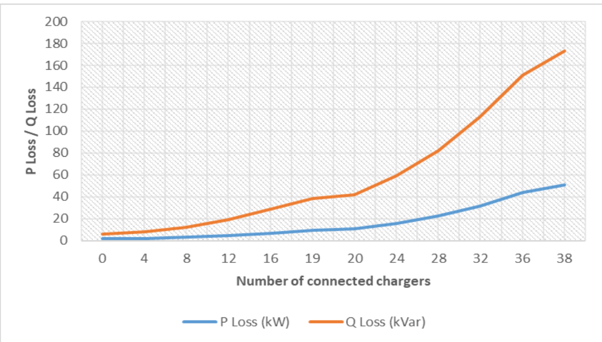

Figure 5. Losses of active power and reactive power in the network when running scenario 2

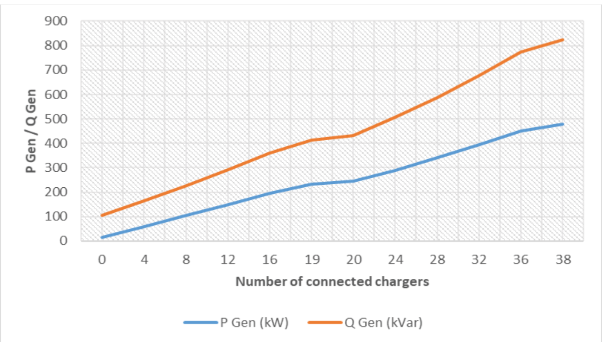

Figure 6. Generated energy in the network when running scenario 3

The average household household reaches a maximum output of 3-5 kW. In the case of electric underfloor heating it can be even more. Photovoltaics on the roofs of these homes would be higher than the current household consumption when simulated during a sunny day. Therefore, it would be ideal to add a battery pack to each PV power plant. By accumulating, the energy produced on a family home could be consumed to a greater extent, thereby reducing household consumption.

V. CONCLUSION

Smart grids will have a significant impact on the operation of distribution systems not only in Slovakia. The effect of PV panels and chargers on e-cars was simulated on this paper. It should be noted that there is little likelihood that all chargers will run simultaneously. If a maximum of 15 out of 38 chargers were running at the same time, we can say that the simulated network would do it if it was a day (PV panels go) or even if it was night (PV panels won't go).

This simulation is only approximate as the software offers only limited possibilities to simulate network behavior. Values are static rather than dynamic. If we wanted to be more precise, it would be necessary to simulate the change of load during the day. It would also be necessary to simulate the course of solar radiation during the day in different conditions and different seasons. E-car charging itself could then be divided into different parts of the day based on charging scenarios.

Finally, smart grids play an important role now. Currently, we can only perceive it through smart metering, but several pilot projects are already running not only abroad but also in our country. Even this paper can be a small grain of sand in the desert of smart grids.

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.

This work was supported by the Slovak Research and Development Agency under the contract No. APVV-17-0372.

REFERENCES

[1] P. Hocko, M. Novak, M. Kolcun, and Z. Conka, “Influence of photovoltaic power plants on the power system to the prediction for year 2020,” presented at the 2014 14th International Conference on Environment and Electrical Engineering, EEEIC 2014 - Conference Proceedings, 2014, pp. 116–121..

[2] M. Shamshiri, C. K. Gan, and Chee Wei Tan, “A review of recent development in smart grid and micro-grid laboratories,” in 2012 IEEE International Power Engineering and Optimization Conference Melaka, Malaysia, 2012, pp. 367–372. doi:10.1109/PEOCO.2012.6230891

[3] “Directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014 on the deployment of alternative fuels infrastructure.” [Online]. Available: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32014L0094. [Accessed: 11-Jun-2019].

[4] “Directive 2010/31/ of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings.” [Online]. Available: https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32010L0031&from=SK. [Accessed: 11-Jun-2019].

[5] S. Borlase, Ed., Smart Grids: Infrastructure, Technology, and Solutions, 1 edition. Boca Raton, FL: CRC Press, 2012. 607 p. ISBN-13: 978-1439829059.

[6] J. A. Momoh, Smart Grid: Fundamentals of Design and Analysis, 1 edition. Hoboken, N.J: Wiley-IEEE Press, 2012. 232 p. ISBN-13: 978-0470889398.

[7] F. P. Sioshansi, Smart Grid: Integrating Renewable, Distributed & Efficient Energy. Academic Press, 2011. 510 p. ISBN 978-0-12-386452-4