Power Loss in Smart Grids

Maksym Oliinyk
Department of Electric Power Engineering; Faculty of Electrical Engineering and Informatics
Technical University of Košice
Košice, Slovak Republic
maksym.oliinyk@tuke.sk

Jaroslav Džmura
Department of Electric Power Engineering; Faculty of Electrical Engineering and Informatics
Technical University of Košice
Košice, Slovak Republic
jaroslav.dzmura@tuke.sk

Abstract — **SMART GRID is a system of transmission of electricity from the producer to the consumer, monitoring and distributing the flow of electricity to achieve the highest energy efficiency. The basis of the new generation network is the use in the general power system of numerous various distributed energy sources, which include low-power stations and installations that operate, including renewable energy sources. Using distributed energy sources makes it possible to reduce power losses during power transmission. In today's market conditions, in financial calculations between the energy system and consumers, it is important to analyze the energy balance, which includes the technological consumption of electricity for its transmission. Therefore, the issues of determining electricity losses are very relevant. However, with introducing information-measuring systems, the information security of calculations increases, so it became possible to take into account additional factors while calculating losses, determining the structure of losses in the entire transmission and distribution system of electricity, and identifying the place of increased losses. Gathered information makes it possible to take measures for the rational reduction of losses. Energy storage systems are rapidly developing a class of high-tech devices that open new opportunities in the energy power industry. They make electricity stored and portable, eliminating the need for strict simultaneity of its generation and consumption - the fundamental constraint of power balance, which was a key factor to make a modern architecture of energy systems operating around the world. Electric power storages are fundamentally new element of their architecture, complementing the objects of generation, transmission, and consumption and opening wide opportunities for the effective realization of the potential of new types of distributed generation. The new active consumers will be using already commissioned and new energy capacities and operate energy systems in general.**

Keywords: Smart Grid, Electricity storage systems, renewable energy sources

I. Conversion Of Classic Electrical Networks to SMART GRID

At present, the Smart Grid concept is being introduced into power supply systems. To create a power supply system according to the concept, Smart Grid requires a large number of technologies. They provide consumers with improved power supply reliability and high quality power [1].

To create a smart network, technologies from the following areas are mainly used:

1. Modern measurement systems
2. Communication systems
3. Control systems
4. Automation systems
5. Renewable energy sources and energy storage systems

Renewable energy sources transform centralized systems into a distributed system. Intelligent power management systems are a promising direction for energy development. This system comprising traditional energy sources of renewable energy sources. Optimization of the combined work of various energy sources, increasing energy efficiency and reliability of the system is an important issue in the modern energetic industry. [2]

One of the important elements of smart grids is electricity storage systems. Electricity storage systems (ESS) are developing a class of high-tech devices that open new opportunities for developing the electric power industry. They are sufficient technologies that create all the conditions for smart energy management [1].

Traditional cars will become a thing of the past as the use of traditional energy sources is reduced. So, according to the Deloitte forecast, in 2030 annual sales of electric vehicles, including plug-in hybrids (PHEV) [3], will reach 21 million units (20% of global sales of light vehicles). This is quite different from the latest BNEF forecast (30 million electric cars by 2030) and even slightly less than in the baseline scenario of the International Energy Agency, which differs in a rather conservative approach to forecasting the development of new energy technologies (21.5 million electric vehicles in 2030 d) [4]. According to a report by analysts J.P. Morgan by 2030 the share of electric vehicles will reach approximately 39% of the total number of cars [5].

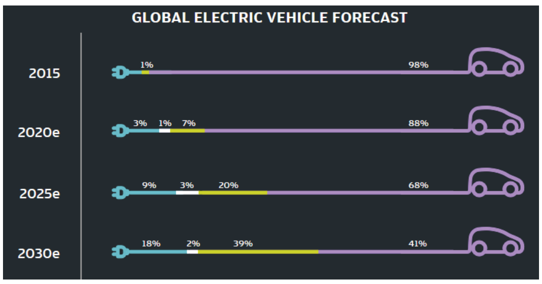

Figure 1. Forecast number of electric cars to 2030

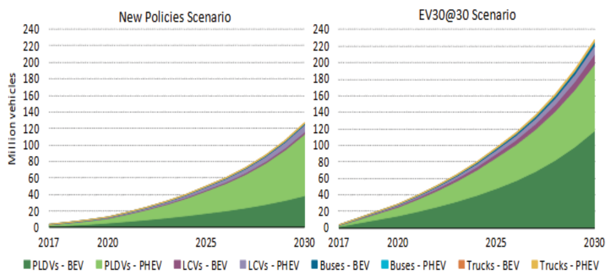

Figure 2. Forecast number of electric cars to 2030

II. 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 [6], 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 [7] and Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings. [8] In article 6 about new buildings suggesting that all new building need to take into account:

- Cogeneration;
- Heat pumps;
- Block or district heating or cooling;
- Decentralised energy supply systems on energy from RES.

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 [6].

III. Methods for Reducing Power Loss During Transmission

Measures to reduce energy losses can be divided into four groups[9]:

1. **Measures to improve the management of electrical network modes.** These activities are aimed at the ability to optimize the generation and consumption of electricity during peak periods due to: control of electrical equipment of consumers; the use of distributed generation and alternative sources of electricity at the consumer (batteries, solar batteries and other renewable sources), as well as increasing the capacity of transmission lines [10];
2. **Measures to automate the management of electrical network modes.** This direction is to increase the number of active elements, allowing to change the topological parameters of the network [11].
3. **Electrical network reconstruction activities.** The main source of reducing losses in this direction is to reduce the number of system failures and the time it takes to restore normal operation, by creating a self-diagnostic system. Which would track the current state of the system, and as a result of the accident, independently reconfigure the network [12].
4. **Measures to improve electricity metering, methods and means of information transfer.** In this direction, the focus is on creating communication systems, which will lead to improved consumption forecasting. Based on this, it will be possible to optimize the operation of the electrical system [13].

This article discusses the use of energy storage systems to regulate the load curve.

IV. Creating a Grid Model

To analyze the effect of accumulation systems, a village electric grid model was created. This model includes the elements shown in Table 1. For calculations in the article were used used matlab and Excel.

Table. 1. Elements of the model

Elements in the model	Number of elements	Installed power, kW
Line	91	-
Loads	58	-
battery	4	48
Photovoltaic	58	191,4
Transformer	2	-

A. Loads

The load model is the average home consumption per year. Each place consumption within the model represents a real home. The load is expressed in the annual load schedule Figure 3.

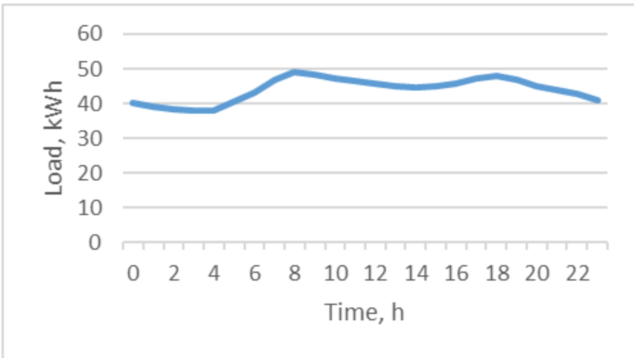

Figure 3. Annual load schedule

B. Renewable energy sources

To create a model of solar panels, real data were used. The All-Black CS6K-300M model from Canadian solar with a maximum output of 3.3 kW was chosen for the simulation. The parameters of the solar panel are presented in Table 2[14].

Table 2. Parameters of photovoltaic [14]

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

And data on solar radiation were obtained by measuring our department. For calculations, we selected the average power per hour for the whole calendar year.

C. *Electric car charger*

To create a model of an electric car, an analysis was made of possible charging stations. Charging is made according to the nominal values. The rated power of the selected charging station is 3.7 kW. [15] Charging time depends on the degree of battery discharge during the day. To study the influence of the state of the batteries of electric vehicles, it was analyzed the possible discharge of an electric vehicle by an ordinary user under different usage scenarios. According to the results of this analysis, a battery discharge scenario was made in the design model; it is presented in Figure 4.

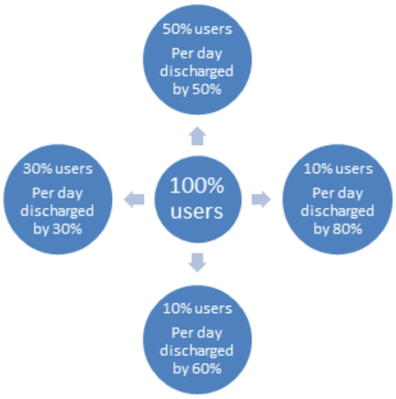

Figure 4. The distribution of discharge on the total number

As a prototype electric car was used Nissan Leaf 24kWh. [16] Fully charging this vehicle with the selected charging station takes about 7 hours.

V. SIMULATION RESULTS

As part of the simulation, three options for charging electric cars were analyzed.

- 19:00-1:00
- 22:00-4:00
- 17:00-23:00

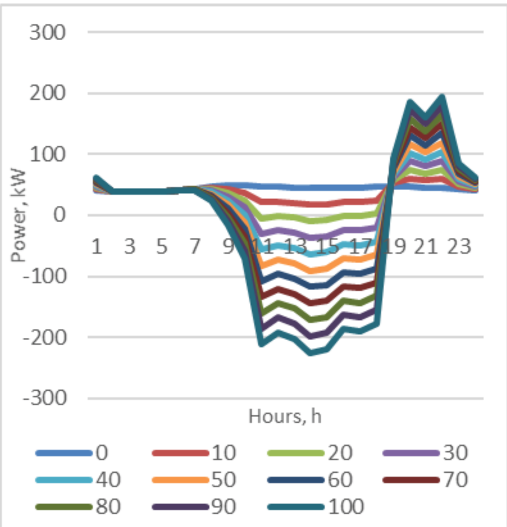

Figure 5. Schedule of power consumption by the network when charging electric vehicles in the period 19:00-1:00. Curves indicate the percentage of use of smart elements in the network.

As we see from the graphs, with an increase in the number of smart elements, losses in the network begin to grow [13]. In the daytime, this is due to the fact that solar panels produce a large amount of electricity that is transmitted over a low voltage network of 0.4 kV. In the evening, the increase in losses is caused by the fact that the load on the network increases significantly, and consequently also the losses. As we can see on the graph of the losses of the third network operation mode, the optimal solution is to charge electric vehicles at the time of producing power on solar panels. But as a rule, people are at work during the daytime and they cannot put their electric car on charge.

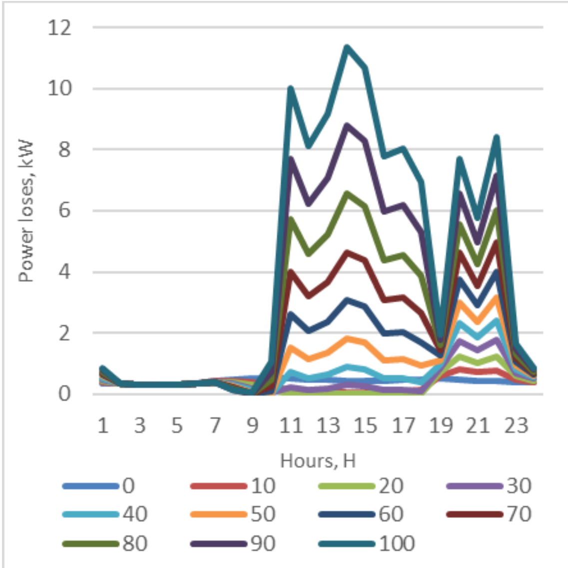

Figure 6. The graph of the loss of active power when charging electric vehicles in the period 19:00-1:00. Curves indicate the percentage of use of smart elements in the network.

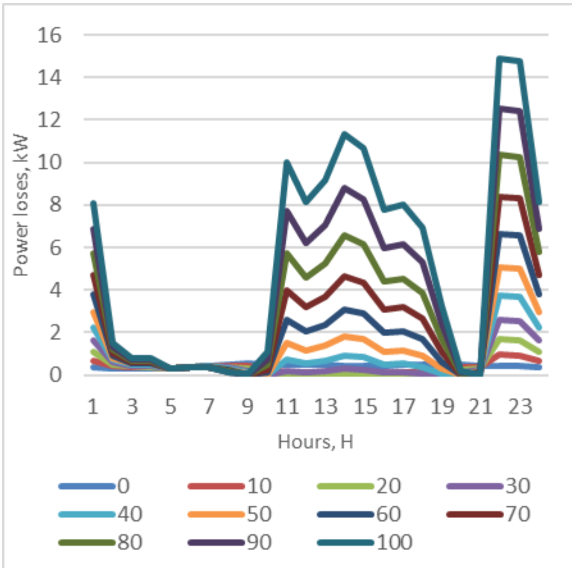

Figure 7. The graph of the loss of active power when charging electric vehicles in the period 22:00-4:00. Curves indicate the percentage of use of smart elements in the network.

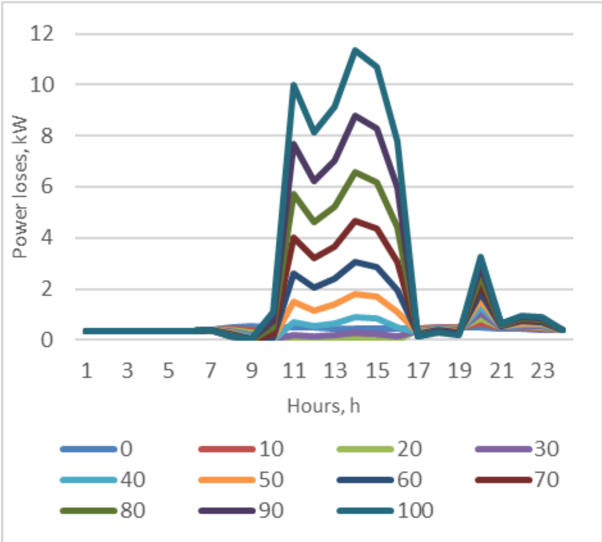

Figure 8. The graph of the loss of active power when charging electric vehicles in the period 17:00-23:00. Curves indicate the percentage of use of smart elements in the network.

To reduce power losses in the network, an increased power energy storage system was installed.

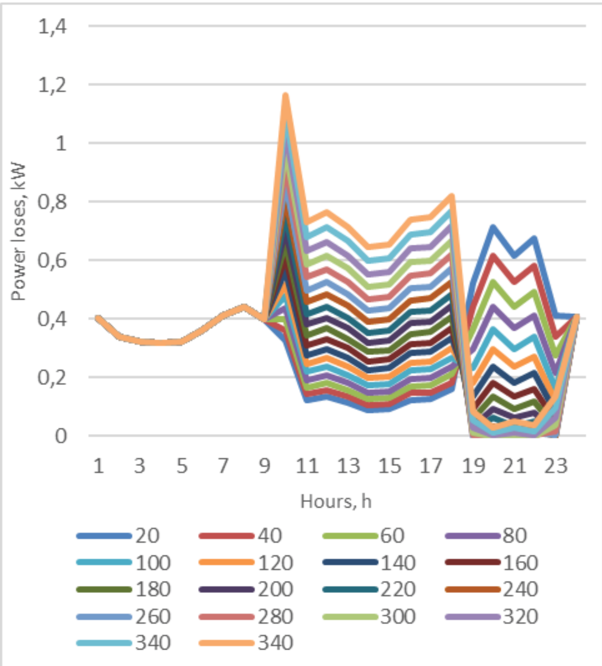

Figure 9. Graph of changes in losses in the electrical network when using different powers of accumulation systems (range 20-360 kW). Using 10% of smart elements.

Figure 9 shows the change in losses due to changes in battery capacity. The calculation is made using only 10% of smart elements and a charging period of 19:00-1:00. Analyzed the results of this calculation, we can conclude that high-capacity batteries can also cause increased losses. However, if you install a charge and discharge control system, you can maintain an optimal level of losses in the network [17].

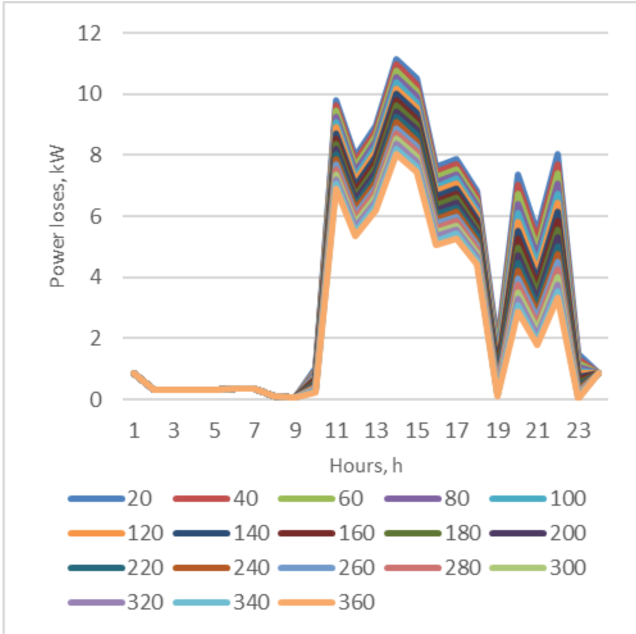

Figure 10. Graph of changes in losses in the electrical network when using different powers of accumulation systems (range 20-360 kW). Using 10% of smart elements.

Figure 10 shows the change in active power loss depending on the change in battery capacity from 20 to 360 kW. The analysis was carried out for the most difficult mode, that is, 100% of smart elements were installed in the network. Losses have decreased by approximately 25% during the generation of power by solar panels. And by almost 50% during the purchase of electric cars with the maximum capacity of the energy storage system. It is worth noting that when installing a control system, it is possible to adjust the losses in the electrical network with sufficiently high accuracy. That is, to increase or decrease the amount of energy that the battery consumes or vice versa gives into the network [18].

VI. Conclusion

As part of the analysis of the use of accumulation systems to reduce the loss of active power was established:

- Accumulation systems need to develop and install a power control system
- Electric energy storage systems are flexible enough to use.
- Accumulation systems can reduce power losses, voltage deviations, reduce the current load in the lines.
- It is quite easy to increase power.

They also have a number of drawbacks, for example, they are:

- Expensive
- Have a short lifespan
- Require careful adjustment.

Based on forecasts for the future, the number of renewable energy sources will increase, the number of electric vehicles will increase, and consumption of ordinary consumers will also increase[19]. Current electrical networks will not be able to fully perform their tasks. They will have to be updated, and the installation and use of energy storage systems is one of the ways to solve future problems[20] [21].

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