Smart energy systems and smart metering systems in them

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Abstract. The authors of the article evaluated the level of digitalization and the achieved effects during using digital technologies by means of the digitalization index at present and its predicted values. Tools were given to support and stimulate prosumers as active participants in smart energy systems. The integration into the power supply system of 2 prosumers is considered – a logging plant and a shopping center. Their consumption of electricity from the network is analyzed in the case when the generation of electricity from its own sources is insufficient from 2018-2019. The calculations were carried out in several price categories. The calculations showed that in the conditions of accurate planning, in the absence of emergency situations, prosumers who are legal entities can save. To switch to these calculations, it is necessary to install metering devices that allow you to measure hourly consumption. Thus, the smart energy system allows the consumer to choose a price category that suits him based on the energy consumption data of previous months.

1. Problem statement
Energy companies consider smart grids as the basis for their sustainable development, which is based on innovation. According to the Regulation of PJSC ROSSETI “On a Unified Technical Policy in the Electric Grid Complex”, approved by the Board of Directors of the company (Protocol No. 378 of 11.08.2019), one of the purposes of the technical policy is the transition to risk-based management based on the introduction of digital technologies and big data analysis.

A distinctive feature of equipment, materials technology and integrated systems is the availability of smart electronic devices. This also applies to electric energy metering systems. The purpose of the technical policy in this area is the formation of unified approaches to the creation of automated electricity metering systems.

A smart energy system is understood to mean an electric power network consisting of producers, consumers, prosumers, capable of smartly integrating the actions of all users, to ensure reliable and safe electricity supply. The smart energy system is controllable, automated, compatible with existing systems [1]. To create such systems in the Russian energy sector, its transition to digital technologies is necessary. In smart energy systems, a new role appears for already familiar participants – the role of the prosumer, transforming the familiar role of the consumer to create new services for the electricity market.

The link that binds the automation levels of the technological model of digital smart grids is the CIM model. The Common Information Model is a standard that enables the interchange of information for managing elements regardless of their supplier or manufacturer. This is a single information model.

2. Current level of electric grids Digitalization in Russia and its perspectives
According to calculations carried out by the largest Russian transmission and distribution system operator PJSC ROSSETI the digitalization index for Russian power grid has amounted to 14.5%, which indicates the scale of the forthcoming digitalization as about 85.5%. In addition, during the
digital transformation, the planned values of key performance indicators should be reviewed. Fig. 2 shows the current and calculated forecast values for digitalization index $I_D$ corresponding to the digitalization of technological information systems, corporate systems and cybersecurity systems, and digitalization index $I_{DT}$ as a component of $I_D$ corresponding to digitalization of technological information systems and directly related to smart energy system infrastructure [2,3].

![Digitalization index forecast](image)

**Figure 1.** Current and forecast values of the digitalization index for power grid in Russia.

The concept of the development of digital technologies is relevant not only for Russia, but also for the EU countries. The state structures of these countries consider Smart Grid as the ideology of national programs for the development of the electric power industry, borrowed funds with a low interest rate are attracted to implement these technologies, as a rule, and there are no talks about payback periods in this case.

In Russia, the digital transformation is based on three strategic planning documents: Decree of the President of the Russian Federation dated 05.05.2018 No. 204, the Digital Economy of the Russian Federation Program, and the Strategy for Scientific and Technological Development of the Russian Federation.

At the value level in society, as well as at the level of state policy, in comparison with the EU and the USA Russia lacks the main message of the digital transformation which is decarbonization. Taking into account the total amount of power based on renewable energy sources, Russia in comparison with other countries is an outsider in this direction. Therefore, it is not necessary to link together all types of energy sources in the country. It’s more rational to install solar power plants, wind farms, hydroelectric or geothermal power plants only in areas with a large number of energy sources to develop distributed generation [4]. The introduction of Smart Grid technology will solve the problem of inefficient use of power lines and the capacity of transformers [5, 6]. In particular, according to the statistics the actual load of the grid transformers today does not exceed 30% of their nominal capacity.

Since 2019, each subsidiary of ROSSETI should constitute at least 20% of the entire investment program annually as tools to support and stimulate the digitalization of the electric grid complex of Russia. Thus, the budget, which is aimed at these goals, is formed from tariffs for the transmission of electric energy and differs depending on the region. Indirectly, these investments can be increased by using equipment manufactured on the territory of the said region to build power grid infrastructure. Since the seller of the products, in this case, returns part of the funds in the form of a tax to the budget of the region, from which in the future, in particular, the investment program of the company purchasing the products is formed [7].

Expensive power is the main challenge for the Russian power industry, which is determined by the constant costs for the operation of the power system. The total cost does not depend on the volume of consumption and includes not only the payments for generating capacity but also the payment for the
maintenance of electrical networks. The growth of forecast values indicates the scale of the upcoming digitalization.

3. Integration of prosumers in the power supply system
However, the strategic integration of prosumers in the power supply system is currently a problem for Russia. Firstly, the mass installation of smart metering systems is necessary, for which Federal Law No. 522 of 27.12.2018, “On Amending Certain Legislative Acts of the Russian Federation in Connection with the Development of Electricity (Power) Metering Systems in the Russian Federation,” was passed. Secondly, it is necessary to carefully consider an effective tariff setting for the prosumer. This will make it possible to get additional profit and adjust its consumption, and will also contribute to the emergence of a competitive retail energy market (REM) [8-10]. The authors of the article suggest calculating the electricity tariff options for a prosumer on the REM by analogy with the calculation of legal entities in the wholesale market of electric energy and power (WMEP) [11, 12]. Table 1 presents the characteristics of price categories for the consumers of the WMEP.

| Price category | Metering       | Consumption planning | Transmission tariff   |
|---------------|----------------|----------------------|----------------------|
| 1             | Month          | Don't need to plan   | Single-rate tariff    |
| 2             | Zones of the day | Don't need to plan   | Single-rate tariff    |
| 3             | Hour           | Don't need to plan   | Two-rate tariff       |
| 4             | Hour           | Don't need to plan   | Two-rate tariff       |
| 5             | Hour           | Need to plan         | Single-rate tariff    |
| 6             | Hour           | Need to plan         | Two-rate tariff       |

In calculating prices, it is not profitable for a prosumer to use price categories for which independent planning of consumption by the enterprise is provided (fifth and sixth), because it is not possible to plan hourly consumption for a day ahead with a 100% probability, resulting in deviations from the declared volume, which must be paid to the energy supplier [13, 14].

Table 2 presents the electricity and power consumption of the shopping center. The main costs of electrical energy are due to the costs of lighting, air conditioning and ventilation. In the period from November 2018 to October 2019, the power regime was 196-297 thousand kWh and 315-497 kW of active power per month.

| Year | Month       | Electricity, kWh | Power, kW |
|------|-------------|------------------|-----------|
| 2019 | January     | 270527           | 452       |
| 2019 | February    | 232461           | 414       |
| 2019 | March       | 256972           | 410       |
| 2019 | April       | 237720           | 371       |
| 2019 | May         | 248856           | 453       |
| 2019 | June        | 268374           | 497       |
| 2019 | July        | 196352           | 360       |
| 2019 | August      | 197063           | 315       |
| 2019 | September   | 245148           | 398       |
Table 3 presents the electricity and power consumption of the logging plant. The main costs are due to lighting and technical equipment. In 2018, the power regime amounted to 448-667 thousand kWh and 857-1106 kW of active power per month.

| Month   | Electricity, kWh | Power, kW |
|---------|------------------|-----------|
| January | 592 415          | 1 071     |
| February| 472 250          | 1 086     |
| March   | 506 548          | 1 089     |
| April   | 542 744          | 1 006     |
| May     | 490 239          | 1 048     |
| June    | 515 535          | 1 006     |
| July    | 506 686          | 938       |
| August  | 533 470          | 857       |
| September| 527 574          | 909       |
| October | 584 756          | 913       |
| November| 447 758          | 1 004     |
| December| 666 589          |           |

Both legal entities are consumers with a relatively even load. Based on the analysis of data for several years, it is possible to predict the schedule of consumption of electric energy and power [15, 16]. This will allow the consumer to switch to calculating the costs in 5 or 6 price categories.

In terms of accurate planning, in the absence of emergency situations, this will help legal entities save. To switch to these calculations, it is necessary to install metering devices that allow you to measure hourly consumption [17, 18]. Thus, the smart energy system allows the consumer to choose a price category that suits him based on the energy consumption data of previous months.

4. Conclusion
The Smart Energy system is intended to become a driver of the transformation of the traditional energy complex as well as its implementation involves the creation of single information space for the Russian energy sectors. In calculating prices, it is not profitable for a prosumer to use price categories for which independent planning of consumption by the enterprise is provided (fifth and sixth), because it is not possible to plan hourly consumption for a day ahead with a 100% probability, resulting in deviations from the declared volume, which must be paid to the energy supplier.

However, the commissioning of smart energy systems can help in this regard. Based on monthly data, a consumer with a relatively even load is able to predict their consumption. Thus, the smart energy system allows the consumer to choose a price category that suits him based on previous data.

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