Optimization of the daily load schedule with the help of energy storage device in order to ensure compliance with the declared tariff price category in the retail electricity market

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Abstract. This paper is devoted to the analysis of electricity consumption by a real enterprise in Western Siberia and the development of recommendations for optimizing its electricity consumption in the context of the tariff policy for the region. The paper discusses the possibility of using energy storage device to reduce the maximum power consumption by organizing charge and discharge cycles of the drive in certain periods of the day. During minimum power consumption, the daily load curve is levelled due to the process of charging the drives. The energy is released into the circuit at the maximum power consumption of the enterprise, reducing its peak load. Aligning the daily schedule of the projected power consumption allows selecting a price category with a lower tariff rate when applying for technological connection. It is concluded that the use of energy storage device for saving for these purposes is unprofitable, since the payback period of the drive significantly exceeds its service life. It is noted that a possible area of application of energy storage device includes enterprises where process violations lead to significant economic damage, the minimization of which justifies the use of expensive energy storage devices.

For medium and large industrial enterprises with installed electric power in the range from 670 kW to 10 MW and from 10 MW and above, price categories from 3 to 6 are applied [1]. We will consider the extreme options of possible price categories.

The third price category is used for the volumes of electric energy (power) purchase, for which hourly accounting is carried out for the billing period, but hourly planning is not carried out, and the cost of electric power transmission services is determined by the tariff for electric power transmission services in one-stage terms.

The sixth price category is used for the volumes of electric energy (power) purchase, for which hourly planning and accounting is carried out for the billing period, and the cost of electric power transmission services is determined according to the tariff for electric power transmission services in two-part terms.

We will make the analysis on the basis of actually performed measurements of hourly electricity consumption in summer and winter time for one of the enterprises located in the territory of the Tyumen region. The daily graph of its load is presented in figure 1.
Figure 1. Schedule of enterprise load in June and December 2017.

This schedule is fairly smooth. The maximum load during the summer measurement falls on the period from 0:00 to 1:00 h.; and during the winter measurement - from 6:00 to 7:00 and from 14:00 to 16:00 h.

Figure 2 shows a graph of the average level of electricity prices for enterprises in June and December 2017 according to the data of the Tyumen Energy Retail Company [2] with a total installed load capacity of over 10 MW, 3 CC, 110 kV voltage class.

Based on the data (figure 2), we can conclude that the average daily price for December is 2,207.52 rubles per MWh of energy consumed; for June it is 2169.51 rubles per MWh.

Figure 3 shows a graph of the average level of electricity prices for enterprises in June and December 2017 with a total installed load capacity of over 10 MW, 6 CC, voltage 110 kV class.

Based on the data (figure 3) it can be concluded that the average daily price for December is 1041.89 rubles per MWh of energy consumed, in June it is 1030.65 rubles per MWh.

Comparing 3 and 6 price category (PC), we can conclude that the hour schedule has a similar structure for the 3rd and 6th PC, but for the 6th PC the average tariff is 2 times lower. In the warm season, there is a greater cost difference per MWh. In the power range from 670 kW to 10 MW for the
corresponding price categories at the same voltage, the graphs have a similar shape with the graphs presented above and are not considered separately in this paper.

**Figure 3.** Chart of the average price level (excluding VAT) for June and December 2017, 6 CC, 110 kV with a power over 10 MW.

Figure 4 shows the graphs based on the data (figure 1 - figure 3), which demonstrate the hourly dynamics of changes in the cost for the amount of electricity consumed by the enterprise at the appropriate time intervals.
Figure 4. Hourly dynamics of changes in the cost of electricity: a) December 2017, 3d PC; b) June 2017, 3d PC; c) December 2017, 6th PC; d) June 2017, 6th PC.

After the analysis of these graphs, it can be noted that in the time intervals, characterized by the cost of consumption below the average, the accumulation of electricity using the energy storage device (ESD) is rational. Work in the field of ESD and their integration into energy systems is of interest all over the world and is one of the priority areas for the development of the electric power industry in Russia.

As a rule, ESD is made on the basis of lithium-ferrophosphate batteries, comparable in price to industrial lead-acid batteries, but being more secure and compact. On the basis of lithium-ferrophosphate batteries, it is easy to implement high-capacity storage devices that provide redundancy of the required capacity for a long time.

Let us calculate the economic effect and payback period for the enterprise. For example, for the warm period of the year, the amount of accumulated electricity is 1.6 MWh in the period from 5:00 to 6:00 (figure 3) at a cost of 712.91 rubles per MWh. We give the stored energy to the circuit in the period from 12:00 to 13:00 at a cost of 1,193.77 rubles per MWh similarly for the cold season. Capital investment in the creation of ESD of the specified capacity is 105 million rubles. The calculation results are given in table 1.

Table 1. Summary table of ESD profitability.

| Parameter                                           | Value       |
|-----------------------------------------------------|-------------|
| Drive charging hours                                | 5:00-6:00   |
| Hours of energy output into the network             | 12:00-13:00 |
| Savings per day, rub. / MWh                         | 480.86      |
| Payback period with an estimated capacity of 10 MW, years | 60          |
| Payback, taking into account the non-simultaneity of the load, years (Kn = 0.85) | 70.5        |
Thus, with an estimated service life of an ESD equal to 25-30 years, its estimated payback period is much longer: 60-70 years, which is obviously not profitable.

To improve the efficiency of the energy storage system and increase the possible economic effect from its use, it is necessary to apply a special system of control and management (SCM) [6]. In general, the SCM provides tracking of the specified parameters of individual batteries and the battery as a whole, as well as the transfer of the values of monitored parameters to the user. So with the help of customized algorithms it is possible to adjust the charging current of the battery, focusing on the value of the tariff at the current time, taking into account the value of the current power consumption (graphs in figure 4). Thus, the acceleration of the drive charge process by means of SCM is carried out on the basis of an analysis of the hourly dynamics of changes in the cost of electricity, which leads to greater savings during periods of the day with a high cost of electricity.

Based on the analysis we can draw the following conclusions. The obvious solution to reduce the money spent on payment for consumed electricity is to switch to a more advantageous price category, which requires providing the enterprise with a system of analytics and electricity consumption forecasting [7, 8]. The use of such a system allows the enterprise to inform the guaranteeing supplier (GS) about the expected volumes of electricity consumption, and basing on this information the GS can predict and plan capacity flows more accurately (based on statistical data accumulated during the operation).

A possible option to optimize the power consumption of the enterprise is the use of ESD. At the moment, their cost is too high, which cannot ensure the mass of their use. In addition, it is necessary to develop optimal control algorithms for ESD and their interaction with the network of each specific enterprise, which is a multi-criteria optimization problem and is carried out individually.

To calculate the economic component of the proposed system implementation, it is also necessary to take into account emergency power outages, their possible negative consequences, taking into account the required category of power supply reliability. ESD in this case can be considered as the second independent power source, reducing the cost of creating a power supply system and increasing the payback of ESD.

References
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