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Modeling of electricity consumption in the systems with smart equipment

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Abstract

Big data is the foundation of modern energy management systems. There are two energy consumption models where systems are one of the consumers with intelligent equipment: static and dynamic. The dynamic model uses a two-tariff closed-loop accounting scheme, which implies changes in tariffs based on the analysis of current consumption. The results of an experimental study of both models using energy consumption data are presented. The influence of the number of such devices on the possibility of achieving uniform consumption when using the second model is shown. Usage of machine learning for generation a consumption forecast based on time series is shown.

Keywords: big data, self-organizing, smart equipment, electric energy consumption, energy consumption modeling, energy consumption forecasting

According to analytical resources [1,2], the energy sector is one of the growth drivers of the big data analytics market. Thus, in [2] for this market in the energy sector, a CAGR of 11.28% during the 2021-2026 is indicated. The use of big data analytics can improve quality of problem solution in the field of reducing energy consumption and improving energy efficiency.

Big data technologies are gaining particular importance in the face of a significant increase in the number of automatic and intelligent equipment both in the industrial sector and in the household.

In private sector of electricity consumption analytics is the backbone of smart buildings. Using an advanced analytics platform allows obtaining actionable analytics insights based on monitoring data, which allows improving building management systems and constantly optimizing energy consumption.

Another important application is predicting, detecting and preventing overhead or peak demand (Identify Times of Peak Demand). The integration of big data analytics with machine learning methods allows ensuring the adaptation of the energy consumption system in various unplanned situations, for example, equipment malfunctions, problems with thermal insulation, and unusual consumer behavior.

Big data is also the basis for the development of consumption management systems with the usage of smart metering of electrical energy.

One of the critical issues is tariff setting. Dynamic tariffs is profound interest as on their basis it is possible to obtain more efficient solutions.

Electricity consumption systems have a high degree of self-organization, which is partly regulated by certain rules and applicable tariffs. The use of dynamic tariffs increases the degree of self-organization, but requires constant monitoring of the system in order to prevent emergence of critical situations. The use of smart devices makes it necessary to consider consumption patterns that take into account this new dimension of consumer heterogeneity. Intelligent devices have ability to independently regulate their own energy consumption, as well as interact with other consumers in decision-making and control processes. Consequently they can demonstrate much more rational behavior as electricity consumers in comparison with humans.

The relevance of considering such models is confirmed by the statistics of the rapid growth in the number of such devices. Primarily they include electric vehicles and equipment for a smart home.

The analysis of existing models for setting tariffs was carried out on the basis of the following models. The static model is based on the allocation of two zones with a fixed duration of each zone and with fixed tariffs for each zone. The dynamic two-tariff metering model with feedback which implies a change in tariffs based on the analysis of current consumption.

In the static model “smart” devices that can independently set the time of their electricity consumption are automatically connected during the period of the lower tariff (usually set at night). However, when there is no feedback with an increase in the share of energy consumption by “smart” devices, a situation may arise when the average hourly consumption at a low tariff under the conditions of two-tariff metering may exceed the average hourly consumption at a high ("daily") tariff.

In order to prevent such a cause of events, a dynamic model of two-tariff metering with feedback was developed. It implies an increase in tariffs in time intervals when, according to the analysis of current data, average hourly consumption begins to exceed average daily consumption with a corresponding decrease in tariffs during time intervals with low-intensity consumption.

An experimental study of both models was carried out using real data on the energy consumption of one of the cities of Russia. In the experiments it was investigated how an increase in the share of smart devices in the composition of electricity consumers, as well as options for setting zones and tariffs, affect the ability to achieve uniform consumption throughout the day.

An increase in the number of actors in the system inevitably leads to the need to include a feedback mechanism in the system. It allows the resource provider to prevent excessive concentration of smart devices during the period of the cheaper tariff. The calculation results with the share of electricity consumption by smart devices equal to 16% are shown in Fig. 1. If the graphs coincide at different iterations, the color corresponding to the number of the largest of these iterations is displayed.

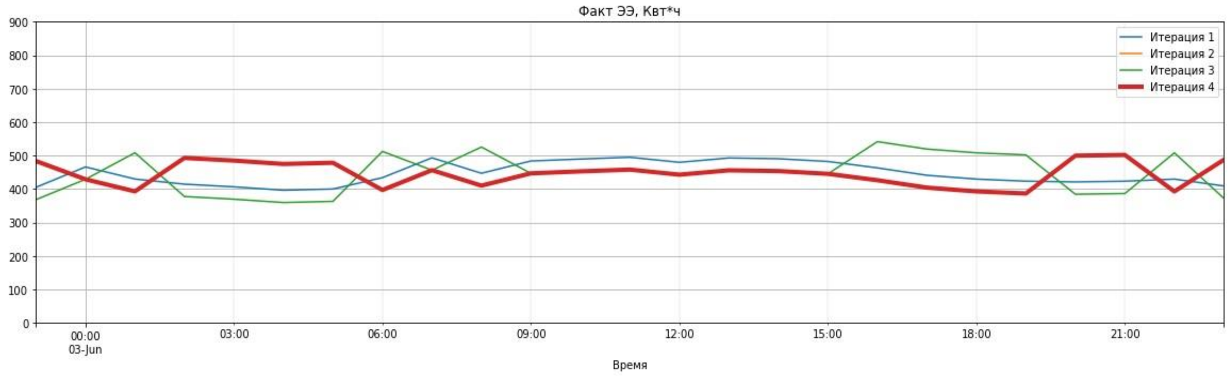

Fig. 1. Daily electricity consumption with a share of electricity consumption by smart devices equal to 16% (iterative model).

However, when the share of "smart" devices begins to exceed a certain critical value, a pronounced inversion of the times of cheap and expensive tariffs occurs in two successive iterations. In such a situation, in order to ensure a more or less even distribution of electricity consumption, it is advisable for the supplier to return to the single-tariff rate. Thus, an excessive increase in the number of intelligent actors in the system can neutralize the effect of their use.

Forecasting electricity consumption is a key challenge for many industrial enterprises that own smart devices. The formation of dynamic pricing will help stabilize electricity consumption, which is an advantage for all market players. Consumers will receive electricity at a cheaper price, and suppliers will start their generators more consistently, which affects their depreciation and, consequently, their service life.

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