Methodological Bases of Rationing of Electric Energy Consumption in Industrial Enterprises

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Abstract. This article discusses the issues of rationing electric energy consumption in industrial enterprises in modern energy saving conditions. It is noted that the existing methods for determining specific electricity consumption rates do not always reflect the actual production conditions, which leads to overestimation or underestimation of planned indicators and inefficient use of energy resources. The main attention is paid to the improvement of methodological approaches to the rationing of electricity consumption in manufacturing industrial enterprises. Computational and analytical, experimental and computational and statistical methods for the development of electricity consumption standards based on the analysis of energy balances, features of technological processes and operating modes of equipment are proposed.

INTRODUCTION

Modern requirements for the problem of energy saving have increased significantly, which requires a significant analysis of the methods used in industrial enterprises to estimate the parameters of specific electricity consumption rates. The state of affairs in this matter is still far from perfect, and this is primarily due to the variety of factors that make it difficult to optimally determine the indicators for rationing electricity consumption. The latter causes cases of overestimation or underestimation of the planned specific rate of individual industries, which leads to unjustified overspending of electricity, which is not confirmed by either technical and economic calculations or an actual decrease in electricity consumption. [1].

The analysis carried out at individual enterprises of the petrochemical industry has shown that the approved production standards for specific electricity consumption in many cases do not stimulate energy savings, and the establishment of regulatory values from the baseline indicator, taking into account 3-5% savings, cannot be applied in modern production conditions with significant variation in technological parameters.

Rationing and control of electric energy consumption under the prevailing operating conditions of electrical equipment should be carried out according to the final performance indicators (for the final product), which will make it possible to organize adequate forecasting of specific electricity consumption at the enterprise and will allow economical use of electric energy [4, 21]. In the light of these tasks, the development and further improvement of scientifically sound methods for rationing and planning the demand of industrial enterprises for electric energy is of great importance.

One of the most important components of reducing the power consumption of manufacturing enterprises is a system of progressive norms and regulations. It is a set of well-founded indicators of specific electricity consumption, the procedure for their formation, organizational, methodological and instructional documents, the application of which regulates production and management activities related to the issues of rationing electricity consumption in conditions of multi-nomenclature production and saving of electric energy.

In order to achieve the indicators of the development of renewable energy sources in 2020-2030, it is planned to build 3 GW of wind and 5 GW of solar power plants. the target parameters of the capacity of renewable energy sources put into operation annually have been established [1-5].

METHODS

Improving rationing in the manufacturing industry involves scientific, technical and economic justification of established consumption rates, their compliance with the actual state of the art, technology and organization of production. In this regard, the requirements for the quality of methodological support for standardization, which determines the level of scientific validity of standards, are significantly increased. The principles laid down in the methods should be simple and based on reliable and comprehensive information, as closely as possible linked to the main technological and operational characteristics of the process.

In this regard, this article proposes new methodological approaches to the rationing of electricity costs in the manufacturing industry, taking into account [2, 9]:

- energy balances of technological installations;
- the nature of production;
- the nature of electric receivers and their operating modes;
- changes in product output and its nomenclature, and a number of other factors.

The calculation and analytical method is proposed as the main method for developing technological and general production standards of electric energy consumption for manufacturing industrial enterprises. In addition, experimental and computational analytical methods can be used.

The computational and analytical method provides for the determination of electricity consumption rates by calculation according to consumption items based on the analysis of energy balances of technological installations and progressive indicators of electricity use in production.

An experimental method for developing individual consumption rates; it consists in determining the unit cost of electrical energy based on data obtained as a result of tests (experiments). At the same time, the equipment must be in technically sound condition and debugged, and the technological process must be carried out in the modes provided for by technological regulations or instructions [13, 16].

It is advisable to use the experimental method when conducting energy audits of enterprises.

The computational and statistical method of rationing is based on determining consumption rates based on statistical data on electricity consumption and output over 3-5 years of operation of a workshop or enterprise [6, 8, 14]. This method is most convenient when it is necessary to take into account the load (performance) of equipment and other factors that are probabilistic in nature.

The main initial data for determining the norms of electric energy consumption are [5, 12]:

• primary technical and technological documentation; technological regulations and instructions, experimentally verified energy balances and regulatory characteristics of energy and technological equipment, raw materials, equipment passport data, regulatory indicators characterizing the most rational and efficient production conditions (power utilization coefficient, standards for energy consumption in production, standards for energy losses during transmission and conversion, and other indicators) [7, 20];

• data on the volume and structure of production (work);

• data on planned and actual specific energy consumption over the past years, as well as certificates of inspections of its use in production;

• data from the best practices of domestic and foreign enterprises producing similar products on the economical and rational use of energy and the achieved unit costs;

• a plan of organizational and technical measures to save electricity.

The general production factory consumption rate of active electricity W is determined by the expression (kW*h):

$$W = \sum W_{wi} + W_{a.n} + \Delta W_{lf} \tag{1}$$

where $W_{w.i}$ - is the general production workshop standard for the i-th workshop, in kW*h; $W_{a.n}$ - is the electrical energy consumption for the enterprise's auxiliary needs (production of compressed air, cold, oxygen, nitrogen; water supply; production needs of auxiliary and service workshops and services; operation of in-plant transport; outdoor lighting, etc.), kW*h; $\Delta W_{l.f.}$ - is losses in the plant's electrical networks (to workshop metering points) and transformers, in kW*h.

The general production workshop consumption rate of active electrical energy W_w is determined by the expression (kW*h) [10, 15]:

$$W_w = \sum W_{t.n.} + W_{a.n} + \Delta W_w \tag{2}$$

where $W_{t.n.}$ - is the energy consumption for the process needs of the workshop, kW*h; $W_{a.n.}$ - is the energy consumption for the auxiliary needs of the workshop, kW*h; ΔW_w - is the energy loss in the workshop networks and transformers, kW*h.

The consumption of electricity for auxiliary needs consists of the consumption of lighting, ventilation and other consumers of electricity that are not directly related to the technological process (household and sanitary needs).

Calculation of electricity consumption for auxiliary needs and losses. Monthly lighting costs are determined using the expression (kW*h) [11, 16].

$$W_l = W_{l.d} + W_{s.l} + W_{l.l} \quad (3)$$

where $W_{l.d}$ - is the energy consumption for general lighting during working hours, in kW*h; $W_{s.l}$ - is the energy consumption for emergency and standby lighting, in kW*h; $W_{l.l}$ - is the energy consumption for local lighting, in kW*h.

The components of expression (2) are defined as:

$$W_{l.w.} = \left(\sum_{1}^{n} P_{i.p}\right) \cdot \alpha \cdot k_d \cdot T_m \quad (4)$$

$$W_{l.l.} = \left(\sum_{1}^{n} P_{l.p}\right) \cdot \alpha \cdot k_d \cdot T_m \quad (5)$$

where $P_{i.p.}$ - is the installed power of the i-th luminaire, n - is the number of luminaires in the workshop, T_m - is the luminaire operating time during the month, k_d - is the demand coefficient; α is the coefficient accounting for losses in the control gear; $P_{l.p.}$ - is the installed power of the i-th local lighting luminaire, kW; n - is the number of local lighting luminaires, units; k_d - is the demand coefficient for luminaires.

In industrial enterprises, electricity consumption for lighting systems is an important component of overall energy usage. Properly calculating lighting energy consumption allows engineers to create accurate energy balance models and establish justified energy consumption norms.

Interpretation and Engineering Remarks [8, 12, 19].

1. Lighting electricity use can be optimized by:

- replacing lamps with LED systems.
- using automatic control systems (motion sensors, daylight sensors).
- creating lighting zones for selective activation.

2. The coefficients α and k_d directly influence the result.

- Lower values mean lower losses and higher efficiency.
- LED lighting typically has a lower loss coefficient.

3. Accurate estimation of T_m (operating hours) is crucial.

Real monitoring or automatic metering improves accuracy.

4. For advanced accuracy, dynamic correction factors can be used for:

- seasonal daylight variation
- occupancy-dependent lighting
- dimming and automation systems

These formulas provide a rational and scientifically sound approach to estimating electricity consumption for lighting in industrial facilities [13, 16]. They are integral in energy audits, budgeting, and establishing energy efficiency policies. Using these methods ensures: accurate energy planning: prevention of excessive consumption norms: development of energy saving strategies based on real operational characteristics.

DISCUSSION

The presented methodological approaches highlight the increasing importance of scientifically justified energy rationing in industrial enterprises under modern production conditions. The results of the analysis confirm that traditional standard-setting mechanisms, which rely on fixed or baseline consumption values with nominal savings targets (e.g., 3–5%), are insufficient for current highly dynamic and technologically diverse industrial systems. The variability in production loads, changes in product assortment, and the complexity of modern technological processes demand flexible, adaptive, and data-driven approaches to electricity consumption rationing [8, 19].

A critical aspect revealed by the study is the necessity to shift from purely statistical or historically established norms to more analytical, balance-based, and experimentally verified models. The proposed methodological framework, which integrates calculation-analytical methods with experimental validation and statistical analysis, ensures higher accuracy in determining normative electricity consumption. This approach supports energy-efficient decision-making and prevents the overestimation or underestimation of electricity needs—issues that often lead either to unjustified energy losses or to artificial constraints that may reduce production efficiency.

Equally important is the emphasis on establishing norms on the basis of final output indicators. This principle provides transparency and objectivity in energy planning and improves accountability in production units. It also aligns energy consumption standards with actual production outcomes, enabling enterprises to forecast electricity usage more accurately and identify areas with the greatest energy-saving potential.

The integration of energy balances, technological parameters, and operational modes of electrical equipment into the rationing methodology further strengthens the scientific validity of the proposed approach. In particular, the focus on equipment operating regimes, probabilistic technological loads, and actual production factors ensures that the norms reflect realistic operating conditions rather than theoretical assumptions. Moreover, applying experimental methods during energy audits enhances precision and allows enterprises to verify normative values under optimal operating conditions [8, 15, 22].

The review of practice shows that a unified method cannot fully address the diversity of industrial systems; thus, combining analytical, experimental, and statistical techniques constitutes a rational and modern solution. It also supports continuous improvement and adaptation to technological innovation and market dynamics. The methodology presented promotes a systematic culture of energy saving and encourages industrial enterprises to adopt digital technologies, including automated metering systems, real-time monitoring tools, and intelligent energy-management platforms.

Overall, the proposed methodological basis significantly contributes to improving the quality and reliability of energy rationing in industrial enterprises. It not only enhances energy efficiency, but also fosters sustainable production practices and competitiveness in industries with high electricity intensity. Future research may focus on incorporating artificial intelligence, machine-learning models, and digital twins into the rationing process, offering real-time predictive capabilities and further optimizing energy consumption in industrial environments.

Energy consumption regulation measures at industrial enterprises can reduce electricity consumption by 30-50% [3, 18]. However, many of these measures are costly, so their implementation requires a feasibility study. This group of measures includes:

1. Organizational and technical measures;
2. Selecting the most cost-effective energy sources;
3. Implementing technological processes, equipment, machines, and mechanisms with improved energy-technological characteristics;
4. Increasing the utilization of secondary energy resources.

This group of measures includes:

• Compiling and strictly implementing "energy maps" for all types of process equipment;
• Increasing the utilization rate of process equipment;
• Timely preventive maintenance and repair of process equipment;
• Increasing the degree of automation of technological processes;
• Developing scientifically based energy consumption standards for manufactured products;
• Equipping all enterprises with automated energy metering systems (AES).

An analysis of foreign publications on energy saving [8, 17, 22] shows that savings of 5 to 15% can be achieved if all technological operations have energy maps of the process equipment, which indicate the main parameters of the technological processes: temperature, pressure, flow time, specific energy consumption, etc . These maps should be developed jointly by the services of the chief technologist and the chief power engineer of the enterprise.

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