10.63550/ICEIP.2026.54.76.037

Rationing of Electric Energy Consumption in Industrial Enterprises

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Keywords: rationing, energy consumption, consumption.

Abstract: This article examines the determination of energy consumption standards for enterprises with fluctuating power consumption. Particular attention is paid to the development of energy consumption standards that optimize energy use, reduce costs, and improve production energy efficiency. Factors influencing energy consumption are analyzed, and recommendations for the implementation of energy metering and monitoring systems are offered. Standardization ensures the rational distribution of energy resources, which contributes to the sustainable development of industrial enterprises and reduces the negative impact on the environment.

1 INTRODUCTION

Energy rationing is the process of establishing energy consumption standards for various activities, equipment, production facilities, or facilities. It is used to effectively manage energy consumption, conserve resources, and plan energy expenditures.

The standard for electrical energy consumption is the established value of electrical energy consumption for the performance of a certain task, the production of products, the provision of services, or the operation of facilities, calculated per unit of measurement (products, time, area, etc.).

Planning for future energy supply should begin with energy consumption standards. Progressive, scientifically based standards allow for assessing the performance of existing equipment and identifying and exploiting untapped reserves. Standards should be based on the energy characteristics of process equipment and take into account optimal operating conditions.

The basis for the development of specific energy consumption standards per unit of output are: the Law of the Republic of Uzbekistan "On the Rational Use of Energy" dated April 25, 1997, the Resolution of the State Inspectorate for Supervision of Electric Power Industry of the Republic of Uzbekistan №29-P, the Resolution of the President of the Republic of Uzbekistan №PK-3379 dated October 8, 2017 "On measures to ensure the rational use of energy resources".

The application of technically and economically sound energy consumption standards will enable the most efficient use of electricity and ensure energy savings.

An analysis conducted at individual petrochemical industry enterprises showed that approved production standards for specific energy consumption in many cases do not stimulate energy

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savings, and establishing standard values from a baseline indicator taking into account 3-5% savings cannot be applied in modern production conditions with significant variations in process parameters.

Standardization and control of electrical energy consumption under established operating conditions of electrical equipment should be based on final performance indicators (the final product), which will enable adequate forecasting of specific energy consumption at the enterprise and enable energy conservation (Sattarov, Bakhadirov, 2023). In light of these objectives, the development and further improvement of scientifically based methods for standardizing and planning the electrical energy needs of industrial enterprises is of great importance.

2 MATERIALS AND METHODS

One effective measure aimed at rationalizing energy consumption is a well-established system of metering, standardization, and analysis of energy use.

Technically justified means a specific standard developed under the following conditions: advanced technology, full equipment utilization, optimal equipment operation, and proper production organization.

Fuel, thermal, and electrical energy consumption standards are developed by all enterprises with daily consumption for production needs: fuel in quantities of 2 tons or more (in conventional terms, 7000 kcal/kg); thermal energy of 15 Gcal or more; and electrical energy with a connected electrical capacity of 100 kVA or more, regardless of the energy supply sources (power grid or in-house generating units).

All fuel, heat, and electricity consumption at the enterprise, both for primary and auxiliary technological processes and for ancillary production needs, is subject to standardization, including the production of refrigeration, compressed air, oxygen, water supply, heating, ventilation, lighting, and losses in internal plant networks and converters.

Specific energy consumption standards are divided into process-specific, general shop floor, and plant-wide.

Technological standards are established for the execution of individual operations or processes in accordance with existing technology. These standards include energy costs directly related to the main physical and chemical processes and inevitable losses due to the nature of the equipment and the technological process.

The technological specific standard serves as a means of monitoring the work of those directly involved in the technological process—workers (operators) and the energy consumption area, as well as compliance with the established, most efficient operating mode for a given equipment. This standard can be used to organize a bonus system for workers for achieving fuel and energy savings directly in the technological process.

Shop-wide standards are set per unit of output manufactured by a given shop. They include all fuel and energy consumption within the shop: costs for primary and auxiliary processes, shop ventilation, lighting, heating, losses in intra-shop networks, etc.

General plant standards ensure control over energy use in the plant, serve as the basis for planning energy consumption within the plant, and serve as a criterion for organizing a bonus system for energy savings in engineering calculations for plant and enterprise-wide engineering and technical staff. They are also used to justify plant-wide specific fuel and energy consumption standards.

The general plant standard is also set per unit of output. It includes all fuel and energy consumption for the plant's production needs. This standard is used in aggregate calculations for enterprise-wide energy resource planning and for sectoral planning. Furthermore, it can be used in designing the plant's energy supply and developing the energy sector in the region where the plant is located.

General plant standards must:

- include all fuel and energy consumption across the enterprise, both for process and auxiliary needs;
- reflect the actual energy costs of producing a given product;
- enable energy analysis of process and equipment operation;
- identify various factors influencing specific fuel and energy consumption and sources of inflated losses;
- identify potential for energy savings;
- outline effective measures to reduce energy consumption per unit of output.

Specific fuel and energy consumption standards in the industry must be developed according to a specific structure to enable comparison of specific consumption across individual enterprises. It is necessary to determine which cost elements are included in the standard.

The structure of specific energy consumption standards must include a list of all consumption items and be established based on the standard's purpose, technology, and organization of the production process.

The unit of output for which specific fuel and energy consumption is established can be a ton, piece, meter, cubic meter, etc. At enterprises producing a diverse range of products, a unit of 1,000 sums (the cost of the output) can be established. However, this unit is undesirable, as it does not reflect the actual energy intensity of production due to fluctuations in the cost of raw materials, supplies, and semi-finished products (Mikhailov, Ikonnikov, 2009; Mikhailov, 2009).

Two methods are used in calculating specific consumption rates: computational and experimental. The computational method is based on item by item determination of consumption rates and progressive energy use indicators, while the experimental method uses various measurements. Let's consider the methodology for developing specific consumption rates for electricity.

Technological Specific Energy Consumption Rate

The initial calculation data here is the manufacturing process for a given product, broken down into individual operations. During the calculation process.

The specific consumption rates for each individual technological operation are calculated based on:

Testing the electrical equipment used in the operation, both under load and in idle mode.

Determining the time spent performing the technological operations.

The technological specific consumption rate for each operation is determined by the equation (Sattarov, Bakhadirov, 2024):

$$W_{ут} = \frac{P \cdot t}{3600} \cdot n\ [kW \cdot h/unit] \quad (1)$$

where P - the power consumed by the drive mechanism motor under load during the operating cycle, kW; t - the time interval corresponding to different values of power P and a certain output, seconds; n is the value corresponding to the unit of standardization.

If the given technological process provides for the idle running of the machine, then the equation for determining the technological specific rate for the operation will have the form (Niyozov, Khushbokov, Saidova, 2019; Mikhailov, Ikonnikov, 2008):

$$W_{ут} = \frac{P \cdot t + P_{xx} \cdot t_{xx}}{3600} \cdot n\ [kW \cdot h/unit] \quad (2)$$

Shop-wide specific energy consumption rate

Calculated for each type of product manufactured by a given shop. One structure of the shop-wide specific energy consumption rate may be as follows (Mikhailov, Ikonnikov, 2009):

Technological specific consumption rates.

Shop lighting consumption.

Shop ventilation consumption.

Total (main consumption for the shop)

Overhead consumption.

Consumption by auxiliary shop departments.

Each item in the shop-wide standard is determined using the following methodology.

Technological standards for specific consumption for each type of product manufactured by the shop.

Lighting consumption is determined based on the types of products manufactured by the shop. If the shop produces a single type of product, the proportion of the specific lighting consumption standard for that product is determined (Sattarov, Bakhadirov, 2024; Cormen, Leiserson, Rivest, 1990; Mikhailov, 2009):

$$W_{осв.} = \frac{A_{lig.}}{n} \cdot n\ [kW \cdot h/unit] \quad (3)$$

where $A_{lig.}$ - the daily electricity consumption for lighting the workshop (taken from the workshop electrical balances); n - the average daily output.

If a workshop produces several types of products, the distribution of lighting costs by type of product is carried out proportionally to the technological specific consumption according to the expression:

$$W_{осв.} = W_n \cdot A_{lig} / \sum_{1}^{n} A_n \quad [kW \cdot h/unit] \quad (4)$$

where W_1, W_2, … W_n, - the technological standard for specific energy consumption for a certain type of product; $A_{lig.}$ - the total energy consumption for a given workshop for lighting (taken from the workshop electrical balances); $\sum_1^n A_n = A_1 + A_2 + A_3 ... + A_n$ electricity consumption in process equipment for each type of product for the calculated period of time (day). It is being determined: $A_1 = W_1 \cdot n_1$; $A_2 = W_2 \cdot n_2$; $A_n = W_n \cdot n_n$; where n_1, n_2, n_n - the quantity of products manufactured by the workshop by type for the calculated period of time (day).

The ventilation consumption for a shop is determined similarly, with the difference that instead of A_{lig}, the ventilation consumption A is used.

Consumption by auxiliary shop departments is calculated as a percentage (0,4-0,5% of the total of previous expenses).

Power losses in the shop's electrical network and its components are determined using a special method (see below).

Plant-wide specific electricity consumption rate.

Calculated based on shop-wide specific consumption rates, taking into account plant-wide electricity consumers. The main items of plant-wide specific consumption rates should be the following

(Sattarov, Bakhadirov, 2023; Heather, Taylor, 2019; Wilf, 1994):

Main shop-wide specific consumption rates.
General plant lighting consumption.
General plant ventilation consumption.
Steam production consumption..
Cooling generation costs.
Water supply costs.
Consumption by lifting and transport equipment.
Equipment repair costs.
Container manufacturing or repair costs.
Total (primary plant costs).
Overhead costs.
Consumption by plant support departments.
Losses in shop floor electrical networks.
Losses in the plant electrical network.
Losses in transformer losses.
Total for the plant.

Each item of the general plant standard is determined using the following methodology:

The cost of general plant lighting, allocated to a unit of output, is determined by the following expression (Bakhadirov, Musajanova, Ostonova, Musajanova, 2024):

$$W_{\text{осв.}} = W_n \cdot \mathrm{A}_{lig} / \sum_{1}^{n} A_n \;\; [kW \cdot h/unit] \qquad (5)$$

where A_{lig} - the total electricity consumption for general plant lighting, determined either by electricity meter readings or by calculation, kW*h

The meaning and calculation of the remaining values in this formula are specified in the definition of shop floor standards.

Unproductive electricity consumption is determined as a percentage and amounts to 1.5-1.8% of the total of all previous expenses.

Consumption by the plant's auxiliary departments is also determined as a percentage and amounts to 0.4-0.5% of the total of all previous expenses.

Losses in shop floor electrical networks, in the plant electrical network, and in transformers are determined using the method described below.

The general plant standard for active energy consumption $W_{w.sh.}$ is determined by the expression (kW*h) (Goldberg, 1991):

$$W = \sum W_{w.sh.} + W_{a.n.} + \Delta W_3 \qquad (6)$$

where $W_{w.sh.}$ - the general production workshop standard for the i-th workshop, in kW*h; $W_{a.n.}$ - 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; ΔW_3 - 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 $W_{w.sh.}$ is determined by the expression (kW*h) (Sattarov, Bakhadirov, Umarov, 2024; Sattarov, Bakhadirov, 2023):

$$W_{\text{ц}} = \sum W_{\text{T}} + W_{sh.a.} + \Delta W_{sh.n.} \qquad (7)$$

where W_T - the shop's process energy consumption, in kW*h; $W_{sh.a.}$ - the shop's auxiliary energy consumption, in kW*h; $\Delta W_{sh.n.}$ - the power loss in the shop's networks and transformers, in kW*h.

Auxiliary energy consumption consists of the consumption of lighting, ventilation, and other energy consumers not directly related to the process (household, sanitary, and hygienic needs).

3 RESULTS AND DISCUSSION

Energy resources play a key role in modern industrial production, and the efficient use of electrical energy is a significant factor in improving the economic efficiency of enterprises. Energy consumption regulation is a system for establishing acceptable and optimal consumption levels, aimed at reducing costs and improving energy efficiency.

This article examines the main methods of energy regulation used in industrial enterprises. These include the technological method, based on calculating standards for specific equipment and processes, and the statistical method, which involves analyzing actual consumption data. A combined approach is often used to account for production specifics and ensure more accurate energy consumption planning.

Particular attention is paid to factors affecting energy consumption: equipment type and operating mode, technological features of production processes, and the level of automation. The implementation of standardization facilitates the control and monitoring of energy consumption, the identification of deviations, and the implementation of energy-saving measures.

Energy rationing at industrial facilities not only reduces energy costs but also improves resource management, increases production sustainability, and reduces environmental impact. However, implementing these standards requires constant updating of the regulatory framework, consideration of changes in production conditions, and active employee engagement.

4 CONCLUSION

Energy consumption regulation at industrial enterprises is an important tool for rational energy use and improving production efficiency. Implementing regulation systems not only allows for monitoring energy consumption but also identifying opportunities for reducing it without compromising technological processes.

Implementing regulation can significantly reduce energy costs. To achieve these goals, systematic and comprehensive application of regulation within the enterprise's energy management system is essential, including regular review of regulations and their adaptation to changing production conditions.

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