Improvements in industrial energy rationing methods

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Abstract. The article analyzes the existing methods of rationing the electrical consumption of industrial enterprises. The results of the analysis of the state of normalization of electric consumption in the ferrous metallurgy industry are given. The developed multilevel structure of normalization of electric consumption by results of research which gives prospects of definition of possibility of energy saving on considered object is described.

Progress in electric steel production equipment and technology, reducing specific energy consumption per unit of production, as close as possible to the electric performance level converters, as well as environmentally friendly electric steel production make it more attractive to the industry.

Priority development of secondary metallurgy processes using modern electric smelting and rolling should be one of the areas of restructuring in the steel industry. The use of powerful electric furnaces will provide savings of up to half of the energy costs compared to integrated steel-making enterprises.

Given the global trend of faster growth of electric smelting steel production that by improving the process has reached 34% of world production and its cost has become competitive with the converter mode of production, it is proposed to install 80 tons of AC electric arc furnace (EAF) with scrap drying capable of production volume of 700,000 tonnes per year.

Currently, the share of steel produced in electric arc furnaces around the world is more than 30% (33% in 2010). Steel output in 2020 is forecast at 830 million tonnes / year, with the share of 40% of electric. Electric steel smelting with oxygen converter steel production continues to increase to 14-16% surpassing the open-hearth production, which was a major in steel production in the early 20th century. Capacity furnaces increased from 3 tons in 1900 to 150-200 tonnes in 2000. Experience has shown that the use of 1 ton of metal saves 4-5 tons of crude ore, 1.2 tons of coking coal, reduces emissions of pollutants into the atmosphere in 6.5 times, reduces the consumption of energy throughout the metallurgical cycle in 3 times. Electric smelting plays leading role in the production of high-quality and high-alloy steel. Due to a number of fundamental features this method is adapted to produce a diverse in composition superior metal with a low content of sulfur, oxygen and other harmful and undesirable impurities and a high content of alloying elements imparting steel special properties - chromium, nickel, manganese, silicon, molybdenum, tungsten, vanadium, titanium, zirconium, and other elements.
Arc furnace compared with other melting units have advantages as in electric furnaces metals can be quickly heated, melted with fine-tuned temperature, creating an oxidizing, reducing and neutral atmosphere or vacuum. These furnaces can produce steel and alloys of any composition, more fully deoxidize the metal to form a minimum number of nonmetallic inclusions - deoxidation products.

Minimizing the raw material and energy costs, the share of which in the production of electric is more than 70%, it is the main focus of the art and technology of melting in an arc furnace.

Improvement of material and energy resources use and creation of real and perspective norms of specific power consumption are one of the main directions of ferrous metallurgy efficiency increase. The regime of saving energy resources becomes really significant only when scientifically grounded progressive norms which would promote application of optimal energy modes in technological processes are introduced into production. This rule would increase metal products and reduce electricity consumption. Electricity consumption rationing should be the focus of attention of power engineers, technologists and economists. The task is to determine the electric power consumption on the basis of the actual economic need of the technological process taking into account everything new and progressive achieved in each individual industry, at each enterprise or workshop [1-4].

At a time when fuel and energy consumption is increasing and extraction, production and transportation costs are increasing significantly, radical improvements in fuel, electricity and heat efficiency are required [5].

Rationing of energy consumption acquires primary importance in solving these tasks, because in the absence of specific scientifically grounded consumption rates and strict control over their implementation it is impossible to save energy resources. Justified norms promote the development of new, less energy-intensive technological processes and elimination of irrational losses of energy resources [6].

All electric power consumption at the enterprise, both for main and auxiliary technological processes, and for auxiliary needs of production, including production of cold, compressed air, lighting, water supply, heating, ventilation and losses in internal networks is subject to regulation. Electricity consumption rationing means setting the planned value of electricity consumption for production of a unit of production, processing of raw materials or the volume of work performed. Value of electric power consumption for production of a unit of production is taken to be specific electric power consumption [7-8].

In this case, the planned value of consumption is called the norm of specific consumption (or simply the specific norm), and the actual consumption of electricity per unit of production is called the specific consumption.

Specific rate of consumption means not an arbitrarily accepted amount of consumption, but objectively necessary consumption of electric energy for the production of a unit or volume of work under these conditions of production, due to the organization and technology of the production process, the technical level of technological and energy equipment used, the technical condition and mode of operation of production equipment.

Specific power consumption rate is established on the basis of technical and economic calculation and is the maximum permissible value of power consumption for the production of a unit of production (or the volume of work) of the established quality [9-10].

The norms of specific consumption shall be progressive. The standards that meet this requirement shall be those that do: reflect to the fullest extent the scientific and technological progress in production, which ensures the most efficient and rational use of electric energy; - take into account the implementation of the planned plans of organizational and technical measures to save energy; promote revealing and mobilization of internal reserves of economy of electric power in manufacture on the basis of wide circulation and introduction of advanced receptions and working methods of the modern enterprises of the most rational modes of operation of the technological and power equipment.

As a rule, for industrial enterprises annual norms of specific consumption of electric energy are established with their differentiation by quarters of the year taking into account the influence of seasonality, as well as by shops, energy-intensive technological processes and units.
At the same time, the weighted average value of differentiated norms shall not exceed the approved general plant annual norm.

Energy consumption rates should be reviewed when improving (changing) the technology and organization of production and introducing new equipment.

Systematizing the methods of norms determination, we can distinguish the following methods: use of energy characteristics of the production unit; computational and analytical; computational and experimental; use of probabilistic numeric characteristics; use of electrical capacity; method of multifactor models; use of H-distributions; method of regression models; price analysis; probabilistic and statistical analysis [11].

We have developed a multilevel system of rationing based on the synthesis of classical, probabilistic-statistical and censological mathematical apparatuses, models and methods. And each level of system of rationing should be compared to the system of the accounting and reporting on electric consumption accepted at the enterprise in figure 1.

Ferrous metallurgy, as already mentioned, has a number of specific production characteristics which distinguish it from other industries. Existing methods of forecasting and rationing of electricity do not include these features which characterize the process of production, modes of power consumption of the equipment, as well as the impact of technological and operational factors on the energy performance. As also noted above, energy services have to rate, evaluate and distribute energy on the basis of experience and intuition with regards to the data on actual and planned performance of individual enterprises, which leads to certain inaccuracies and errors.

Figure 1. Electricity rationing system for the enterprise
In this regard, we set the task of science-based calculation, analysis and forecasting of energy consumption for each production site in view of its specific features.

Forecasts of energy consumption should take into account a variety of factors related to the technological features of production, organization of the equipment operation, etc. Although at this time there is a sufficiently large number of energy consumption forecasting methods, the results of their application are not always reflect the real situation.

To improve the reliability of forecasting it is necessary to identify patterns of change in electric capacity of the products, determine the conditions under which the dynamics of electricity may change significantly. In each industry the scale and pace of technological improvement and growth in the volume of output are different, in addition, the amount of electric capacity of production and the level of power consumption can be significantly affected by changes in energy consumption patterns due to changes in demand for such components of the process, as compressed air, oxygen, water, et al., as well as energy-intensive consumption such as ventilation, air conditioning, etc.

The proposed rationing system compares the types of specific and general rates of electricity consumption with the levels of administration of the enterprise, with the levels of financial accounting, as well as with the levels of electricity consumption meters. Each type of norms has its own mathematical method that most adequately simulates and describes power consumption at this level. In addition, for each type of norms, a method for assessment of energy-saving potential, compared to the method of rationing, is recommended.

The proposed system consists of three levels of rationing.

The first level corresponds to the general plant level, at which the general plant expenses of the enterprise are accumulated and accounted for.

In the financial system of cost analysis, the bills for the total amount of electricity consumed by the enterprise in the corresponding billing period are processed (usually for one calendar month). These values of electric power consumption volumes are used to form the electric capacity of the main type of the enterprise’s products, determined by the formula $A_{fac} = A/M_{fac} = E/W_{fac}/M_{fac}$ as a ratio of the total annual electric power consumption of the enterprise to the output of this type of products.

In case the total electricity consumption is unstable and depends on different factors (quantity of different types of products, ambient temperature, etc.), the target figures are presented as follows in the form of functional dependence of electric energy consumption on selected parameters. The target function of type $W = f(x_1)$ or $W = f(x_1, x_2, x_3)$ is constructed, where $x_1, x_2, x_3$ are factors (e.g. production of one or more types of main products). For rationing, a confidence interval of acceptable values is set around the target function, within which the consumption is considered normal.

At the first level of rationing, an expenditure part of the electric balance is formed, in which the entire volume of electric power received from the energy system is distributed to the shops and directions of electric power use [12-14].

The second level of the rationing system corresponds to the level of accounting for general shop floor costs. As an indicator of rationing of electricity consumption in the general case for each object of accounting a specific norm of workshop $A_{sp} = A_{sp}/M_{sh}$ is developed as a ratio of the volume of electricity consumption of workshop $i$ to the volume of products produced by this workshop. Initially the database is formed from monthly (weekly, daily, shift, etc.) values of power consumption of the metering object and corresponding to them volumes of products, composition and temperature of raw materials, type or parameters of products, ambient air temperature and/or other factors. Based on the data obtained, the actual specific power consumption for a number of time periods is calculated.

The third level of the rationing system corresponds to the level of individual components of in-shop cost accounting. This is the power consumption of individual power-consuming units or process lines with dedicated meters for technical metering within the unit (shop, section). As an indicator of power consumption rationing in the general case for a separate unit, a specific norm $A_{sp} = A_{sp}/M_{rat}$ is developed as a ratio of the volume of power consumption of the $i$-th unit to the volume of products manufactured by this unit.
The proposed rationing system is a universal tool for enterprises when implementing energy saving and energy efficiency measures, which can be used not only for rationing electricity consumption, but also for developing norms for other types of energy resources.

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