OPTIMIZING THE CONDITIONS OF ELECTRICITY USE AT METALLURGICAL PLANTS

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Improving the technical-economic indices that characterize the performance of metallurgical plants will require more efficient use of electricity, mainly by reducing total electric power consumption and finding alternative methods that will minimize energy use as a whole.

The problem of optimizing the conditions of electricity use is being exacerbated by the extremely unfavorable dynamics of the energy and production indices at these factories, which is in turn related to the sharp drop in the production of certain types of goods and an increase in the output of certain other types, as well as to restrictions on open-market purchases of energy resources – especially natural gas and electric power.

The optimum regime of electricity use for a given set of conditions in metallurgical production depends on the level of unit energy costs which has been adopted as the norm. In optimizing an electric power regime, the usual practice is to focus exclusively on the minimum possible unit consumption of electric power \( \omega \to \min \). In this case, the criterion of the efficiency of electricity use at the factory level can be expressed by the following functional:

\[
\sum_{i=1}^{n} \sum_{j=1}^{k} \omega_{ij} Q_{ij} \to \min,
\]

where \( i \) represents the type of production process; \( n \) is the number of types of production processes; \( j \) represents the types of products being made; \( k \) is the number of product types; \( \omega_{ij} \) is the unit consumption of electric power in making the \( j \)th type of product in the \( i \)th type of production process, KW·hr/ton; \( Q_{ij} \) is the number of products of the \( j \)th type made by the \( i \)th production process, tons. The ranges of the parameters are determined by planning goals \( Q_{ij} \geq Q_{pl} \) and by technical conditions that determine the allowable deviations of the parameters.

While such an interpretation of criterion (1) is both logical and natural for higher-level systems (factories, manufacturing conversions), for lower-level systems (shops, sections) the minimum electricity use under a specific set of production conditions is not always the most economically expedient criterion. For individual energy-intensive shops and sections, there may be multiple objectives, and their attainment may be characterized by the sum of such technical-economic indices as production volume, product quality, production cost, and unit electric power consumption. For many processes in metallurgy, there is a well-known contradiction between these characteristics, and their respective optimum values are obtained under different sets of service conditions. For example, an improvement in the quality of a rolled product is necessarily accompanied by a reduction in production volume. In sintering, the lowest electric power consumption is achieved at loads smaller than the maximum capacity of the sintering machine, and so forth.

It is correct to focus on the minimum consumption of electric power when reducing the use of electric power is the main goal for a given set of production conditions. In other cases, it might be more expedient if energy use is managed in such a way as to optimize another index – such as production volume or product quality – that is more important during the given time period for the specific production process. In this situation, the criterion of efficient electricity use might be formulated as follows: it is necessary to find the extreme value of unit electric power consumption \( \omega \to \text{ext} \) that will ensure the optimum value of another index \( S \to \text{opt} \).
Thus, the regime of electricity usage which is chosen as the optimum regime depends both on the optimization criterion and on the possibilities for influencing different factors in the production process. Process factors can be placed in one of two groups on the basis of the extent to which they can be controlled. The first group includes those factors that are specified for the given production process. These factors are either regulated as part of the plan of operation (production volume, product quality, product mix, etc.) or are unregulated during the time period in question (the composition and characteristics of the equipment, the type of technology, etc.). We will designate them as \( x_1, x_2, ..., x_n \). The second group of factors includes those which can be changed by factory personnel within various limits for the given product. Among these factors are the regime and process parameters, the loads on the equipment, the organization of production, etc. (\( z_1, z_2, ..., z_m \)).

In those cases (energy-intensive production process, a shortage of power in the energy supply system, high utility rates) in which the minimum possible consumption of electric power is chosen as the norm of unit electric power consumption, the process of establishing the optimum level of electricity use can be represented as follows. Suppose that it is necessary to find a certain function which links values of the process factors with the unit consumption of electric power:

\[
\omega = f_1(x_1, x_2, ..., x_n, z_1, z_2, ..., z_m). \tag{2}
\]

We assume that the groups of factors \( x_n \) and \( z_m \) have no effect on one another. We also assume that the parameters \( x_n \) are constant and we choose their values to be equal to the plan targets for the calculated period or to the values actually obtained for the given production process. Then to calculate the norm of electric power consumption it is necessary to find the minimum of function (2) with permissible values of the factors \( z_m \). The constraints imposed on the changes in the factors \( z_1, z_2, ..., z_m \) are determined by the capabilities of the production process, the production regimes used, and product quality requirements.

If a multivariate function of the form (2) and the constraints on the parameters \( z_m \) are specified in linear form, then the problem is solved by the methods of linear programming. If the relation for unit electric power consumption is related nonlinearly to process factors, then the search for the optimum solution becomes more complicated and nonlinear programming methods are used. To reduce the problem to linear form, a correspondence must be established between each type of production process and its unit consumption of electric power for a specific type of product. In this case, the energy characteristics are expressed in the form of a matrix

\[
\omega = \begin{bmatrix}
\omega_{11} & \omega_{12} & \ldots & \omega_{1l} \\
\omega_{21} & \omega_{22} & \ldots & \omega_{2l} \\
\omega_{j1} & \omega_{j2} & \ldots & \omega_{ji}
\end{bmatrix}, \tag{3}
\]

where \( \omega_{ji} \) is the unit consumption of electric power for the production of the \( j \)th type of product in the \( i \)th production process. This problem is solved by linear programming methods.

When the chosen norm is the unit electric power consumption that ensures the optimum value not of function (2) but of some other index \( S \) (production volume, product quality, etc.) that links electricity usage with process factors, we find the regression dependence of \( S \) on those factors:

\[
S = f_2(x_1, x_2, ..., x_n, z_1, z_2, ..., z_m). \tag{4}
\]

Determining the optimum of this dependence in terms of the criterion \( S \), we find the values of the controlled variables \( z_1^{(s)}, z_2^{(s)}, ..., z_m^{(s)} \) that ensure this optimum. Then the values obtained for \( z_m^{(s)} \) are inserted into function (2) and calculations are performed to determine the unit electric power consumption that is to be adopted as the norm.

The unit electric power consumption for the production of a certain type of product is determined as the weighted mean power consumption, which is calculated for each shop on the basis of planning indices by using the expression:

\[
\omega = \frac{\sum_{i=1}^{k} \omega_i Q_i}{\sum Q_i}, \quad \text{kW} \cdot \text{h/ton}. \tag{5}
\]