Developmen of recommendations for improving the level of energy consumption process management in mining enterprise

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Abstract. Mining and processing enterprises are among the major electricity consumers, where energy costs account for a significant portion of the production expenses. Consequently, the share of electricity in the cost of production is higher in the mining industry. Therefore, creating models of energy consumption that can serve as a foundation for managing the energy use process becomes a crucial task. Analyzing electricity consumption is essential for assessing the energy demand under different operating conditions of mining enterprises. To effectively study and plan electricity consumption, as well as to develop approaches for its regulation, it is necessary to identify the role of each technological stage within the overall energy balance. This article explores the patterns of electricity consumption in mining and processing industries. Examining these patterns makes it possible to evaluate the effectiveness of energy management at mining and processing plants.

INTRODUCTION

Insufficient management of the energy consumption process is associated with poor use of technical and management factors affecting the consumption of energy resources. The research conducted in this article shows that there is great potential for the use of technical and management factors that determine energy consumption in the process of increasing energy efficiency at mining enterprises. In this regard, it seems appropriate to develop recommendations for assessing the level of use of technical and management factors in the process of energy management. Planning, operational management and reporting of energy consumption are currently based on point calculations that do not take into account the nature of the dependence of energy consumption on production factors (volume, production, type of ore, etc.) [1]. In this regard, it seems appropriate to develop recommendations for increasing the level of planning, operational management and reporting of energy consumption [2]. The energy consumption process, a process that covers all links of the production and technological chain of a mining enterprise, currently does not have tools that form a system for full-scale management of energy consumption. In this regard, it seems appropriate to develop recommendations for creating an energy resource management system for a mining enterprise[3-6].

In order to realize the potential of increasing the energy efficiency of mining enterprises, it is necessary to increase the level of energy management by developing and implementing an energy management system. It is advisable to develop this system based on the recommendations developed in this article. It is advisable to introduce an energy management system using a software-analytical complex which is a network of automated workstations for employees at all levels of the production and management chain participating in the energy consumption proces. The recommendations developed in the article allow to increase the energy efficiency of mining enterprises by increasing the level of management of the energy consumption process.

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Planning, operational management and reporting of energy consumption should be based on the energy-technological characteristics of the main technological units, technological stages and production facilities. These recommendations are based on the results of a study of electricity consumption, but studies conducted outside the scope of this article show that the recommendations can also be applied to other energy resources of mining enterprises. Increasing the level of energy consumption planning It is advisable to increase the level of electricity consumption planning in the following ways:

The transition from planning of electric energy based on point calculations to planning based on regional calculations obtained on the basis of the characteristics and properties of electric energy. reflects changes in energy consumption when the volume of production changes. The transition from planning of energy consumption based on point calculations to regional calculations reflects changes in energy consumption with changes in production volumes. It is advisable to implement this planning method according to regional calculations using the electrotechnological characteristics of the main energy production facilities obtained in the article.

The relationships under consideration were obtained for gold ores. Thus, electrotechnological characteristics - daily electricity consumption to the total daily volume of processed ore (grinding, grinding) and the daily volume of concentrate produced for different types of ores (flotation, dewatering) has the following expression:

For the technological stage of "grinding".

$$W_g = 36935 + 0{,}39338 * Q_m \quad (1)$$

For the "Mill" technological stage

$$\mathrm{W}_{mill} = 1748\mathrm{E}2 + 1{,}752 * Q_m \quad (2)$$

For the technological stage of "flotation".

$$\mathrm{W}_{fl} = 95353 + 0{,}8543 * Q_{fl} \quad (3)$$

For the "dehydration" technological stage

$$\mathrm{W}_{deh} = 41691 + 1{,}361 * Q_{fl} \quad (4)$$

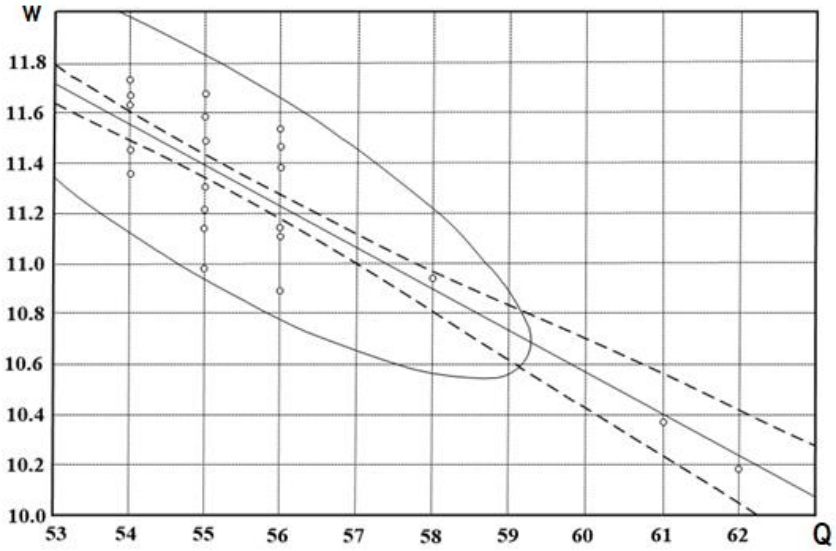

FIGURE 1. Correlation area and enrichment relationship .$\omega = f(Q_{\mathrm{p}})$

For gold ores, the electrotechnological characteristics of the daily specific energy consumption from the daily volume of processed ore (grinding, crushing) and the daily volume of the produced concentrate (flotation, dewatering) have the following expression: [1]

For the technological stage of "grinding".

$$\omega_{\text{g}} = 26{,}321 - 0{,}0020 * Q_m \quad (5)$$

For the "Mill" technological stage

$$\omega_{mill} = 127{,}07 - 0{,}0102 * Q_m \quad (6)$$

For the technological stage of "flotation".

$$\omega_{fl} = 251{,}33 - 0{,}0976 * Q_{fl} \quad (7)$$

For the "dehydration" technological stage

$$\omega_{deh} = 105{,}62 - 0{,}0411 * Q_{fl} \quad (8)$$

The obtained energy-technological descriptions of technological processes in the form of correlation equations have a strong enough correlation between the parameters included in them [1].

It is advisable to use the obtained energy-technological characteristics for planning, operational management and reporting on energy consumption. Modeling of energy consumption of primary energy production of mining and processing enterprises

MODELING OF ENERGY CONSUMPTION OF BENEFICIATION PRODUCTION AT A HYDROMETALLURGICAL PLANT

Increasing the level of energy management, including. To increase the level of planning, operational management and reporting of electricity consumption, it is necessary to establish energy-technological characteristics of the processing plant, which include the dependence of specific electricity consumption on the monthly volume of processed ore - the energy-technological characteristics of the processing plant are carried out on the basis of statistical materials on specific energy consumption and monthly volumes of ore processing[1]:

$$\omega = f(Q). \quad (9)$$

As a result of examining the correlation field of these factors (Figure 1), we can conclude that 2 types of linear relationships are possible between them[10].

Processing statistical data on specific monthly electricity consumption and monthly volume of processed ore using the rules of correlation analysis theory made it possible to obtain the relationship in the form of an expression. $\omega = f(Q_{\text{p}})$

$$\omega_{\text{м}} = 68{,}052 - 0{,}106 * Q_{\text{p}} \quad (10)$$

here: $\omega_{\text{м}}$- monthly specific power consumption of the plant, kW/t;

$Q_{\text{рм}}$- monthly volume of ore processing by the plant, thousand tons [3,4] ;

The resulting energy-technological characteristics of the plant are shown in Figure 1. It is recommended to use this feature to increase the level of control over the electricity consumption process, including. along with increasing the level of planning, operational management and reporting for energy consumption. $\omega = f(Q_{\text{p}})$

Currently, annual and monthly planning of electricity consumption is carried out according to the approved norm of specific electricity consumption, which does not take into account the actual change in electricity consumption when production volumes change during the planning period (monthly) [5-7]. Thus, taking as an example the planning reporting period for a month, the approved rate of ore processing at Hydrometallurgical Plant 1 is shown in Figure 2. Directly planned. $(1 - \omega) = 42{,}42\ kVt * soat/t$

Existing mathematical models of the grinding process are developed based on mass or energy balance equations, which describe the reduction of the particle size of the ground material in terms of grinding time or specific energy consumed. In both cases, the main parameters of the model are the unknown selection and distribution functions, and their determination requires additional experimental studies. Decentralized and multivariable control methods prevail in the research results and practical applications reviewed in process control[8-10].

Since the electrotechnological characteristics of the plant determine that the specific power consumption depends on the volume of ore processed, the area limited by the COB angle is the area of underestimated planned power consumption, and the area limited by the FOD angle is the area of overestimated planned power consumption[11]. So, when the planned volume of ore processing in October was 218.5 thousand tons, the planned specific electricity consumption should have been 48.9 kW/t (point C) compared to the planned 42.4 kW* h. However, this should be the target value

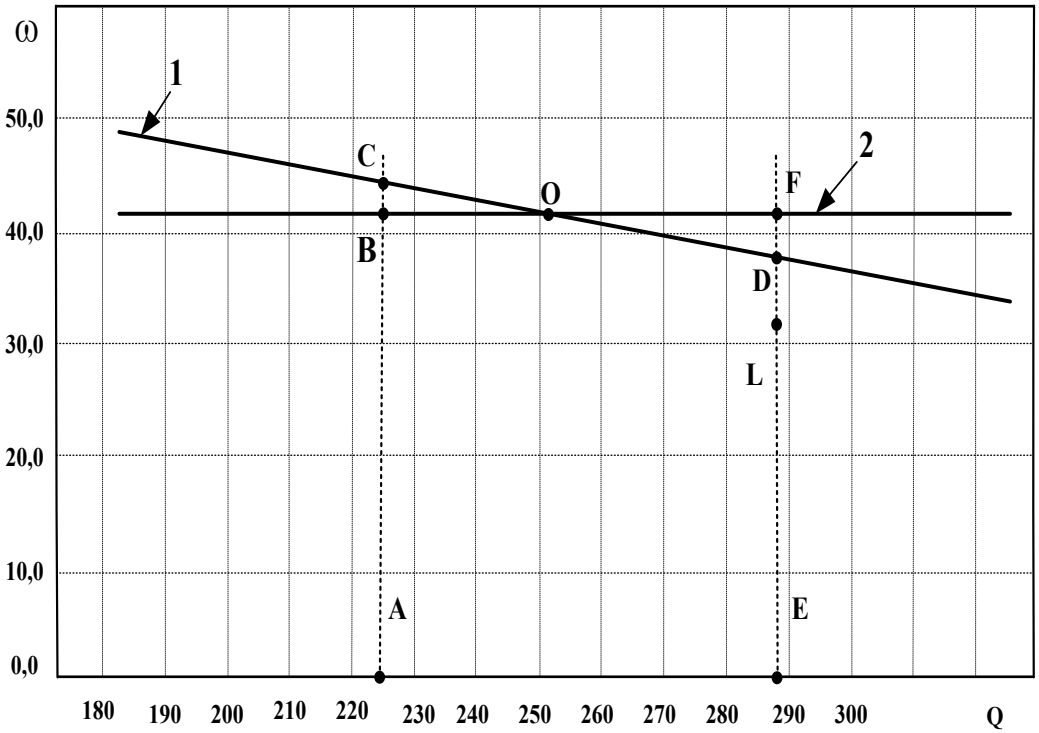

FIGURE 2. Scheme of planning electricity consumption based on "planned" (1) and "regional" (2) calculations

In October, 275.6 thousand tons were adjusted to the actual volume of production. (Point E) and should be 38.8 kW / t (Point D), and not the same planned 42.4 kW / t. The actual specific consumption was 37.9 kW / t (Point L). Thus, it follows from the above that the planning of electricity consumption using point calculations is not adjusted to changes in production volumes and leads to the emergence of planned zones of underestimated (NE segment) and overestimated (BD segment) electricity consumption. The report on electricity consumption is based on values that are not adjusted depending on the actual volume of production.

Mining enterprises are large consumers of electricity. In addition, recently they are characterized by an increase in electricity consumption, which is the main source of energy consumption (up to 70-75 % on average for mining enterprises). This is due to changes in the conditions of extraction and processing of minerals, reduction of useful content in ore, use of energy-intensive mechanisms, introduction of environmental protection measures, etc. The most energy-intensive process in mining enterprises is the beneficiation process, which accounts for 55-63 % to 75-82 % of the enterprise's total electricity consumption. At the same time, a large number of factors affect the consumption of electricity[11].

RECOMMENDATIONS FOR DEVELOPING AN ENERGY RESOURCE MANAGEMENT SYSTEM IN MINING ENTERPRISES

The consumption of energy resources in mining enterprises is a complex process that accompanies almost all technological processes of enterprises. Currently, energy consumption management in mining enterprises is not systematic, which significantly reduces the opportunities for increasing energy efficiency. Among the circumstances confirming the feasibility of developing an energy management system are the following[9]:

1. In many mining enterprises, the growth in energy consumption costs is outpacing the growth in production.
2. Technical energy saving measures do not fully and effectively cover their costs due to the lack of an energy consumption management system.
3. Responsibility for energy consumption and its costs is not clearly distributed among energy resource users,
4. There is no functional-organizational structure covering the entire mining enterprise that implements management policies in the field of energy efficiency improvement.
5. Energy conservation programs represent only the technical part of the necessary efficiency improvement system.

6. In most mining enterprises, an energy policy has not been formulated and has not been adopted as an officially approved document.

7. Low employee motivation in energy efficiency issues.

8. Information systems for accounting for energy resources are local and do not cover all stages of the distribution of energy resources used in the enterprise. They are considered primarily as technical monitoring systems, not as information and management systems.

9. Insufficient level of staff service in the field of energy efficiency policy. There are practically no problems with marketing support for energy efficiency.

10. Insufficient technical and economic development of the proposed solutions on energy saving issues, weak development of investment protection issues and, as a result, ineffective investment policy in the field of energy efficiency [22-51]. At the same time, the research conducted in this dissertation shows that the level of energy resource management at mining enterprises has a significant growth reserve. Based on the above, it seems appropriate to develop recommendations for creating an energy resource management system for mining enterprises. in this regard, the main conceptual provisions of the energy resource management system should be.

1. The purpose of the energy resources management system should be to ensure the effective operation and strong interest of the management and production structures of the mining enterprise in implementing optimal energy-saving consumption.

2. Along with the technical components of energy supply, energy consumption and energy saving, the basis of consumption management should be: organizational, motivational, information, marketing, financial and investment components of the management process[12-14].

3. The energy resources management system aimed at comprehensively increasing the energy efficiency of production should operate on the basis of the implementation of the energy policy of the mining enterprise.

4. In the system under consideration, systematic management of energy resources should mean the following: - management of energy resources is carried out at all levels of the production and management process: from the lowest (employee, team, shift) to the highest (production teams, management).; Management is distributed over all types of primary energy resources (electricity, gas, solid and liquid fuels) and resources obtained as a result of the use of primary energy resources (thermal energy, cold, hot water, compressed air, air for heating, ventilation, air cooling); - management of energy resources in structural divisions of a mining enterprise is carried out as a subsystem included in the general system of the enterprise[15-17]

It is advisable to implement an energy management system using software and an analytical complex, which is a network of automated workstations for employees of all levels. production and management chain involved in the energy consumption process. The software-analytical complex serves to collect, summarize and process information about the energy consumption process in order to ensure its effective use in order to increase energy efficiency. The objectives of the software-analytical complex of the energy management system are.:

1) to meet the information and analytical needs of all participants in the energy management process at the enterprise in a single system;

2) discretization of information flows about the energy consumption process at the organizational and technological levels of enterprise management;

3) energy integration; production and economic indicators in a unified energy resources management system;

4) real-time display of production indicators analyzed in the software-analytical complex;

5) combining energy consumption regimes with technological regimes and budget indicators;

6) ensuring a unified communication of all participants in the process of managing the consumption of energy resources of the plant [18-21]. The proposed recommendations serve as the basis for creating an energy resources management system for mining enterprises.

CONCLUSIONS

Currently, the improvement of energy efficiency of mining enterprises is limited by the insufficient level of management of the energy consumption process. The insufficient level of management of the energy consumption process is associated with the improper use of technical and management factors affecting energy consumption. The energy consumption process, a process that covers all links of the production and technological chain of a mining enterprise, currently does not have system-forming tools for full-scale management of energy consumption. It is advisable to assess the level of use of these factors based on the analysis of the organizational and technical profile of a mining enterprise, which represents the levels of achievement of the use of factors in managing the energy

consumption process. To create these profiles, it is necessary to use the qualitative scales developed in the article to assess the influence of factors on the energy resources management process and the algorithm for building organizational and technical profiles. Improving the energy efficiency of mining enterprises should be carried out on the basis of better adaptation of energy consumption planning to the actual process of energy consumption, taking into account its temporal, production, organizational and other features. Increasing the level of energy consumption planning should be achieved in the following ways:

1. Transition from planning energy consumption according to point calculations to planning according to regional calculations, which are obtained on the basis of the characteristics of electricity and reflect changes in energy consumption with changes in production volumes.

2. The stratification of planned energy consumption by production into energy consumption by technological stages allows, on the one hand, to plan the technological structure of energy consumption, and on the other hand, to assign responsibility for energy consumption to the personnel performing these technological processes.

3. When planning energy consumption, taking into account the energy intensity of processing various types of ores based on the relevant electrical and technological characteristics.

Ensuring energy efficiency of mining enterprises should be based on increasing the level of operational management of energy consumption. Increasing the level of operational management of energy consumption should be ensured through management actions based on assessing the deviations of actual energy consumption from the planned one using the electro-technological characteristics taken into account in the industry. These deviations should be formed as follows:

a) for technological units - based on the actual hourly specific energy consumption and planned hourly consumption determined in accordance with the relevant electrical and technological characteristics of the units;

b) for technological stages - based on the actual daily specific consumption of electricity and the planned daily consumption; determined in accordance with the relevant electrotechnological characteristics of technological processes;

c) by production - based on the actual monthly specific consumption of electricity and the planned monthly specific consumption of electricity determined in accordance with the electrical technological characteristics of production.

The management actions formulated in the above manner allow to increase the level of operational management of electricity consumption at the temporal (hour, day, month) and organizational-production scale (technological unit, technological process, production). Increasing the level of reporting on energy consumption should, on the one hand, ensure increased accuracy, reliability and timeliness by adapting energy consumption planning to its actual regimes.

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