UDC 622:658

A. V. LYAKHOMSKII[1], *Professor, Doctor of Engineering Sciences, mggu.eegp@mail.ru*
A. B. PETROCHENKOV[1], *Professor, Doctor of Engineering Sciences*
S. V. PETUKHOV[2], *Deputy Head of Department, Candidate of Engineering Sciences*
E. N. PERFILEVA[1], *Associate Professor, Candidate of Engineering Sciences*

[1] *National University of Science and Technology–NUST MISIS, Moscow, Russia*
[2] *JSC SUEK, Moscow, Russia*

CONSULTING ON ENERGY MANAGEMENT SYSTEMS IN MINING INDUSTRY

The experience gained in energy use and energy saving management is described. The relevancy of the energy efficiency consulting and control in the framework of the energy management systems, with integration of engineering and administration components of the energy use process with association of personnel on the basis of a unified production-and-organization platform. The conception and the functions of the consulting services on the energy management systems in industry are discussed. As a case-study of SUEK's coal mines in the Krasnoyarsk Krai and in the Republic of Khakassia, the application of the programming and analysis system within the consulting services on the energy resource management integrated in the existing intelligence systems of energy control in mines is demonstrated.

Keywords: *mining industry energy efficiency, functions and implementation of consulting, energy management*
DOI: *10.17580/em.2022.02.07*

Introduction

Expenses connected with energy resources are appreciable in the overall production cost in the mining industry. In this regard, it is of the current concern to enhance efficiency of utilization of energy resources in mining activities.

Stimulation of energy efficiency in coal mining is included in the Integrated Economic Growth Plan approved by the Government of the Russian Federation on 19 April 2018.

The Russian Energy Agency estimates that energy efficiency grows sluggishly, which throws back the improvement rates set by the governmental programs and hampers profitability increase.

Improving energy efficiency by an innovation-based scenario requires better control over energy resources using energy management methods and means.

An energy management system (EnMS) is a package of interconnected and interrelated elements of control over energy resources toward higher efficiency of their use, including such aspects as technology, organization, motivation, information, marketing and investment.

According to international agencies such as ENERDATA, UNIDO, Statistics and ODYSSEE, the energy efficiency increase potential with EnMS introduced ranges from 10 to 35% in various sectors of industry abroad.

The State Report on Energy Saving and Energy Efficiency Growth in the Russian Federation [1], the power intensity of GDP in Russia dropped by 12% in 2018 as against 2007. This figure is much lower than the target set by the President of the Russian Federation in Decree No. 889: Measures to Improve Ecological and Energy Efficiency of the Russian Economy as of 4 June 2008.

Experts expect the possible increase in energy efficiency as a result of full-fledged introduction and functional maintenance of EnMS in the Russian industry may reach 8–12%.

At the same time, energy efficiency management in all industries, including the mineral sector, faces considerable limitations.

Evaluation of the coal mining industry performance and its compliance with the energy efficiency standards set by the international standard ISO 50001-2018 and the Russian State Standard GOST R 50001-2012 (both entitled as: Energy Management Systems—Requirements with Guidance for Use) [2–4], shows that only 16.7% of coal mines, which produce 69.8% of coal in Russia, use EnMS.

In the meantime, 83.3% of these coal mines are unable to implement the modern-level monitoring of energy efficiency in production as they lack information systems capable to provide personnel, on a timely basis, with the power engineering data required for the energy efficiency management. Consequently, it is impossible to implement the energy efficiency-targeted approach Plan, Do, Check and Act (PDCA).

The full-fledged backing of EnMS has an inter-disciplinary and inter-industrial nature, which adds a process-specific work content to the production activities and needs experts competent in the energy management and energy efficiency control.

Based on the aforesaid, the system-based energy efficiency control toward improvement of energy effectiveness in industry requires supporting EnMS with consulting services.

The literature review [5–20] and the operational background show that the described situation of energy resource management and energy efficiency improvement is the same in coal mining and in the other sectors of mineral extraction-and-processing industry.

1. Conception and functions of EnMS consulting.

EnMS consulting services aimed at all-enveloping support of activities connected with saving of cost of energy resources through the increase in energy efficiency should ensure:

- regulatory and broadly instrumental supervision of energy use control to pursue energy effectiveness improvement;
- maintenance of the energy improvement culture in the industry, using the energy efficiency criteria set in terms of factors which have influence on energy consumption, namely, geology, climate, production technology, management, etc.;
- feasibility of integrating control over energy resources in the current activities of a mining company based on the PDCA process approach;
- compliance of specific activities of a mining company to the standards of continuous energy effectiveness improvement, including complexity of production processes, system concept of control of energy resources with regard to the man–machine nature of the energy use process, monitoring of power use indices, paperwork management and available assets.

In line with this conception, the scope of functions of EnMS consulting should embrace:

- application of the technology, organization, motivation, information, marketing and investment aspects in management of energy resources;

• development, revision and amendment of normative and technical documentation as a regulatory framework for EnMS;

• development and updating of instrumental supervision of PDCA process approach to management of energy resources using the unified digital technology and organization platform uniting personnel engaged in administration of energy-consuming facilities (ECF) and personnel responsible for energy-consuming operations and processes;

• real-time analytical description of the energy use process as dependences of the total and specific energy consumptions on the accomplished work quantity with intent to manage energy effectiveness;

• information support of personnel by shift-time data on the assigned and actual power indices, and on the actual specific energy consumption deviation from the preset reference with a view to managerial decision making and implementing to increase energy efficiency of performance;

• targeted motivation of personnel (from operators of excavators and heavy-duty dump trucks, overmen and mechanics to production supervisors and mine managers) to pursue energy efficiency improvement based on continuous information on actual power use effectiveness.

2. EnMS consulting services in the mining industry.

In accordance with the above conception and functions, SUEK's coal mines in the Krasnoyarsk Krai and in the Republic of Khakassia have introduced consulting services to support functioning of developed EnMS.

The scope of the consulting services encompasses the interdisciplinary (in terms of the contents: technology, power engineering, energy management, control, economy) and interindustrial (in terms of the implementation: excavation, loading, transportation, processing, heat generation, etc.) topics of EnMS.

The consulting allows management of energy resources with regard to the technology, organization, motivation, information, marketing and investment aspects.

Figure 1 presents the organization and functioning chart of energy use control.

The key component of the chart is the cross-functional management group (CFMG) composed of Deputy CEOs, managers of primary energy-consuming facilities, and head officers and chief specialists of administration departments and services responsible for EnMS functioning. The mission of CFMG includes: proposal and discussion of the internal energy efficiency auditing; expansion of organization, motivation, information and investment aspects of EnMS; policy and methods of improvement of energy use efficiency in production processes; technological innovations capable to enhance energy efficiency; coordination of activities of departments in achieving targeted energy efficiency.

Consulting includes advice, information analysis and supervision of energy use control in accordance with the chart in Fig. 1.

Stimulation consulting involves advice, training, information support and other-type backing in motivation of personnel in conformity with the chart in **Fig. 2**. Based on the content of work per shift at an *i*-th ECF, the personnel of a *j*-th shift (block 1) at this energy-consuming facility is assigned a certain specific energy consumption (block 4). Using the data on the actual amount of work (block 2) and the actual energy consumption (block 4), the actual shift energy consumption EC is determined (block 5). The difference between the assigned and actual shift EC is assessed (block 6). The overall (average) EC per month is found (block 7). Then, the financial power-and-technology effectiveness of ECF personnel at the increased, scheduled and decreased EC is evaluated (blocks 8, 9 and 10, respectively). Based on the financial power-and-technology effectiveness, stimulation of ECF personnel is carried out in accordance with the Regulations for

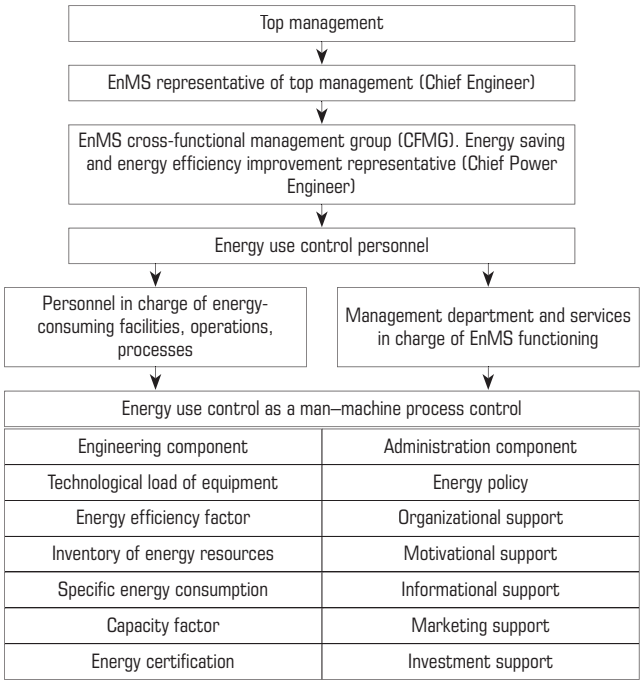

Fig. 1. Organization and functioning chart of energy use control

Motivation (blocks 11, 12 and 13). 2, 13). This procedure enables targeted motivation of personnel with reasoning from the actual energy effectiveness of the work done.

The consulting services also include information support with the help of the energy resources management programming and analysis system (EMPAS). **Figure 3** describes implementation of EMPAS as an information and commutation system integrated in the existing intelligence system of a mine, which unites all energy users into an organization-and-technology pool to actualize energy management toward improved energy efficiency.

The EMPAS enables:

• power effectiveness monitoring by means of accumulation, systematization, conversion and real-time dissemination of data on energy intensity of works on hand between the energy users (in terms of the work contents, energy resource inputs, assigned and actual specific energy consumptions, as well as their differences);

• modeling power profiles of energy-consuming facilities (statistical dependences of different-type energy consumptions on the amount of work fulfilled);

• routine shift-by-shift assignment of energy consumption for each ECF crew, and routine shift-by-shift reporting of each crew on actual energy consumption during fulfillment of works;

• description and analysis of information (with computer-aided visualization) on the effectiveness of work done in the form of graphs of the performed work content, energy resource inputs and specific energy consumptions, as well as in the form of a table on the power effectiveness per days of a month, on a certain date of a month, and during the whole month;

• analysis of fulfillment of shift-by-shift assignments on specific energy consumption per each ECF, based on which personnel makes decisions on operational energy use control in order to maintain and enhance energy efficiency;

• targeted motivation of personnel to ensure and increase energy efficiency with regard to actual power effectiveness.

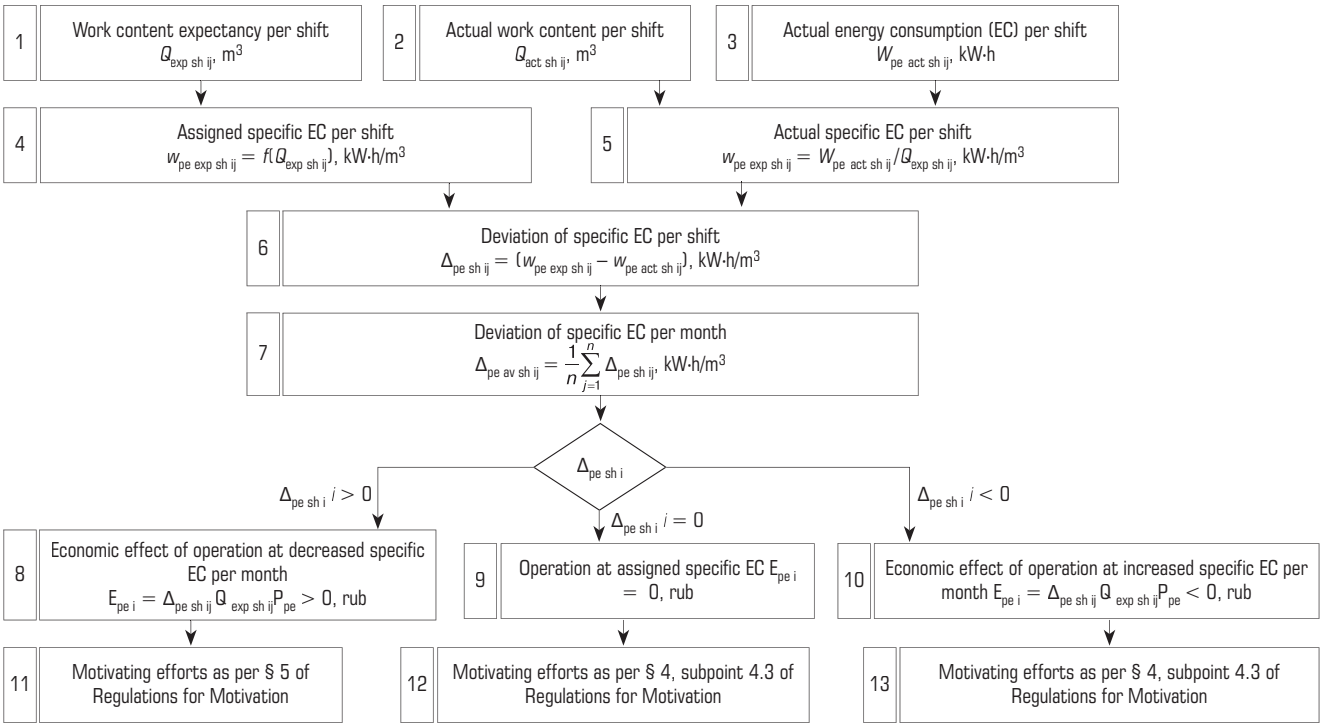

Fig. 2. Chart of targeted motivation of personnel to ensure and improve efficiency of energy use (in terms of extraction-and-loading)

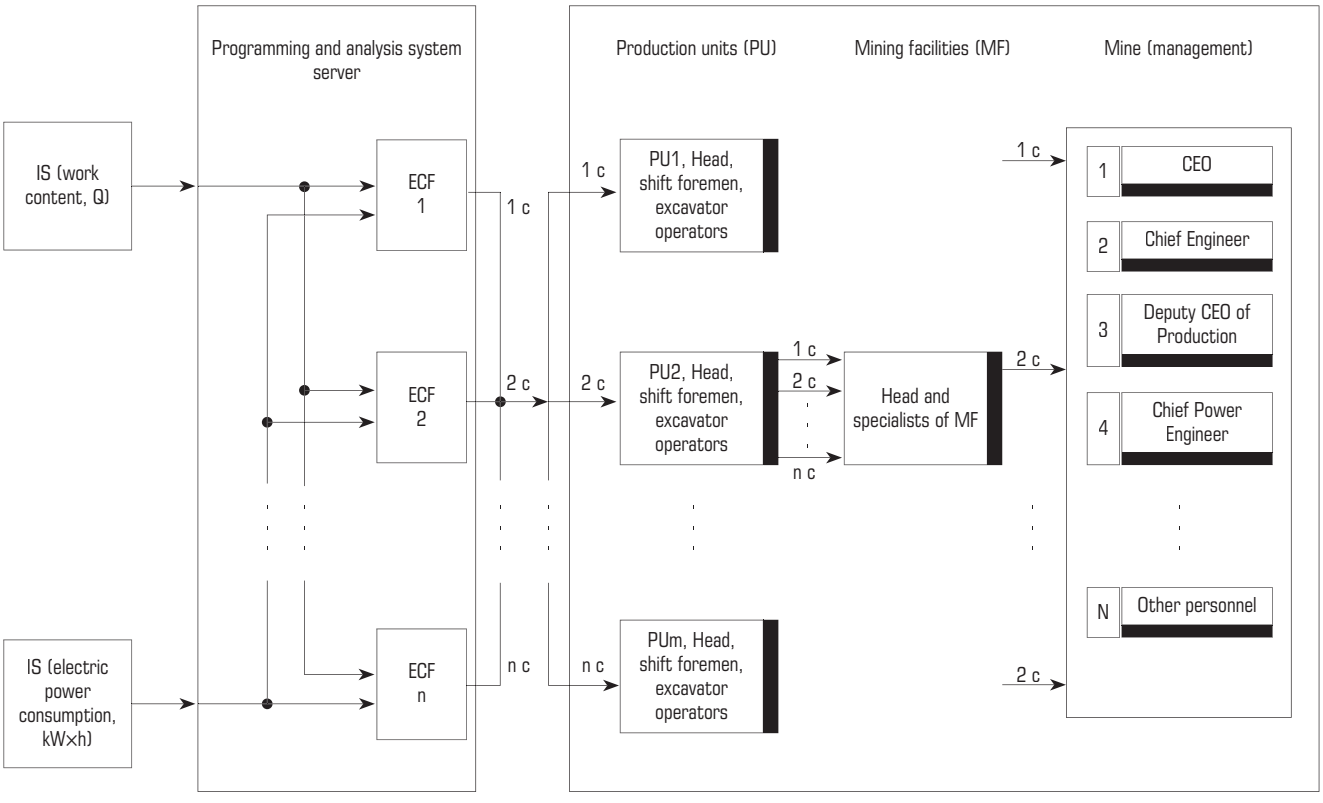

Fig. 3. Basic diagram of programming and analysis system for management of energy resources (in terms of mining facilities)

The marketing consulting intends to produce, evolve and deliver organizational, motivational and informational support to personnel in the field of EnMS, to offer personnel development and re-education by the Energy Control–Energy Management Program, as well as to ensure advanced vocational training of personnel at the Production Energy Efficiency Improvement Workshops.

Conclusions

1. Improvement of energy efficiency in the mining industry follows an inertia scenario and lags behind the preset rates. Stimulation of energy efficiency improvement requires an innovation-based scenario, through the development, introduction and maintenance of energy management systems in conformity with the international standard ISO 50001-2018 and the Russian State Standard GOST R 50001-2012 Energy Management Systems—Requirements with Guidance for Use.

2. The topics of EnMS are interdisciplinary in terms of their contents and interindustrial in terms of implementation, which requires that skilled and competent personnel maintain the EnMS functioning.

3. Functioning of EnMS, alongside with the labor intensity of the production and management activities, conditions an additional labor input, which requires attraction of specialized agencies engaged in the energy management consulting.

4. It is advisable to maintain functioning of EnMS with regard to the conception and consulting functions formulated in this article.

5. SUEK's mines in the Krasnoyarsk Krai and in the Republic of Khakassia develop and operate EnMS with the backing provided by the consulting services sufficiently described in this article. The annual cost of the consulting services totals not higher than 0.2–0.5% of the annual expenses connected with the energy resources in the industry.

References

1. Energy Saving and Energy Efficiency Growth in the Russian Federation: State Report. Moscow : Ministerstvo ekonomicheskogo razvitia RF, 2019. 114 p.
2. Guidance on Energy Efficiency Improvement and Management in Coal Mining Industry. Approved by the Ministry of Energy of Russia, Order No. 853. Moscow, 2019.
3. ISO 50001:2018(R). Systemes demanagement de l'energie—Exigences et recommandations de mise enoeuvre. Introduces: 2018-08-01. Switzerland, 2018.
4. GOST 50001-2012. Energy management systems – Requirements with guidance for use. Moscow : Standartinform, 2013.
5. Best Available Technologies : Reference Book 48-2017. Energy Efficiency Improvement During Economic and/or Other Activities. Moscow, 2017.
6. GOST 56828.24-2017. Best available techniques. Energy saving. Guidance on the application of the best available techniques for increasing the energy efficiency energy saving. Moscow : Standartinform, 2019.
7. Available at: https://normativ.kontur.ru/document?moduleId=1&documentId=394824 (accessed: 02.12.2021).
8. Available at: https://old.economy.gov.ru/minec/about/structure/depGostarif/doc20100115_02 (accessed: 02.12.2021).
9. Coal Industry Development Program of Russia up to 2035. Moscow, 2020. Available at: https://www.rosugol.ru/programme/%D0%9F%D0%A0%D0%A3%D0%9F-2035.pdf (accessed: 02.12.2021).
10. Available at: http://www.kremlin.ru/acts/bank/33591 (accessed: 02.12.2021).
11. GOST 31607-2012. Energy conservation. Norm-method securing. Basic concept. Moscow : Standartinform, 2019.
12. Karpenko S. M., Dyomin A. A. On the question of energy management's effectiveness increasing at industrial enterprises. *Energy Safety and Energy Economy*. 2014. No. 4. pp. 10–15.
13. Petrochenkov A. B., Romodin A. V., Luzyanin I. S. et al. Developing of the decision support system for intelligent control of oil producing installations on the oil and gas fields. *Information-Measuring and Control Systems.* 2018. No. 9. pp. 59–67.
14. Olunina L. A., Larin A. N., Larina I. V. Modern tools energy efficiency. *Innovatsionnaya ekonomika i obschestvo*. 2015. No. 2(8). pp. 86–92.
15. Logacheva D. A. Improving energy efficiency of industrial enterprises. *Ekonomika i predprinimatelstvo.* 2013. No. 6(35). pp. 388–391.
16. Brahmana R. K., Ono H. Energy efficiency and company performance in Japanese listed companies. *International Journal of Energy Technology and Policy*. 2020. Vol. 16, No. 1. pp. 24–40.
17. Amado L. F., Marto H. J., Tavares P. F. Energy efficiency measures for an electrical material industry. *International Journal of Energy Production and Management*. 2019. Vol. 4, Iss. 3. pp. 217–229.
18. Wakabayashi M., Arimura T. H. The role of staff assignment in implementing energy-conserving practices in small- and medium-sized firms: an empirical analysis based on data from a Japanese survey. *Energy Efficiency*. 2020. No. 13(8). pp. 1763–1780.
19. Arriola-Medellín A. M., López-Cisneros L. F., Aragón-Aguilar A. et al. Energy efficiency to increase production and quality of products in industrial processes: case study oil and gas processing center. *Energy Efficiency*. 2019. No. 12(6). pp. 1619–1634.
20. Mahapatra K., Alm R., Hallgren R. et al. A behavioral change-based approach to energy efficiency in a manufacturing plant. *Energy Efficiency*. 2018. Vol. 11, No. 2. pp. 1103–1116. EM