Applying the potentiating procedure for optimal management of power consumption of technocenose

V I Gnatyuk, S A. Polevoy, O R Kivchun and D V Lutsenko

1 Kaliningrad State Technical University, 1, Sovetsky Prospekt, Kaliningrad, 236022, Russia
2 Financial University under the Government of the Russian Federation, 15, Verkhnyaya Maslovka Verkhnyaya, Moscow, 127083, Russia
3 Immanuel Kant Baltic Federal University, 14, A. Nevskogo street, Kaliningrad, 236016, Russia
4 Kaliningrad Innovation Center «Technocenose», 8, Zemelnaya street, Kaliningrad, 236029, Russia

E-mail: okivchun@gmail.com

Abstract. The concept of energy saving potential is introduced and justified in the article. A technique for assessing the energy saving potential of technocenoses is presented. The basis of this technique is the following stages: analysis of information on power consumption, rationing and analysis of power consumption. As an experimental verification of the methodology, the results of determining energy saving potentials for the regional electrical complex of Gasprom extraction Urengoi are presented.

1. Introduction

The development of digital technologies in the end of 20th century contributed to the technical progress rising to the new level. Due to that, industry and economics are developing, new scientific theories and technologies are being elaborated, innovative means of communication are upgrading, medicine is improving, new branches are appearing.

Furthermore, the development of digital technologies has improved dramatically the efficiency of resource management in big technical systems – technocenose. Technocenose is a limited in space and time interconnected complex consisted of further indivisible technical items united by weak connections (region, city, municipality, organization, enterprise, company, trading network etc.).

However, comprehensive analysis [1-7] has showed that use of digital technologies alone does not solve the whole spectra of problems of resource management in technocenose. Taking this into the account, one of the solutions of these problems is the development of scientifically proved methodology of management of electrical energy consumption in technocenose based on the potential of electrical energy saving.

Therefore, the aim of the research in this area is the development of methodological basics of resource management in technocenose based on the potential of electrical energy saving. The object of the research is considered the system of resource management in technocenose; the subject is the methodology of optimal management of electrical energy consumption in technocenose.
2. Materials and methods
The aim of the work is to analyze the potentiation procedure for optimal control of the energy consumption of the technocenosis. The objectives of the study are as follows:

- Analysis of technocenosis approach to determining the potential for energy conservation;
- Studying the algorithm for the implementation of potentiation procedures;
- Determine the energy saving potential for the regional electrical complex of Gazprom extraction Urengoy.

The study is based on the use of scientific methods and information sources, which allowed the authors to formulate recommendations and suggestions in the field of industrial complex development.

3. Results
The methodology of optimal power management of technocenoses consists of the following calculation blocks: data preparation, identification of objects that abnormally consume electricity, forecasting and rationing [2-3]. To improve the quality of managing the process of power consumption of technocenosis objects, the “potentiation” procedure has been developed and is proposed as an addition to the above method.

Potentiation is a procedure that calculates the required integral value of power consumption, the value of which can reduce the power consumption of all objects [2]. The determining concept for potentiation is the energy-saving potential, which is the absolute difference between the values of power consumption and the lower boundary of the variable confidence interval (figure 1) [2].

Figure 1. Rank curves for calculating energy conservation potential.

The mathematical calculation of the power consumption potential includes the calculation of the integral from zero to infinity under the rank curve, which can be obtained from empirical values of power consumption or correspond to the lower boundary of the variable confidence interval.

A great deal of projects and scientific works of foreign scientists and businessmen are devoted to the problems of calculation of the potential for energy savings. A group of foreign specialists in the
field of increase of effectiveness of consumption of natural resources (Weizsecker E.U., Bloch-Levins A., Mountain R., Hunter-Lovins L.) introduced into everyday life so called «Factor four» that implied to live twice as good and spend half as much resources at the same time. Actually, this is a new approach to calculate the potential for energy savings putting at the top the increase of efficiency of resources by means of constructive and organizational actions. Nowadays this particular method is used in the countries below: USA, Germany, Great Britain, Netherlands, Austria, Denmark, Finland [1; 8-11].

The invaluable contribution in the development of the theory of calculation of the potential for energy savings was made by scientists in huge Research Centers in Europe and USA. As a part of the famous National laboratory of the ministry of energy of USA (Lawrence Berkeley National Laboratory – LBNL) Arthur Rosenfeld arranged a department devoted to energy savings in constructions which became one of trend-setter in this field. That was LBNL that worked in close rapport with European specialists and developed the technology of industrial production of magnetron application of heat-reflective coatings on large-sized flat glasses that became a significant breakthrough in the window field [1; 8-11; 13-15].

Scientific papers of F. Haiek, M. Fridman, R. Lukas offer approaches to calculate the potential for energy savings on the basis of company-internal management of expenses of production, technological and economical efficiency due to the introduction of progressive energy technologies.

The representatives of Keynesian and Neo-Keynesian economics (D. Mid, D. Tobin, R. Solow, N. Kaldor, J.M. Keynes) believe that the state is able to undertake functions of invention of the conception of calculation of the potential for energy savings for all participants of economical activity.

In Russia current approaches to calculate the potential for energy savings can be divided into two large groups according to the kind of approach: classical or technocenose one.

The classical approaches (scientific works of N.I. Danilov, Ya.M. Shelokov, V.V. Dobrodei, O.L. Danilov, A.B. Garyaev, I.V. Yakovlek, A.N. Dmitriev, V.V. Litvak, V.S. Stepanov and others), that are based on the Gaussian mathematical statistics, suggest normal distribution of parameters of a real object and conversion of its power consumption on the basis of some model analogue in the model and basic technological process. The calculation of the potential for energy savings of objects, that have the same structure but work in different conditions, lead to different assessments so it is necessary to take into account specific feature of each one. Received assessments of the potential for energy savings for a complex of objects are individual and their sum doesn’t let objectively estimate this amount for a company overall.

The technocenose methods (scientific works of B.I. Kudrin, V.I. Gnatuk, V.V. Fufaev, O.E. Lagunkin, M.G. Oshurkov, B.V. Jilin, A.E. Severin, S.N. Grinkevich and others) are based on the technocenose approaches, the digital mathematical statistics and the theory of hyperbolic endlessly divisible N-assignments. It is assumed that the complex of objects of a concerned enterprise forms a system of particular kind called technosenosis that appears to be limited in time and space integrated complex of functionally completed technic products that are poorly connected. The connections in a technocenose are specific depending on the technological self-sufficiency and diversity of solving tasks [8-11].

The main feature of the technocenological approach to determining the energy saving potential is represented by the calculation method. It is calculated as the sum of the separately taken differences of the actual power consumption and the values based on the optimal indicators of energy conservation.

The energy saving potential, which is calculated for the objects of the technosenosis, is designated - “Z-potential” - by the first letter of the scientist’s name Zipf [2] and is calculated as:

$$\Delta W_1 = \int_{0}^{\infty} W(r)dr - \int_{0}^{\infty} W_1(r)dr,$$

Whereas \(W_1\) - is technocenose electricity saving potential;
W(r) - is approximation curve obtained for empirical values of facilities' electricity consumption (r – rank);

W₁(r) - is the limit of variable confidence interval obtained based on database processing [6; 10; 11].

Based on the analysis of the multiple implementation of standard procedures for the optimal power management methodology to improve the quality of the power management process, refinement procedures have been developed (figure 2) [3]. Figure 2 shows the structural diagram of the correspondence of standard and subtle rank analysis procedures.

![Figure 2. Conformity of the procedures for evaluating the energy saving potential.](image)

The study of the energy saving potential has allowed us to develop a refinement procedure - ZP analysis. This analysis is carried out at the stage of potentiation of power consumption to draw up an energy saving plan (ZP-plan). Its basis is a methodology for assessing potential, which includes two levels [2] (figure 3).

On the first, the potential Z₁ is calculated, and on the second, the potential Z₂. The first potential is the lower limit of the variable confidence interval, built on the actual values of power consumption. The second potential is the boundary of the variable confidence interval obtained as a result of normalization of power consumption (ZP-normalization) [2].
Figure 3. Potential based power analysis block diagram.

At the last stage of the ZP analysis - the preparation of the ZP plan, two stages are implemented. First, the power consumption values of technocenosis objects should be reduced to the level of the Z1 potential, and then to the level of the Z2 potential. Moreover, the reduction is carried out individually for each object [2].
The input data for the ZP-module is generated from the database on power consumption and may include information on the organizational and staff structure, geo-information, information about leading parameters, power consumption values, etc.

The first stage of the ZP-module is the implementation of the potentiation procedure, in the framework of which the initial data on power consumption are imported, the construction of rank distributions and obtaining the Z1-potential.

At the second stage, the effectiveness of the process of managing the power consumption of the technocenosis is assessed based on a criterion that shows the ratio of integrated quality and cost indicators [2].

In the third stage, ZP analysis is implemented. Moreover, ZP-rationing is carried out first, and then ZP-planning. It is important to note that ZP-rationing has the goal of determining the Z2-potential and is a preparation stage for ZP-planning. ZP-rationing operations are based on the study of the organizational system of technocenosis. The result of which are formed technology groups. For each group, a leading parameter is determined. According to which the specific power consumption is calculated [2].

At the final stage of the ZP analysis, which is also the output of the ZP module, ZP planning is carried out. Important information for ZP planning are the obtained values of Z1 and Z2 potentials. As a result, on the basis of the chosen strategy, the volume of reduction in energy consumption is calculated. Next, the calculation of the difflex parameters is carried out, according to which the weight coefficients of the norms for reducing power consumption are determined. The above operations make it possible to calculate the amount of the energy conservation fund, which can be used to reward staff or be used to modernize the technocenosis electrical equipment [2].

Thus, the obtained ZP-plan is the result of the potentiation procedure and includes individual norms for reducing energy consumption and the amount of bonus staff.

4. Discussion
Quantitative estimate of authenticity of results of the offered methodology was realized on the data of energy consumptions of the local electro technical complex Gasprom extraction Urengoi and it included an examination of adequacy of the methodology of the ZP-analysis [2; 12].

The examination of adequacy is based on the analysis of statistic hypothesizes that prove legitimacy of use of chosen probability laws. Assessments of working efficiency are based on the comparative analysis of quality in the long run of 5 years of 2 options of the ZP-plan (table 1) with the use of the system of indexes below.

| Table 1. Indicators of the first and second potentials. |
|---------------------------------|-----------------|-----------------|
| Index | A strategy to reach the level of Z1-potential | A strategy to reach the level of Z2-potential |
| Δ, % | 99.97 | 99.95 |
| $\bar{S}$, % | 0.28 | 0.21 |
| $S_{max}$, % | 5.92 | 6.41 |
| $n_{ZP}$, % | 85.95 | 90.08 |

The proportion of the realized Z-potential for energy savings is $\Delta$, average $\bar{S}$ and maximum $S_{max}$.

The accounts of statistic criteria haven’t exceeded critical ones during the examination of adequacy. The amounts of quality indexes of both variations of the ZP-plan conform to each other and that complies with the concept of the methodology of the ZP-analysis and determines by gist and specific features of the Z1-
and Z2-potentials. The received results let make a conclusion that the developed methodology is adequate and its use is explained for the control for energy consumption of a large industrial enterprise.

The economical assessment of the results of the methodology involves quantitative comparison between expenses and the amount of incoming profit. This comparison is made due to the pay-off period of enterprises on the objects of the local electro technical complex Gazprom extraction Urengoi with consideration to discounting of receiving incomes, the amount of the index of profitableness of investments and other indexes (tables 2, 3). Direct repayment of investments in energy savings was expected to be according to calculations [2; 12].

Table 2. Indicators of the first and second potentials.

| Index                                           | Steps of the ZP-plan |
|-------------------------------------------------|----------------------|
| Energy saving Fund, millions of rubles           | 0 1 2 3 4 5          |
| Discounted income, millions of rubles            | -4.15 2.68 2.19 1.8 0.91 0.08 |
| Net profit, millions of rubles                   | -4.15 -1.44 0.76 2.54 3.45 3.59 |
| Amount of income in Energy Saving Trust          | 0 0.47 0.46 0.44 0.42 0.41 |
| Profit after energy saving                       | 0 6.9 6.82 7.0 4.5 0.41 |

Table 3. Indicators for obtaining the second potential.

| Index                                           | Steps of the ZP-plan |
|-------------------------------------------------|----------------------|
| Energy saving Fund, millions of rubles           | 0 1 2 3 4 5          |
| Discounted income, millions of rubles            | -34.39 29.15 23.01 17.47 12.13 5.93 |
| Net profit, millions of rubles                   | -34.39 -5.24 17.78 35.24 47.37 53.8 |
| Amount of income in Energy Saving Trust          | 0 0.7 0.65 0.58 0.47 0.3 |

Analysis of tables 1-3 showed that when investing funds in 4.15 million rubles. upon receipt of the first potential and 34.39 million rubles. - for the second, the benefit will amount to 3.59 and 53.8 million rubles. In addition, these results show that the second potential obtained has the best indicators, as it allows for the modernization of the electrical equipment of objects, and also makes it possible to rationally use the profit over the entire planning interval. At about the second step of the plan, obtained with the help of the second potential, the first investments will be paid off and new income will appear. The conducted experiment confirms the economic feasibility of applying the energy saving potential for optimal management of the regional electrical engineering complex Gazprom dobycha Urengoy [2; 12].

5. Conclusion
Thus, in order to improve the quality of optimal power management of technocenoses, a potentiation procedure was developed and implemented. Its subtle addition is the ZP analysis, which is based on the methodology for assessing the energy saving potential. The main result of the ZP analysis is the individual norms for reducing power consumption for technocenosidad facilities and the amount of bonus payments to personnel.
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