Management of Energy Supply of Production as a Factor of Sustainable Development of Machine-building Enterprises

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Keywords: Organization, Management, Power Supply, Energy Efficiency Improving, Information System, System Analysis.

Abstract: Complex analysis of organization of energy efficient machinery production was carried out, trends of efficiency improvement of power resources utilization and production costs reduction were defined. It is shown that increasing the efficiency of machine-building enterprises depends on many factors: market conditions, the tax system, tariffs and prices for energy resources, transport services, etc. A serious problem is a significant increase in the energy component in the cost of production. The energy efficiency of machine-building enterprises is inextricably linked with production technologies, which in a certain way affects the cost of production. Cost reduction can be achieved not only by solving optimization problems, but also by solving problems related to the energy intensity of production. Such problems include: high energy consumption of products; insufficient efficiency of generation, transportation and distribution of energy resources; low reliability of energy supply; insufficient volume or low reliability of information about the operation of the energy infrastructure. The high energy consumption of products is a serious problem that affects the increase in the cost of production and, consequently, the decrease in the competitiveness of the enterprise. The sustainable development of a machine-building enterprise is possible by increasing its competitiveness. The economic effect is determined by a set of actions that ensure the efficiency of production in all ke indicators, which ensures the sustainability of the company's development.

1 INTRODUCTION

Machine-building enterprises are complex production systems producing highly engineered manufactured articles of different purpose. Specialization of machine-building enterprises is defined by industry classification of product consumers used in aircraft industry, machine tool industry, chemical and petroleum machine building, automobile construction, agricultural machinery industry, ship building, road construction machine building, tool engineering.

Modern economic conditions have essentially changed the conditions and the mode of operation of manufacturing enterprises. The integration of Russia into the global economy requires enterprise improving competitiveness, improvement of product quality both in the sense of technical features and in the sense of cost performance, using advanced information technologies.

In recent years, as part of the implementation of the tasks set out in the national project "Improving productivity", work has been actively carried out to replace outdated technologies and equipment, which can significantly increase labor productivity at enterprises. In addition, these measures can reduce the energy consumption of production and, accordingly, make products more competitive (Matveeva and Simagina, 2016, 2017; Merker, 2014).

Improvement of efficiency of national machinery production depends on numerous system-wide

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Anna, G., Elena, M. and Svetlana, S.
Management of Energy Supply of Production as a Factor of Sustainable Development of Machine-building Enterprises.
DOI: 10.5220/0010610308330839
In *Proceedings of the International Scientific and Practical Conference on Sustainable Development of Regional Infrastructure (ISSDRI 2021)*, pages 833-839
ISBN: 978-989-758-519-7

factors: market conditions, taxation system, tariffs and prices of power resources and transportation services etc. Machine-building enterprise is a complex system carrying out a number of principal and auxiliary processes. The processes of preproduction and engineering output require harmonized and rhythmical performing of all types of activities: solving organizational and technical tasks, and material service operation of productive processes. Nowadays a serious problem is the essential increase of energy component in product cost which is up to 40% (Gavrilova and Salov, 2020; Industry Standard 27322–87, Industry Standard 31607–2012, Industry Standard P 51750–2001; Merker, 2014; Paramonov, 2009).

2 RESEARCH METHODOLOGY

As a comprehensive analysis of the management systems currently operating at enterprises has shown, the most significant problems arise when solving production planning tasks, logistics tasks, as well as tasks related to the energy efficiency of production (Matveeva and Simagina, 2016, 2017; Mesheryakova, 2020).

One of the most important aspects of the study of complex systems is the endowment of their structures. Since it is necessary to consider the mutual coordination of various aspects of the system, as well as the interaction of the elements of the system, it is necessary to model not only the individual elements of the system, but also the system as a whole.

Quite often, tuple modeling of systems is used. Tuple modeling is a description of the model in mathematical form and allows us to consider the system from the point of view of a set of interrelated factors (Matveeva and Simagina, 2016, 2017).

Management Mashinostroitelny enterprise can be represented as a multidimensional problem-oriented models in the form of a "tuple-six":

$$M_l = \{Q_l, P_{lm}, S_{lmk}, F_l, N_{lm}, J_{lmk}\} \quad (1)$$

where Ql – essential content problems; - Plm – breakdown structure of the underlying issues Ml;- Slmk – functional model and objectives formalizing the described structure Plm;- Fl – methodological means of addressing Ml; - Nlm – solving methods decomposion problems Plm and functional tasks Slmk; - Jlmk – the set of information needed to solve the problems of Plm and objectives Slmk methods Nlm.

In the selection of characteristic properties and characteristics, and the index m corresponds to the feature of isolating the structures of the problem Prl, the index k in the constructions and-the feature of determining the functional properties of the components.

Identifying the processes and parameters of the system allows you to solve the problem of ensuring the adequacy of the model to the real system. The tuple representation of the model reflects its structure, defines the purpose and characteristics of the functioning of the system.

Considering the enterprise model as an object of management, we can conclude that the essence of Q1 is the specifics of production from the point of view of management theory. The decomposition of Ql at the lower level of the hierarchy is implemented by separating the structural models:- P11-consistency of plant-wide, inter-shop and intra-shop plans; - P12-balance of flows of products, materials, components, variety of technological processes and operations, multiple routes of movement of parts; - P13-relationships and interactions of production, management, social, financial, energy and logistics factors.

The composition of functional models and tasks corresponding to the isolated structural models, m=1,2,3, is determined by the components: - S111-calendar plans; - S112-operational plans; - S113-division plans; - S121-structuring of the nomenclature of processed products, raw materials and components; - S122-sequence of operations and routes of movement of batches of processed products; - S123-loading of equipment by technological processes and workplaces; - S131-approval of production models; - S132-decomposition of all levels of goals, strategies and plans into production tasks; - S133-setting new management tasks in accordance with energy consumption and improvement of production technologies.

The methodology for solving Pr1 problems has adopted the concept of system analysis of management objects.

The basis for solving the P1m and S1mk problems are the methods:

- N11 - theory of active systems; - N12-operations research; - N13-diagnostics and identification.

The J1mk information required to build the P1m, S1mk models is determined by the following data sets: - J111-time horizons of planning; - J112-output volumes; - J113-planned production tasks; - J121-nomenclature and batch volumes of processed products, parts, and assemblies;- J122-composition of equipment, technologies, operations;- J123 - routes of movement of parties on workplaces; - J131-components of material costs; - J132-available capacities and resources; - J133-disturbing factors and impacts.

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- J123 - routes of movement of parties on workplaces; - J131-components of material and energy costs; - J132 –disturbing factors and impacts; - J133-the cost of creating a control system.

In general, the enterprise management system is a complex system. The complexity lies in the huge number of factors and states of the object under consideration and the variety of relationships between them, which must be taken into account when making decisions to improve management (Matveeva and Simagina, 2016, 2017). One of the most important factors is the organization of energy supply to the enterprise. The management of the energy system is the most important component of the sustainable development of the enterprise.

3 THE RESULTS OF THE STUDY. ANALYSIS OF PRODUCTION ENTERPRISES POWER SUPPLY

For machine-building enterprises energy efficiency is closely related to production techniques. The carried-out analysis demonstrated that to reduce production cost it is necessary to solve problems related to energy-output ratio such as: high product energy consumption; insufficient generation efficiency; transportation and distribution of energy resources; poor power supply reliability; insufficient volume of information or low data reliability about energy infrastructure performance; excessive energy consumption of obsolete and worn-out principal process.

High energy consumption of products is the main problem owing to the fact that it influences on production cost increasing and as a result it influences on reduction of enterprise competitiveness (Merker, 2014).

To carry out productive process machine-building enterprises accommodate ensembles of shopfloors which are the main enterprise structural units.

Every shopfloor in its turn has a complex structure with its division into production and auxiliary sections which are likewise main enterprise structure elements (Matveeva and Simagina, 2016, 2017; Mesheryakova, 2020). Enterprise efficiency of performance in whole crucially depends on organization of business process management of enterprises at all the stages and levels in reference to resource allocation, supplies and utilities and financial support (Matveeva and Simagina, 2016, 2017; Merker, 2014).

Generation of energy resources in its turn needs industrial consumers for reliable power supply of production processes with high technical-economic indicators. In recent 20 years specific energy consumption of production has increased by one and a half times mainly on account of industrial consumption reduction which resulted in energy efficiency decrease not only in production, but also in energy consumption.

Energy component of product costs is summarized as part of the processes of energy transformation, distribution and utilization. The maximum effect of energy conservation measures is achieved in the process of energy efficiency consumption which is carried out effectually at machine-building enterprises.

The value of energy component is also affected by energy to output ratio, heat and electrical energy tariff values, and overall power consumption of enterprises, which contribute to possible directions of energy component reduction of product costs (Merker, 2014).

Electric power supply system is divided into separate power generating companies, transmission companies and retail companies; moreover, a lot of power subpurchasers have appeared which on the whole results in essential increase of energy resources costs.

We intend to carry out the analysis of production enterprises power supply organization. For production enterprises centralized, decentralized, combined modes of power supply are possible. In accordance with specific situation each mode can have both advantages and disadvantages.

Large-scale energy-consuming industrial enterprises connected to the centralized power supply systems, purchase heat and electric energy according to approved fares. This scheme does not require substantial investments, the energy for consumers remains an external business resource.

Some large-scale energy-consuming industrial enterprises having fuel resources, switch to decentralized power supply systems, creating their own energy sources. This mode of power supply allows eliminating costs of fixed power payment, de facto consumed energy and power transmission.

However, substantial costs of new energy production organization are needed which requires carrying out complex analysis of costs, risks, and payback time. Constant demand in resources for energy production occurs: investments, labour, information, fuel and water resources and etc., which in its turn requires numerous reconciliations with compliance monitoring authorities, implementation of legislation, rules and normative standards, and compliance with safety rules at hazardous production facilities.

To manage machine-building enterprises effectively it is necessary to create information management systems of energy production which are necessary to integrate into existing management systems. For this purpose it is necessary to organize information automated systems of control and regulating of energy production technological process parameters, and constructing new, more complex management hierarchical structure of enterprises totally.

Thus, the organization of decentralized power supply systems for machine-building enterprises contributes to occurrence of new objectives and functions which require the transformation of existing production facility business structure, and management system transformation with account for energy production management.

Some industrial enterprises choose a combined mode of power supply if a part of energy resources are purchased at energy market but another part is generated by themselves. In this case there are disadvantages of both decentralized power supply systems and combined power supply systems (Gavrilova and Salov, 2020).

Let us analyze the activity of energy facility which uses decentralized power supply system or is a part of a combined power supply system of industrial consumers.

Power utility system performance is defined by interaction of internal components combined into subsystems, and by the impact of the environment. For our analysis we use an abstract infrastructural model of a power generating company which is analyzed as represented by Figure 1 (Gavrilova and Salov, 2020).

Internal and external activities of a power generating company are the main subsystems of the infrastructural model.

1. Internal activities includes blocks of “production resources”’ “energy resources”; “industrial processes”; “management systems” of power facilities and power facilities products (block “energy output”).

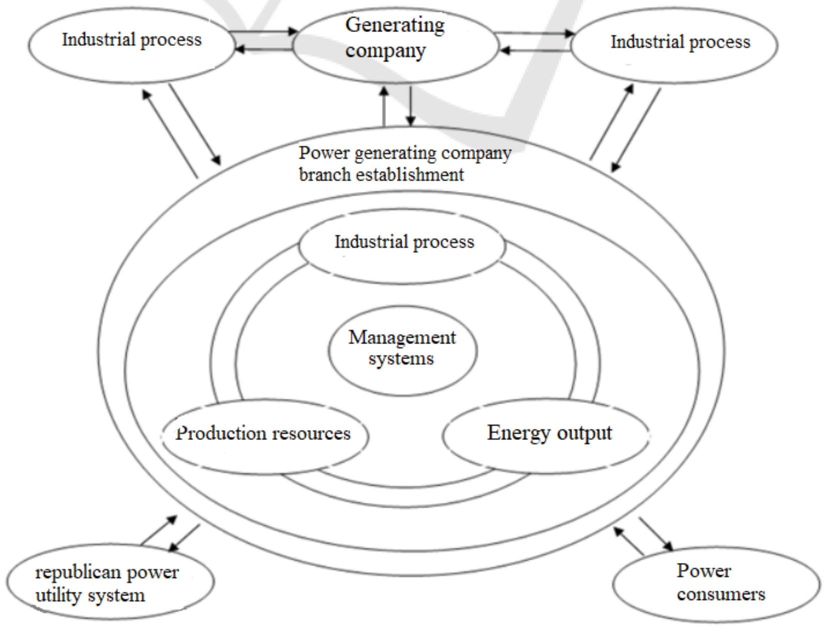

Figure 1: Infrastructural model of a power generating company.

2. External activities of a power generating company are the interaction processes with the environment. The block “republican power utility system” includes federal grid companies, regional grid companies, power generating companies and power supply companies. Block “Power consumers” includes industrial enterprises, state and public establishments, residential energy consumers.

Power supply system connected with other power generating companies and power suppliers, which generate electric power, has an opportunity in case of economic viability either to supply electric power excess amount to the federal market, or purchase electric power from Unified Energy System.

4 DISCUSSION OF THE RESULTS. ENTERPRISE POWER UTILITY SYSTEM MANAGEMENT

The main task of power utility system management, taking into account the external effects, is the identification of external essential factors in solving the following internal tasks.

1. Power generation with the highest economic indicators. Herewith, it is necessary to generate power at a rate which is demanded by consumers at the given moment. This condition overlays fairly hard constraints on the choice of utilities equipment operational conditions.

2. Timely supply of power utility system with necessary production resources in real time. Specific nature of utilization gas as a fuel makes energy production support with continuous process, which requires taking into account a number of factors.

3. Uninterrupted operation support of the principal and auxiliary equipment of power generating companies. Accidents at power facilities shut the power supply process, result in power cuts to consumers, and consequently, disrupt uninterrupted operation of industrial (machine-building) enterprises.

The interaction structure of power engineering and management technologies of a power generating company is presented in Fig.2. Power engineering technologies of a power generating company are structurally presented in the form of three interrelated subsystems:

1. Subsystem “infrastructural technologies” conduct processes of converting steam heat energy of high parameters into mechanical energy of generator unit rotor spinning generating electrical power.

2. Subsystem “energy-saving technologies” handles a problem of process optimization of converting internal fuel energy into heat energy and electrical power.

3. Subsystem “resources preparation technologies” carries out processes of preparation fuel, water and energy resources to utilization in the principal technological processes.

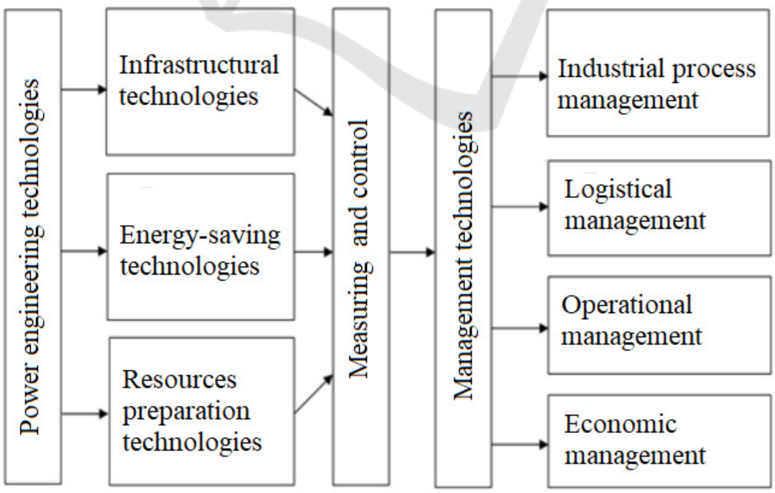

Figure 2: Structure of power engineering and management technologies of a power generating company.

For maintenance of subsystem activities it is necessary to organize control of principal and auxiliary technological parameters which feature power generating processes. At present control and measuring of the parameter majority is carried out constantly by means of automated control facilities, or by carrying out repetitive manual probing in the absence of automated facilities.

For improvement of power generating multiple efficiency within the conditions of constant reforms in principles of organization and management techniques of power generating companies it is necessary to conduct studies of internal and external industrial-engineering relations and enterprise parameter state on the basis of system approaches and mathematical model method, it is necessary to evaluate operating benefits of power generating companies taking into account the participation of different resources in electrical power system activity outcomes (Matveeva and Simagina, 2016).

Furthermore, it is necessary to introduce energy efficiency technologies including energy conservation equipment fitting and implementation of measures of energy saving; energy saving measures in buildings and structures, which are a complex of measures targeted at reduction of utilized energy resources volume without sacrificing gross output, volume of works etc.; organisational energy saving, conditioning energy saving culture increase and administrative procedures on managing energy consumption within 24 hours (Gavrilova and Salov, 2020; Merker, 2014). These measures give the possibility identify increased costs of energy resources owing to low load ratio of machines and equipment, erratic operation of principal equipment, related to downtime without source of power cutting-off, which occurs owing to the fact not related to equipment reset of the shopfloor to start output of another type of product (Matveeva and Simagina, 2016, 2017; Merker, 2014).

5 CONCLUSIONS

The implementation of comprehensive measures to improve production efficiency, including measures to reduce the energy component, led to the following results: the volume of production from the same capacities increased by 30-43 %, the duration of the production cycle decreased by 24-32 %, the cost of products decreased by 28-36 % (Matveeva and Simagina, 2016, 2017). Problem solving of improvement of power resources utilization efficiency makes it possible to reduce energy component in product cost, increase enterprise competitive abilities. To identify possible energy consumption at all stages of product life cycle it is necessary to carry out a system-related energy audit of all stages of machine-building industry (Gavrilova and Salov, 2020; Merker, 2014).

While analyzing production systems it is critical to begin with ultimate customers, afterwards it is necessary to proceed to distributive system and in the last turn to conduct studies of energy conversion.

Systems-based approach identified the dependence of energy efficiency of energy distribution and energy conversion processes on final consumption decrease which results in decrease of losses while distributing energy, since less energy for transmission. To reduce energy consumption is possible by means of automation employment, process improvement and loss enhancement.

Taken as a whole, energy management of a machine-building enterprise is a complex process which requires influencing factor complex studies, system relations studies, and enterprise performance and development mechanisms studies with reference to economic change.

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