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The technique of optimal choice of energy sources in the electrical systems with distributed generation

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Abstract. The article describes the technique of choice of primary energy sources of electrical systems with distributed generation. This issue is highly relevant considering the development of these systems in Russia. To optimize the building of electrical systems subject to the requirements the objective function of optimization, which takes into account both the normal operating modes of the elements, and damage caused by the interruption of electricity supply when disconnecting the source is proposed. A software product developed by means of algorithmization and programming based on the methodology of the objective function of optimization is described. The results presented in this work indicate that the proposed method allows to satisfactorily optimize the design of primary energy sources and can be used in the design.

I. Introduction

The last decade all industries in both Russia and abroad, regardless of the size and activity of the organizations, face an acute problem related to the shortage of energy resources and the high, constantly rising consumption costs.

Currently many local technologies of combined production of heat and electrical energy were developed. (figure 1).

Conversion technology can be based on combustion and subsequent conversion of heat into mechanical energy rotating the generator (reciprocating engines, Stirling engines, gas turbines, steam engines, etc.), and also on the direct electrochemical conversion of chemical energy into electricity (e.g. fuel cells). The combined technologies also include thermoelectric and photovoltaic conversion (thermophotovoltaics device).

Therefore, the development of new methods of mathematical modeling and optimization of electrotechnical systems (ETS) and complexes represents an important direction in the energy sector.

Since the optimal choice of the number and capacity of generating plants electrical system helps to ensure uninterrupted and economical supply of electric power receivers of a given size.

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As noted in the works [1-5] one of the most promising technological areas is the introduction of intelligent mini - and micro-networks on the basis of distributed generation, the use of which in Russia is considered in [6-9].

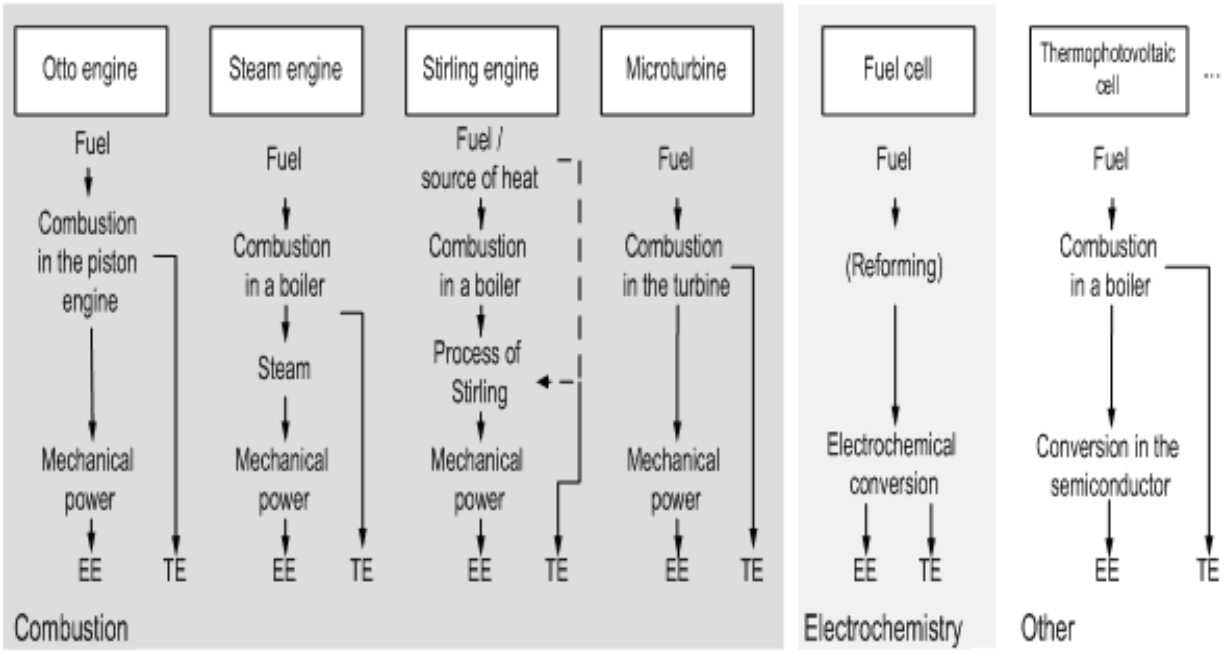


Figure 1. Cogeneration technologies technology and stages of transformation: EE – electrical energy, TE – thermal energy.

2. Formulation of the problem

"Virtual power plants" the principles of organization of which are described in [1, 7, 10], make it possible to supply several users from a single generating unit. However, it should be taken into account when constructing electrical systems based on the principles of cogeneration it is necessary to resolve the issue with the generation not only electrical, but also thermal energy. The power of such systems with distributed generation at low loads from the external power grid is solved in each case separately, as the cost of electricity when using external power supply is usually higher than that of produced by created electrical system.

3. Theory

Load of the electrical system at any point in time is determined by the number and capacity of included consumers and is not constant, so it depends on the mode of operation of the system, as well as climatic conditions, season, the type of the performed technological processes, etc.

Thus, the change of the load of electrical systems refers to random processes which are described using the mathematical apparatus of probability theory.

The choice is made considering the requirements given in standards, electrical installations code (PUE) and other normative documents, in addition, choosing the sources one should be guided by the following provisions:

- the load sources when operating in continuous modes should be at least 70-90% of the nominal, and when working in transient modes (forced, emergency, disaster) load can be reduced to 50-60%;

- the number of generating plants under consideration ETS often does not exceed two to four, with some installations (two or three) long connected to work in parallel, as some of them (at least one) is on standby;
- it is advisable to choose the sources of the same type to provide interchangeability of their parts and components and facilitate maintenance;
- often an installation of the generator operating in a period of declining electric loads with nominal power less than that of majo onesr, working in nominal or peak modes is inappropriate
- increase in the number of sources by reducing the unit's rated power increases their loading, however, complicates the structure and makes the system maintenance difficult.

The power of standby power sources is defined by the number and capacity of consumers pertaining to critical reliability, and specified in the EMP.

At the accepted provisions the economic effeciency of sources of ETS at the design stage of the structure can be determined by comparing the options of generating capacity by the value of reduced costs.

The form of the objective function in a mathematical model depends on the specified performance criterion. The main criterion in the optimization is the costs of ETS (sets) subject to the limitations on reliability and safety

$$Z_{ETS} = \tilde{N}_{ETS} + \frac{(\Delta P_i \cdot \dot{O}_o + \Delta P_{sc} \cdot \tau) \cdot \tilde{N}_{\dot{a}} + Q \cdot C_r}{\text{Đ}_{dc} + \mathring{A}_n} + D, \quad (1)$$

where DRH and DRCS – load losses and short circuit in elements of the ETS; Q – reactive power; the CA and SR – unit costs for compensation of losses of active and reactive power; ton – period of the ETS; τ – time work with nominal load; RAM – ratio of depreciation; Yong – normative coefficient of economic efficiency; – damage caused by breaks in supply, worsening the electric power quality, etc.; SETS the value of ETS determined from the expression:

$$\tilde{N}_{ETS} = \sum \left[\grave{I}_{\ i} \cdot \left(\frac{P_i}{\eta_i} + E_i \cdot k_n \right) \right] + \sum \grave{I}_{\ i} \cdot E_s, \quad (2)$$

where *Mi* – the number of electrical facilities; TSI – the price of the object; Ni is the utilization of the facility; *Zi* – unit costs on wages of production/installation; n – normative coefficient; DSD – specific payroll costs for other types of work.

In more detail the principle of construction and analysis of the target function is given in [11, 12], also used in the analysis position of the analysis of systems with distributed generation by methods described in [13, 14].

4. The Results Of The Experimets

Primary sources in all modes must be reliable and economic, with priority given to the reliability. This leads to a waste of fuel, since, in practice, in most modes of operation the generating units ETS are underutilized by capacity. It is worth considering that at decreasing of power of gas-piston units to 75% and 50% of rated power specific fuel consumption increases up to 105% and 115% of rated flow, respectively. For gas turbines under similar conditions of flow rate the consumption is 115% and 125% of nominal. Modes of operation of these and other installations considered in [15, 16], as well as on the websites of the generate equipment manufacturers.

Increasing the efficiency of the ETS at the design stage is achieved by a phased exhaustive search in picking generating units ETS, for example, using the technique of dynamic programming [12, 14]. The purpose of this overkill is the inclusion of primary sources of generators to ensure efficient

operation, as at the upper limits of permissible loads and with reduced values of the generated power. Also increasing the efficiency of the ETS, with a large number of primary sources, can be achieved by optimization of their location.

Ways of increasing the efficiency of the ETS in the process of operation are also factored in their structural and parametric synthesis, which allows you to consider the following recommendations:

timely disabling of one or more primary sources with the aim of reducing excess power margin ETS, because download generators in each mode is desirable for the upper range (nominal power);

- reduction of residence time settings in idle status (idle mode) to increase the consumption of energy, which they promptly disable.

to prevent a short increase of the load due to an automatic start of standby sources, for which when combining receivers in the group consuming from the same source, to consider their combining schedules.

5. Discussion of results

The optimal choice of the composition of primary sources allows to provide reliable and efficient operation of the ETS, for which the results of the calculation load of the consumers of ETS in all modes of operation are used . The total installed capacity of generators is the mode with the highest power consumption, the minimum installed capacity gives a discrete choice (the minimum installed capacity of one source) which is performed after the selection of the number and power of sources in each mode. This outlines the variations of sources of ETS which are compared by the optimization function (1), resulting in the selection of the best option.

To select the primary sources of ETS, the installed capacity is defined as the sum of the rated capacities of individual primary energy sources (figure 2).

Usage of sources is defined separately for each of them, depending on connected loads. In this case the optimal load factor is considered to be KZ = 1, the value of individual factors may differ from unity down to values at which the efficiency of the sources is not significantly different from the coefficient of efficiency under nominal mode (in program settings, this value is assumed to be 5%, but can be adjusted by the user). The value of the load factor of the whole ETS may not exceed 1, the excess means that it is deficient and requires replenishment from the outside.

A software product is written in Delphi 7 of Borland to perform computational procedures of receiving data for machine analysis and synthesis database elements required in the design of the structure and composition of ETS are organized.

6. Conclusion

Thus, the method of solving problems of synthesis of the structure and composition of primary energy sources of ETS with distributed generation with the help of developed optimization technique, and computer programming was considered. The result of the produced work is a practical implementation of a methodology for the design of ETS with distributed generation.

The proposed method using for search for optimal values the method of dynamic programming and shown target functions is well established in design practice. The theoretical framework presented in this paper was applied in the optimization of variants of reconstruction asorbing of the plant intended for power supply of oil fields.

The results show that, in principle, the developed method, the model gives the optimal estimates different from the estimates obtained by using traditional methods due to taking into account more parameters of the target function.

Thus, the methodology and the optimization algorithm presented in this article may be used for design optimization of primary energy sources in the electrotechnical systems

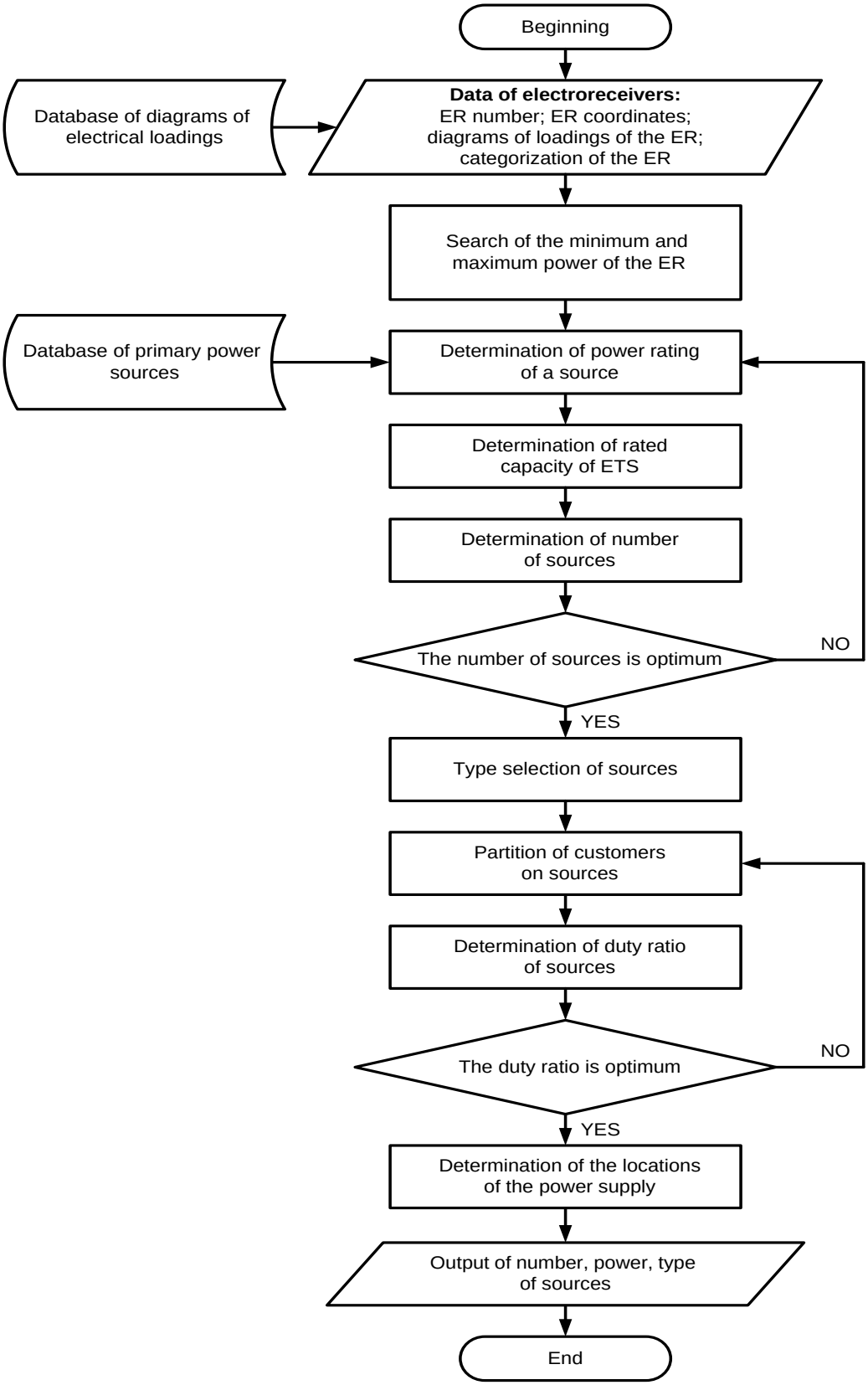


Figure 2. The block diagram of the developed algorithm of choice of primary energy sources of electrical systems.

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