Integral Models of Developing Electric Power Systems

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ABSTRACT

The first part of the paper is devoted to the problem of optimal control in the area of electric power industry which is described on the basis of a one-sector variant of Glushkov integral model of developing systems. The authors consider the ways uncertain conditions of future electric power system development influence the optimal service life. The results of calculations for the Unified Electric Power System of Russia are presented and analyzed. The second part of the paper deals with the application of Prony method to identification of the Volterra equations in the two-sector models of developing systems. The authors suggest a numerical method for identifying the efficiency function parameters. An illustrative example is given.

Keywords: Developing Electric Power Systems, Electric Power System Optimization, Glushkov Two-Sector Model, Identification, Integral Models, Numerical Methods, Prony Method, Service Life

INTRODUCTION

For about half a century Russian researchers have been systematically conducting studies on the mathematical modeling of electric power system (EPS) development. As a result they have created a methodology for the mathematical modeling of EPSs and their facilities (Melentiev, 1983; Belyaev, Voitsekhovskaya & Saveliev, 1980; Volkenau, Zeiliger & Khabachev, 1981). From the point of view of its content the model of EPS development relates to the territorial and production type. The problems formulated on its basis are solved by the linear programming methods.

In the late 1990s the Russian economy has faced radical changes that required new approaches to the prediction of electric power industry development to be worked out. Therefore, the studies on possible changes in such essential factors as the structure of electric power industry, equipment service life and introduction of new technologies become very urgent (Trufanov & Fedotova, 1995).

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The well-known models of EPS development do not usually describe the processes of optimizing the age structure of capacities. Such processes are analyzed outside the framework of these models on the basis of the general technique for improving the efficiency of investment projects (Veselov, Erokhina & Novikova, 2006).

There are very few models that involve optimization of the EPS age structure. Note first of all the paper of the German researcher (Schwarz, 2005), who applied the linear programming method to optimize construction of new capacities in a large EPS with fuel resources divided into types (exemplified by Germany). Here the optimization model considers modernization of existing power plants as an alternative to the construction of new ones. The results (Schwarz, 2005) showed that the average age of operating and removed equipment as well as the removal rate significantly depended on uncertain economic conditions in the forecast period. The crucial factors are: discount factor, fuel prices and maintenance costs.

In the paper the integral approach to the modeling of electric power industry to study the optimal age structure of EPS generating capacities is used for the case, where the given level of power consumption is provided. The considered integral model is based on the application of Glushkov models (Glushkov, 1977) to solving the problems on EPS development.

The work (Glushkov, 1977) formulates the problems of optimizing the economic system development and simultaneously its technological structure and suggests the ways to further generalization of these problems. Subsequently, this allowed the researchers to obtain interesting qualitative results in the optimization of macroeconomics functioning (Glushkov, Ivanov & Yanenko, 1983; Yatsenko, 1991).

The first part of this paper is devoted to the application of a one-sector variant of Glushkov model (without a subsystem of development) to the problem of optimizing the dynamics of generating equipment removal, when the given level of power consumption is provided. A number of papers (Apartsyn, Markova & Trufanov, 1999; Apartsyn, Markova & Trufanov, 2001; Apartsyn, Markova & Trufanov, 2002; Karaulova & Markova, 2003; Karaulova, Markova, Trufanov & Khamisov, 2003; Karaulova & Markova, 2004; Apartsyn, Karaulova, Markova & Trufanov, 2005; Karaulova & Markova, 2008) consider one-product models of EPS development aggregated to a different degree in accordance with the types of power plants. The suggested models are described in detail in Karaulova, Markova, Trufanov and Khamisov (2003), Karaulova and Markova (2008), Ivanov, Karaulova, Markova, Trufanov and Khamisov (2004).

The first part of the paper is aimed at studying the influence of uncertain economic conditions of future EPS development on the optimal service life. Moreover, as well as in Schwarz (2005), the optimization model considers modernization of existing power plants as an alternative to the construction of new ones.

The second part is devoted to the modeling of technological progress in Glushkov two-sector model of developing systems.

A developing system is characterized by: the separation of a subsystem of development and a flexible dynamic structure allowing for the introduction of new technologies and removal of the old ones. In the 1970s there appeared a new direction in the mathematical economy which considered the renewal of technologies and the dependence between great efforts and moment for the creation of these technologies in the production function (Glushkov, Ivanov & Yanenko, 1983; Yatsenko, 1991). The approaches to the modeling of production functions described in the monograph (Yatsenko, 1991) were used in the global models of market economy, which made it possible to obtain new theoretical and numerical results.

The paper presents the efficiency functions as exponential sums and suggests an approach to solving the problem of identification of these functions that is based on one of the methods for processing signals (Marple, 1987). The paper
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