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Ideology and problems of systems and economic optimization of NPPs

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Abstract

Iterative technique for optimization of components of nuclear fuel and energy complex (NFEC) is described. Nuclear power (NP) is one of such NFEC components. Optimization of nuclear power plant (NPP) is iteratively interconnected with optimization of the structure NP as the component within the NFEC system. Correlation functions between the components describing material flows and their costs as time functions are obtained by sequential optimization of components of the NFEC system. External flows and costs for each iteration step during optimization of specific component are taken from other components of the NFEC system optimized during the same iteration step. Flows and costs obtained during optimization of the component of the NFEC system examined during the consecutive iteration step are transmitted for optimization of other system components during the same iteration step. Specific NPPs are optimized following the same principle. Convergence of plans (solutions) of development and arrangement of all components is achieved by sequential optimization of all components within the NFEC system. Thus, convergence of all time functions including material flows and their costs is achieved allowing finding one or several locally optimal plans of development and arrangement of the fuel and energy complex (FEC) of Russia, as well as power plants (PPs) fueled with coal, gas, NPPs and other PPs. If the number of locally optimal plans is countable, then it is possible to select the best among them by comparing their functionals (values of the objective function). Upon obtaining new information with regard to any of the factors of mathematical models of components of the NFEC system optimization of components of the system must be repeated. In this case optimization must be performed taking into consideration the incurred costs under construction and already commissioned PPs.

Problems of systems optimization of components of the NFEC system as the functional of NPP optimization are identified. The task of optimization of complex systems refers to the most complex class of degenerate optimization problems [1]. No theory of degenerate optimization problems exists as of the present moment, although specifically these problems are real. Degenerate optimization problems should not be associated with degenerate matrices. Degenerate optimization problems deal with non-singular matrices having inverse matrices and, consequently, having solutions. However, the nature of these problems is such, that these solutions are degenerate (one or more components of the basis vector of the solution are equal to zero). The problem of convergence in the optimization of arbitrary component of the NFEC system to locally optimal plan coordinated with locally optimal plans for other components of the NFEC system is one of the main problems of degenerate optimization problems. Appearance of iterating loops during internal iterations in the process of optimization of plans for separate component of the NFEC system is not less important for problems of this class. This feature requires including incorporation of additional algorithms for exiting from the loops in the optimization algorithms.

Keywords: Degenerate optimization problem; System; Nuclear fuel and energy complex; Economy; Power engineering; Electric power system; Power plant; Nuclear power plant; Optimality; Competitive strength.

Iterative algorithm by Ya.V. Shevelyov for obtaining locally optimal plans for complex systems

As it was demonstrated in [2,3], neither of the promising NPPs currently under operation or under design is optimal

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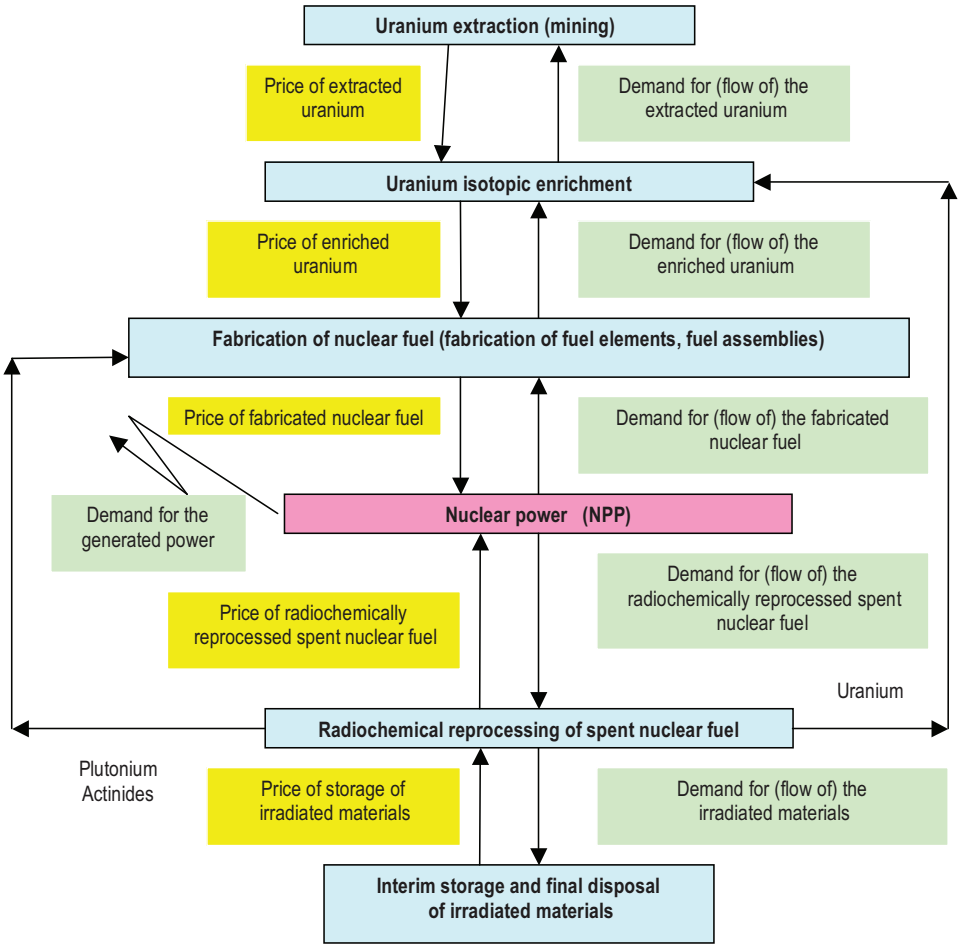

Fig. 1. Iterative algorithm by Ya.V. Shevelyov for obtaining locally optimal plan for complex systems (on the example of simplified system of the nuclear fuel and energy complex).

according to the economic criterion of summary discounted costs for the whole program of development of fuel and energy complex (FEC) of Russia (theoretically for infinite planning interval). As the consequence, competitiveness of such NPPs as compared with power units of conventional power engineering is under threat.

Economic criteria accepted in business, for instance, NPV (net present value, IRR (internal rate of return), DPB (discounted payback period), are the derivatives from the universal criterion of summary discounted costs. The values of these criteria are calculated automatically for the optimal plan according to the value of the criterion of summary discounted costs and do not change the optimal plan.

Let us examine the methodology of optimization of NPP parameters within the system of the nuclear fuel and energy complex (NFEC) according to Ya.V. Shevelyov [4].

NFEC system is presented in simplified form in Fig. 1. The presented layout is not detailed because it is represented by only integral components of uranium extraction (mining), uranium isotopic enrichment, nuclear fuel fabrication (fabrication of fuel rod and fuel assemblies), nuclear power (including all NPPs under operation or design), radiochemical reprocessing of spent nuclear fuel and final disposal of irradiated materials.

Problem of development and arrangement of production facilities utilizing technology including optimization of parameters for both the facilities (time moments for commissioning the facilities into operation, installed capacities, operational modes, types of production technologies, material flows at the input and output, inventories of materials under storage, etc., and the production technology i per se (parameters of geometry, controlling parameters and intensities of production processes) is solved in the optimization of ith component of the NFEC system. Dynamic models of optimization of components are constructed in order to achieve this. Material flows and costs for all factors of the model including the costs of all materials appear as the output solutions of such models. Since the algorithm of NFEC system optimization is iterative, then during the successive iteration step for ith component flows of raw materials obtained during optimization of $(i+1)$th component are used as the indicators of external demand for the materials produced by this component and prices of the products manufactured by $(i-1)$ component serve as the external prices of raw materials at the input of ith component. Material flows and inventories of materials in storage are corrected (specified) as the result of optimization of ith component for products fabricated by this component and transferred as the "raw material" to the $(i+1)$th component