Optimization Models and Methods Developed at the Energy Systems Institute

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ABSTRACT

The paper presents shortly some optimization models of energy system operation and expansion that have been created at the Energy Systems Institute of the Siberian Branch of the Russian Academy of Sciences. Consideration is given to the optimization models of energy development in Russia, a software package intended for analysis of power system reliability, and model of flow distribution in hydraulic systems. A general idea of the optimization methods developed at the Energy Systems Institute is given including the reduced gradient method, interior point algorithms, method of modified Lagrange function, and cutting-plane algorithms.

Keywords: Algorithms, Energy System, Expansion, Mathematical Programming, Operation, Optimization Models

INTRODUCTION

The Energy Systems Institute (ESI SB RAS) was founded in 1960. It is situated in Irkutsk, the center of Siberia. Until 1997 it was called Siberian Energy Institute. ESI is one of the eight institutes constituting the Irkutsk Research Center of the Siberian Branch of the Russian Academy of Sciences. Originally the main direction in the studies conducted by the Energy Systems Institute was search for the best variants of creation, operation and expansion of complex energy objects and systems (Voropai, 2010). The main
instrument in these studies is mathematical models. In order to implement the mathematical models of energy system operation and expansion it is necessary to apply special methods of computational mathematics. These include optimization methods (algorithms for selection of the best variants from those possible according to the specified criteria) that play a special part. Creation, development, experimental and theoretical studies of the optimization methods, their application to the energy-related models are also a direction in the scientific studies of the Institute.

The authors of the paper will try to familiarize readers with some optimization models that were developed at the Energy Systems Institute as well as with the original methods of solving the optimization problems that have been created by the researchers of the institute and gained wide recognition.

The paper does not claim to be exhaustive in describing all or even individual mathematical models created at the institute. Nor claims it to completely present all the methods ever developed and applied at the institute to solve optimization problems. Our goal is only to give an idea about the studies and developments of the Energy Systems Institute in mathematical modeling and optimization methods.

First, we will give a short characteristic of some mathematical optimization models created at the institute. Then we will discuss the optimization methods that were created at the institute. Here the focus will be made on four classes of optimization methods. These methods will be personified with the authors of their original ideas, although, many researchers of the institute took part in their development and implementation. It should be noted that the authors of the optimization methods to be considered here were both professional mathematicians (V. P. Bulatov, I. I. Dikin) and energy experts (L. A. Krumm, S. S. Churkveidze). This demonstrates the benefit of symbiosis of different sciences which has underlain the research done at the Institute since its foundation.

OPTIMIZATION MODELS OF ENERGY SYSTEMS OPERATION AND EXPANSION

A Model of Selecting the Optimal Long-Term Variants of the National Energy Development (Kuznetsov, Makarov & Melentiev, 1966; Makarov, 1984)

One of the major comprehensive developments of the Energy Systems Institute that involved specialists of different profiles is the model (in several versions) for the study of long-term (20 years and longer) variants of the national energy development. The model is intended for determination of the most rational ways of energy development in terms of existing interaction among individual kinds of energy resources when produced and their interchangeability when consumed. Many energy facilities (power plants, oil and gas production enterprises, oil refineries, urban heat supply systems) are very capital intensive and require long time to place them into operation and retrofit (pre-design and design studies, construction planning and construction itself). This generates the need to conduct in advance feasibility studies on construction of various capacities for production, processing and transportation of energy resources in certain regions.

The first energy optimization models were developed at the end of the 1960s and belonged to the class of conditional dynamic models. The state of the energy industry at years $t = 1, 2, \ldots, T$, was considered. These years corresponded to the last years of five-year periods. The model had the form of linear programming problem:

$$ A'x' + C'y' = b' $$

$$ N' \geq x' \geq 0 $$

$$ M' \geq y' \geq 0 $$

$$ (c', x') + (k', y') \rightarrow \min $$
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