Optimal Expansion and Reconstruction of Heat Supply Systems: Methodology and Practice

V. A. Stennikov, Energy Systems Institute, Siberian Branch of the Russian Academy of Sciences, Irkutsk, Russia
T. B. Oshchepkova, Energy Systems Institute, Siberian Branch of the Russian Academy of Sciences, Irkutsk, Russia
N. V. Stennikov, Energy Systems Institute, Siberian Branch of the Russian Academy of Sciences, Irkutsk, Russia

ABSTRACT

The paper addresses the issue of optimal expansion and reconstruction of heat supply systems, which includes a set of general and relatively specific problems. Therefore, a comprehensive approach to their solving is required to obtain a technically admissible and economically sound result. Solving the problem suggests search for effective directions in expansion of a system in terms of optimal allocation of new heat sources, their type, output, operating area; construction of new heat networks, their schemes and parameters; optimal detection of “bottlenecks” in the system and ways of their elimination (expansion, dismantling, replacement, strengthening of heat pipeline sections, construction of pumping stations and other components of heat supply networks). The authors present a mathematical statement of the problem, its decomposition into separate subproblems and an integrated technique to solve it. Consideration is given to a real problem solved for a real heat supply system. A set of arising problems is presented. The application of developed methodological and computational tools is shown.

Keywords: Heat Network, Heat Source, Heat Supply System, Optimization, Parameters, Pipeline, Reconstruction, Reliability, Scheme, Structure

INTRODUCTION

The paper deals with the problem of modeling complex heat supply systems (HSSs) which includes a number of subproblems. The main of them are: the choice of an optimal structure, the determination of optimal parameters and the calculation of flow distribution in HSS. Optimization problem of the multi-loop HSS development cannot be completely formalized and solved by one universal technique. Decomposition of a general problem into sev-
eral subproblems makes it possible to separate their solving in time and adjust the process of solving, taking into account individual features of systems.

The following methods are applied to determine an optimal structure of heat supply system:

1. Comparison of variants specified by an engineer (Shifrinson, 1940; Zanfirrov, 1933);
2. Search for an optimal configuration of the system (Courant & Robbins, 1941);
3. Solving a transport problem (Ford & Fulkerson, 1966);

This is the approach to be considered further.

The second and third methods do not take account of such features of HSSs as their distribution on the territory, obstacles to their construction, etc. They have limited practical application, whereas the method for comparison of variants and the technique of redundant design schemes are applied more widely to design heat supply systems.

**Optimization problem of HSS** parameters is described by a set of balance equations (flow rates and heads) and by technical and economic relationships. Optimization criterion is the minimum estimated (discounted) costs.

The parameters of branched HSS (without rings) are optimized by the dynamic programming (DP) method based on Bellman’s principle of optimality (Bellman, 1957).

Parametric optimization of multi-loop HSS is a multieextremal problem of nonlinear programming with discrete variables and complex constraints. A method of multi-loop optimization (MMO) (Sumarokov, 1976) was suggested to solve it. The method combines the techniques for calculation of flow distribution and optimization of branched heat network parameters. Methods similar to the MMO have not been found in publications.

Traditionally heat supply systems are reconstructed by determining pipeline diameters by the linear programming methods (Dantzig, 1963) or by the dynamic programming method for branched systems (Appleyard, 1978; Garbai & Molnar, 1974). However, for Russian large and multi-loop HSSs with a heat capacity above 4500 MW this leads to non-optimal solutions.

**The flow distribution model** includes a set of balance equations (analogues of Kirchhoff laws) (Cross, 1936; Kirchhoff, 1847; Maxwell, 1873) and closing relationships (Equations 11-14) that describe the relationship between pressure losses and flow rate in a heat network section.

The paper presents a new technique for solving the problem and results of its practical application in expansion and reconstruction of HSS in one of Russia’s cities.

**PROBLEM STATEMENT**

Modern HSSs have become complex engineering structures. They represent an integrated system of heat generation plants and numerous nodes for connection of various consumers. They are characterized by large scales and distribution throughout a vast territory. The structural complexity of HSSs manifest itself in a great number of loops and their spatial schemes, presence of active devices and regulators, inhomogeneity and nonlinearity of individual technical and economic characteristics of the network components. The large number of loops in the HSSs schemes is determined by the presence of two-line heat networks (HNs) that provide closed circulation of heat carrier and by the process of expansion, when individual main lines are connected by links, thus forming multi-loop systems of supply and return pipelines. Considerable length of HSSs, rugged relief and their irregular operating conditions require a large number of active components (pumping and throttling stations, regulators of flow rate, pressure, temperature, etc.).

Continuous complication and development of the existing HSSs call for expansion of old and construction of new heat sources (HSs),
A Novel Approach for Load Frequency Control of Interconnected Thermal Power Stations


[www.igi-global.com/article/novel-approach-load-frequency-control/65753?camid=4v1a](http://www.igi-global.com/article/novel-approach-load-frequency-control/65753?camid=4v1a)