Methods for Comprehensive Analysis of Heat Supply Reliability

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ABSTRACT

The paper deals with the problem of comprehensive analysis of heat supply reliability for consumers. It implies a quantitative assessment of the impact of all stages of heat energy production and distribution on heat supply reliability for each consumer of the heat supply system. A short review of existing methods for the analysis of fuel and heat supply reliability is presented that substantiates the key approaches to solving the problem of comprehensive analysis of heat supply reliability. A methodological approach is suggested, in which mathematical models and methods for nodal evaluation of heat supply reliability for consumers are developed and the studies on the impact of different elements of fuel and heat supply systems on its level are described. Mathematical modeling is based on the Markov random processes, models of flow distribution in a heat network, deterministic dependences of thermal processes of heat energy consumption and some other models.

Keywords: Comprehensive Analysis of Reliability, Decomposition Reliability Analysis, Heat Supply Complex, Markovian Process, Method of Statistical Testing, Nodal Indices of Reliability, Postemergency State

INTRODUCTION

Heat supply is the most important component in support of vital activity of population and development of virtually all economic branches. High socio-economic significance of the heat supply sphere imposes heavy demands to reliability and economic efficiency of heat supply systems (HSSs) that combine heat supply sources (HSSs) and heat networks (HNs) in the unified structure. During the long period of formation and development these systems have acquired complex structure and large sizes. Such specific features of current HSSs as a multitude of diverse heat sources, large length of heat networks (hundreds of kilometers), combined into complex multi-loop schemes, numerous heat energy consumers, multilevel structure of heat supply system management all stipulate complexity of the problems to be studied.

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provision and improvement of their reliability. These problems aim primarily at determining the reliability level of heat supply to consumers and considering the normative requirements to the values of reliability indices at system designing and operation. Increasing scales of HSSs and the corresponding complication of their structure caused by the growing number of consumers and their loads necessitated creation of effective methods for assessment of their reliability and measures on reliable heat supply. The situation is aggravated by disunity in HSS management structure, technical imperfection of the systems, essential wear of their pipelines and equipment, low operation technologies of some system components, thermohydraulic misadjustment of heat networks and consumer installations. Moreover, the methodological base on standardization of heat supply reliability should be developed and improved.

The first studies on HSS reliability by the methods of reliability theory were carried out at the late 1960s – early 1970s (Khasilev & Takaishvili, 1972; Sennova, 2000). Initially improvement of HSS reliability was based only on enhancement of the quality of manufacturing the elements and structures and the corresponding theoretical approaches did not take into account many specific features in operation of these systems. The reliable elemental base, however, has not been created and development of large centralized systems became the main trend in the sphere of heat supply. In these conditions many specialists considered redundancy of heat network schemes as one of the basic methods for reliability control. Later on a great number of studies on reliability of HSS and its elements have been performed, the techniques and models for solving the problems of reliability analysis for heat sources and heat networks have been worked out that characterize their different specific features, the algorithm of constructing HSS with the required reliability level has been developed, the system of standards needed for its solving has been substantiated (Sennova, 2000).

HSS operation starts with fuel provision for sources. Hence, fuel supply reliability is inseparably linked with reliability and quality of heat output to consumers and consideration of fuel component is an integral element in the system approach to solving the problems of analysis and synthesis of heat supply reliability alongside with the reliability of heat production and transportation.

Application of all methodological developments in the area of heat supply reliability depends to a great extent on available information on the reliability indices of heat and fuel supply system elements and classification of information on fuel use conditions depending on different external conditions. The long-term period of HSS operation made it possible to accumulate a deal of statistical data on failures and restorations of HSS elements and as a result of their processing the reliability characteristics of these elements, in particular normative ones, were obtained. However, new systems are designed and existing ones are reconstructed based on introduction of the up-to-date energy saving equipment, whose reliability characteristics cannot be objectively estimated because of insufficient experience in its operation. Therefore, the necessity arises to create systems for automatic information collection from the objects of the whole process of heat energy production and distribution.

Recently the works on heat supply reliability have become more topical due to a high extent of HSS equipment tear and wear (for example, capital equipment of many cogeneration plants in Russia was installed more than 50 years ago, wear of heat networks on the average for the country reaches 60%), creation of new management forms for the heat economy of cities with participation of numerous owners in the unified system and also future trends in HSS development on the basis of distributed generation principles, which requires new approaches to the reliability analysis, standardization and provision for systems under reconstruction.
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