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Ecological and Economic Advantages of Remote Heat Supply from Reactor Plant of Advanced Safety BN-1200

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Abstract

The heat supply based on the combined heat and power production is the basis of rational use of energy resources. This will increase the efficiency of existing nuclear power plants (NPP) and give a significant cut in the nitrogen oxide and greenhouse gases emissions from burning fossil fuels. The data of the remote heat transport are summarized. The technical, economic, and ecological preconditions determining the long-distance transportation of heat possibility are given. The estimation of the efficiency of long-distance transport of heat from NPP is made. A variant of a scheme of Ekaterinburg heat supply from Beloyarsk NPP is given.

Keywords: nuclear power plant, efficiency, the heat supply based on the combined heat and power production, waste heat, heat pump, radiation safety

1. Introduction

In the present time, increasing of energy sources prices and reducing amount of fuel make us find ways to improve efficiency of energy conversion. Heat supply based on combined production of heat and electricity is the basis of rational use of energy sources. Taking into account different factors, long distance heat supply becomes more competitive. European countries have long-term experience of heat supply from NPPs. Their economic indices are evidence of successfully combined production of heat and electricity. There is also a positive experience of nuclear heat supply in Russia. This experience and modern technical capabilities allow using NPPs for heat supply more widely.

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2. Methods

2.1. Bilibino NPP

Bilibino NPP is a striking example of the longstanding successful heat supply (Figure 1). It is the first polar NPP, unique construction in the heart of Chukot that ensures vital function of mining and gold-mining enterprises. It runs in an isolated power system in power regulation mode. Bilibino NPP generates 80% of electricity of isolated Chyan-Bilibino power system. It is the only source of heat supply in Bilibino town.

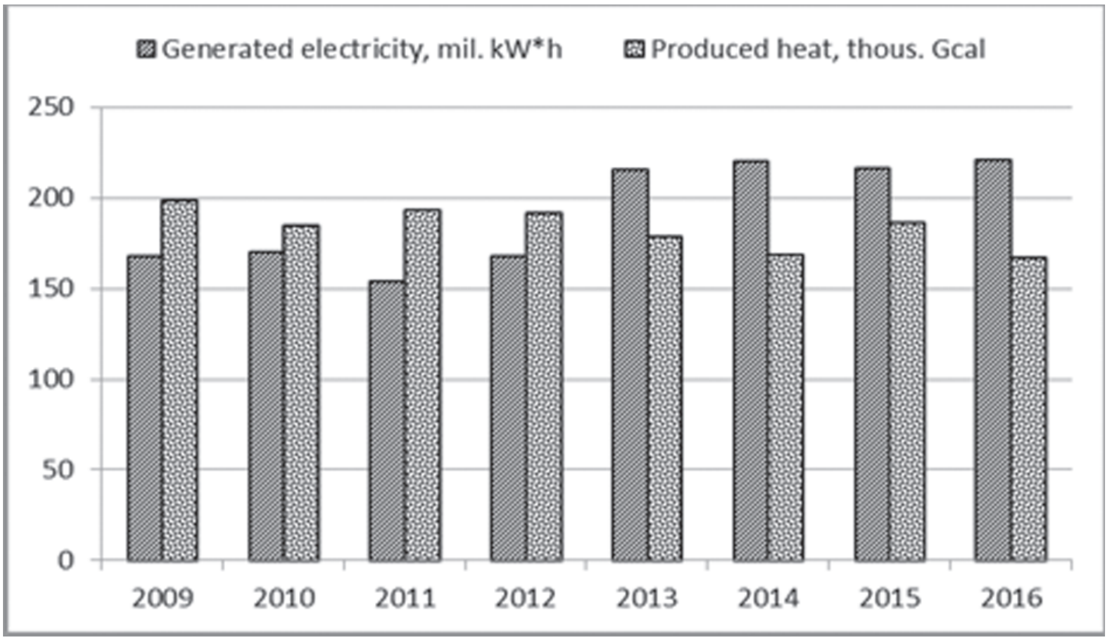

Figure 1: Generated electricity and produced heat at Bilibino NPP.

2.2. Foreign experience of nuclear heat supply

One is also interested in central heat supply from NPP abroad. So, in the article [1] the data about functioning of the central heat supply systems on the base of running NPPs in Switzerland and Slovakia are provided. There is also a description of unrealized projects in the Ukraine and Finland. About 40% of all electricity in Switzerland is generated at five units of four NPPs. Gosgen NPP supplies a pulp and paper mill with 220°C steam since 1980. Beznau NPP is the second nuclear heating source in the country and the only NPP supplying enterprises and people with heat. The using of the waste heat is organized at Beznau NPP. It supplies with heat 11 communes and several industrial consumers. Total length of the main and distributing heating network is about 137 km

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for two pipes. The main pipelines are about 25% of total length (more than 35 km). The overall number of consumers is about 2600 (approximately 15 000 people).

The utilization of a part of the waste heat at Beznau NPP, which was traditionally thrown off into the Aare river, allows saving up to 20 tons of liquid fuel annually. This is 50 000 tons of CO_2, 100 tons of SO_2, and 50 tons of NO_x in harmful gases for equivalent.

2.3. Perspectives of nuclear heat supply

Heat supply provided by combined production of heat and electricity is the basis of rational energy sources use. Classical solution of the heat supply is the use of the heating plant located nearby. But in many cases heat supply is profitable from the distant heating plants [2].

The development of nuclear heat supply is important for our northern country with traditional district heating. A nuclear power plant is the most environmentally appropriate source of heat in comparison with conventional fossil-fueled heat sources. It does not consume oxygen, minimizes water consumption, and has higher available heat factor.

The issue of long distance heat transportation was investigated in 1980s. The efficiency of heat transportation at 100–150 km distance was proved [1].

To implement the technology of long distance heat transportation, the complex approach to the design of the heat supply system is required. It must include sources of heat, heat delivery pipes, peak sources and networks, and heat consumers. Innovative solution of the heat supply problem is composed of a set of new technical decisions for all the components of the system, which make it possible to reduce the heat transport costs and increase the system reliability. Nowadays, the reasonableness of long distance heat transportation is determined by a complex of technical, economic, and ecological factors [3].

Technical factors: (1) the increasing use of expansion bellows decreases the amount of metal and resistance of the heating network; (2) the use of lamellar heat exchangers can also reduce the metal consumption; (3) polyurethane thermal insulation of pipelines decreases the heat losses by 1,3 times; (4) the production of the 1600 mm diameter pipes is developed; (5) the turbine equipment that allows selecting low potential heat in large scale and ensures heat factor of nuclear heating plant up to 80% is developed.

Economic factors: (1) relatively accessible supplies of gas are limited; (2) specific metal consumption of the gas pipelines and energy consumption for 2000–3000 km delivery to the towns exceed the same values for 100 km heat delivery from NPP; (3) in case of use of the large diameter main pipelines for high thermal power, metal consumption decreases by 25% over smaller diameter pipelines.

Ecological factors: significant reduction of the emissions of nitric oxides and greenhouse gases from fossil fuel combustion, atmosphere heat pollution by cooling towers, and dumping of bleed water form circulation cooling systems of NPP.

Thematic example of profitable nuclear heat supply is the project of heat supply of Saint Petersburg from Leningrad NPP-2 (over 80 km). Operating Leningrad NPP and new Leningrad NPP-2 gives an opportunity to transfer over 7000 Gcal/h of heat to consumers in Saint Petersburg instead of dumping heat into the environment. In this case, over 5 milliard m^3 of gas will be saved.

Another solution is to use adsorption heat pumps for heat supply of Saint Petersburg from Leningrad NPP. This allows significant reducing the temperature and pressure of the energy carrier at the stage of delivery and bringing it to the required parameters near the places of consumption.

The project of nuclear heat supply of Ekaterinburg from Beloyarsk NPP was considered as a solution of harmful gases emission from heating plants reducing the problem (Figure 2). The scheme of heat supply from Beloyarsk NPP with fast breeder reactors with sodium coolant (three circuit scheme) can be a base for the project [4–6]. The scheme must be completed according to the geographic and NPP equipment features.

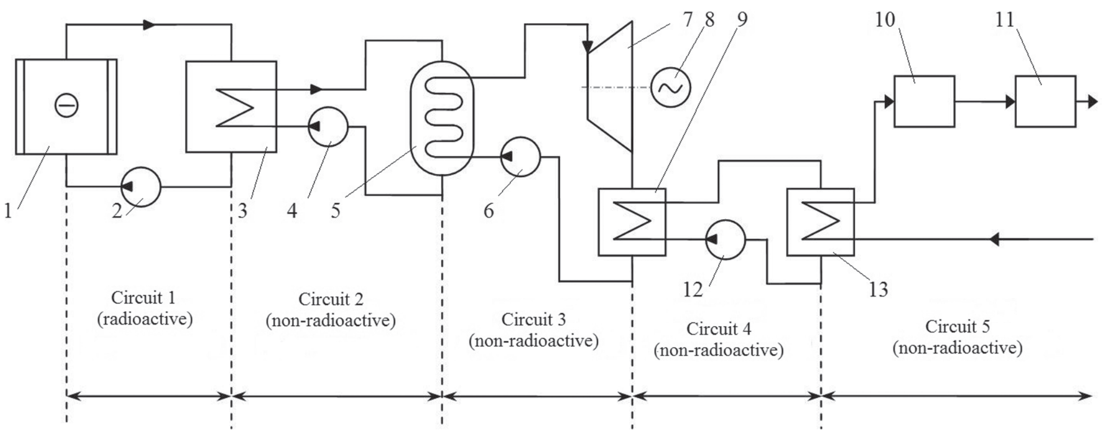

Figure 2: The schematic diagram of Ekaterinburg heat supply from Beloyarsk NPP: 1 – nuclear reactor; 2 – reactor coolant pump; 3 – sodium to sodium intermediate heat exchanger; 4 – secondary circuit coolant pump; 5 – steam generator; 6, 12 – circulating pumps; 7 – steam turbine; 8 – electric generator; 9 – heat exchanger; 10 – peak boiler; 11 – consumers; 13 – heat exchange plant.

The main pipeline is divided into two independent circuits (circuit 4 and 5 on the scheme). As a result, the longest part of the main pipeline is less than 35–40 km. The third circuit of NPP with BN reactors is separated from the second one by the surface of the steam generator. So, it is non-radioactive. The fourth circuit consists of the heat exchanger at NPP and the heat exchange station. It excludes even hypothetical possibility of the heat transfer agent radioactivity. This circuit ensures optimal border of responsibility (without intermediate pumps) and reduces the length of the main heating network. The fifth circuit is the heat exchange station consisting of the peak boiler unit and the consumer. It works on a temperature chart 165/50°C. The heat transfer agent of the fourth circuit delivers its heat via heat exchange equipment to the high quality cold water that comes from water intake or main water pipelines of Ekaterinburg. The water, being deaerated and heated up to 165°C, delivers the main thermal power to the heating plants circuits that are switched to the peak mode.

Estimated calculation of the pipeline was completed in order to verify economic efficiency of the heat supply of Ekaterinburg from unit with reactor BN-1200. New micro district of Ekaterinburg that will be built in the east side was chosen as a consumer of heat. The number of citizens is taken about 100 000 people for calculation. Pre-school and additional educational institutions, general educational institutions, health objects, trade objects, food objects, and objects of culture are planned to build. Possible version of the pipeline designed to avoid railways and settlements is shown in Figure 3. Total length is 41 km. The new apartment houses and objects of social purpose are expected to be supplied by heat through the heating network from Beloyarsk NPP. Total heating power of the apartment houses and social objects is 150 Gcal/h.

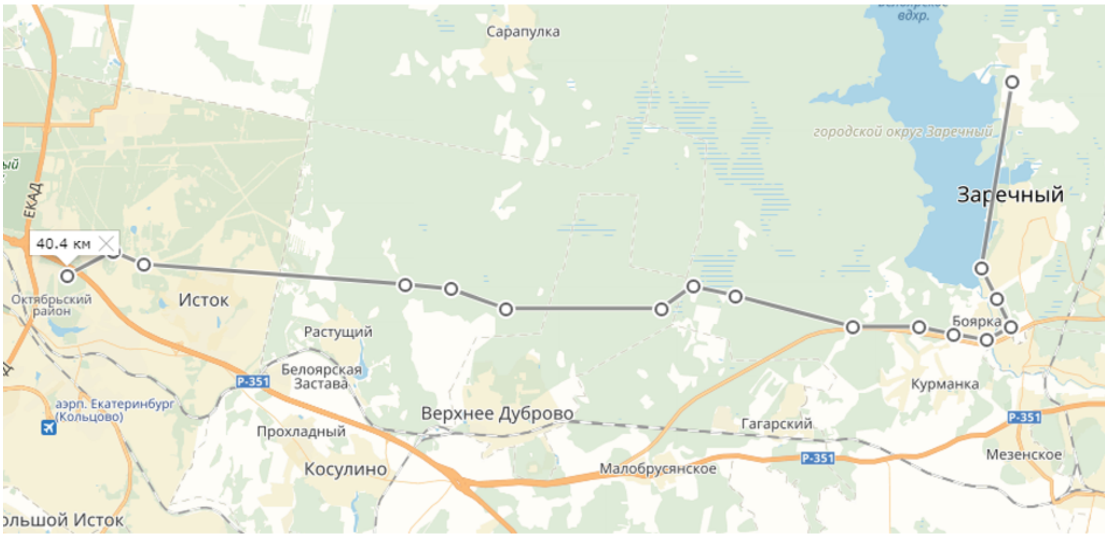

Figure 3: Possible version of the pipeline designed to avoid railways and settlements.

3. Results

Carried out research has shown that Russia has technical, economic, and ecological factors for long distance heat supply from NPPs. Different projects of cities heat supply are designed nowadays. Advance estimation of the pipeline construction value from Zarechniy to Ekaterinburg demonstrates that this project is competitive.

Reactor BN-1200, being a reactor of advanced safety, can be used for heat supply. Control area is within NPP's border for any design-basis accident. Operation experience proves that reactors of the type BN are the most ecologically clean.

4. Conclusion

Reliable heat supply plays an important role in creating comfortable accommodation conditions and discovering northern areas in Russian climate. There are a number of projects of cities heat supply from operating and constructing NPPs. Economic efficiency estimation of Ekaterinburg heat supply from Beloyarsk NPP gives a possibility of implementation of this project. The use of NPPs will allow solving a heat supply problem of big cities, reducing harmful influence on the environment and increasing energy sources use efficiency.

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