Conference Paper

The Construction of Floating Nuclear Power Station in Pevek as Innovation in the Electricity market

Anisimova A. I., Kopin M. R., and Allenykh M. A.

Finance University under the Government of the Russian Federation, Russian Federation, 125993 (GSP-3), Moscow, Leningradsky Prospekt, 49)

Abstract

The article considers efficiency issues of the innovative project construction of floating thermal nuclear power station (FNPS) as the instrument of increasing investment attractiveness of the region. The project is aimed to ensure energy supply in the Arctic zone of the Russian Federation. The necessity of building a FNPS is determined by the requirement to ensure the independence from transport infrastructure, logistics and pricing for the delivery of fuel. The long-term development of the district, aimed to attract prospective investors through the formation of the necessary infrastructure, enabling large companies to make the necessary investments in the cluster area.

Keywords: Chukotka Autonomous Okrug, clusters, Bilibino nuclear power plant, Chaunskaya CHP, FNPS, investment, Pevek

Corresponding Author:
Allenykh M. A.
maallenyh@fa.ru

Received: 23 December 2017
Accepted: 15 January 2018
Published: 21 February 2018

Publishing services provided by Knowledge E

Selection and Peer-review under the responsibility of the AtomFuture Conference Committee.

1. INTRODUCTION

The current situation in the market of the Russian power industry is characterized by the stability and resource availability. Economic development of the Russian regions and the state as a whole is due to the energy intensity of GDP, which the rate of the growth in average coincides with the energy consumption growth rate [11]. In accordance with the Resolution of the Government of the Russian Federation about increasing the energy efficiency of the national economy sectors [1], the Russia's Energy Strategy up to 2035 [4] and the general layout of power facilities by 2035 [4] development of nuclear energy as an alternative to carbon is a priority purpose of the state. In Russian energy structure predominates proportion of the organic fuel [11]: Thermal power stations - 58.64%, nuclear power plants - 18.3%, hydroelectric power stations - 17.4%, power industry - 5.6%, wind power plants - 0.013%, solar power plants - 0.044%, which is graphically illustrated in Figure.1.

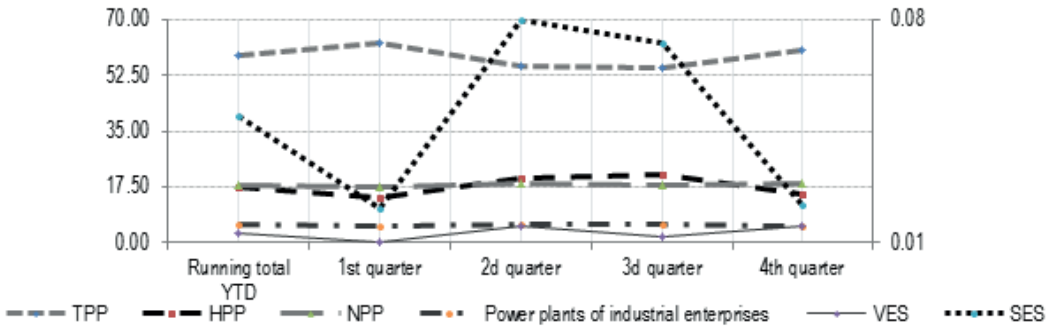

Figure 1: The structure of Russian power in 2016 on a quarterly basis, %.

However, development of power generation based on organic resources (construction of thermal power plants and hydroelectric power station) is complicated by the fact that most of the traditional raw materials for the production of electricity, such as water, deposits of coal and natural gas, are located behind the Ural Mountains, while the bulk of end-users is concentrated in the central part of the country, which makes the transportation of electricity economically unjustified. Regions, in which fields are contained and developed, nowadays keep up with the leading Russian regions in the development of the economy and social sphere. In this case, it is Eastern Federal District (DFO) in general and Chukotka autonomous district (CHAO), in particular. However, this is the subject of a promising ground for the installation of the modern nuclear power plant.

Current trends in the world market of nuclear technologies demonstrate the competence building of a number of companies. Clustering, mergers and acquisitions and their subsequent vertical - horizontal integration, the creation of transnational alliances nuclear coalitions lead to increased influence of the world leaders: Government corporation "Rosatom" (Russia); «Toshiba» - «Westinghouse» (Japan - USA); «General Electric» - «Hitachi» (USA - Japan); AREVA - «Mitsubishi Heavy Industries» (France - Japan) [15]. Development of the regions of the State Corporation "Rosatom" is due to the presence of the formation and the successful implementation of nuclear technology clusters, the aim of which is to use the competencies of public and private enterprises. [10] All this can be realized on the basis of the Chukotka Autonomous District.

Long-term Development Strategy of the Chukotka Autonomous District involves the development of two advanced development zones in the form of industrial clusters: Chaun-Bilibino and Anadyr area (Bering coal basin and the Anadyr oil and gas province). The basis for the development of Chaun-Bilibino cluster will be the development of polymetallic deposits in the western part of Chukotka. The project involves

the development one of the largest in the world porphyry copper fields in Baimskoy area which is located in Chukotka Autonomous District. The resource potential: 27 million tons of copper and 2000 tons of gold, of which 7 million tons of copper and 537 tons of gold has been transferred in MI & I category standard JORC<fn>JORC - international organization. engaged in accounting and categorization of reserves of minerals in the world</fn>. Field development involves the development related transport and energy infrastructure in the region, which will address several key challenges in the region, including:

- The replacement of retired capacities of Bilibino Nuclear Power Plant (48 MW), the final closing is scheduled for the 2019-2021 years, Chaun TPP (38 MW) in Pevek, decommissioning planned after commissioning FNPS [18] and the construction of new generation capacities to provide the electricity for new industries;
- The construction of additional power lines for routing grid region.

2. GENERAL DESCRIPTION OF THE POWER OF THE PROJECT

Chaun-Bilibino energy system of the industrial cluster has evolved as an isolated energy system, covering three districts of electric production and consumption: Chaun, Bilibino and Zelenomyssky (Republic of Sakha - Yakutia) network areas associated overhead lines with a voltage of 110 kV (Northern Electric Networks).

In each of these areas there were their own sources of electricity and heat. The electric power of Chaun-Bilibino energy cluster (CHEC) consists of Chaun TPP (38 MW) in Pevek, Chaun DEL composed Chaun TPP (4.5 MW), Bilibino Nuclear Power Plant (48 MW) in the Bilibino, Northern electric networks, which include overhead line -110 kV (772 km), 35 kV (172 km), overhead and cable transmission lines 10 - 6 kV (100 km) and 0.4 kW (72 km).

The total installed capacity in CHBEU is:

- power plants - 90.5 MW. On December 2017 productive capacity used is 30-35% due to the high cost of tariffs, which significantly complicates the development of the region;
- transformer substations 110/35/6 kV - 202000 kVA;
- transformer substations 35/6 / 0.4 KV, including switching point 35 kV - 161 030 kVA.

Networks of CHBEU, including Chaun, Bilibino and Zelenomysskogo network areas constitute a system of centralized electricity supply to consumers. The government of Chukotka Autonomous District is planned to carry out the replacement of retiring Bilibino NPP and Chaun TPP capacities through the implementation the project of floating nuclear power plants construction.

3. PROJECT FLOATING NUCLEAR STATION [17]

The project envisages the construction of floating nuclear power plant (FNPS) in the region of Pevek city (Chukotka Autonomous District) with the electrical capacity of 70 MW and heating capacity of 50 Gcal / h for the power supply of consumers of Chaun-Bilibino industrial and economic region in Chukotka.

The main objectives of the project are to provide the growing energy needs of the region, efficient energy exploration and development of gold and other fields in Chaun-Bilibino energy system of the industrial cluster, ensuring stabilization of tariffs for electric and heat energy for the population and industrial consumers, the creation of a reliable energy base for economic and social development of the region.

The major characteristic of floating nuclear power plant is the possibility to use it for energy supply of industrial facilities and population in areas outside the central zone of energy supply and at the same time to have a high untapped economic potential.

The key features FNPS are:

- industrial technology construction of the station on the basis of complete equipment deliveries made in a specialized industrial production;
- the construction of a placement station only supporting facilities to ensure the installation of the station and the transfer of heat and electricity from the station to the shore;
- full service and operation of radioactive waste (RW), carried out at specialized enterprises with a periodicity of 12 years, which is a solution of the urgent problem of handling spent nuclear fuel (SNF) and radioactive waste [14];
- The mobile station, which allows it to install in almost any coastal zone, as well as in line with the great rivers;
- implementation after the operation of FNPS concept of "green lawn", ensuring the absence of the effects of impacts on the environment [14].

The station includes a floating unit (FPU), waterworks, ensuring reliable installation and detachment FPU and transmitting generated electricity and heat on the shore, onshore facilities for receiving and transmitting the generated electricity and heat to external networks for distribution to consumers.

Main technical characteristics FNPS based FPU with KLT-40C are shown in Table. 1

Table 1: Basic specifications FNPS based FPU with KLT-40S.

Parameter. characteristics	Value
Thermal power reactor facilities	2 150 MW
Maximum electric power in condensing mode	238.5 (77) MW
Maximum thermal capacity	146 Gcal/h
The maximum electric power at the maximum Heat	219.4 MW
Nominal heating mode:	
• electric power	235 MW
• Heat and power	225 Gcal/h
Power consumers own needs	22.5 MW
Number of staff	176 human

Moreover, there is the low number of staff, which indicates a high level of technological development of the project, which ensures a higher average labour productivity [5].

4. FLOATING POWER UNIT (FPU)

FPU is a flush-propelled vessel with strut-type hull lines close to rectangular and developed multi-tiered superstructure. FPU is welded housing, equipped with special tools for towing, and means for fastening the location. Underwater hull part is protected against electrochemical corrosion protection and lacquer coating (Figure 2).

In the middle part of FPU there is a reactor compartment and handling nuclear fuel. The nose of the reactor compartment and electrical turbogenerator has compartments abaft - compartment auxiliary units and residential block. In the technology block there is two reactors (EDM) and two steam turbine (STI) installations, systems and equipment to ensure the normal operation of the power unit. Each RI is enclosed in a sealed steel sheath configured as an extremely durable FPU body construction and designed for the maximum pressure that can be occurred in it during accidents. On

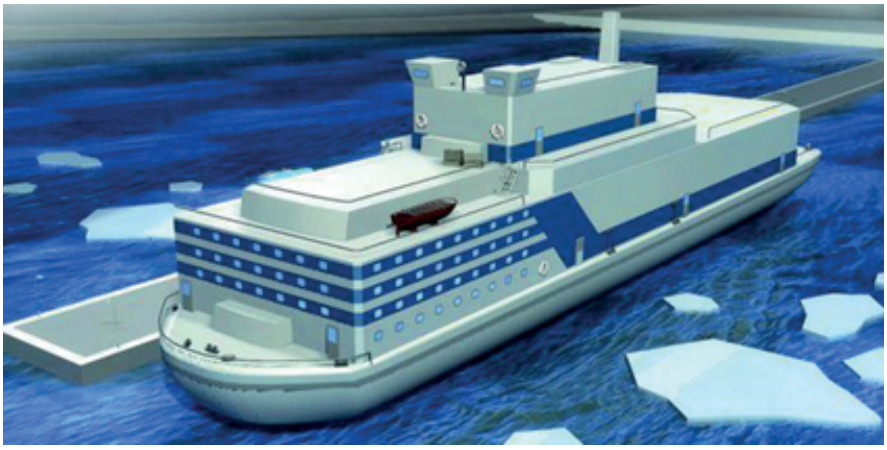

Figure 2: Appearance FPU.

board the FPU it is provided the accommodation of storages of spent reactor cores and means ensuring the implementation of recharges reactors.

Building of FPU is carried out in a shipyard with the organization of strict control of manufacturing quality at the level established for nuclear ships. After conducting the necessary tests, the fully stocked and ready to work FPU is towed to the operation site, where it is secured with special booms to starboard mooring piers with special devices (bow and stern). Main technical characteristics of FPU from reactor units KLT-40C are shown in Table 2.

Table 2: Basic specifications FPU with KLT-40S.

Parameter characteristics	Value	Parameter characteristics	Value
A type	Propelled boat rack	Draft, m	5.6
Class Russian Register	KEJ [2] A2	Displacement, t	21000
Length m	140.0	Design life, years	38 (3 ekspl.tsikla)
Width m	30.0	The service life before overhaul, years	12
Depth, m	10.0	Repair time, year	1

The fuel used is highly enriched uranium dioxide. Russia has developed fuel enrichment technology, the competitiveness of which is very high on the world enrichment market [12, 13]. So, enrichment value of the Russian market is 24 Doll. USA/kg SWU, in the world - 43 Doll. USA/kg SWU. However, the latest dynamics of the global nuclear fuel cycle market (NFC) development is characterized by a decrease in spot prices for major redistributions NFC and an access to the corporate market with new developments. It leads to a change in the major players in key positions [12, 13]. Summarizing,

it can be concluded that there are unconditional technical-economic advantages of floating nuclear power plant technology.

5. HYDRAULIC STRUCTURES

Waterworks are designed to provide breakout, in normal operation, and transport-technological communication FPU to the shore. Their main functionalities include:

(1) special quay with portions of shore protection length 185 m, which is designed as a set of interconnected structures:

- two piers (fore and aft). Along the length, FPU piers arranged opposite the entrance (exit) of vehicles and feeding pipelines. Mounted on piers attachment structure FPU retaining rod, and in reception areas, with the dispensing energy mediums FPU response mounted transceivers; two wings and sheet pile walls and ensuring the safety of the end portions, the existing shallow embankment and passenger berth; underwater excavation (dredging), if required by the terms of FPU placement. Dredgings (underwater trench) is made of calculation software for 12 years required depth under the bottom margin FPU at all fluctuations of the water level in the water area.

(2) three sections of bank protection sheet pile type.

6. ONSHORE FACILITIES

Onshore FNPS includes the following auxiliary facilities of the station:

- Technical complex building, which are used to accommodate the power distribution and transmission devices to consumers, as well as equipment for the preparation and dispensing consumer heating water;
- auxiliary structures, including ground with two tanks, accumulators hot water capacity of 1000 m3 semi-recessed slurry tank water checkpoint; site fencing, lighting masts;

To ensure the passage of vehicles on the territory of the site there is the construction of roads and platforms with concrete covering, for the passage of personnel - sidewalks. On the coastal territory FNPS, any handling of nuclear materials and radiation-hazardous environments is not provided.

7. CIRCUIT OPERATION FNPS

In accordance with the law on the use of atomic energy, FNPS is a state property. Branch of JSC «Concern Rosenergoatom» «Directorate for the construction and operation of floating nuclear power plants» operates a floating nuclear power plant and the implementation of the electricity and heat produced by it.

Sale of electricity and heat is planned to be based on long-term contracts with the regional energy company and direct contracts with consumers, in accordance with the requirements of the wholesale market. It was revealed that the main consumers of FNPS products are mining companies, leading the development of gold deposits in Chukotka Autonomous District and towns of Bilibino and Pevek.

8. INVESTMENT AND FINANCIAL COSTS

The project's organizational and financial scheme determines the order of formation financial results and the distribution of responsibility for the overall result. Investment Committee of the Russian Federation Budget RF (17%) and JSC «Concern Rosenergoatom» (83%) participate in the project of building floating nuclear power plant. It should be noted, that the main methods used choosing a construction project of nuclear power are LCOE and LUEC, in which discounting factor are laid [6-8,16]. At the moment, when assessing the effectiveness, the rate of discounting of Russian projects is 5%, with proven value of is in 15-25% [9].

In this case, the circuit uses a unique financing project, which is not used in the construction of overseas projects of nuclear energy, as the beneficiary or the final consumer (beneficiary) is a private company (JSC «Concern Rosenergoatom»). The cost of capital of the Investment Committee of the federal budget of the Russian Federation must be equal to zero. Traditional schemes of financing project public-private partnership (PPP) nuclear power provisionally classified into three categories: non-recourse project financing. the balance and the consortium model Mancala [7].

In the case of non-recourse project financing, it is supposed to create a special company with no credit history for the development of design, construction and facility management, financial loan. In this case, the emphasis is on project revenues as a source of loan payments, ensuring that there is a limited list of assets. In the case of balance sheet financing is carried out with full recourse. Specific credit company or

alliance fully responsible for all liabilities. Lenders provide financing at a price determined in accordance with the assessment of the creditworthiness of the company. The essence of the model consortium Mancala is what is responsible for the implementation of the project of NPP construction company is also the owner and consumer of electricity. Design elements of the model are to bring together a consortium EPC contractor, operator and direct consumers of electricity.

The investment performance of the project of building floating nuclear power plant is shown in Table 3.

Table 3: The investment performance of the project construction of floating nuclear power plant.

Indicator	Amount in rubles
Estimated investment in the project, mln. Rub.	30000000000
Subsidies from the state budget	5000000000

Perspective directions of investment in Rosatom isolated projects without funding with implementation period (return on) 5 years [2]. However, unqualified social-economic results in the case of realization the project of building a floating nuclear power plant in Chukotka suggest the desirability of funding from the state. Invested in the development of the region determine the means of favorable investment climate for the private sector.

9. CONCLUSION

Proposed the construction of floating nuclear power plant is a unique source of energy of a new generation, created on the basis of Russian technologies for civilian and military shipbuilding and nuclear power engineering, designed to provide reliable electricity and heat supply in the Arctic zone.

The project of building a floating nuclear power plant will create conditions for the successful development of the mining industry and related sectors of the economy Chukotka, will provide the commercial benefits to all its members and the growth of tax revenues to budgets of all levels, which confirms the effectiveness of the implementation of the directions of formation of clusters of nuclear and non-nuclear technologies.

Shows the project of building floating nuclear power plant will fully meet the energy needs of the system of Chukotka, offsetting, in this case, the outgoing power of Bilibino NPP and Chaun TPP.

FNPS is isolated from other parts of the Far East. Under the development of the power system, mining and the emergence of new industries in the Chukotka Autonomous Okrug reserve capacity is planned, without which it is impossible to invite investors for major projects. In turn, investors are usually interested in projects with the available reserves of power generation necessary for the start of production. Putting a station into operation will allow developing those fields that exist in remote areas, providing electricity to villages and towns in these fields and other infrastructure that is being built around them.

According to the authors, the greatest interest is further declared by the Government of Chukotka Autonomous Okrug Chukotka infrastructure and planned changes in the investment attractiveness of the region.

THE CONFLICT OF INTERESTS

The authors confirm that the submitted data does not contain the conflict of interests.

References

[1] The Resolution of 15 April 2014 No. 321 URL: http://government.ru/docs/11951/ (accessed: 07.12.2017)

[2] PublicreportingofRosatom. URL: http://www.rosatom.ru/about/publichnaya-otchetnost/ (accessed: 07.12.2017)

[3] The General scheme of placing of objects of electric power industry. URL: `https://minenergo.gov.ru/node/8504` (dateaccessed: 07.12.2017)

[4] Russia's energy strategy up to 2035 URL: https://minenergo.gov.ru/node/1913 (date accessed: 07.12.2017)

[5] Airapetova N. G., Saakyan S. P., Tkachenko V. V., Kotkov V. A. Training and professional development of employees of the nuclear industry in the INPE NRNU MEPhI // the Safety, efficiency and Economics of nuclear energy: plenary and sectional reports of the X International scientific and technical conference (MNTK-2016), Moscow, 25-27 may 2016. – M.: JSC "Concern Rosenergoatom". 2016. P. 757-759.

[6] Yegorov A. F., Korobeynikov V. V. Application of multi-criteria analysis for comparison of innovative nuclear energy systems // problems of atomic science and technology. Series: Nuclear-reactor constants. 2017. No. 2. S. 5–14.

[7] T. Ivanov, Yu. V. Chernyakhovskaya Methodology of funding as a component of successful implementation of NPP construction projects /Vestnikivanovskogogo-sudarstvennogoenergeticheskogouniversiteta. 2010. No. 2. S. 80-85.

[8] Klimenko A. V., M. V. L. Ideology and the problems of the system-economic optimization of nuclear power systems // Izvestiyavuzov. Nuclear energy. 2016. No. 1. S. 149-157.

[9] Klimenko A. Q. Can nuclear energy be competitive in a free energy market // Izvestiyavuzov. Nuclear energy. 2013. No. 4. P. 17-28.

[10] Osetskaya M. M. Cluster development of nuclear energy in the regions of presence of the state Corporation "Rosatom" // Economics and innovations management. 2017. No. 1 (64). P.34-36.

[11] Osetskaya M. M., E. V. Galkovskaya Planning production for thermal power plants, hydropower, nuclear power plants Russia // Economics and entrepreneurship. 2017. No. 8-1 (85-1). P. 1085-1090.

[12] Osetskaya M. M., Ukraintsev V. F. galkovskaya, V. E. Management of the fuel component (initial and final stages of the nuclear fuel cycle) cost of electricity in the formation of the production program at nuclear power plants of Russia // Economics and entrepreneurship. 2017. No. 4-2 (81-2). With.590-599.

[13] Osetskaya M. M., Zherdev G. M., Allenykh M. A. Evaluation of the impact of fuel costs on the production program of electric power companies of Russia // Fundamental research. – 2017. No. 10-2. – S. 381-386.

[14] Synzynys, B. I., Mirzabekov O. A., Lavrentyeva G. V., Shoshina, R., Momot, O. A. Assessment of radiation environmental risk and its uncertainty in the biocenosis of the regional radioactive waste storage // Radiation and risk (Bulletin of the National radiation and epidemiological registry). 2014. T. 23. No. 4. S. 43-54.

[15] Cherkasenko A. I. Competitiveness of nuclear energy of Russia on the world market (theoretical and applied aspects): author's abstract of dis.... doctor of economic Sciences: 08.00.14, 08.00.05 / Cherkasenko Andrey Ivanovich. – Moscow, 2009. – 47 S.

[16] Chernyakhovsky Yu. V. Evolution of methodological approaches to the valuation of electricity. The analysis of foreign experience // Vestnikivanovsko-gogosudarstvennogoenergeticheskogouniversiteta. 2016. No. 4. P. 56-68. DOI: 10.17588/2072-2672.2016.4.056-068.

[17] http://www.rosatom.ru/mediafiles/u/files/IX_reg_forum_2016/3._Ipatov_20160510_Obshhestvennyj_forum_po_razvitiyu_Arktiki.pdf (accessed: 07.12.17)

[18] URL: http://чукотка.рф/ (accessed: 07.12.17)