Prospects for the Applying of Nuclear Energy to the Seizure of the Arctic Zone of Russian Federation

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Abstract. The land use planning and management of the Arctic zone (AZ) is among the most significant items on the agenda today in terms of geopolitics and at the same time in terms of economics and technology. For Russia, the AZ is a strategically important part of the country, which occupies a significant territory; as a result, the problem of ensuring the developing of the energy network operating here is one of the priorities. Within this work, an analysis of the energy sector and prospects for its expansion are proposed, with a special emphasis on nuclear energy as the most competitive source of energy in the Extreme North.

Keywords: nuclear energy, Arctic zone, Russia, small nuclear power plants, floating nuclear power stations.

1. Introduction
AZ of the Russian Federation (RF) is regarded among the ones having strategic importance regions of the country. Taking into account the gradual increase in the temperature of the globe, due to human economic activities, there is a gradual melting of permafrost and, accordingly, the opening of new prospects for the use of the physical and geographical features and resource potential of the AZ. Today, many states are striving to gain access to this region and its wealth (both countries that are geographically included in the AZ, such as Russia, Canada, the United States, etc., and countries that do not have their state territory directly in the region, but have sufficient resources for its development, such as, for example, China, Vietnam, the Philippines [1]), in addition to states, TNCs and NGOs conduct an active policy here, all these actors together create a strategically important geopolitical center of attraction in the Arctic. To develop such a complex region from the standpoint of climatic conditions, a stable corresponding infrastructure and energy capacities are required, capable of ensuring the uninterrupted operation of various objects in conditions of low temperatures and low levels of insolation during the polar night. Nuclear energy is one of the directions of energy development that meets the requirements of the environment. Moreover, the high level of development of nuclear energy and related technologies in Russia promote the choice in favor of this energy source.

In connection with everything mentioned, the conducted research revolves around the potential for the expansion of nuclear energy in the AZ of the RF.

Based on the foreseen, the purpose of the conducted study was to identify promising trajectories for the introduction of nuclear energy in the AZ of the RF. In order to accomplish the objective, the below
problems have been solved: 1) analysis of the current energy utilities network of the AZ of the RF; 2) determination of energy requirements for the AZ of RF; 3) analysis of the governmental policy in the sphere of nuclear energy and policy in relation to the development of the AZ of the RF; 4) identification of promising proposals and solutions in the field of nuclear energy.

2. Materials and Methods

This section proposes to refer to the main methods used in preparing the study. Among these, it is important to indicate the analytical (used when studying the features of the existing energy infrastructure), the study of documents (when working with government projects and documents related to field of energy and expansion of the Arctic) and the hypothetical-deductive method (when making assumptions about the tracks for the development of nuclear energy in the AZ of the RF). Taken together the methods used allowed for a comprehensive and multifaceted study.

3. Results

3.1. Thesaurus

To begin with, it seems critical to introduce the key components of the concept for the study. So, by prospects for the use we mean potential applications accompanied by corresponding projects. At the same time, nuclear energy refers to the energy sector engaged in the yield of electricity and heat by converting nuclear energy. Development is proposed to mean the reclaiming of a territory, the creation of an appropriate infrastructure and its maintenance. Finally, the AZ of RF in this study includes the exact climatic zone on the territory of the RF, which starts from 66˚ 33'N \[2\] and stretching to the north, also marked by the presence of Arctic plants and animals, and a graph of the summer isotherm temperature of 10˚C (thus, it includes the Rep. of Sakha, Murmansk Oblast and Arkhangelsk Oblast, Krasnoyarsk Kray, Nenets Avtonomny Okrug, Yamalo-Nenets Avtonomny Okrug and Chukotka Avtonomny Okrug, also including territories in the Arctic Ocean).

3.2. Current Energy Infrastructure in the AZ of RF

The industrialization of the 20th century \[3\] is what has made a great contribution to the active development of the existing energy infrastructure in the Russian Arctic, especially during the Soviet period (mining became more active and the territory acquired a military-strategic importance, which required the development of power grids). The special climatic conditions of the AZ required new technological solutions and constant monitoring of environmental changes, as a result of which the Center for Standardization and Metrology was created, which still exists today, providing monitoring of samples of produced hydrocarbons, the ecological state of the environment, the consequences of climate change, etc. \[3\]. During the Soviet period, most of the key energy facilities were created on the territory, including nuclear facilities, water power plants, fuel-fired power plants of various types, etc.

In the 90s, there was a technological decline and de-industrialization, which affected the energy infrastructure, but in the late 2000s a new milestone of reclamation of the region began, the starting point of is marked by an expedition to the North Pole, carried out in 2007 \[3\]. An analysis of the existing energy infrastructure of the AZ of the RF will be presented below.

Firstly, it is essential to mark that there is no unified energy system in the region (more precisely, it does not have the corresponding characteristic features \[4\]), so there are several isolated systems. Today, diesel generators and thermal power plants are the main source of electricity supplying polar stations located far from the city's main power grid and resource extraction enterprises. However, their use is fraught with a number of difficulties, such as the need for reserves of large amounts of fuel, environmental pollution (the region is regularly cleaned of diesel fuel tanks \[5\], moreover, there is a program to eliminate damage to the environment \[6\], which, reinforces the need to overcome the existing situation), greenhouse gas emissions, etc. The main reason for the use of diesel generators is long experience in their operation, reliability, compactness and relative cheapness of energy production in the AZ climate. Also, in this region, in case of providing large or energy-intensive
facilities with electricity, thermal power plants are used, which have almost all the same set of advantages and disadvantages as diesel generators. There are also a number of problems associated with the extraction and production of hydrocarbons in the country, which require a revision of the use of this type of energy resources for electricity generation. Thus, according to the estimates of the IOGP of the RAS, hydrocarbon production in the Arctic (especially on the shelf) will not be able to compensate for the decline in production at existing fields in the RF [7] due to the depletion of those (it was initially assumed that the region would play a stabilizing role in the dynamics of energy production [8]).

Contrary to the use of existing hydrocarbon energy sources, there is a potential for the expansion of other sources for producing electricity within the AZ of the RF. So, regarding the coast of the Arctic Ocean, there is a potential for the utilization of wind generation, due to high average wind speeds, as well as a higher air density in comparison with other warmer climatic zones [9]. The greatest potential for the development of wind farms in the coastal zone is possessed by the Nenets AD, the Yamalo-Nenets AD, the northern part of the Krasnoyarsk Territory and the Chukotka AD [10]. In general, to date, projects for the development of wind generation are concentrated in the southern and central parts of Russia, but there are a number of projects in the Murmansk Oblast (Figure 1). The main limitation factor in the deployment of wind farms here is the high cost of wind power plants, the need to supply power plants with their own batteries, as well as significant financial costs associated with maintenance.

![Projected total capacity (MW)](image)

**Figure 1.** Projected Total Capacity of Wind Farms (at the end of 2020).

If we talk about the use of solar energy, then its potential may be unlocked by means of high thickness of the layer passed by solar radiation, compared to regions located at lower latitudes, which is associated with a lower solstice above the horizon. Moreover, according to a number of studies, it was revealed that the Republic of Sakha (which is part of the region under consideration) has the highest indicators of solar radiation falling on the surface relative to the Arctic region [11]. The corresponding indicators contribute to the emergence and development of projects for the construction of solar power plants (it is planned to build 64 SPP, with a total capacity of more than 70 MW [12]. Despite the existing plans, building projects of SPPs, equally as in the case of wind farms, are being concentrated in the southern and central parts of the country (Figure 2). However, as mentioned earlier, the development of SPP in Arctic region is restrained by the polar night, during which the SPP will be unprofitable (they will require stranded operating costs, while not producing electricity), moreover, the operation of SPP in low temperatures is quite expensive.
Nuclear energy is an important component of the energy infrastructure and potential directions of development, which will be considered and analyzed in detail in the last section. However, the following should be noted already here. Nuclear energy has key components for the use within this region: environmental friendliness, which prevents pollution of the region, and fuel energy intensity, which contributes to high autonomy [13]. Russia has extensive experience in the exploitation of NPGs, including those in the Far North (for example, we are talking about nuclear icebreakers, nuclear submarines), most of the projects in the AZ were realized within the marine infrastructure, often non-civilian. Nevertheless, land-based civil nuclear power engineering has also found its application. Today in the Arctic region, there are two northernmost nuclear power plants [14]: Bilibinskaya (commissioned in 1974 and as of 2018 produced 212 million kWh with an installed capacity of 36 MW) [15] and Kola (commissioned in 1973 and as of 2020 produced 9,425 million kWh with an installed capacity of 1,760 MW) [16]. In general, the construction and operation of nuclear power plants affects various regions, in contrast to renewable energy sources, including the AZ (Figure 3), moreover, at present, the development of small nuclear power plants (small modular reactors), as well as transportable nuclear power plants are underway.
Despite the commissioning of new capacities, this is not aimed at covering the existing deficit, but at maintaining the existing volume of generating capacities (Figure 4 and Figure 5).

**Figure 4.** GDP growth and electricity consumption in the region.

**Figure 5.** Dynamics of the needs for generating capacities in the Russian Arctic.

When increasing the amount of generating capacities, such factors should be taken into account as the lack of infrastructure for energy transport, especially over long distances; the need to replace or modernize existing energy supply networks (in particular, for example, power supply networks [19] or heat supply networks [20]); the dispersal of objects subject to power supply; the need for uninterrupted operation of energy sources; the need to ensure high autonomy of power plants. Among the significant points to be noted here is the state policy in the region, which is characterized by low efficiency, the increase of which through the deployment of coordinated multilateral projects (for example, the renovation of industrial territories or the creation of new points and growth poles [21]), as well as local projects (we are talking about the use of local energy sources and the creation of a distributed
generation network [22]) can affect the reconsideration in the metrics and quality of the emphasized factors.

3.4. Governmental Policy in the Field
Turning to state policy, it is necessary to highlight the fundamental documents that determine the social and economic modernization of the AZ, as well as documents that determine the vector of development of nuclear energy in the country and in the Arctic in particular. The first group includes the following documents:
- Strategy for the development of the AZ of the RF and ensuring national security for the period until 2020 [23] (defines the main national values of RF in the AZ);
- Strategy for the development of the AZ of the RF and ensuring national security for the period until 2035 [24] (follows up the previous document);
- Fundamentals of the governmental policy of the RF in the AZ up to 2020 and beyond (of the most important aspects related to the topic of this study, this document is aimed at improving the management efficiency of the AZ of the RF, as well as supporting economic entities) [25];
- Strategy for the socio-economic development of the Far East and the Baykal region up to 2025 (aimed at consolidating the population in these regions by creating a developed economy and comfortable living conditions, as well as achieving the country's average level of socio-economic development) [26];
- Energy Strategy of Russia until 2035 (aimed at achieving a qualitatively new state of the energy sector, which will maximally contribute to the dynamic socio-economic development, and ensuring the national security of Russia; the strategy is focused on the development of liquefied natural gas, systems for gas and fuel transportation and on developing the energy system) [27];
- General Scheme for the Placement of Electricity Facilities until 2035 (aimed at preventing the forecasted shortage of electricity and capacity in the most efficient ways) [28].

During the analysis of the documents stated above, it was determined that, to date, there is no necessary consistency between them. So, this problem has several different aspects, including the administrative component, expressed in the absence of consensus between regional and state policies, including the economic component, expressed in the inconsistency of territorial development programs and energy development programs. Perhaps another important aspect should be noted the unstructuredness of plans for the development of territories, resulting in contradictions between them, as well as the recommendatory nature of many of these provisions. In general, based on the state papers, it can be concluded that the government is focused on improving the management system in the Arctic and energy policy, but the existing documents require significant revision in order to increase their efficiency.

Further, moving on to the field of nuclear energy, it is essential to note the document, which determines the direction of such development - the state program "Development of the nuclear power industry complex" involving the State Corporation "Rosatom" and the Federal State Budgetary Institution NRC "Kurchatov Institute" [29]. The main objectives of this program, implemented in course of the goal of backing up the sustainable development of the nuclear power and industrial complex, are the effective development of nuclear generation, the innovative development of the civilian sector of the nuclear industry and the extention of the use of nuclear technologies, the creation and uptick of advanced nuclear and technological infrastructures, the creation and strengthening of the base for thermonuclear research.

3.5. Promising Proposals and Solutions in the Area of Nuclear Energy
Finally, here it is proposed to move on to the analysis of nuclear energy, technologies associated with it and the prospects for its use within the AZ of the Russia. Firstly, it should be marked that in Russia, the nuclear energy sector is actually monopolized (for example, the only player in the industrial production of nuclear reactors is the State Corporation Rosatom and its divisions), due to this feature, the construction and development of nuclear energy in the AZ is being done only with the state
sanction, without which it is extremely unlikely. Nevertheless, state support for the nuclear industry is available and is aimed, in particular, at ensuring the development of nuclear generation in the AZ of the RF [30]. It is also significant that Rosatom State Corporation, vested with powers and functions to track the development and functioning of the nuclear energy infrastructure. Among the main types of nuclear power plants potentially subject to implementation in this region, it is necessary to highlight the following: small nuclear power plants (SNPP) - are most suitable for single industrial enterprises operating in the AZ (for example, oil and gas producing enterprises located on the shelf [32]); transportable nuclear power plants (more specifically, floating nuclear power stations) - which might be utilized to produce electric energy for industrial purposes and objects (continuing until the entire cities, as for instance Norilsk city, for the purpose of reduction of the produced energy cost or, as applied to the introduction of renewable energy sources, in particular, SES, it can be used to compensate shortage of electricity during the polar night) [33] located in remote areas with access to the sea; nuclear power plants of medium and big size - this type of reactors are suitable for cities and power-intensive industrial facilities.

Further, it seems necessary to consider each type of power plant separately. Per the criterion of reliability, independence from the fuel component and environmental impact, SNPP is the most promising energy alternative in comparison with other low-power sources of electricity (SES, wind farms, diesel generators, etc.). The development of projects is exercised by the Rosatom State Corporation, so, in the process of development there are about 20 projects [34]. Existing projects have a high level of adaptability, including placement options (traditional, underground or above water), as well as a wide range of generator capacities (from several to hundreds of megawatts). Compared to other types of nuclear reactors, SNPP has a low construction cost, which reduces risks for energy companies, and also have a simplified decommissioning method [35] and are independent of the organization of logistics and spent fuel storage. In Russia today, SNPPs are implemented using pressurized water reactors (RITM-200) [36], which makes this technology insufficiently promising, since the use of fast breeder reactors is most promising, which, in contrast to pressurized water reactors, allow increasing fuel volumes, thereby reducing uranium mining, which is all the more important for remote and isolated territories or facilities. Another type of energy generators developed under the SNPP is the Shelf type reactors, their main advantage is the use of dry cooling towers, in the absence of access to water resources as a coolant [37], as well as low cost and low number of maintenance personnel, however, as in the case of RITM-200 reactors, the development of this technology may be hampered by the development of breeder reactors.

Within the framework of transportable nuclear power plants, it is proposed to turn directly to the case of floating nuclear power stations (FNPS), which are rapidly growing within the expansion of the nuclear power industry complex. As mentioned earlier, such power plants solve the problem of providing energy to remote, hard-to-reach areas, as well as areas with high risks for the construction of land-based nuclear power plants [38]. Moreover, given the multifunctionality of this type of nuclear power plant, it can be used for desalination of water in case of a shortage of it. As for the reactors used, the existing FNPS (Akademik Lomonosov) uses two reactors of the KLT-40S type (thus, the electric power is 70 MW), however, one should expect the commissioning of a FNPS with RITM-200 reactors, which have already been mentioned earlier within the framework of the SNPP (thus, the total capacity will be 100 MW) [39]. The most perspective places for deployment of this type of energy reactors are the ports of Dikson and Tiksi, oil and gas platforms on the shelf in the Barents and Kara Seas, as well as the Novaya Zemlya archipelago, provided the development of lead-zinc deposits begins [36]. The main limiting factor for the construction of floating nuclear power stations and their operation in the region is the high cost, which raises doubts about recoupment. In this connection, it seems unlikely that the FNPS will be widely used while maintaining the existing technological solutions.

Finally, the last type of nuclear power plants is traditional nuclear power plants of medium and big size. To date, this type of projects is not being implemented in the AZ of the RF, which is primarily due to the high level of costs associated with the climatic and geological features of the region (which
are at the stage of dynamic changes due to global warming and the melting of permafrost). Another factor holding back the potential construction of traditional nuclear power plants in the Arctic is politics, for example, the construction of traditional nuclear power plants is a priority within the portfolio of foreign projects of the State Corporation Rosatom in competition with other large companies, and not within the framework of domestic construction.

4. Conclusion
Speaking about the existing energy infrastructure, it is important to note that it is characterized by remoteness and, often, isolation, and the predominant sources of electricity supply are diesel and hydrocarbons, but there are several projects aimed at the deployment and usage of renewable energy sources and nuclear energy.

There is a deficit of generating capacities in the Arctic, which is many times greater than the existing capacities. State programs and development plans are aimed at doubling the existing capacities, however, given the depreciation of the existing ones at 60%, they will not be able to cover the existing deficit.

As for state policy, it was revealed that there are a large number of documents and programs dedicated to the reclamation of the AZ and installation of energy, but they are contradictory and do not contain a roadmap of specific steps. In the area of nuclear energy exists a program for the expansion of the industry, which is under implementation.

To summarize, it is essential to state that the prospects for the usage of nuclear energy in the region are high for SNPP, which are adaptable and flexible compared to other types of nuclear power plants and renewable energy sources and are more environmentally friendly than hydrocarbon power plants, therefore, they can be widely used. With regard to FNPS, the projects related to floating nuclear power stations are in a somewhat suspended state due to the high cost of the project in the case of application of existing technologies. If ways are found to reduce the cost, then it is likely that in the scope of global warming and the capturing of the NSR, these power plants will become widespread in this region. Finally, referring to traditional nuclear power plants, it should be said that their construction is unlikely in the immediate future under the high costs associated with construction.

References
[1] Krasnozhenova E E, Kulik S V, Chistalyova T, Eidemiller K Yu and Karabushenko P L 2021 How Do Southeast Asian Countries Participate in the Development of the Arctic IOP Conf. Ser.: Earth Environ. Sci. 625 012009
[2] De Witt M, Stefansson HL, Valfell A and Larsen J N 2021 Energy Resources and Electricity Generation in Arctic Areas Ren. Ener. 169 p 144-156
[3] Alexandrov O B 2017 Russian Approach to the Development of the Arctic: History and Geopolitics Russia XXI 4 p 34-53
[4] Stoyanov A 2019 Energy Complex of a Municipality on the Example of Luleå (Sweden) E3S Web of Conf. 140 03005
[5] Volokhov N A, Ryndin I A and Kosmynina N M 2018 Analysis and Evaluation of the Efficiency of Use of Different Electricity Sources in the Conditions of the Arctic Arctics and Its Def. 6 p 283-285
[6] Antyushina N M, Govorova N V 2014 Prospects for Economic Development of the Arctic Zone of Russia Modern Europe 4 (60) p 48-60
[7] Bogoyavlenskiy V Production of Hydrocarbons in the Arctic Does not Compensate for the Decline on Land Available from: http://ipim.ru/discussion/4489.html [Accessed 1st February 2021]
[8] Andreassen N 2016 Arctic energy development in Russia—How “sustainability” can fit? Ener. Res.&Soc. Sci. 16 p 78-88
[9] Popel A S, Kiseleva S V and Morgunova M O 2015 Use of Renewable Energy Sources for Energy Supply of Consumers in the Arctic Zone of the Russian Federation Arctic:
[10] Andrenko T I, Gabderakhmanova T S, Danilova O V 2015 Atlas of Renewable Energy Resources in Russia M.: RKhTU 160 p

[11] Gabderakhmanova T S, Kiseleva S V, Popel O S, Tarasenko A B 2016 Some Aspects of the Development of Renewable Energy in the Arctic Zone of the Russian Federation Alt. Ener.&Ecol. 19-20 p 41-53

[12] Soloviev D A, Morgunova M O, Gabderakhmanova T S 2017 Adaptation of Energy Infrastructure in the Arctic to Climatic Change with the Use of Renewable Energy Sources Energy & Climate 4 p 72-80

[13] Chumakov V 2015 We Say - Arctic, We Mean - "Rosatom" In The World of Sci. 12 p 72-77

[14] Rumyantseva E I, Rumyantseva A V, Suvorov A S 2016 Development of Nuclear Energy in the Arctic: Problems and Prospects Sci. Year Book of the Anal.&Forcast Cent. 1 p 195-200

[15] Bilibin Website Rosenergoatom Available from: https://www.rosenergoatom.ru/stations_projects/sayt-bilibinskoy-aes/ [Accessed 1st February 2021]

[16] Kola NPP Website Rosenergoatom Available from: https://www.rosenergoatom.ru/stations_projects/sayt-kolskoy-aes/ [Accessed 1st February 2021]

[17] Smolentsev D O 2012 Energy development in the Arctic: problems and opportunities for small generation Arctic: Ecol.&Econ. 3 p 22-29

[18] Ivanchenko D S 2016 Nuclear Energy and the Development of the Arctic Young Res. Int. J. 26 p 39-42

[19] Makaridina E V 2017 On the Problem of Energy Security in the Arctic Zone of Russia Bulletin of the Stats. Dep. of Plekhanov RUE p 182-184

[20] Biev A A 2020 Current trends and problems in the formation of heat supply infrastructure in the Russian Arctic IOP Conf. Ser.: Earth Environ. Sci. 539 012146

[21] Pilyasov A N, Putilova E S 2020 A Modern Arctic Resource Project for Russia's Industrial Policy: A Pole of Growth for the National Economy or a “Cathedral in the Desert”? The North and the Market: Form. Of The Econ. Order 3(69) p 4-17

[22] Biev A A, Serova N A 2020 Features of the organization of fuel supplies to the Arctic regions of Russia: assessment of transport conditions IOP Conf. Ser.: Earth Environ. Sci. 539 012017

[23] Strategy for the Development of the Arctic Zone of the Russian Federation and Ensuring National Security for the Period Until 2020 Russian Government Available from: http://static.government.ru/media/files/2RpSA3setElhAGn4RN9dHrztz0A3wZm8.pdf [Accessed 26th January 2021]

[24] Strategy for the Development of the Arctic Zone of the Russian Federation and Ensuring National Security for the Period Until 2035 President of Russia Available from: http://static.kremlin.ru/media/events/files/ru/J8FhckYOPAQQfNx6Xlt6i6XzpTVAvQy.pdf [Accessed 27th January 2021]

[25] Fundamentals of the State Policy of the Russian Federation in the Arctic for the Period up to 2020 and Beyond Russian Government Available from: http://static.government.ru/media/files/A4qP6brLNN175140U0K46x4SsKRHGfUO.pdf [Accessed 26th January 2021]

[26] Strategy for the Socio-Economic Development of the Far East and the Baikal Region for the Period up to 2025 Russian Government Available from: http://static.government.ru/media/files/L1VhVv1lw0VrQ09s5vhGPamkWKBipB8B8.pdf [Accessed 27th January 2021]

[27] Energy Strategy of Russia Until 2035 Russian Government Available from: http://static.government.ru/media/files/w4siegF0iDqGV5YT4lgsApssm6mZRb7wx.pdf [Accessed 27th January 2021]
[28] General Scheme for the Placement of Electricity Facilities Until 2035 Russian Government Available from: http://static.government.ru/media/files/zzvuuhfq2f3OJIkJ8AzKVsXrGlbW8ENp.pdf [Accessed 26th January 2021]
[29] Development of the Nuclear Power Industry Complex Russian State Programs Portal Available from: https://programs.gov.ru/Portal/program/22/passport [Accessed 29th January 2021]
[30] Shulga R N, Petrov A Yu 2019 Possible Ways of Arrangement of the Arctic Ener. Sav. and Water Treat. 4(120) p 51-57
[31] Nechaeva S V, Vorobiev A S 2018 The Development of Carbon-Free Energy as the Basis for Sustainable Spatial Development of Russia Scient. Year Book of the Anal. & Forecast. Cent. 1(2) p 131-135
[32] Belov A M 2019 Application of Nuclear Energy in Arctic Sci., Tech. and Business Coll. of Conf. Mat. 2019 p 6-10
[33] Stoyanov A D and Sakharova A S 2020 Problems of Monocities of the Extreme North and Their Place in the Economic Development of the Arctic Zone IOP Conf. Ser.: Earth Environ. Sci. 539 012071
[34] Rogacheva E A, Prokofiev A I 2020 Energy Supply of the Arctic Zone of the Russian Federation from the Point of View of Small Nuclear Power Development Grad. Stud. 4(55) p 146-148
[35] Sarkisov A A, Antipov S V, Smolentsev D O, Bilashenko V P, Kobrinsky M N, Sotnikov V A, Swedes P A 2020 Small Nuclear Energy in the Context of Transformation of Electric Power Systems News of Higher Education Institutions. Nuclear Energy 4 p 5-14
[36] A Small Nuclear Power Plant Will Be Built in Yakutia by 2028 Rosatom Available from: https://rosatom.ru/journalist/news/k-2028-godu-v-yakutii-budet-postroena-atomnaya-stantsiya-maloy-moshchnosti/ [Accessed 31st January 2021]
[37] Goltsov E N, Kulikov D G, Pimenov A O, Rapnitsky V A 2016 Reactor Installation Shelf for SNPP Innov. Proj. & Tech. of Nucl. Ener.: Coll. of Artic. 1 p 582-586
[38] Solovev D A 2017 Small Energy in the Arctic: Problems of Adaptation and Risks Ener.: Econ., Tech., Ecol. p 14-21
[39] Floating Nuclear Power Stations (FNPS) Rosenergoatom Available from: https://www.rosenergoatom.ru/development/innovatsionnye-razrabotki/razrabotka-proektov-aes-s-reaktorami-novogo-pokoleniya/plavuchie-atomnyye-teploelektrostantsii-pates/ [Accessed 31st January 2021]