**IMPLEMENTATION OF PROJECTS**

**OF NUCLEAR FLOATING POWER UNITS**

**WITHIN THE FRAMEWORK OF**

**MARITIME AND NUCLEAR LAW**

**AND APPROACHES TO REGULATION**

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## Abstract

**The world is facing growing global energy demands and the need to reduce reliance on non-ecological energy sources. Floating nuclear power units (FNPUs) can serve as a flexible and sustainable option for generating power. The identification of FNPUs as nuclear vessels and facilities underlines the need for adherence to international regulations of both the nuclear and maritime law, because the deployment of FNPUs presents unique challenges in terms of safety and optimal regulatory approach. There are no specific nuclear safety regulations for FNPUs in the maritime and nuclear law, moreover the standard scenario for licensing stationary nuclear power plants is not applicable to FNPUs. Operating different types of nuclear vessels, including the first of a kind FNPU Akademik Lomonosov, has provided the unique operation experience. FNPUs comply with safety and regulatory requirements for nuclear vessels, except for those specific to the nuclear power unit, except the distinction that FNPUs are non-self-propelled. The IAEA General Safety Requirements and Specific Safety Requirements seem also to be applicable in general. In the future when more FNPUs operation experience is gained it would be possible to develop special nuclear safety requirements and to adapt the practices of regulating nuclear vessels in relation to FNPUs.**

1. INTRODUCTION

The global community is increasingly talking about the need to find, develop and implement new ways to meet the growing global energy needs which would help reduce the use of traditional energy sources and dependence on unstable market relations within the global energy sector. In the context of accelerating scientific and technological progress and worsening energy problems, nuclear energy is gradually beginning to occupy one of the leading positions in stabilizing the energy sector in line with the global environmental agenda.

Floating nuclear power units (hereinafter – FNPU) are an innovative tool for meeting the needs of various energy systems efficiently, safely and with minimal environmental impact. However, in order to solve the issue of competitiveness of FNPUs in comparison with large-capacity land-based nuclear power plants or land-based nuclear power plants with small modular reactors (hereinafter – SMR), it is necessary to investigate the issue of choosing not only the optimal business model, but also an approach of regulating facilities within the framework of the implementation of international FNPU projects, taking into account the requirements of both nuclear and maritime law.

With regard to the ARIS data base (Advanced reactors information system), developed and maintained by the IAEA's Nuclear Power Technology Development Section since 2009, which contains design descriptions of evolutionary and innovative advanced nuclear reactors, today two thirds of the advanced reactor projects relate to small modular reactors (hereinafter - SMR). On the basis of SMRs, designers from Russian Federation, China, South Korea, the United Kingdom, the USA and other countries are actively developing land-based, submersible and floating projects of small-scales nuclear power plants.

The Russian Federation is the only country in the world where the FNPU *Akademik Lomonosov* is operated. At the same time, there is currently no experience in implementing international FNPU projects. This is, among other things, due to the need to adapt international safety standards for nuclear floating power units, as well as the need to develop a unified approach to regulating FNPUs, since current requirements and existing standards for nuclear power plants cannot be applied to FNPUs "as is".

1. DESCRIPTION OF THE RUSSIAN FNPU PROJECT *FNPU-100* AND THE PRIORITY BUSINESS MODEL FOR ITS IMPLEMENTATION

The *FNPU-100* is the next stage in the development of nuclear floating power units based on marine based reactor units. In comparison with the FNPU *Akademik Lomonosov*, the main dimensions of the vessel, refueling machine, living compartment and fuel storage on board were reduced. There are two pressurized-water reactor units of RITM-200M on the board of the *FNPU-100*. The refuelling interval is increased up to ten years with fuel enrichment of less than 20 percent and the power capacity increased up to 100 MW. The *FNPU-100* can supply electricity to various domestic and industrial consumers.

The *FNPU-100* is a non-self-propelled rack-type vessel with a double bottom and double sides along the entire length of the hull from the forepeak to the afterpeak bulkhead, with a superstructure developed along the length of the vessel, a reactor unit compartment in the middle part of the hull and a block of rooms providing habitability in the bow of the hull. The *FNPU-100* is designed for operation with waterfront structures, including, for example, port infrastructure and power distribution devices.

The Russian Federation has significant reference experience in the design and operation of an icebreaking fleet based on technologically mature Russian developments of pressurized-water reactors.

As part of the implementation of the *FNPU-100* project abroad with regard to its technical features, it becomes possible to use a business model based on a fleet of several FNPUs where each is built at a shipyard in the Supplier State, than FNPUs in a ready-for-use condition transported to a deployment site in the Host State and after the completion of the fuel cycle FNPUs return back to the Supplier State where all fuel handling and vessel maintenance operations are carried out. The operation of the *FNPU-100* at all it's life cycle stages is the responsibility of the operating organization-the owner of the FNPU (a special legal entity established with the participation of legal entities – residents of the Supplier State).

Such a business model assumes that the Host State is responsible for the construction and adaptation of coastal facilities required for electricity transmission from FNPU to the electric power grid system; a contract for the electric power supply under the *take or pay* scheme is concluded between the operating organization, which owns the FNPU, and the organization providing electricity to end users in the Host State. Thus, potential external investment funds and enterprises in different Host States will not bear the risks associated with the operation of a nuclear facility, only the risks associated with the sale of electricity in the Host State.

1. LEGAL IDENTIFICATION OF FNPU IN THE FRAMEWORK OF MARITIME AND NUCLEAR LAW

From the point of view of the prospects for commercialization of FNPUs on international markets, issues of legal support at all stages of FNPU life cycle are of significant importance, which also have a significant impact on the financial and economic model of the project and, as a result, on the competitiveness of FNPU projects as a whole.

At the moment, nuclear floating power units do not have an unambiguous legal classification: in fact nuclear floating power unit is a vessel in relation to the technologies that are planned to be used during floating power units construction, also it is designed and built in accordance with vessel regulations. Also, the Classification Society will assign a certain class and number of the vessel in relation to FNPUs. For example, the FNPU *Akademik Lomonosov* has the following class of the vessel: KE(\*) [2] Berth-connected ship AUT2 А floating power plant. FNPUs will have all the seaworthiness of the vessel and specific "marine" legal characteristics. The result of the classification carried out by the Classification Society should be recognized by all Classification Societies, activities of which are based on common principles laid down by the International Maritime Organization (IMO) within the procedure of work of the International Association of Classification Societies [2].

The IMO is a forum in which Member States exchange information, discuss legal, technical and other issues related to marine navigation. These developments form the basis of maritime conventions and codes. The key issues of international marine navigation covered by the provisions of international maritime law are binding on all participants in relations arising from navigation and other uses of the oceans, therefore, most IMO documents contain the principle of mandatory compliance with the provisions of international agreements for all countries, including those States that are not IMO Members.

There is no single fixed term of a vessel in the IMO documents. Thus, from the definition of a vessel in the International Convention for the Prevention of Pollution from Ships, 1973 (hereinafter – MARPOL-73/78), paragraph 4 of Article 2, it follows that this is an object that is operated in the marine environment, within the framework of MARPOL-73/78, in general, a broad identification of the vessel is assumed, including floating craft, fixed or floating platforms and others [3]. Within the framework of the International Regulations for Preventing Collisions at Sea, 1972 (COLREGs-72), item a of Rule 3, a vessel is identified as a water craft that is used as a means of transportation on water [4]. In particular, the United Nations Convention on the Law of the Sea, 1982 (hereinafter – UNCLOS) and the International Convention for the Safety of Life at Sea, 1974 (hereinafter – SOLAS Convention) do not define term of a vessel.

At the same time, the presence of a reactor unit on board the FNPU allows it to be identified as a nuclear vessel. The SOLAS Convention establishes the basic requirements for the safety international marine navigation, the FNPU as a nuclear vessel falls under the SOLAS Convention. At the same time, according to the SOLAS Convention «nuclear ship» (Chapter I, part A, Rule 2 (j)) is a ship provided with a nuclear power plant. The goal of the nuclear power plant on board the FNPU is not used for propulsion, but it is used for providing consumers with electric and thermal energy. Thus, the safety of FNPUs from the point of view of legal norms is closest to nuclear vessels, but the maritime law also requires improvement. The explanation of the term "nuclear power plant" is not given in the SOLAS Convention, however, the Code of Safety for Nuclear Merchant Ships (hereinafter – Nuclear ships Code) defines a "nuclear ship" as "any merchant ship the normal mode of propulsion of which is based upon nuclear energy and whose characteristics are those of conventional displacement ships", and than the Nuclear Ships Code defines a "nuclear propulsion plant", which means "the total ship main propulsion system, including the nuclear steam supply system" [5]. Also, since the FNPU is a non-self-propelled vessel with a nuclear power unit, with regard to the application of the provisions of the SOLAS Convention, the following contradiction arises: according to the SOLAS Convention (Rule 3 of Part A of Chapter I), nuclear floating power units fall out of the coverage of the SOLAS Convention as they are non-self-propelled vessels. At the same time, Rule 3 of Chapter VIII establishes that nuclear vessels, which also can include FNPUs, under no circumstances can be exempted from fulfilling the requirements of any of the rules of the SOLAS Convention [6].

The IMO requirements enshrined in the UNCLOS, in the Nuclear ships Code for self-propelled vessels with nuclear propulsion plants are applicable to self-propelled civilian nuclear vessels. The FNPUs implementation differs from the experience of operation of self-propelled nuclear vessels, since the nuclear floating power unit is a non-self-propelled vessel and does not use a reactor unit for propulsion. Meanwhile FNPUs meet the safety requirements for nuclear vessels of the Nuclear ships Code, with the exception of those that relate to a propulsive nuclear power plants.

Currently, there are no specialized requirements for nuclear floating power units in the sphere of maritime law and in the field of nuclear safety. According to the IAEA Statute this organization defines and develops standards of safety for all types of nuclear facilities. The IAEA safety standards are constantly being improved. Currently, there is a system of Safety Standard Series, which has been developed since 1996 on the basis of a common approach and has a pyramid structure. At the top of the pyramid are the Safety Fundamentals (SF), which set goals and principles of safety. This is followed by General Safety Requirements (GSR) for all nuclear facilities and activities. Then there are the Specific Safety Requirements (SSR) applicable to specific nuclear facilities and activities. The pyramid is completed by General Safety Guides (GSG), which are intended for all nuclear facilities and activities, and Specific Safety Guides (SSG), applicable to specific nuclear facilities and activities [7]. Meanwhile these standards are non-binding. It is worth noting that in the period 2021-2022 at the IAEA site, within the framework of the SMR Safety Working group, an analysis of GSR, SSG, SSR to non-water cooled reactors and SMRs, including transportable SMRs, was carried out. In 2023 a final report of Working group was released with the results of the study "Safety Report on Applicability of Safety Standards to Non-Water-Cooled Reactors and Small Modular Reactor". Based on the results of the analysis, the IAEA experts concluded that SSR and GSR are more applicable to nuclear power plants with small modular reactor, including transportable SMRs. At the same time, a list of standards was identified that are not fully applicable to non-water-cooled reactors, in particular to liquid salt reactors and "floating" reactors. I.e., the IAEA standards themselves require improvements or the development of analogues in relation to FNPUs and a number of other innovative technologies [8].

It is worth noting that there is no clearly structured hierarchy of regulatory documents within the framework of the IMO documents, as it is provided for by the IAEA Safety Standards Series.

Analysis of international law indicates that there are no prohibitions on the FNPUs implementation. However, the application of the IAEA nuclear safety standards for large-capacity land-based nuclear power plants to FNPUs is associated with a number of limitations. So the vessel's design of FNPUs and its implementation model involve the FNPUs transportation (from the site of construction in a Supplier State to the operation site in a Host State and back). It includes a review of ensuring nuclear safety during FNPUs transportation.

The existing standards for ensuring the safety transportation of radioactive material in packages are also not applicable to FNPUs. So in contrast to packages, the safety concept of the RITM series reactors is based on the defense-in-depth protection principle in combination with its inherent safety characteristics. In addition, external impact scenarios and methods of managing them will differ significantly for packages and FNPUs. Therefore, it is advisable to compare the transportation of radioactive material in packages and as part of reactor units on board an FNPU only for the purpose of demonstrating the performance of certain safety functions (for example, retention of nuclear material) during normal operation, and in emergency situations, the general approaches and criteria differ significantly.

In view of technical features and the issue of classification of FNPUs, nuclear floating power units are regulated both by the maritime law and nuclear law. Within the framework of these it is necessary to form unified approaches and interrelated documents in order to ensure nuclear safety of the FNPUs operation.

1. DEVELOPING OF INTERNATIONAL APPROACHES TO SAFETY OF FNPU

Within the framework of existing work on international sites, there are two approaches to the development of the nuclear and maritime laws with regard to non-self-propelled floating nuclear power units.

On the one hand, it is possible to adjust the IAEA standards, in particular the SSR-6 "Regulations for the Safe Transport of Radioactive Material" (hereinafter – SSR-6), in order to introduce a special section on safety standards for FNPUs. At the same time, a performance approach is applied to FNPUs as nuclear vessels, where the requirements set general safety goals and objectives, the rules are less detailed, and the specific way to achieve the goals remains with the FNPUs operating organization. So the inclusion of a section in the SSR-6 dedicated to nuclear floating power units will violate the original structure of the document. Also, taking into account the FNPUs classification, the question of attributing a reactor loaded with nuclear fuel to a new type of package becomes irrelevant. In addition, the SSR-6 requirements apply only to the FNPUs transportation, and regulation of nuclear floating power units is required at all stages of the life cycle. Also, the mechanism for the correlation of the SSR-6 requirements with those in the field of the maritime law is not clear.

In this regard, the development of specialized nuclear safety requirements for FNPUs seems to be an optimal alternative to the SSR-6 revision. In particular, it is possible to create a separate IAEA document in order to integrate these requirements into the documents of the maritime law, for example, in the form of a separate legally binding international code on the safety of floating nuclear power units. Such work should be carried out with the IMO experts as experience in the operation of FNPUs is accumulated. At the same time, in the course of developing regulatory approaches to international FNPU projects, both the requirements of the Nuclear ships Code and the IAEA Specific Safety Requirements can be used.

1. APPROACHES TO REGULATION OF INTERNATIONAL FNPU PROJECTS

The practice of implementing projects in the nuclear industry demonstrates the use of two main licensing and regulatory models, certain distinctive features of which can be taken into account in each specific case of interaction between the Supplier State and the Host State during the regulation of international FNPU projects with regard to the to the potential use of a new business model for their implementation. This logic will allow, in each specific case of such kind of interaction between the Supplier State and the Host State to take into account the specific requirements of the designer and supplier of the technology, and also particular needs of Host States and consumers of electricity. At the same time, taking into account the prospects for serial manufacturing of FNPUs and the imperfection of existing approaches, it is still important to assert the need to develop a new unified approach to the regulation of international FNPU projects.

Thus, the experience of licensing large-capacity land-based nuclear power plants during construction on a foreign operation site can be adapted to FNPUs in such a way that the FNPU is transported to the Host State, moored to waterfront structures, than a new object that can be defined as a nuclear power plant is formed in the territory of the Host State. Further, the operating organization, specially created within the framework of the national legislation of the Host State, goes through all the necessary procedures provided for by the national nuclear regulator in order to obtain an operating license. At the same time, throughout the entire stage of the licensing procedure, the object must comply with the national standards of the Host State. The responsible organization of the Supplier State can assist the operating organization of the FNPU in preparing the relevant documents and passing the licensing procedure.

A different regulatory scenario is based on the experience of the nuclear vessels *Savannah*, *Otto Hahn*, as well as Russian nuclear icebreakers and the FNPU *Akademik Lomonosov*. Its main advantage is that this scenario fully takes into account the features of the transboundary movement of a FNPU during its life cycle. In particular, under this scenario, a FNPU that has on board the necessary certificates confirming its identification as a nuclear vessel, also has an operating license, which is issued by the nuclear regulator of the Supplier State to the operating organization, which is also a legal entity of the Supplier State. In this case, the movement of an FNPU from the Supplier State to the Host State is considered as a stage of its operation and is covered by the operating license. In order to enter the territorial waters and the port of the Host State, the nuclear vessel provides the Host State Administration with the necessary documents in advance to indicate the safety of the object. This procedure, carried out according to all the rules defined in international documents on the maritime law, will allow a nuclear vessel to successfully cross the borders of the territorial waters of the Host State and enter its port. Thus, the operating organization of the Supplier State is responsible for the operation of the FNPU in the Host State. At the same time, the possibility of operating a nuclear facility by a legal entity registered abroad must be permitted by the national legislation of the Host State.

Despite the fact that the regulatory scenario, by analogy with nuclear vessels, looks preferable for the FNPU, at the moment issues related to the regulative procedures for recognition by the competent authority of the Host State of posting information on the safety of the FNPU, which is verified by a foreign regulator, as well as the regulation of supervision procedures and the division of areas of responsibility in matters of control over the safety of operation on the territory, need to be worked out the countries where the object is located with a foreign jurisdiction. Since the solution of these issues affects not only the security sphere, but also intellectual property law and commercial confidentiality, this requires a full-fledged analysis with the participation of experts from various fields and will be resolved at the level of national legislation.

In addition, even if the basic principles of the nuclear vessel regulation model are followed, it becomes quite obvious that it is necessary to develop programs of bilateral cooperation between regulators of both the Supplier State and the Host State in order to develop and subsequently implement a program of nuclear regulatory infrastructure in the Host States during the implementation of FNPU projects and in order to regulate the procedure for transport FNPU between different jurisdictions. In order to ensure the full and effective development of regulatory frameworks in various Host States, regardless of the degree of development of the nuclear energy sector, the formation of international recommendations that take into account the reference experience of interaction between regulators can play an important role in the formation of support mechanisms for nuclear regulators in Host States.

1. CONCLUSION

Floating nuclear power units can serve as a solution to the issue of energy supply for various consumers, and therefore interest in them from newcomer countries in the field of nuclear energy is constantly growing.

With regard to the novelty of FNPU projects and the lack of extensive international experience in the operation of such objects, there is currently no international regulatory framework that would fully cover, describe and regulate all aspects of the FNPU life cycle. In this regard, the key issue is the legal identification of FNPUs within existing terms and legal documents, since the identification will determine the requirements, including from the point of view of safety, and, as a result, may have an impact on the economic characteristics of FNPUs and its competitiveness.

Given the maturity of the pressurized-water reactor technology the IAEA has an extensive system of relevant Safety standards that are generally applicable to FNPUs’ pressurized-water reactors. At the same time, the safety of the object should be assessed comprehensively, taking into account vessel's decisions, which requires involvement in the analysis of the maritime regulatory framework. The basic requirements for self-propelled vessels with nuclear power units are defined in the SOLAS Convention and the Nuclear ships Code, however, the applicability of these documents to non-self-propelled FNPUs, despite their technical feasibility, is limited by existing definitions.

The definition of a FNPU as a vessel with a nuclear power unit also opens up the possibility of using regulatory approaches adopted in maritime law, which makes it possible to increase the efficiency of regulating an object moved between operating sites during its life cycle.

As experience is gained during the implementation of pilot projects, the most successful practices can be consolidated in a special regulatory framework established under the auspices of the IAEA and the IMO.

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