# General approaches to physical protection of small modular reactors

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**Abstract**

The responsibility for establishing its own physical protection regime of nuclear material and nuclear facilities rests entirely with the State.

As with other nuclear facilities, any type of small modular reactors requires implementation of physical protection measures.

The establishment of a physical protection system for small modular reactors should be based on the fundamental principles and categorization of nuclear material defined by the Convention on the Physical Protection of Nuclear Material and Nuclear Facilities. Based on the category of nuclear material used, the physical protection system of a specific atomic energy facility is being established.

New technologies of small modular reactors have a number of differences, including their compactness, mobility and the ability to be located in remote regions. The compactification of nuclear technologies implemented in small modular reactors should not mean an automatic and proportional reduction in the amount of funds and resources required to ensure their physical protection (such as the installation of engineered features, hiring and training of physical protection personnel, the cost of maintaining an effective physical protection system).

General approaches to and possible challenges for maintaining physical protection of small modular reactors will be set forth in the paper.

## Introduction

When discussing the issues of ensuring the physical protection of nuclear material and nuclear facilities, it should be borne in mind that the only legally binding document at the international level is the Convention on the Physical Protection of Nuclear Material and Nuclear Facilities, as amended (A/CPPNM). In accordance with the A/CPPNM, each State itself determines the physical protection regime of nuclear material and nuclear facilities on its territory [1]. At the same time, within the framework of this responsibility, States determine the procedure for categorizing nuclear material, as well as establishing levels of radiological consequences, which serve as initial data for the development of physical protection systems for nuclear facilities.

Small modular reactors (SMR) are a new type of reactors. According to IAEA publications [2], these are reactors with a capacity of up to 300 MW, the components and systems of which can be manufactured in advance and then delivered as modules to the site for installation as needed. They have great potential for generating electricity and other peaceful purposes that do not require the construction of high-power nuclear power plants. It is precisely the variety of such tasks that causes greater interest in SMR.

The SMR configuration has a number of features. A reduced footprint, technologically connected auxiliary facilities, a compact reactor plant and its control sites - all this requires the universalization and adaptation of existing solutions in the field of physical protection. At the same time, the SMR physical protection system should be effective, taking into account the design basis threat which is typical of the SMR placement location.

The Russian Federation has successfully found all the necessary solutions to such a difficult task.

Our country has a unique experience in the operation of a marine-based SMR physical protection system. The floating power unit (FPU) named after Academician Lomonosov is located in the city of Pevek. Together with the coastal infrastructure, the FPU forms a floating nuclear thermal power plant (FNTPP). The paper will outline the challenges faced by Russian organizations in developing a physical protection system of the FNTPP.

## Small modular reactors features

To begin with, it is necessary to describe the SMR in general terms. These types of reactors can meet the need for flexible power generation for a wider range of users and applications, including replacing aging fossil fuel power plants, providing cogeneration in developing countries with small power grids, remote areas and areas not included in the general power grid, as well as the development of hybrid energy systems based on nuclear and renewable energy.

According to the IAEA [2], there are currently more than eighty (80) SMR projects under development and deployment at various stages in 18 countries, including the Russian Federation, China, Argentina and the United States. Such SMR projects can generally be divided into three broad categories:

* *Land–based –* reactor designs involving onshore deployment that use technologies related to most operating large nuclear power plants*;*
* *Maritime–based* – reactors that can be installed on a floating platform or on an underwater platform. An example of this category is the KLT-40S installed on the ‘Akademik Lomonosov’, which is the first SMR connected to the power grid;
* *Micro-reactors* – reactors designs, the range of electric power of which is usually up to 10 MW (electric). Their intended niche is the provision of electricity to areas not connected to the power grid, rapid deployment in the event of natural disasters to ensure the operation of critical infrastructure (e.g. hospitals, water purification, etc.) [2].

SMR designs can also be classified by type of coolant.

As you can see, already at the typology level, SMRs have a great variety. The special characteristics of SMR inevitably lead to the fact that the organization of measures to ensure their physical protection has its own features.

## FEATURES OF organizing THE ACADEMICIAN LOMONOSOV FPU PHYSICAL PROTECTION SYSTEM

Rosatom State Corporation believes that the requirements for organizing physical protection of nuclear materials, which are given in the A/CPPNM, and the approaches to nuclear security set out in the IAEA documents [3], are fully applicable to reactors of this type. There is no fundamental difference from organizing physical protection of various types of reactors. The fundamental parameters for determining the configuration of the physical protection system and physical protection measures are, as already mentioned, the category of nuclear material, as well as the consequences of radiological exposure.

At the same time, the features of the SMR force to work out physical protection measures in more detail at each stage of the life cycle of the SMR’s PPS, and most importantly, to fully apply the ‘security by design’ approach. Turning to the experience of developing a physical protection system of the Russian FNTPP, here are just some of the features:

* *Construction of a floating power unit.* One of the fundamental issues determining the configuration of the PPS is the definition of the most complex intruder model throughout the life cycle to determine the physical protection measures of the FPU for years to come. Such a PPS is created during the construction of the vessel and is only being upgraded further.
* *Transportation and loading of fuel.* The ‘Akademik Lomonosov’ FPU was built at the shipyards of St. Petersburg, then transported to Murmansk, where fresh nuclear fuel was loaded. The rest of the route to the berthing location in Pevek was made by the FPU through the internal waters of the Russian Federation. In this regard, only Russian national standards in the field of physical protection were applied.
* *The place of operation*. The place of operation of the SMR is of fundamental importance in the organization of physical protection measures. In the Russian Federation, various approaches are used to ensure the physical protection of ships with nuclear power plants, stationary nuclear facilities, as well as nuclear materials during their transportation. The pier for the PEB is equipped with a separate independent PPS, which can operate autonomously. In the same way, the FPU’s PPS operates autonomously, which is a non-self-propelled vessel during transportation. After mooring the FPU at the pier, both PPS are combined into a single one.
* *Functioning of the PPS.* The climatic and temporary conditions of the PPS operation should also be taken into account in advance at the stage of the PPS development. In addition, given the harsh weather conditions of the North, we paid a lot of attention to the comfortable and effective stay of the security forces at the FNTPP. A separate infrastructure has been developed for them. The technical means of physical protection of FPU and of pier have passed additional tests in advance, and appropriate certificates confirming the possibility of use have been obtained for them.

### Features of place of operation of the FNTPP

First of all, it is necessary to clarify the terminology. The floating power unit ‘Akademik Lomonosov’ is a non-self-propelled vessel that remains so throughout its life cycle. After mooring the FPU at the pier and connecting to onshore hydro-technical facilities, the FPU becomes a floating nuclear thermal power plant - a FNTPP.

The principal feature of the FNTPP is that the power unit is located on water. This significantly influenced the development of the design basis threat and the definition of a way to implement potential threats. In this regard, the choice of technical equipment providing physical protection of the water area played an important role.

In addition, the location of the FNTPP forced a review of the lighting system, which during the polar night should be bright and allow the video surveillance system to clearly record the movement of objects both on the territory of the FNTPP and in the surrounding area.

### Features of the construction of FPU and FNTPP

The construction of the FNTPP took place in several stages:

* Construction of a vessel without a nuclear installation;
* Towing of the manufactured vessel to the port of Murmansk;
* Loading of nuclear fuel;
* Towing a vessel with nuclear fuel to the place of operation;
* Connection of the FPU to the coastal infrastructure and commissioning.

Based on the analysis of regulatory documents and in order to strictly comply with the requirements of the A/CPPNM, the IAEA recommendations and the legislation of the Russian Federation, fuel for the FNTPP was loaded at one of the organizations of the Rosatom State Corporation, which has the appropriate license from the Russian regulatory authority, and in which all requirements for physical protection were met.

Before loading nuclear fuel onto the ship, its physical protection system was commissioned. Also, before the arrival of the FPU to the place of operation, the PPS of the coastal infrastructure was put into operation. The unified PPS was also commissioned before the physical start-up of the nuclear installation.

### Features of transportation

From August 25 to September 14, 2019, four power units with two KLT-40S reactors were successfully transported from Murmansk to Pevek, where they are currently in operation. Transportation was carried out with loaded fuel and the crew on board by towing by water.

During the construction, special attention was paid to ensuring the physical protection of the FPU work site:

* taking into account the potential consequences of malicious acts;
* the response forces were fully prepared;
* access control regime was organized.

It should also be noted that in order to ensure an appropriate level of physical protection during transportation, a certain set of documents has been developed, which is necessary in accordance with Russian legislation. The developed documents included:

* Transport security plan;
* Contingency plans;
* Written instructions for physical protection personnel.

### Features of development of the documentation for PPS

It is also worth mentioning the topic of developing documents on the PPS.

The specifics of physical protection measures for SMRs in the Russian Federation are defined by federal rules and regulations of Rostechnadzor.

According to the practical experience of the Russian Federation and after proper analysis, some minor changes have been made to the current regulatory requirements for the PPS of ships with a nuclear power plant, reflecting some features of the application of the general requirements for the FNTPP PPS as a new type of nuclear facility.

For ‘Academik Lomonosov’, three sets of documents were developed that define measures to ensure physical protection and/or the configuration of the PPS:

* Directly for PPS of the FPU,
* For transportation of FPU to the place of operation;
* For the operation of the FPU as part of the coastal infrastructure.

## Conclusion

The general design methodology and the definition of the necessary physical protection measures, as well as the justification for the configuration of the PPS, are similar for different types of nuclear facilities. SMR is no exception.

The experience of developing physical protection measures for SMR allows us to form new practices when the PPS is designed and developed for each SMR based on its place of operation and transportation route.

Currently, both the A/CPPNM and the IAEA publications on nuclear security are fully applicable to SMR. The experience of operation of the ‘Akademik Lomonosov’ FNTPP confirms this point.

Currently, the Russian Federation is actively working to promote the safe operation of SMR around the globe. Our proposal also includes the development of an effective turnkey PPS based on existing experience.

We call on all States to continue developing international cooperation in the field of the SMR development.

Rosatom State Corporation is ready to cooperate with foreign partners in this field, using best practices to develop a secure future.

References

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3. IAEA Nuclear Security Series No. 13, Nuclear Security Recommendations on Physical Protection of Nuclear Material and Nuclear Facilities (INFCIRC/225/Revision 5), IAEA, Vienna (2012).