**REGULATORY CONTROL FEATURES AND PRINCIPLES FOR the DESIGN of a LAND-BASED SMALL-SIZED NPP INCORPORATING the RITM‑200N REACTOR PLANT**

Ya.O.Bykh

Afrikantov OKBM JSC

Nizhny Novgorod, Russian Federation

Email: [okbm@okbm.nnov.ru](mailto:okbm@okbm.nnov.ru)

I.V.Yurina

Afrikantov OKBM JSC

Nizhny Novgorod, Russian Federation

Email: okbm@okbm.nnov.ru

D.V. Shchekin

Afrikantov OKBM JSC

Nizhny Novgorod, Russian Federation

Email: [okbm@okbm.nnov.ru](mailto:okbm@okbm.nnov.ru)

**Abstracts**

The RITM-200N reactor plant design for the land-based small-sized NPP is based on the engineering solutions for a marine RITM-200 reactor plant. The issue arose as to the compliance of the RITM-200N reactor plant engineering solutions with the requirements of the current legislation of the Russian Federation in the field of atomic energy use for NPPs. In order to bring the engineering solutions for the land-based small-sized NPP incorporating the RITM-200N reactor plant in line with the current Russian regulations, to eliminate the risks of untimely obtaining a construction license, as well as to take into account the requirements and recommendations of international regulatory documents, a decision was made to establish within State Atomic Energy Corporation ROSATOM the Inter-Industry Working Group on Regulatory Documentation used in the land-based small-sized NPP design equipped with the RITM-200N reactor plant.

## INTRODUCTION

Small-sized nuclear power plants (small-sized NPPs) are one of the most promising directions for the development of energy technologies in the field of atomic energy use.

The Federal Project “Design and construction of reference power units for NPPs, including small-sized nuclear power plants” of the State Program of the Russian Federation “Development of the Nuclear Power Generation Complex” provides for implementation of the pilot small-sized NPP based on the RITM-200N reactor plant in the territory of Russia near the village of Ust-Kuiga, Ust-Yansky ulus, the Republic of Sakha (Yakutia), Russia.

The RITM-200N reactor plant design has been developed by Afrikantov OKBM JSC on the basis of engineering solutions taken from the RITM-200 reactor plant design for multipurpose nuclear-powered icebreakers which are operated at the moment as part of nuclear-powered icebreaker fleet of the Russian Federation.

The main distinguishing feature of small-sized NPP designs is the use of small modular reactors that feature enhanced inherent safety due to introduction of innovative technical solutions and the predominant use of systems based on passive operating principles.

In this context the world community and international organizations such as IAEA, WENRA and EUR are actively discussing the possibility and specifics of applying the current regulatory requirements to the regulation and safety assurance of small modular reactors.

The developers of the small-sized NPP design incorporating the RITM-200N reactor plant interacted with the Federal Service for Environmental, Technological and Nuclear Supervision (Rostekhnadzor); within the framework of this interaction multiple discussions took place regarding the application of the requirements of the Russian regulatory legal acts and regulatory documents in the field of atomic energy use for the small-sized NPPs.

## Marine reactor plant RITM-200

The Russian Federation has a significant advantage over other countries and is the world leading marine reactor plant producer. In nuclear shipbuilding technologies, a special concept of a modular reactor plant has been formed, which is characterized by an extremely small footprint required to accommodate a steam generating plant in a limited space of the reactor compartment, maneuverability, leak-tightness, low amount of radioactive waste, enhanced reliability and survivability.

Marine reactor plants RITM-200 are the latest development of Afrikantov OKBM JSC in the Generation III+ SMR lineup. While possessing all the best characteristics of their predecessors, these reactors are based upon the time-tested pressurized water reactor (PWR) technology and upon of State Atomic Energy Corporation ROSATOM’s 400-reactor-year operating experience with small-sized reactors onboard icebreakers. Eight RITM-200 reactor plants have been installed on icebreakers *Arktika*, *Sibir*, *Ural* and *Yakutiya*. The lead icebreaker *Arktika* with two reactors on board was commissioned in October of 2020. The first in the series, the icebreaker *Sibir,* was commissioned in January of 2022. In late 2022, the icebreaker *Ural* was commissioned. The construction of two icebreakers of this class is being completed— the icebreaker *Yakutiya*, to be commissioned in 2024; and the icebreaker *Chukotka*, to be commissioned in 2026 There are plans to build two more serial icebreakers to be commissioned by 2030.

The concept and technical solutions of RITM-200N RP, developed by Afrikantov OKBM JSC, which are employed in the configuration of the new all-purpose nuclear icebreakers, are basic to the RITM-200N RP design for a pilot land-based small-sized nuclear power plant [1].

## Main Design Provisions of the RITM-200N reactor plant

RITM-200N RP is based on the main reference technical solutions of RITM-200 RP, such as sealed primary circuit. To ensure the tightness of the primary circuit, sealed main circulation pumps, sealed (in terms of the absence of blowdowns) steam generators, high-speed localizing pneumatic actuators, as well as gas pressurizing systems for the primary circuit and a self-sustaining ammonia water chemistry are used.

The reactor layout was developed with placement of the main circulating path equipment in the integrated vessel which is a combined vessel consisting of a reactor body and four hydraulic chambers. These bodies are connected with each other by welding with short power nozzles made according to the "pipe in pipe" type. The core, the steam generators made of titanium alloy are placed in the reactor vessel. The CRDM drives are placed on the reactor vessel cover.

The main circulation pumps (MCP) with valve boxes are installed in the hydraulic chambers. In the PCP design, the design solutions widely applied in the designs of the prototype electric pumps, which passed testing during long-lasting operation on operating marine reactor plants, have been implemented to the maximum.

Four steam generators are placed in the integral reactor vessel. Each SG consists of three cassettes, interconnected by feed water and steam. The SG cassette is a direct-flow, vertical, straight-tube heat exchanger of the surface type. Cassette design has been developed based on the solutions which have proved their operability with a big scope of R&D implementation, as well as with the experience of operating similar items.

The main equipment of RP operating under the primary circuit pressure (integral reactor, volume compensation system, purification and cooldown system, segments of reactor coolant system pipelines etc.) are assembled inside steel containment of leak-tight enclosure of RP. The layout of the main equipment and systems of the primary circuit is made on the metal-water protection tank, similarly to marine reactor plants.

Features of the layout and operation of propulsion plants required the development of a specific method for refueling the cores of propulsion reactor plants, the so-called "ship" method of refueling without using a refueling machine, as well as the development of specific container equipment for this method of refueling.

## SNPP with the RITM-200N reactor plant

Currently, the Russian Federation is implementing a pilot industry-wide project titled “Construction of a small-sized nuclear power plant based on the RITM-200N reactor plant.” The RITM-200N SNPP project is included in the general siting schematic for electricity generating facilities and the Russian Federation territorial planning scheme.

Objectively, there are some factors that are to be taken into account in development and operation of the RITM-200N reactor plant in configuration of SNPP (solutions for ensuring safety and economic efficiency, regulatory database, features of operation, etc.).

The enhanced safety characteristics are achieved by a combination of defense-in-depth implementation, inherent safety properties and balanced application of active and passive safety systems. Such approach prevents a maximum number of risks, reduces probability of heavy accident and minimizes its consequences if an accident still takes place.

The equipment and pipelines of the RITM-200N reactor plant remain operational during an earthquake with an intensity of 8 points as per the MSK-64 scale, and with a maximum design earthquake with an intensity of 9 points as per the MSK-64 scale, they retain the ability to perform functions related to ensuring the safety of the reactor plant. All RP equipment is designed taking into account the operation model of a power unit operating in a local small energy grid [2], [3].

## Arrangement of the activities aimed at regulatory support of the project

During development of the project of SNPP incorporating the RITM-200N reactor plant the question arose as to how conformity of the marine technical solutions to the requirements of the effective Russian legislation, standards and regulations in the field of atomic energy use for NPPs could be provided.

In order to bring the technical solutions for SNPP incorporating the RITM-200N reactor plant in line with the efficient Russian Federal Standards and Regulations, and to to eliminate the risks of untimely obtaining a construction license during design of SNPP, as per the efficient Federal Standards and Regulations in case of deviations from/inconsistencies with the efficient Russian Federal Standards and Regulations, a decision was made to establish the Inter-Industry Working Group on Regulatory Documentation used in SNPP design equipped with the RITM-200N reactor plant.

The Inter-Industry Working Group on Regulatory Documentation does its activities in parallel with development of SNPP design.

The key feature of these activities is the pursuit of norm-setting activities in parallel with the facility design development to exclude the risks of untimely receipt of the license for construction of SNPP and justification of safety based on the decisions made.

The main vectors of the working group’s activities are:

- to analyze the compliance of the design solutions adopted for the SNPP with a the RITM-200N reactor plant with the requirements of the federal rules and regulations and to form proposals on introduction of changes in the Federal Standards and Regulations;

- to develop State Atomic Energy Corporation ROSATOM's standards and to include the regulatory documents for the materials into the "Consolidated list of standardization documents”;

- take into account in the design the requirements and recommendations set in foreign regulations due to the fact that the SNPP project is export-oriented [4].

## The results of analyzing the conformity of the technical solutions in the RITM-200N reactor plant for SNPP to the requirements of the regulatory documentation of the Federal Standards and Regulations in the field of atomic energy use for large NPPs:

In 2019 and 2020 a preliminary analysis of conformity of the technical solutions used for the marine reactor plant RITM-200 to the requirements of the Federal Standards and Regulations in the field of atomic energy use for NPPs was performed. Several fundamental non-conformities were found in the SNPP project with RP RITM-200. They seem to be unavoidable without changing the project concept dramatically, improving it or issuing new regulatory documents.

In 2021 during development of non-conformity analysis a decision was made to create a unified and all-purpose format for revealing of non-conformities, evaluating and classifying them and further developing of compensating measures.

The order of performance of non-conformity analysis and development of compensating measures as well as the recommendations for composition and content of the report on the performed analysis are specified in the safety manual for using atomic energy “The analysis of non-conformities of nuclear plant unit to the requirements of the efficient regulatory documents” as per the recommendations of document РБ-028-04.

The approach given in РБ-028-04 regarding formulation of more global safety issues based on the existing non-conformities of NPP unit, as well as the approach to the prioritization of the safety issues is completely applicable to the designed units. Meanwhile, the approach to development of compensating measures is often not applicable to innovative design solutions considering which it is feasible to provide for the possibility of changing the requirements of Federal Standards and Regulations which were developed obviously without consideration of such innovative technologies.

The report “Analysis of SNPP non-conformities to the requirements in the applicable regulatory documentation in the field of atomic energy use in the part of the RITM-200N reactor plant”) developed in accordance with recommendations of the regulatory document of РБ-028-04 was issued in 2022 by the project developers. The given report was aimed at revealing the non-conformities of the technical solutions for SNPP with the RITM-200N reactor plant to the requirements of the Federal Standards and Regulations in the field of atomic energy use for NPPs, then analyzing them and preparing suggestions for correction of the technical solutions used for reactor plant, correction of the existing and/or development of new regulatory documents for SNPP. The development of the Report is also aimed at confirmation of compliance with requirements It. 1.2.2 НП*(NP)*-001-15 in part of nuclear plant safety assurance due to compliance with the requirements of federal laws, Federal Standards and Regulations in the field of atomic energy use.

During analysis of non-conformities of SNPP with RITM-200N with the requirements of the efficient regulatory documents the non-conformities impacting safety were found (as per terminology of РБ-028-04, having consequences).

Based on the analysis of the revealed non-conformities 9 safety issues were stated, their significance was assessed with consideration of various factors having impact on safety of SNPP.

The safety issues categorized by the classes of importance as “high” and by the degree of influence on the power unit safety were not revealed. 2 issues were categorized as “medium” , and 7 issues were categorized as “insignificant”.

The prevailing number of non-conformities in the RITM-200N SNPP project which seem to unavoidable without changing the project concept dramatically, improving it or issuing new regulatory documents, are focused on the following documents:

– НП*(NP)*-082-07 “Nuclear safety rules for reactor installations of nuclear power plants”**;**

– НП*(NP)*-084-15 “Regulations for inspections and testing of base metal, welded joints and weld-deposited surfaces during operation of equipment, piping and other elements of nuclear power plants”;

– НП*(NP)*-089-15 “Rules of design and safe operation of equipment and pipelines of nuclear power installations”;

– НП*(NP)*-094-15“Basic requirements for justification of strength and thermo-mechanical behavior of fuel assemblies and fuel elements in the nuclear core of pressurized water reactors”;

– НП*(NP)*-104-18 “Welding and surfacing of equipment and pipelines of nuclear power plants”;

– НП*(NP)*-105-18 “Regulations for inspection of metal of equipment and pipelines of nuclear power installations during manufacture and assembly”.

The enumerated non-conformities are conditioned by the features of RITM-200N SNPP: integral implementation of the main equipment of reactor plant within the limits of reactor vessel, compact arrangement of the normal operation systems and safety systems inside steel containment, structural features of the reactor core.

At the same time, during designing of equipment and pipelines in part of welding and quality control of welded joints the marine documents (OST, RD) were applied. For the purpose of standardization of the approved technologies in the part of welding and quality control of welded joints there emerged a necessity of issuance of the new standards in the field of atomic energy use for NPPs.

## The major lines of the activities on regulatory support of the RITM-200N SNPP project.

The current plan of the Inter-Industry Working Group’s activities regarding regulatory documentation come roughly under the following 6 headings:

1. Introduction of changes to the RP design in order to fulfill the requirements of the Federal Standards and Regulations in the field of atomic energy use.

In order to bring the engineering solutions for the marine RITM-200 reactor plant in line with the regulatory documentation of the Federal Standards and Regulations in the field of atomic energy use for NPPs a few design changes were adopted. One of the major changes is the increase in the number of channels of the reactor plant safety systems, which led to the increase in the number of equipment and I&C in the safety systems. A few changes were introduced to the reactor design. We managed to place 5 sets of witness-samples due to the possibility of removing all in-vessel structures from the reactor vessel and excluding a mixer from the reactor structure. In a part of requirements for periodicity a non-conformity to the unloading periodicity has remained – it is possible only during the overhaul of the reactor plant (for the purpose of partial compensation the witness-samples with radiation exposure anticipation factors are to be placed). Installation of two level meters is provided for in the reactor cover.

2. Issuance of measures compensating the deviations from the requirements of the Federal Standards and Regulations in the field of atomic energy use as part of technical design the RITM-200N reactor plant and justification of sufficiency of these measures.

The decision was made on necessity of issuance of documents as part of technical design for the RITM-200N reactor plant which justify the deviations from the Federal Standards and Regulations as part of documents НП*(NP)*-082-07, НП*(NP)*-084-15, НП*(NP)*-089-15, НП*(NP)*-094-15.

The set of compensating measures is given in Chapter 3 of SAR “The general provisions and approaches to design of buildings, erections, systems and elements”

3. Introduction of changes to the efficient Federal Standards and Regulations in the field of atomic energy use.

Development of projects of changes introduced to the Federal Standards and Regulations was carried out in accordance with the Unified industry-wide procedure for preparation, consideration and agreement of the projects of the Federal Standards and Regulations in the field of atomic energy use (State Atomic Energy Corporation ROSATOM).

By now the final versions of the projects for introduction of changes to the Federal Standards and Regulations have been prepared and agreed with the interested organizations.

4. Development of State Atomic Energy Corporation ROSATOM’s standards.

Standards of State Atomic Energy Corporation ROSATOM are being developed in order to standardize the technologies of equipment manufacturing tested on ship-based reactor plants.

5. Regulatory support of manufacturing of SG cassette from titanium alloys.

The requirements for the steam generators made of titanium alloys are missing from the existing regulatory framework of the RF for land-based NPPs. In order to bring the engineering solutions for the RITM-200N reactor plant steam generators in line with the requirements of the Federal Standards and Regulations in the field of atomic energy use for land-based NPPs correction of НП*(NP)*-089-15, development of the corresponding standard of State Atomic Energy Corporation ROSATOM and development of procedures of testing systems were required.

6. Consideration of the requirements and recommendations of the foreign regulatory documents in the design of SNPP incorporating the RITM-200N reactor plant.

The efficient IAEA standards are generally applicable to land-based stationary nuclear power plants (NPPs) with water-cooled reactors the majority of which are the reactors having a capacity ranging from 600 to 1.500 MW. For other types of reactors including SNPPs, some safety provisions may turn out to be not applicable or to be applicable after some specific changes.

The structure of IAEA Safety standards related to NPPs includes three categories:

– Fundamental Safety Principles - SF1;

– General Safety Requirements (GSR) and Specific Safety Requirements (SSR) establishing the safety requirements that shall be fulfilled in order to assure Safety Fundamentals and are applicable to any kind of activity or object independently from its type and the technologies related to them;

– General Safety Guides (GSG) and Specific Safety Guide (SSG) соntaining more detailed specifications and recommendations for assuring the compliance with the Safety Requirements and considering the specificity of a technology.

During development of technical design of the RITM-200N reactor plant in Afrikantov OKBM JSC within the period from 2020 to 2022 a comparative analysis of the requirements of the regulatory documents of the RF and IAEA, аs well as of the requirements of WENRA and EUR, was performed. The IAEA documents given in Table 1 were considered.

Table 1 List of IAEA documents

| No. | Document name | Designation |
| --- | --- | --- |
|  | IAEA standard "Fundamental Safety Principles. Safety Fundamentals”. | SF-1 |
|  | IAEA report “Basic Safety Principles for Nuclear Power Plants” | INSAG-12 |
|  | The IAEA standard “Radiation protection and safety of radiation sources: International basic safety standards. General safety requirements”. | GSR Part3 |
|  | The IAEA standard “Safety assessment for facilities and activities”. General safety requirements”. | GSR Part4 |
|  | The IAEA standard “Safety of nuclear power plants: design. Specific safety requirements” | SSR-2/1 |
|  | The IAEA standard “Safety of nuclear power plants: commissioning and operation of nuclear power plants. Specific safety requirements”. | SSR-2/2 |
|  | The IAEA guide “The safety assessment and the independent verification for nuclear power plants”. | NS-G-1.2 |
|  | The IAEA guide “Deterministic safety analysis of nuclear power plants”. | SSG-2 |
|  | The IAEA guide “Safety classification of structures, systems and components of nuclear power plants”. | SSG-30 |
|  | The IAEA guide “Design of instrumentation and control systems for nuclear power plants”. | SSG-39 |
|  | The IAEA guide “Design of the reactor core for nuclear power plants”. | SSG-52 |
|  | The IAEA guide “Design of the reactor coolant system and associated systems for nuclear power plants”. | SSG-56 |
|  | The IAEA guide “Design of fuel handling and storage systems for nuclear power plants”. | SSG-63 |

The analysis of the IAEA standards applicability to the design of the RITM-200N reactor plant was carried out in 2 stages:

Stage 1 - comparing provisions of the IAEA requirements and guidelines with the corresponding provisions of the Russian RD;

Stage 2 - analyzing the compliance of the approaches and solutions used in RITM-200N RP to the IAEA recommendations and requirements [5].

The analysis of the requirements of the Russian regulatory documentation and the IAEA Safety Standards, as well as of the WENRA and EUR requirements has shown that the requirements of the Russian regulatory documents are mainly harmonized with the modern approaches and requirements used outside of Russia.

The development of the pilot design of the SNPP is carried out based on the orientation to the most conservative requirements for radiological safety criteria from the RD of the Russian Federation, IAEA and EUR.

There is no need to develop new IAEA upper-level documents (SF, GSR, SSR). The evaluation of the applicability of the IAEA Guidelines (SSG) to the SNPP project showed the need to adjust the existing documents or develop new ones for the innovative projects.

In order to take into account the results of the analysis, the activities were launched to harmonize the federal norms and rules of the Russian Federation in the field of atomic energy use with IAEA standards for SNPP and innovative reactors.

## CONCLUSION

Based on works performed in years 2020-2024 within the activity of the Inter-Industry Working Group on Regulatory Documentation, the following abstracts may be singled out:

– The design of a small-sized NPP with the RITM-200N reactor plant is being developed in accordance with the efficient Federal Standards and Regulations in the field of atomic energy use for NPPs. The design is being developed in compliance with НП*(NP)*-001-15.

- The participants of the Inter-Industry Working Group on Regulatory Documentation have analyzed the compliance of engineering solutions of the small-sized NPP with the RITM-200N reactor plant with the Federal Standards and Regulations in the field of atomic energy use for NPPs. All the deviations from the regulatory documents have been identified.

– The works intended to eliminate the identified non-conformities or to justify the safety of engineering solutions are in process.

– The experts of Scientific and Engineering Center for Nuclear and Radiation Safety (SEC NRS) are involved into work on non-conformities.

– The development of new Federal Standards and Regulations is not required to ensure that the design of a small-sized NPP with the RITM-200N reactor plant passes the expert examination and to obtain the required licenses.

– A pilot design of a small-sized NPP with the RITM-200N reactor plant was developed with account of the requirements and recommendations of the foreign regulatory documentation.

In 2024 it is planned to forward the final versions of the draft amendments of НП*(NP)*-084-15, НП*(NP)*-089-15, НП*(NP)*-104-18 to Rostekhnadzor for approval and registration. The tasks related to development of ROSATOM standards will also be completed in 2024.

With account of the abstracts above, as well as the opinion of experts, it is possible to count for a timely receipt of the license for construction of a small-sized NPP with the RITM-200N reactor plant.

REFERENCES

1. D.L. Zverev, Yu.P. Fadeev, A.N. Pakhomov, V.I. Polunichev, Nuclear Power Plants for the Icebreaker Fleet and Power Generation in the Arctic Region: Development Experience and Future Prospects, Atomic energy (2018), Vol. 125. No. 6, 318–322.
2. V.V. Petrunin, A.V. Kurachenkov, S.A. Fateev, N.V. Sheshina, report “Scientific-Technical and Economic Aspects for Development of Innovative Reactor Plants for Small and Medium Floating and Land-Based Nuclear Power Plants” for presentation at N.A. Dollezhal readings at NIKIET JSC, Moscow, March 12, 2020.
3. V.V. Petrunin, report “Innovative Reactor Plants Developed by Afrikantov OKBM JSC for Low-Power Nuclear Power Plants” for presentation at the XIII International Public Forum-Dialogue AtomEco-2019, Hungary, Pec, November 5-7, 2019.
4. Ya.O. Bykh, report “Specifics for Normative Regulation of the Land-Based SNPP Design with RITM-200N Reactor Plant with Shipboard Pressurized Water Reactor” for presentation at the VI International Scientific and Technical Conference on “Innovative Designs and Technologies for Nuclear Power”, Russia, Moscow, October, 2018.
5. V.V. Petrunin, Doctor of Engineering Sciences, Prof., A.M. Bakhmetiev, Doctor of Engineering Sciences, Prof., A.V. Kurachenkov, V.Yu. Galitskikh, Yu.A. Makeyev, D.V. Shchekin, article “Main analysis results of the IAEA standards applicability of RITM-200N reactor plant design for small nuclear power plants”, collection of SEC NRS articles (2023).