# STATUS OF ACTIVITIES ON THE DESIGN OF A LAND-BASED SMALL NUCLEAR POWER PLANT BASED ON THE RITM-200N REACTOR PLANT

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**Abstract**

The paper describes the status of activities on the design of a land-based small nuclear power plant (hereinafter, the SNPP) based on the RITM-200N reactor plant. Afrikantov OKBM JSC is a leading designer of marine reactors and has many years of experience in developing and operating marine reactors that successfully operate on in-service nuclear-powered icebreakers. The marine reactors have gone through a long-time process of improving their design, manufacturing process, materials and performance. Basing on the Russian nuclear shipbuilding experience, a reactor plant was developed which is compact and maneuverable to the maximum extent, highly reliable and safe at the level of the modern nuclear energy requirements. The RITM-200N reactor plant implemented all the fundamental safety, reliability and efficiency requirements for advanced nuclear power plants of the new generation.

## INTRODUCTION

The paper describes the status of activities on the design of a land-based small nuclear power plant based on the RITM-200N reactor plant [1]. Afrikantov ОКBM JSC is a leading designer of marine reactor plants and has a more than 60 years of experience in developing and operating marine reactors. Currently, this experience is based on the operation of three generations of marine reactors which total operating time is more than 400 reactor-years.

Basing on the Russian nuclear shipbuilding experience, Afrikantov ОКBM JSC developed a reactor plant that is compact, maneuverable, possessing highly reliable equipment and safety indices at the level of the modern nuclear energy requirements.

The sustainable industrial, economic and social development of remote regions requires reliable electricity sources [2]. One of the solutions for this problem is to use a small-sized nuclear power plant equipped with the RITM-200N reactor plant [3].

## Characteristics and status of the pilot SNPP design with the RITM-200N reactor plant

The main advantages of SNPP are the following:

* The minimum size of the territory for construction.
* Capacity value that meets the needs of the customer.
* Shorter construction time.
* The possibility of producing thermal energy.
* The possibility of desalinating seawater (as an additional function at the request of the customer, provided that the appropriate equipment is installed).
* Minimum environmental impact.
* Extensive experience in the use of reference marine reactor operation processes for the fuel handling, plant proficient maintenance and its decommissioning after the plant lifetime is over.
* The SNPPs with RITM-200N reactor plants can operate in load-follow mode, with a maneuvering range of 20 to 100 % Nnom, and a design maneuvering speed up to 6 %/min.

The SNPP site with the RITM-200N reactor plant will be designed with division into two zones. The first zone is the production one, with the power generation systems directly, including a reactor unit, a turbine unit, a special unit, and cooling towers. The SNPP main building is designed to withstand a 20 t aircraft crash and a maximum design-basis earthquake of 9 points on the MSK-64 scale. The second zone is the zone of auxiliary facilities, which consists of a water treatment building, a fire station, an administrative building, etc.

Interest in small-sized reactors as prospective energy sources for regions with decentralized power supply is rapidly growing not only in Russia, but throughout the world.

When developing the SNPP project, Afrikantov OKBM JSC is guided by the requirement to ensure competitiveness and implements new innovative solutions for a layout, systems, equipment, a location, and control automation to reduce the cost of the plant.

Construction of the SNPP with the RITM-200N reactor plant of 55 MW electric capacity will begin in the village of Ust-Kuiga, Ust-Yansky ulus of the Republic of Sakha (Yakutia).

Currently, a license has been obtained for the placement of the first SNPP power unit in Yakutia and the detailed (basic) design of the RITM-200N reactor plant for the SNPP has been completed.

## Engineering Solutions in RITM-200N Reactor Plant

A number of schematic and structural solutions regarding the main equipment and systems, including safety systems, have been adopted during development of the detailed design of the SNPP reactor plant. These solutions take into account the specific regulatory documentation requirements of a land-based SNPP while retaining the concept of the prototype RITM-200 reactor marine plant [4]. The RITM-200N reactor plant implements application of cermet fuel with an increased stored energy of 8 TW\*h, which ensures continuous operation of the reactor plant for 5-6 years and an extended refueling interval; increase of the service life of the permanent equipment from 40 years to 60 years; creation of a complex of safety systems operating on passive principles of operation and ensuring the safe state of the reactor plant for at least 72 hours with a complete long-term blackout, including accidents of the loss of coolant accident (LOCA) type.

The main element of the reactor plant is an integral reactor: the vessel, made of heat-resistant radiation-resistant steel, provides the bearing capacity and integrity of the reactor vessel during the assigned lifetime and the service life of 60 years.

The reactor vessel accommodates the core and four titanium alloy steam generators, and control and protection system drives on the cover. Vane, single-stage, vertical main circulation pumps with valve chambers are installed in the hydraulic chambers. Each hydraulic chamber is connected to the reactor vessel by means of short nozzles (main), made according to the "pipe-in-pipe" type.

The possibility of implementing maneuvering modes in accordance with the requirements of local power grids is due to the use of cermet fuel, the presence of an once-through steam generator with steam superheating.

The high level of SNPP safety is achieved owing to multilevel systems and shell barriers, which prevent the possibility of accidents and eliminate radioactive releases into the environment.

The design of the innovative RITM-200N RP for land-based SNPP implements the unique scientific, technical and production potential of nuclear marine technologies to solve the problem of developing the small nuclear power sources for the domestic and external markets with short implementation periods and attractive technical and economic indicators.

The results of developing the detailed design for the RITM-200N reactor plant and the core confirmed the declared unique characteristics and the adaptability of the marine RITM-200N reactor plant for use as part of a land-based SNPP.

The RITM-200N compact size is achieved through placing the primary coolant system main equipment in special slots of the metal-water shield tank, which is a biological shielding element. It is also designed to cool pressurizers, hydraulic accumulators, a primary circuit filter, and to reduce the thermal impact to reactor pit building structures.

## Safety Concept

The SNPP safety is achieved through the inherent safety properties and the balanced use of active and passive safety systems.

A two-train structure of safety systems is adopted for the RITM-200N reactor plant. All main safety functions are performed by active systems and backed up by passive systems.

The systems are designed with account of the principles of independence, a single failure, redundancy, physical and spatial separation, as well as the principle of a safe failure.

Two independent electromechanical systems for influencing reactivity are provided for an emergency shutdown of the reactor: highly efficient reactivity compensation system, consisting of 12 rods of compensating groups and high-speed emergency protection system, including six emergency protection rods.

The emergency protection system has the necessary speed and efficiency sufficient to transfer and maintain the core in a "hot" subcritical state. The speed of the safety system is achieved by introducing the emergency protection rods into the core under the action of accelerating springs when the holding electromagnets are de-energized.

According to the emergency protection signals, all the rods of compensating groups are lowered under the action of their own weight. The reactivity compensation system ensures the subcriticality of the core in a cold poisoned state at any time of the campaign (fuel cycle) when the most efficient rod of the compensating group becomes hung.

Along with electromechanical systems of emergency protection and reactivity compensation, a system for introducing a liquid absorber into the reactor is also provided.

Decay heat from the reactor core after the emergency protection actuation is removed by emergency cooldown systems.

The emergency cooldown systems include process condenser which cools down the reactor via the secondary circuit through steam generators; purification and cooldown system providing cooldown of the primary circuit through the heat exchanger of this system.

Each of the systems is two-train, each train of the system provides the necessary heat removal efficiency.

The ultimate heat sink for emergency cooldown systems is atmospheric air, heat removal to which is carried out by appropriate supporting systems.

To remove decay heat from the reactor in the case when it is impossible to cool down the reactor through the purification and cooldown system, the system of cooldown through the process condenser (for example, during a complete long-term blackout), a passive heat removal system is provided.

To replenish water losses from the primary circuit and cool the core in accidents with loss of coolant, an emergency make-up system is provided.

Due to steam condensation on the surface of the heat exchangers of the system for removing heat from the sealed enclosure connected to the PHRS heat exchanger unit, the pressure in the sealed enclosure of 0.4 MPa is not exceeded.

Pursuant to the regulatory requirements, the design also considers the course of a severe accident and the transition to it, including a severe beyond-design-basis accident with core meltdown.

The distinctive feature of the set of systems ensuring safety of the RITM-200N reactor plant is the application of means for beyond-design-basis accident management based on passive principles of action, which ensure that the reactor plant stays in a safe state with a leak-tight primary system for an unlimited time; and in loss-of-coolant accidents, for at least 72 hours.

To ensure these characteristics, the main equipment of the reactor plant is located in a thermally insulated steel containment designed to withstand an internal overpressure of 0.9 MPa in case of beyond-design-basis accidents. This solution, assisted by the passive part of the containment heat removal system, ensures that the coolant stops flowing out of the reactor in a LOCA, thus preventing a severe accident in a complete blackout lasting at least 72 hours.

To maintain the core below the coolant level, hydraulic accumulators of the pressure compensation system are connected to the reactor.

Limiting the release of the primary coolant into the sealed enclosure from the reactor is largely ensured by the operation of the passive heat removal system, the heat removal efficiency of which is due to the natural maintenance of high pressure in the sealed enclosure.

## Conclusion

The SNPP project with RITM-200N reactor plant is developed in accordance with the Russian regulatory documentation in the field of nuclear energy use for large NPPs, as well as taking into account the requirements and recommendations of international standards and regulations.

The combination of proven technical solutions for marine reactor plants with experience in creating modern designs of reactor plants with a high level of safety makes it possible to implement all the fundamental safety, reliability and efficiency requirements for advanced new generation nuclear power plants in the RITM-200N reactor plant.

The use of proven technical solutions and technologies for manufacture, transportation, installation and construction makes it possible to develop a design, construct and commission a nuclear power plant in a short time.

The SNPP with RITM-200N RP meets all the requirements for power supply to remote settlements and industrial production in a local small energy grid.

Reference

1. Petrunin, V.V., Reactor Pants for Small Nuclear Power Plants, In the collection: The Academy of Sciences and Nuclear Industry. Scientific sessions of the General Assembly of the RAS and General Assemblies of the RAS Branches, December 2020, Moscow (2021) 213-231.
2. Dmitriev, S.M., Kurachenkov, A.V., and Petrunin V.V, Scientific-Technical and Economic Aspects for Development of Innovative Reactor Plants for Small and Medium Nuclear Power Plants, Journal of Physics: Conference Series, Volume 1683, pap. 042032. — DOI: 10.1088/1742-6596/1683/4/042032.
3. Petrunin, V.V., Fadeev, Yu.P., Pakhomov, A.N., Veshnyakov, K.B., Polunichev, V.I., Shamanin, I.E., Conceptual Design of Small NPP with RITM-200 Reactor, Atomic energy. Vol.125, No. 6, December 2018, 323-327.
4. Petrunin, V.V., Specifics and principles for normative regulation of the land-based SNPP design with RITM-200N reactor plant with shipboard pressurized water reactor, Paper for XVI International Nuclear Forum “Safety of Nuclear Technologies: Safety Culture”, October 2012.