RUSSIAN SMALL MODULAR REACTOR NUCLEAR POWER PLANTS PROSPECTS AND BENEFITS

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The future development of nuclear power is closely aligned with the projects of small modular reactor nuclear power plants. Rosatom already has several decades of experience in the development and safe operation of small nuclear reactors. The first NPP, the nuclear icebreaking fleet, the world's only floating nuclear power plant – all these projects are based on Russian small reactor technologies.

HISTORY OF SMALL NUCLEAR REACTORS DEVELOPMENT

For many years, the only example of effective commercial application of small-scale nuclear power plants was the Russian nuclear icebreaking fleet.

Nuclear icebreakers have now been navigating the Northern Sea Route for more than 60 years, and over all these years marine reactor plants have been constantly improved. In general, we can distinguish between four generations of Russian small nuclear reactors for the icebreaking fleet with their operation experience totalling more than 400 reactor-years. Since 1959, more than 20 nuclear reactors at 11 icebreakers and one light carrier ship have been launched and successfully operated. Currently, six newest RITM-200 reactors are also being installed on three nuclear icebreakers, which testifies to the relevance of this technology. On October 21, 2020, Russia's leading icebreaker the *Arktika* equipped with a RITM-200 plant joined the Russian icebreaking fleet (Figure 1).

WHY SMR NPP?

Many developed and developing countries have recently changed their energy paradigm; they are facing the issue of replacing the existing generation facilities with energy-efficient, reliable, and low-carbon sources of new generation located close to specific consumers.

In this new energy paradigm, mainly determined by the development of renewable energy sources, small modular reactor nuclear power plants can help to strengthen nuclear power's positions in the international market.

SMR NPPs are designed for reliable power supply to isolated and hard-to-reach areas where a large amount of power is required for enterprises engaged in mining gold, diamonds, rare metals, gas, oil and iron ore. Another reason for an increased interest in SMR NPPs is their capability to replace decommissioned coal and diesel thermal power plants.

Figure 1.

Currently, there are at least 72 concepts of small nuclear reactors at different stages of development (IAEA, 2020), which is 40% more than in 2018 (IAEA, 2018).

In the years to come, the SMR NPP market is believed to continue developing in line with decarbonization trends, which will assist in generating demand for dispatched generation facilities with low greenhouse gas emissions.

BENEFITS OF SMR NPPs
Wider geographic diversity

The design features of SMR NPPs allow for a significant expansion of their potential geographic diversity:

- Lower demand for cooling water makes it possible to place SMR NPPs even in deserts.
- The placement of small-power NPPs is less limited by the capabilities of the grid infrastructure, including their power transmission capacity, in contrast to large power generation sources.
- In SMR NPP projects, the reactor unit can be placed underground; this significantly reduces the nuclear power plant's vulnerability to external threats.
- The number of employees is significantly less than at large-scale nuclear power plants, which is especially important when constructing facilities in remote areas.

The innovative features of SMR NPP design with a RITM-200N reactor unit allowed Russia to choose the Arctic terrains at the Ust-Yansky region of the Republic of Sakha (Yakutia) as the site for the new plant, which is expected to be commissioned in 2028 (Figure 2).

- Reactor: RITM-200N;
- Capacity: 55 MWe;
- Area: 6.0 hectares (or 0.06 km2);
- Construction period: 36–48 months;
- Refuelling frequency: 5–6 years;
- Operating life: 60 years with the possibility of extension.

No direct emissions of CO_2

SMR NPPs also contribute to a significant improvement in the environmental situation and reduction of CO_2 emissions in the world. Considering the possible placement of SMRs in isolated power systems, the solution allows keeping the nature and environment of remote regions undisturbed. For example, the implementation of the project in the Republic of Sakha (Yakutia) will reduce CO_2 emissions by 10,000 tons per year as a result of replacing obsolete coal and diesel power sources.

Figure 2.

Small size

An SNPP has the smallest footprint per MW compared to other types of power sources, which contributes to a more efficient use of land resources and maintains the balance of ecosystems in nearby territories.

The small size of the SMR provides an opportunity of modular production, which also ensures the introduction of higher quality standards and reduces the unit cost during mass production. The footprint of Russian design SMR NPPs is significantly smaller compared to fossil fuel generation facilities, hydroelectric power plants and renewable energy sources of the same capacity.

For example, one SMR NPP with a capacity of 110 MWe has a footprint of only eight standard football fields, while a solar power plant of the same capacity would have a footprint of 24 football fields, a wind power plant – 34 football fields, and a hydroelectric power plant – 180 football fields, which significantly reduces the potential geographic diversity of these energy sources in remote areas (Figure 3).

Modularity

In many cases, the modularity of small modular reactor NPP structures in essence allows manufacturing a complete reactor unit at a factory, which is very different from the practice employed in the construction of large and medium-sized nuclear power units of even the latest generations (the modular principle is also applied, but to a much more limited extent).

Because of this and due to a relatively small scope of construction and installation works, the construction and commissioning timescales of nuclear power plants with small reactors can be greatly shortened, which, in turn, reduces the financing costs. Moreover, the design allows increasing the power output depending on the energy needs of the customer.

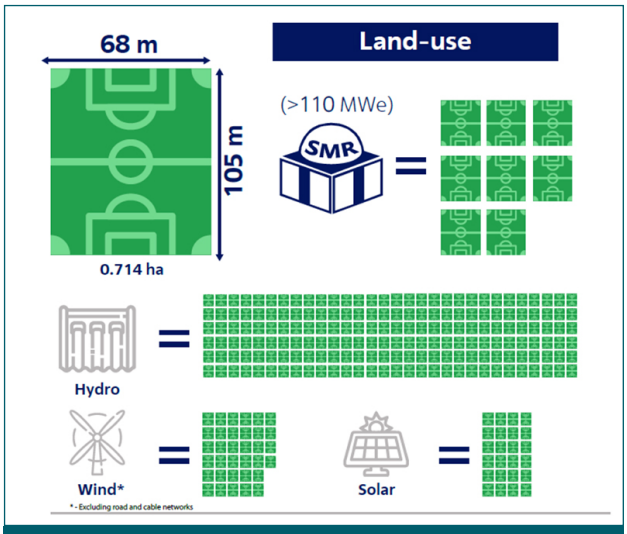

Figure 3.

Energy generation stability

A nuclear generation source allows fixing the cost of power for the entire period of the plant's operation, which is an important aspect for potential investors. In these conditions, the investor does not depend on market volatility and is not exposed to the risks of an increase in the cost of fuel for the power plant.

Wide range of applications

In addition to generating power, SMR NPPs can be used for the generation of thermal energy, desalination of seawater, and production of hydrogen by electrolysis.

Reduced construction period

Today, one of the main factors influencing the competitiveness of nuclear energy is the duration of the construction period. Due to the modular design and the small scope of construction and installation works, the construction of an SMR NPP of Russian design will take on average 3–4 years from the "first concrete" to commissioning.

Transportability

SMR NPP's unique feature is the possibility to transport the main components:

- by railway transport using special flat cars;
- by road using heavy goods vehicles;
- by water.

The rest of the equipment will have a modular design, which makes it possible to transport it using conventional vehicle types (Figure 4).

Long period of operation without refuelling

The unique fuel to be used in Rosatom's SMR NPPs allows for continuous operation without refuelling for up to 6 years (for SMR NPPs) and up to 10 years (for optimized floating power units). This is in compliance with all Russian and international regulations, including non-proliferation requirements.

Figure 4.

Maneuverability

Unlike high-capacity nuclear power plants mainly designed for operation in the base mode SMR NPPs can operate in the frequency and power control mode, which makes this type of plants much more efficient and cost saving for consumers.

Safety

Safety has been a top priority in the design of Russian small NPPs.

Rosatom's nuclear power plants with RITM reactor units have all the safety features of the latest nuclear power plants of generation 3+.

The safety is based on the following:

1. Internal safety factors

   The inherent safety of small modular reactor NPPs is based on natural processes that do not require human intervention or power supply. An SMR NPP includes four integral safety elements:

   - negative reactivity coefficient;
   - high thermal conductivity of the fuel composition;
   - integral reactor structure;
   - high heat capacity of the primary circuit.

2. Several levels of physical barriers.

   Rosatom's small modular reactor NPPs employ the defence-in-depth approach based on the use of several levels of physical barriers. These barriers prevent the release of radioactive materials into the environment.

3. Safety systems for design basis and beyond design basis accidents.

   These independent systems eliminate as many potential risks as possible, reduce the possibility of accidents and minimise the impact in case of an accident.

   In case of an accident with a loss of coolant in combination with a complete plant blackout, the SMR NPP will not require intervention for 72 hours.

   SMR NPP is resistant to various external threats:

   - Extreme temperatures;
   - Tornadoes and wind loads, including impacts from flying objects;
   - Earthquakes.

As a conclusion

Russian SMR NPP technologies are clearly some of the most advanced in the world and have a number of advantages not only in comparison with traditional, but also with renewable energy sources.

The implementation of projects for the construction of SMR NPPs in Russia and abroad on the basis of modern small reactors will contribute not only to improving the environment and reaching the UN sustainable development goals, but also to the stable operation of local energy systems. That's because the small modular reactor NPP is a reliable source of energy for many years to come.■