SMR Based Floating Solutions: Design and Specific Features of Legal Regulation

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JSC «Afrikantov OKBM» – scientific and production centre of atomic mechanical engineering of the Rosatom State Corporation

Date of foundation – December 27, 1945
The mission of JSC “Afrikantov OKBM” is to serve for national interests and development of nuclear industry providing full spectrum of services regarding designing, construction, procurement of nuclear reactors and their maintaining during life cycle.

Personnel

<table>
<thead>
<tr>
<th>Category</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>designers and technologists</td>
<td>1044</td>
</tr>
<tr>
<td>test engineers</td>
<td>142</td>
</tr>
<tr>
<td>production workers and foremen</td>
<td>1500</td>
</tr>
<tr>
<td>auxiliary services</td>
<td>1092</td>
</tr>
<tr>
<td>supervisors</td>
<td>72</td>
</tr>
</tbody>
</table>

Middle age

- Percentage of employees aged 35 and younger: 30%

Employees who have academic degrees

- 1 academician of the RAS
- 19 doctors of science
- 83 candidates of science
- 6 professors
- 8 docents

Russian Government awards in science and engineering

- 47 awards
- 96 laureates

Honoured workers in science and engineering

- 70

* – average number of employees as of December 31, 2019
From icebreakers to floating nuclear power plants: nuclear energy sources in the Arctic

Icebreaker «Lider»
Basic design
Planned commissioning — 2027

OK-900 OK-900A
Reactor nominal thermal capacity
159–171 MW

KLT-40 KLT-40S
135–171 MW

RITM-200 RITM-200M
175 MW

RITM-400
315 MW

FPU «Akademik Lomonosov»
Commissioned in 2020

OFPU
Conceptual design
Planned commissioning — 2028
Reference project: FPU «Akademik Lomonosov»

Commercial operation of FNPP* on the basis of FPU** “Akademik Lomonosov” was commenced on May 22, 2020

The project is implemented in accordance with legal requirements of the Russian Federation established for nuclear vessels and floating structures taking into account recommendations of the IAEA.

Experience of KLT-40S operation:
2 nuclear icebreakers, 1 nuclear-powered cargo ship and 1 FPU

Power supply solutions have been tested on nuclear icebreakers

<table>
<thead>
<tr>
<th>2 reactor facilities</th>
<th>KLT-40S</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operational life</td>
<td>40 years</td>
</tr>
<tr>
<td>Period between refueling</td>
<td>3–4 years</td>
</tr>
<tr>
<td>ICUF</td>
<td>0,7</td>
</tr>
</tbody>
</table>

Net output:
- Electricity: 20…70 MW
- Heat: 50…146 Gcal/h

Feasibility of floating power units is proved TRL 7

*FNPP – floating nuclear power plant
** FPU – floating power unit
Optimization of technical solutions

The most efficient design is a balanced solution based on all factors.

Designing is an iterative process influenced by all factors in a reciprocal way.

Factors that influence product development:
- Vessel design
- Competitiveness and commercial attractiveness
- Civil liability for nuclear damage
- Nuclear and radiological safety
- IAEA safeguards
- Physical protection
- Reactor facility
Optimization of solutions for floating design energy sources

Increasing:
- electrical output up to 100 MW
- refueling interval up to 10 years

Ship optimization
- no refueling equipment on board
- cost reduction
- decreasing ship principal dimensions
- expansion of functionality
- versions for arctic and tropical climate

Two versions of OFPU:
- **self-propelled** (self-moving and positioning in open water areas)
- **non-self-propelled** (a berth-connected ship, relocation on board of a semi-submersible heavy-lift vessel or by towage)

FPU «Akademik Lomonosov»

<table>
<thead>
<tr>
<th>2 reactor facilities</th>
<th>RITM-200M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical capacity</td>
<td>2*50 MW</td>
</tr>
<tr>
<td>Operational life</td>
<td>60 years</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>FPU «Akademik Lomonosov»</th>
<th>OFPU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>140 m</td>
<td>112 m</td>
</tr>
<tr>
<td>Breadth</td>
<td>30 m</td>
<td>30 m</td>
</tr>
<tr>
<td>Draught</td>
<td>5,6 m</td>
<td>5 m</td>
</tr>
<tr>
<td>Displacement</td>
<td>21 000 t</td>
<td>16 680 t</td>
</tr>
</tbody>
</table>
## Conception of cyclic replacement «n+1» implies construction of the energyfleet that consists of several OFPUs, one of which is for temporary replacement

- Consecutive commissioning of identical OFPUs
- OFPU that is for replacement is used as substitute power-generating capacity instead of the first power unit, which is moved to Russia for maintaining and refueling
- OFPUs are replaced one by one providing lack of downtime in energy supply

## Advantages of Conception «n+1» for customers:

1. Unique business-model that can not be implemented on the basis of land-based nuclear power plants
2. Unified, interchangeable floating power units
3. Simplified licensing
4. Financial and infrastructural burden for customers is minimized
5. Benefits from supplier’s capacities that has a wide experience of operation of icebreakers. There is an opportunity of engaging supplier’s employees.
6. Project efficiency as a result of minimized downtime in energy supply
OFPU legal regulation

OFPU has features of

| a vessel | a nuclear power plant |

Existing regulatory framework established in Russia fully covers all aspects of the life cycle, and enables OFPUs and other floating power units to be operated.

Existing international regulatory framework does not prohibit OFPU operation, however, specialized requirements for non-self-propelled floating units with nuclear power facility do not exist.

Self-propelled vessels with nuclear reactors have already accomplished several international voyages:

Savannah
Otto Hahn
Sevmorput

It is needed to establish safety criteria for non-self-propelled floating units with nuclear power facility that would meet international approval. These criteria would give an opportunity:

Safety assessment* is assumed to be a possible solution. It is obligatory for self-propelled nuclear vessels and it can be adjusted to non-self-propelled floating units with nuclear power facility.

to developers and operators: to develop a required scope of documentation in advance in order to prove safe operation

to stakeholders: to objectively assess safety of operation

* Safety assessment is required by SOLAS-74 and by Code of safety for nuclear merchant ships Res. A.491 (XIII) passed by International Maritime Organization
Work streams in creating legal and regulatory environment for floating power units

- Further development and enhancement of national regulatory system concerning safety of floating power units
- Analysis of application of the IAEA safety recommendations to SMRs (in terms of the project *Applicability of the IAEA Design Safety Guides to Innovative Small Modular Reactors*)
- Assessment of SMRs including OFPU using INPRO methodology*
- Project INPRO TNPP-2 «Case Study for the Deployment of a Factory Fueled SMR»:
  - Scenarios of deployment of land-based, floating and submersible SMRs are reviewed. These SMRs are factory fueled and they can be transported to an operating site in foreign countries;
  - Issues of legal requirements for transportation, nuclear safety, IAEA safeguards, physical protection, licensing, etc. are analyzed;
  - Recommendations for decision-makers on deployment of SMRs are developed.
- Other projects under the aegis of the IAEA, OECD and other international organizations

* INPRO - International Project on Innovative Nuclear Reactors and Fuel Cycles
Regulations for the Safe Transport of Radioactive Material No. SSR-6 (Rev. 1)

At the present time SSR-6 is not included in the list of documents that are under analysis

Types of transportable nuclear modules (TNM) and the ways of their transportation with fuelled reactor

- Floating TNM
- Submersible TNM
- Land-based TNM

The current version of SSR-6 is not applicable to the regulation of TNM transportation*:
- SSR-6 is limited to the transportation of nuclear materials in containers.
- Unlike containers nuclear reactors are aimed to ensure controlled nuclear fission chain reaction.
- Nuclear reactors do not comply with requirements of SSR-6 on containers testing.
- Safety of OFPU transportation with a reactor in shutdown condition should be substantiated in a Safety Assessment Report.

In order to from transparent and agreed rules of safe TNM transportation it is needed to:
- exclude TNM from the scope of applicability of SSR-6
- Initiate development of a new document that will regulate safety of fuelled TNM transportation under the aegis of the IAEA

* «Consultancy Meeting about Feedback on Technological and Safety and Security Aspects from Transportable Nuclear Power Plants Deployment» July 30 – August 01, 2019
Working meetings of the TNPP-2 INPRO project.
Conclusion

1. FPU «Akademik Lomonosov» has proved feasibility of floating power units.
2. Optimized floating power unit is developed as a solution for international markets with regards to relevant approaches to nuclear and radiological safety, safeguards against the proliferation of nuclear weapons, physical protection, civil liability for nuclear damage, etc.
3. Formation of a common legal framework is one of the most important conditions of successful implementation of innovative projects of optimized floating power units.
4. Development of innovative technologies of small modular reactors is possible only with the support of the IAEA concerning interpretation of safety issues of innovative technologies and adaptation of existing safety guidelines in relation to new projects of SMR.