Nuclear Technologies in Russia: Sustainable Innovative Development

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Development of nuclear energy

Fast reactors: driver for Russian nuclear industry development

NPP capacity subject to Fast Reactors being commissioned using Pu (A) and using Pu+U (B):
1 – RBMK; 2 – VVER (Gen II); 3 – VVER (Gen III+); 4 – FR
Russia: Fast Reactors Development

Russia: leadership in Fast Reactor Technologies supported by Government

BN Reactor Technology development in Russia

- **BN-5/10**: 1958-2002
- **BOR-60**: since 1969
- **BN-350**: 1972-1999
- **BN-600**: since 1980
- **BN-800**: 2014
- **BN-1200**: 2021
New Nuclear Technology Platform

Background Factors
- Deployment of U-235 resources
- Accumulation of radwastes and SNF
- Need to eliminate accidents in deterministic terms

Basic Philosophy
- Inherent Safety (elimination of accidents resulting in population evacuation)
- Radiation Equivalent Management of Radwastes
- Non-proliferation (no separation of fissile material through technological cycle)
- Sustainable Resources (involvement of U-238 into fuel cycle and Pu recycling)
- Fast reactors’ CAPEX reduction to at least light-water reactors CAPEX

Innovative Solutions To Be Founded

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Current PWR</th>
<th>New Platform</th>
</tr>
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<tbody>
<tr>
<td>Breeding ratio</td>
<td>≤ 0.60</td>
<td>up to 1.50</td>
</tr>
<tr>
<td>Radwaste, %</td>
<td>100</td>
<td>0.5</td>
</tr>
<tr>
<td>Reactivity margin, β</td>
<td>~ 3–5</td>
<td>≤ 1</td>
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</tbody>
</table>
Roadmap of Innovative Nuclear Technologies

**TECHNOLOGY LEADERSHIP**

**Energy Efficiency (EE)**
- 3 TW·h/kg
- 60 GW·h/kg
- 24 GW·h/kg
- 120 MW·h/kg

**Controlled Nuclear Fusion**
- Closed Fuel Cycle (CFC)

**Fast**
- Open Fuel Cycle

**Fundamental core science**

- **Reactor base**
  - Power reactors
    - VVER-TOI
    - Small generators
    - RITM-200

- **Fuel**
  - MOX
  - Dense: Nitride, Carbide, Metal

- **Reactor materials**
  - Zirconium steels
    - E-110M and E-635M
  - Ferritic-martensitic steels
    - EP-823, EK-181 and ChS-139

- **Space nuclear facilities**
  - CFC Technologies
    - Dry technologies
      - Water technologies
      - Hybrid (mixed)

- **Radwaste management**
  - Centrifugal separator
    - 4th Generation CS
  - Extraction
  - Separation
  - Crystallization

- **Inertial CNF**
  - Source of X radiation for thermonuclear target ignition (Baykal)

**Reactor base**
- Sodium BN-1200
- Lead BREST-300
- Lead-bismuth SVBR-100

**CFC Technologies**
- Plasma physics,
  - High power density and materials (FAIR)

**MOX**

[Diagram showing various technologies and their energy efficiencies]
## How It Looks Like in Russia

Unique Russian fast reactor R&D and operation experience, nuclear fuel development and spent nuclear fuel management & recycling:

<table>
<thead>
<tr>
<th>Reactor Technology</th>
<th>R&amp;D</th>
<th>Industrial Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reactor System</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sodium</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Lead-bismuth</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Lead</td>
<td>+</td>
<td>– / +</td>
</tr>
<tr>
<td><strong>Nuclear Fuel</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MOX pellet</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>MOX vibro-packed</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>High-density fuel</td>
<td>+</td>
<td>+ / –</td>
</tr>
<tr>
<td>MA handling</td>
<td>+</td>
<td>– / +</td>
</tr>
<tr>
<td><strong>Reprocessing</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aqueous processes</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Pyroprocessing</td>
<td>+</td>
<td>+ / –</td>
</tr>
<tr>
<td>Gas-Fluoride</td>
<td>+</td>
<td>–</td>
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<tr>
<td><strong>Final Disposal</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deep Geological Disposal</td>
<td>+</td>
<td>– / +</td>
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</tbody>
</table>
Project “Breakthrough”: conversion from demonstration of isolated innovation technologies to global impact integral solution – experimental demonstration complex operated in on-site closed nuclear fuel cycle

Key Deliverables of the “Breakthrough” Project

**Reactor BREST-300**
- 17 tons of year overall production
- Increased level of reactor operation safety

**On-site demonstration SNF complex**
- 20% decrease of SNF handling & management costs

**Reprocessing Unit**
- 5 tons / year SNF
- No staff irradiation due to automated processes

**Dense Fuel Fabrication Unit**
- 17 tons of year overall production
- Increased level of reactor operation safety

**Basic Detailed Design Commercial FR-1200 & on-site CNFC complex**
- Power 1200 MW (e)
- Solemn regarding all regulatory requirements

No analogue for the complex technology in the world
«Breakthrough»: Research & Experimental Base

Innovative solutions:
- Digital I&C for research reactors
- V&V facilities for virtual modeling
- Atomic spectrometry and introscopy

Hot cells with edge equipment
- Protective housing with a shield up to $10^{13}$ Bk
- Loadings up to 10 kg U-235 and 2.5 kg Pu
- All technological operations with fresh and reprocessed powders and fuel fabrication

Upgrade completed in 2012

BFS – complex of fast criticality facilities
- The biggest critical facility in the world
- Both thermal and fast neutron spectrum
- Full-scale core modeling

Modernization in 2016

Supercomputers, virtual models for technological facilities
- Supercomputers 2.0 PFlops
- Compact supercomputers 5.0 TFlops

Completed in 2012

Safety support Modeling

Research Reactor Fleet

Technologies for closed NFC

MBIR

BOR-60
- Power – 150 MW(th)
- Flux – $3.7 \cdot 10^{15}$ /cm$^2$·s
- Heat density – 1.1 MW/I

Decommissioning in 2020

- Max burn-up rate – 6% h.a. per year

Commissioning in 2019
International Cooperation for Future of Fast Nuclear Energy

Worldwide community

International partners

Expansion of cooperation with Russian R&D expertise & experience

Strengthening cooperation atmosphere

Additional expertise and experience
Modern features of I&C
International contracts with multidisciplinary cooperation

Russia

MBIR project
Conclusions

- «Breakthrough» is the top priority project for ROSATOM creating new nuclear inherently safe technologies for worldwide implementation
- Developed in accordance with philosophy principles of New Technology Platform
- Proved & commercialized technologies allow to:
  - Develop New Platform of nuclear power worldwide till the end of this century basing on currently available fissile resources
  - Reprocess of all accumulated SNF
  - Eliminate of weapon-grade reprocessing and enrichment technologies from nuclear fuel cycle
  - Bring back competitive capability to nuclear power