«PRORYV» project as implementation of INPRO basic principals for sustainable development on the basis of New Platform for Nuclear Power


Growth limits for Nuclear Power Industry based on “old” technological platform

Technological platform of Nuclear Power based on LWR is sufficient for the forecasted scale of NPP development (until 2050)

However its potential in solving long-term energy problems is limited because technical safety level doesn’t meet the main requirement of large-scale NPI – elimination of accidents requiring evacuation of inhabitants

Three Mile Island – 1979
Chernobyl – 1986
Fukushima – 2011
Barriers of large scale NPI development

**NPI has been in crisis for the last 30 years.**

Max share of NPP in Global power generation of 18% has been reached in early 90-s. By today it has dropped to 10,7%. Forecasts made by acknowledged energy institutes point at further decrease of this share.

**The main obstacle on the path of modern NPI development is the problem of competitiveness that is interconnected with the safety problem**

**Attempts of improve the safety by creating of active engineering protective systems led to a drop of NPI competitiveness with hydrocarbon and renewable power industries**
CONSISTENT PROBLEMS of “old” NPI technological platform

1. Low efficiency of natural U using (Only 0.7% U-235 are using for nuclear fuel cycle);

2. Absence of ecologically acceptable management of high level long-lived radioactive waste (MA, etc.);

3. Proliferation resistance of nuclear fuel cycle
The initial predestination of INPRO Project

Requirements aimed at overcoming the problems of traditional NPI in terms of safety, natural resources, radioactive waste, proliferation resistance and economy were developed and reflected in the “Strategy of Nuclear Power development in Russia in the 1st half of XXI century”, approved by Russian Government and proposed by the President of Russian Federation V. Putin at Millennium Summit as basis for global sustainable development.

The INPRO project predestination:

Providing competitiveness of NPI in comparison with other power sources under conditions:
1. Eliminating heavy accidents led to inhabitants evacuation and contamination of significant territories;
2. Nuclear fuel cycle with natural radiation balance;
3. Technological enforcement of proliferation resistance by eliminating of production of pure U235 and weapons grade Pu as well as cancellation of U enrichment technologies;
4. Max possible using of energy potential of raw materials (uranium).
“PRORYV” Project Goals

1. Competitiveness of Nuclear Power Industry

2. Technical safety of NPI: elimination of accidents requiring inhabitants evacuation could give opportunity to large-scale NPI development

3. Ecological safety of nuclear fuel cycle: solution of high level long-lived radioactive waste (MA etc.) problems and spent fuel accumulation could improve acceptance of Nuclear Power by society

3. Political neutrality of nuclear fuel cycle: technological support of proliferation resistance might eliminate limitations of political acceptance of NPI

4. Sustainable fuel supply of NPI: Closed nuclear fuel cycle (CNFC) could be the basis for long-term fuel supply of NPI for thousands of years
Integral design of Nuclear plant with fast reactor - deterministic elimination of LOCA type accidents (integral plant design allows localizing coolant leaks in reactor containment and eliminate “drying” of reactor core)
Equilibrium dense fuel – deterministic elimination of reactivity accidents in fast reactors (BN and BR)

Zero burn-up reactivity margin in BN with mixed nitride fuel
PRORYV Project: Closed Nuclear Fuel Cycle implementation

*Involving the whole U potential in energy generation.*

**Energy potential of different raw material stocks in Russia**

*Including U-238 (Closed nuclear fuel cycle with FR)*

*Without U-238 (Open nuclear fuel cycle with TR)*
Reprocessing of irradiated fuel of Fast Reactors for recycling of U and Pu is solution of the high active long-lived waste problem by transmutation of MA in FR and controlled storage of the other radioactive waste for 200-300 years before its radiation-equivalent disposal.
**PRORYV Project: environmental safety and nuclear fuel resources**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Open NFC</th>
<th>Closed NFC</th>
</tr>
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<tbody>
<tr>
<td>Annual consumption of U per 1 GW·year (el)</td>
<td>150 tons</td>
<td>1 ton</td>
</tr>
<tr>
<td>Consumption of U for 60 years by 60 GW·year (el)</td>
<td>9 000 tons</td>
<td>60 tons</td>
</tr>
<tr>
<td>Max capacity of NPI at 600÷700 thousand tons of natural U</td>
<td>68÷80 GW for 60 years</td>
<td>600÷700 GW for 1000 years</td>
</tr>
<tr>
<td>Spent fuel, high-level waste (actinides) per 1 GW·year</td>
<td>15 tons</td>
<td>reprocessed nuclear fuel</td>
</tr>
<tr>
<td>Radioactive waste (fission products) per 1 GW·year</td>
<td>1 ton</td>
<td>1 ton</td>
</tr>
</tbody>
</table>
PRORYV Project: closed fuel cycle and open fuel cycle

- CNFC technology for NPP with FR solves the problem of spent nuclear fuel by elimination of its accumulation;

- Transfer period from ONFC to CNFC (two-component NPI) allows to reduce accumulation of TR (thermal neutron reactor) spent fuel and reduce its management expenses. Replacing one TR with FR:
  - Eliminates accumulation of about 1000 tons of PWR spent fuel (15 tons/year x 60 years, slide 11) and expenses of its storage before reprocessing;
  - ~15 times increase of new fuel output – Pu after reprocessing (PWR spent fuel contains 1% Pu, and FR spent fuel contains 15% Pu);

- Using of reprocessed products for launching new FR with CNFC is an effective way of solving the problem of accumulated PWR spent fuel:
  - One new FR can utilize the whole volume of spent fuel from one PWR for its lifetime;
  - Replacing 10GW of TR by FR almost completely solves the problem of all Russian accumulated spent fuel from VVER (~10 000 tons), eliminates its storage expenses and makes its reprocessing economically viable.
Capital cost of NPP construction with FR should be on 20% lower than for VVER-TOI

Technical and economical parameters of FR NPP of high power should allow to 15% decrease of net cost of generated electricity compared with VVER-TOI and makes it competitive to alternative power generation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>IEC NPP with BR-1200 (requirements)</th>
<th>NPP with WWER-TOI</th>
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<tbody>
<tr>
<td>NPP power, MW(electric)</td>
<td>2400</td>
<td>2500</td>
</tr>
<tr>
<td>Loading factor, %</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>Cost of electricity for own needs, %</td>
<td>5,0</td>
<td>6,5</td>
</tr>
<tr>
<td>Electricity net supply, Bln. kW.h/year</td>
<td>18,0</td>
<td>18,4</td>
</tr>
<tr>
<td>Normal mode ratio, pers./MW(electric)</td>
<td>0,30</td>
<td>0,37</td>
</tr>
<tr>
<td>Construction period of 2 power units, years</td>
<td>8*</td>
<td>8</td>
</tr>
<tr>
<td>Service time, years</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>Unit capital costs, thous. Rub./kW</td>
<td>74</td>
<td>90</td>
</tr>
<tr>
<td>Unit capital costs, $/kW (1$ = 32 Rub.)</td>
<td>2 300</td>
<td>2 825</td>
</tr>
</tbody>
</table>

*Includes CNFL facilities
For production of 1 ton of FR fuel using Pu from PWR SNF (Pu content ~1%) it’s necessary to reprocess ~15 tons of spent fuel.

CNFC economy is less influenced by price fluctuations of resources (natural U) on the long-term basis.

The problems of TR spent fuel accumulation and Pu treatment could be solved.

The reprocessing of accumulated spent fuel should be synchronized with FR commissioning plan.
PRORYV Project: Competitiveness

- Replacement of decommissioned NPPs with TR by NPPs with FR

- Economic effect from commissioning of one Industrial Energy Complex (IEC) with of 2 FR reactors and CNFC facility in comparison with to NPP with 2 VVER-TOI reactors:
  - Capital cost savings – 45.3 bln. Rub.;
  - Operational expenses reduction (fuel + operational) – 146.4 bln. Rub.;
  - At the same time the volume of natural gas that becomes free for export or internal consumption if IEC with BR-1200 is launched instead of CCGT calculated for the whole service life-time is estimated at 205 bln. m3, if only 1 IEC is commissioned.

- Complete recycling of accumulated PWR spent fuel is the solution of postponed problem of NPI;

- Technologies of final disposal of radioactive waste on the basis of radiation-equivalent management of Fissile materials.

**IT IS NECESSARY TO DEVELOP A NEW REGULATORY FRAMEWORK FOR THE NEW TECHNOLOGICAL PLATFORM OF NPI**
“ODEK” project and CNFC technological platform

Target – testing and demonstrating of Closed Nuclear Fuel Cycle (CNFC) technologies for further implementation on industrial scale, including:

• Buildup of scientific-experimental and design base for R&D on operational nuclear facility with BREST-OD-300 reactor at various operational modes;

• Refining of fabrication, refabrication and reprocessing technology of FR fuel;

• Demonstration of CNFC and complex solution for radioactive waste management in “ODEK”;

• Efficiency increase of natural U utilization as well as spent fuel and gradual implementation of radiation-equivalent approach for nuclear material treatment in CNFC;

• Power generation.

(ODEK – Pilot Power Complex)
Four phases of ODEK construction and commissioning:

- **Buildings and facilities of Fabrication Unit and commissioning Refabrication Unit (I and IV phases);**
- **Buildings and facilities of BREST-OD-300 Reactor (II stage);**
- **Buildings and facilities of reprocessing unit (III stage).**
ODEK Project: Construction of the 1st phase (Fabrication Unit)
Current state– readiness~30% (2015)

- Waste water treatment complex
- Decontamination center
- Drinking water reservoir and firefighting lines
- Railway carts deactivation facility
- Temporary storage of commissioned ILW, LLW
- ILW and LLW reprocessing facility
- Fabrication/refabrication unit
- Exhaust pipe
- Technical water reservoir
- Administrative building
Industrial Power Complex (PEK) based on BR-1200 reactor with U-Pu nitride fuel and Closed Nuclear Fuel Cycle (CNFC) is designed for:

- Heat and power generation;
- Spent fuel reprocessing;
- Manufacturing of BR-1200 fuel assemblies from reprocessed products;
- Reprocessing, compacting, temporary storage and predisposal treatment of radioactive waste.

PEK should provide high level of nuclear and radiation safety, economical competitiveness of it’s products compared to other power generation sources, including hydrocarbons and renewable energy sources, considering per unit capital costs and prices of products for the whole service life.

**Current project stage** – conceptual project design.
Thank you for attention!