Competitive ability of FNR NPPs: requirements and implementation in the Proryv Project Direction

D.A. Tolstoukhov, S.A. Panov, I.V. Presnyakov
Private Enterprise “Innovation and Technology Center for the Proryv Project (ITCP) “PRORYV”, Moscow, Russia

Abstract. A key condition for the advanced development of nuclear energy is to ensure the competitiveness of NPPs in comparison with alternative generation in solving system problems. Modern nuclear power technologies on Thermal Reactors, operating in open fuel cycle, cannot guarantee long-term sustainable development of nuclear power; these technologies have almost exhausted the potential for increasing competitiveness. The report is considering the competitiveness of NPPs with thermal and fast reactors in comparison with power plants on organic fuels and renewable energy sources. The analysis performed on actual data of technical and economic indicators of competing generation types. The requirements of competitiveness for NPPs are considered, allowing to ensure development taking into account the possible improvement of technical and economic indicators of alternative generation. Determined the requirements to the criteria for competitiveness of NPPs with Fast Reactors and closed NFC. Also in the report are given facts on the evaluation of the achievement the required indicators for NPPs with BR and closed NFC on the basis of actual work in the Proryv Project.

1. Introduction
According to the analysis of trends in the Russian and world’s power industry by prominent expert organizations (International Energy Agency, U.S. Energy Information Administration, IES RAS, etc. [1, 2, 3]), the share of NPPs in the power generation structure won’t be changing dramatically as far as to 2040. The share of nuclear power generation in the world stays at about 12% (with a decline in Europe and US compensated by growing Chinese and Indian nuclear power industry). In Russia it does not exceed 20%.

The basic condition of an increasing share of NPPs in the total energy balance is its competitive ability ensured, which is directly related to solving systemic issues of the nuclear power industry. Attempts to solve issues of providing the acceptable safety level by developing additional protection systems at plants have inevitable complicated the design, increases the amount of capital investments and reduced the competitive ability of modern NPPs as compared to alternative power generation sources.

2. Requirements to competitive ability of the Industrial Energy Complex with BR-1200 reactor facility
Requirements to key performance indicators of the Industrial Energy Complex with powerful fast neutron reactors operated at CNFC are given in Table 1. The indicated requirements are defined on the basis of sustainable competitive ability as compared with alternative power generation sources with considering available capacity of their performance improvement.
Table 1. Performance requirements for IEC with BR-1200 reactors (cost indicators in 2017 prices, without VAT)

| Indicator                                      | Value |
|-----------------------------------------------|-------|
| Unit capacity, MWe                            | 1,220 |
| Availability factor, %                        | 93    |
| Normal mode ration, people/MWe                | 0.3   |
| Auxiliary rating, %                           | 5.0   |
| Capital investment in construction, thous. rub/kW | 81.3  |
| Capital investment in construction, bln. rubles | 198.5 |
| NF fabrication, thous. rub/heavy metal kg (kg HM) | 131.9 |
| SNF/RadWaste Management, thous. rub/kg HM     | 81.4  |

Figure 1 shows calculation results for Levelized cost of electricity (LCOE) of competitive power generation technologies as adjusted to the Russian conditions according to effective methodical guidelines of ROSATOM State Corporation (Decree No. 1/320-P dated April 14, 2017) at different discount rates. The calculation for BR-1200 is given for the fuel reload of 13 tons HM per year (average burnup of MNUP fuel is 8%FIMA).

![Figure 1](image_url)  
Figure 1. LCOE of competitive types of power generation in the Russian conditions at different discount rates.

The following conclusions may be drawn on the basis of LCOE calculation results:

- Performance requirements established for IEC with BR-1200 reactors ensure their competitive ability according to the LCOE at all discount rates considered;
- Renewable energy losses to all other types of power generation in Russia at all discount rates considered;
- At the discount rate of 10% (current nominal rate for Russia calculated by the WACC methodology), an NPP project with VVER-TOI reactor is competitive with a SGU only compared with conservative performance of gas stations.

3. Efficiency of a typical IEC with BR-1200 reactor

Efficiency (payback) of typical IEC with BR-1200 reactor, which performance corresponds to established requirements for competitive ability, has been analyzed with taking in account the current power energy market model in Russia.

The calculations accounted for the service life of the IEC with BR-1200 reactors being 60 years, provided that it is operated under a PDC (power delivery contract) during the first 20 years, which stipulates that the power energy is sold under 2 rates tariff of 2.44 or 5.56 rub/kW*h (tariff rates of Unit 3 of Rostov NPP and Unit 6 of Novovoronezh NPP) according to 2017 prices, without VAT. After the first 20 years, the power will be sold under 2 rates tariff of 1.43 rub/kW*h according to 2017 prices, w/o VAT, with taking in account rates of CCA (competitive capacity auctions) and insurance...
settlement rates in the Price Zone 1 (Europe and Urals) which are taken as per data of NP Market Council and the System Operator of the Unified Energy System.

The calculations of the NPV (net present value) show that the payback of a typical IEC with BR-1200 reactor is ensured by the current method of defining energy sales tariffs with accounting for PDC and CCA (figure 2).

![NPV of a typical IEC with BR-1200 reactor, bln. rubles.](image)

**Figure 2.** NPV of a typical IEC with BR-1200 reactor, bln. rubles.

The results of analyzing the efficiency of IEC with BR-1200 reactor are documented in “Economic letter on criteria of competitive ability, economic efficiency, and forecasted development rates of the nuclear power industry in Russia”, 2017 (approved by E.O. Adamov (Proryv PD), A.A. Makarov (IES RAS), V.V. Bushuev (Energy Strategy Institute)).

4. Terms and conditions of competitive implementation

The analysis of available experience in constructing NPP power units abroad (including in the USA and in South Korea) has shown there are several factors which can either prevent or contribute to the
technology development, from the point of view of reducing the capital costs of the construction in case of mass implementation.

The factors that adversely affect the technology development include: infeasibility of the technology development due to its initial lack of competitive ability, changes in regulatory safety requirements, changes in external economic factors (for example, outrunning salary growth), exhaustion of the “training” potential due to the technology maturity.

The necessary conditions for a successful technology development are:

- Confirmation of basic design and process advantages in the field of competitiveness and safety.
- Standardization of technical solutions, development of documents with a focus on minimal improvements for reuse.
- Consistent improvement of design and engineering solutions, application and development of modern construction technologies.
- Developing sustainable organizational schemes for construction projects that contribute to the accumulation of participants’ competencies.
- Construction of several typical power units on the same site.

5. Analysis of the IEC competitive ability on the PDEC data

An economic analysis of the facilities that are part of the standard (serial) IEC with BR-1200 reactor was carried out on the basis of scaling indicators of the PDEC facilities with BREST-OD-300 reactor based on the materials of the current design documents (DD).

The economic indicators of IEC FRM are calculated on the basis of scaling the indicators of the PDEC FRM taking into account the elimination of redundancy (conservatism) of design solutions of the PDEC FRM and the use of verified economic indicators (results of analyzing the design documents of PDEC FRM are documented in the Resolution of the Joint Meeting of Scientific and Technical Council No. 8 of ROSATOM and Technical Committee of Proryv PD dated November 01, 2017). In addition, there were considered possible directions for optimizing operating costs when making calculations, determined by the working group on establishing the break-even criteria for the PDEC (Minutes No. 1-9.12/7-Pr. dated March 24, 2017).

The results obtained for the operating costs of the IEC FRM meet established requirements for competitive ability (figure 3).

![Figure 3. Operating costs of the IEC FRM calculated by scaling the PDEC FRM indicators (prices of 2017, without VAT).](image-url)
Figure 4 shows the results of evaluating the competitive ability of the IEC with BR-1200 reactor in terms of LCOE based on scaling the current parameters in the PDEC design documents. The Conservative calculation was made on the basis of scaling the indicators of the current (adjusted) design documents of the PDEC, the Basic Option calculation - with taking into account the revealed potential for removing conservatism in economic and design solutions of the power unit with a BREST-OD-300 reactor and the PDEC FRM, as well as considering the possibility of increasing the capacity of the PDEC PM from 5 to 10 tons HM per year.

![Figure 4. LCOE of IEC with BR-1200 reactor (av. burnup of 8%FIMA), kopeck/kW*h 10% discount.](image)

6. Conclusion
The following main conclusions can be made on the obtained results of analyzing the competitive ability of the IEC with BR-1200 reactor:

1. LCOE deviation for the IEC with BR-1200 reactor is 4% according to the basic option in comparison with the requirements for competitive ability.
2. In-depth analysis and consideration of redundancy of design and cost decisions implemented in the PDEC design documents, performed at the IEC conceptual design stage, shall contribute to the improvement of economic indicators of the IEC with BR-1200 reactor.

References
[1] 2017 World Energy Outlook (International Energy Agency)
[2] 2017 International Energy Outlook U.S. (Energy Information Administration)
[3] 2016 Global and Russian Energy Outlook (The Energy Research Institute of the Russian Academy of Sciences (ERI RAS))