The concept of 50-300 MWe modular-transportable nuclear power plant with sodium coolant and a gas turbine

Anton G. Verbitskiy, Yurij V. Osheyko, Mark M. Trevgoda

Institute of Physics and Power Engineering, Obninsk, Russian Federation

goroshko@ippe.ru; averbitskiy@ippe.ru

Abstract.

Well-known vulnerability points for sodium-cooled reactors are:

- chemical interaction of sodium and water;
- three-circuits reactor design;
- increased material consumption and building cost compared to PWR and BWR;
- increased on-site amount of building and assembling operations.

The most of these difficulties can be solved with replacing steam turbine by specially designed gas turbine.

Since 2001 IPPE is working on development of so-called "BN GT" technology set, including:

- the use for primary circuit BN-600's well-proven materials, elements and technologies of sodium reactor;
- the use for secondary circuit specially designed helium turbine without any intermediate circuits;
- design specification, intended to locate any reactor and turbine equipment in rail-car form-factor and some others.

Currently achieved competitiveness estimates show significant commercial advantage of 300 MWe BN GT power plant in comparison with 1000 MWe water-cooled reactors.

Commercial competitiveness over gas-burning power plants is also possible in case of nuclear fuel recycling.

Key Words: Sodium-cooled Fast Reactor, Gas Turbine

1 Introduction

Well-known vulnerability points for sodium-cooled reactors are:

- chemical interaction of sodium and water;
- three-circuits reactor design;
- increased material consumption and building cost compared to PWR and BWR;
- increased on-site amount of building and assembling operations.

Each these problem individually is solvable, but in sum they lead to a significant deterioration of technical and economic characteristics.

2 Gas turbine as the possible solution

A possible way to improve liquid-metal cooled reactors is use of the turbine with different working fluid rather than water/steam. Attempts to create such reactors are well-known since the 1950s using CO_2, NO_2 and other gases. But the materials available, poor thermal-hydraulic, low resource and other problems had made those attempts less competitive than the steam turbine.

By 1990s gas turbine developers have significantly improved their products. Coal-firing electric plants with gas- and gas-steam turbines has reached an efficiency of 50%, a gas-firing plants has reached up to 60% efficiency. New materials and technologies make it possible to operate in working conditions that are not achievable for steam turbines.

3 BN GT concept

In 1998-99 IPPE has made attempt to apply gas turbine for reactors BN-800 and BREST-1200. Preliminary calculation have shown possibility of gas turbine usage and revealed some improper solutions in the existing reactor designs.

Since 2001 IPPE is working on development of so-called "BN GT" technology set, including:

- the use for primary circuit BN-600's well-proven materials, elements and technologies of sodium reactor;
- the use for secondary circuit specially designed helium turbine without any intermediate circuits;

– design specification, intended to locate any reactor and turbine equipment in rail-car form-factor and some others.

Design work has shown that within these temperature-, size- and weight limitations up to 400 MWe power plant unit could be made. But commercial competitiveness viewpoint revealed 300 MWe unit as more promising [1].

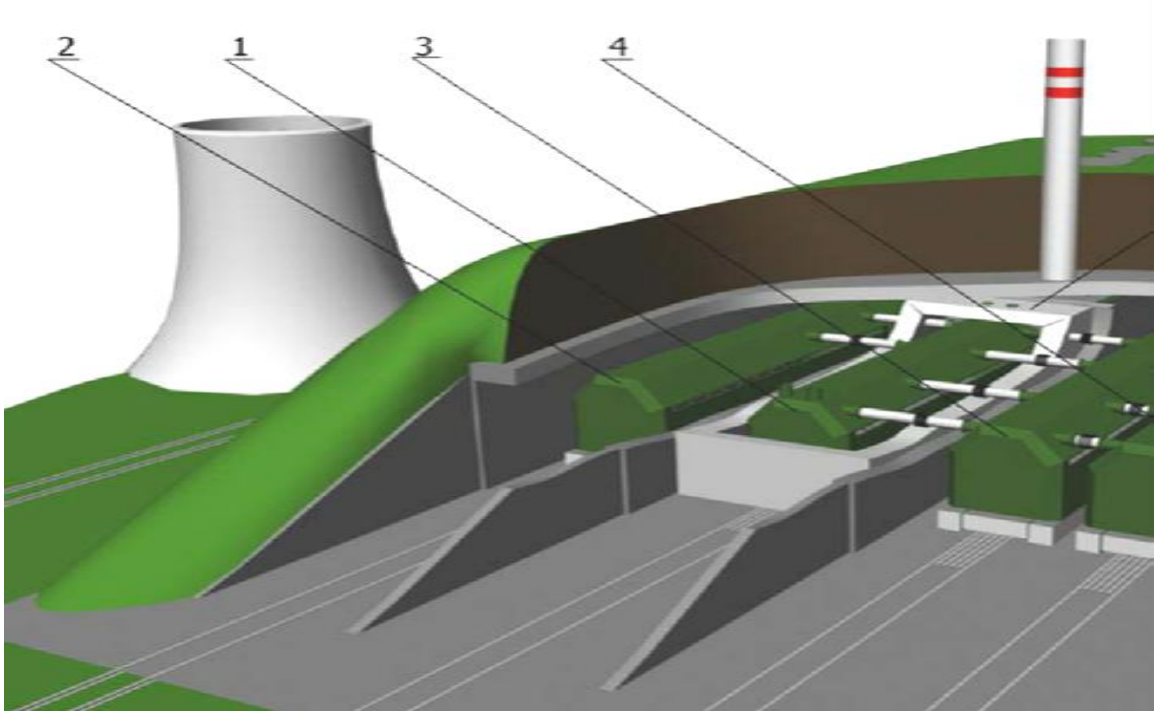

FIG. 1. View on 300 MWe BN GT according to variant of 2001 year

The rail-car sized variant of BN GT-300 has shown on Fig.1, including nuclear reactor car (1), electric generator`s car (2) and heat-exchangers` cars (3, 4).

In 2001-2005 years unit net efficiency was proved to be over 40%. The possibility for significant reduction of the main equipment number and weight was demonstrated. The volume and complexity of the construction work was reduced several times compared with other nuclear power plants. Some reasons of such reduction could be illustrated by Fig.2:

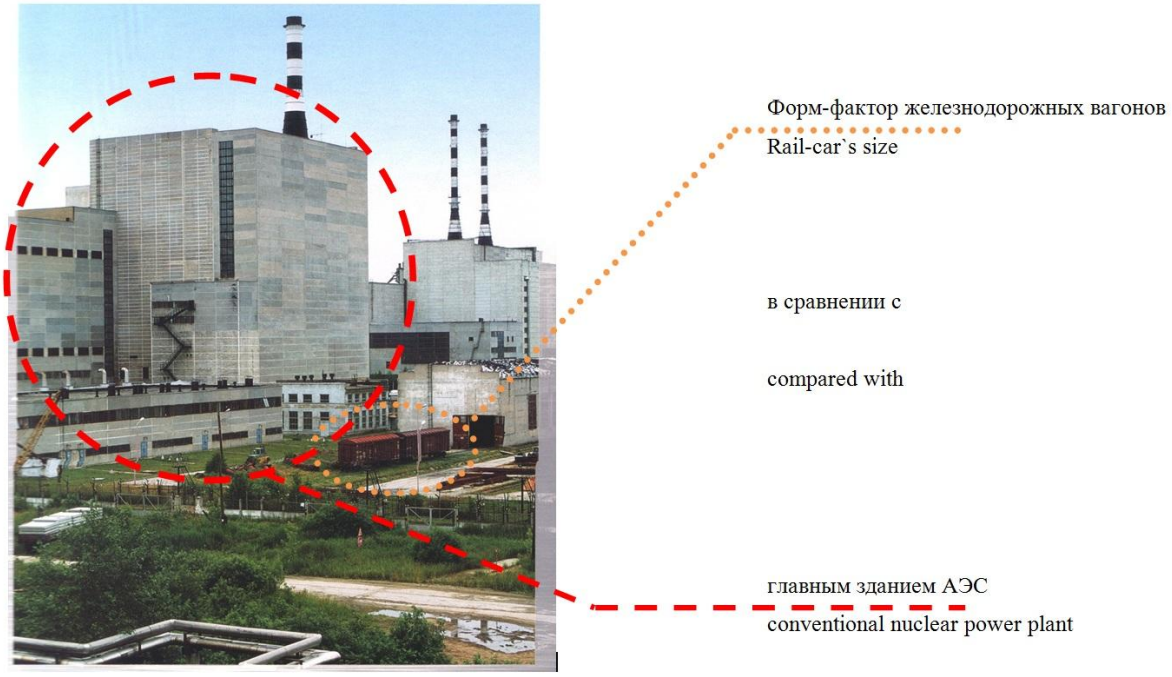

FIG. 2. Size comparison

4 "The most conservative" variant

By 2006 the concept of BN GT was proven and time has come for commercial optimization. Possible Owner of the first BN GT has ordered risk-reduction research. To ensure Owner "the most conservative" variant of reactor, turbine and plant layout was investigated. In cooperation with other institutes variant of conventional power plant`s building was investigated. The same time gas turbine`s pressure and temperature also were reduced for the "conservative" reasons.

Plant layout 2007 has shown on Fig.3

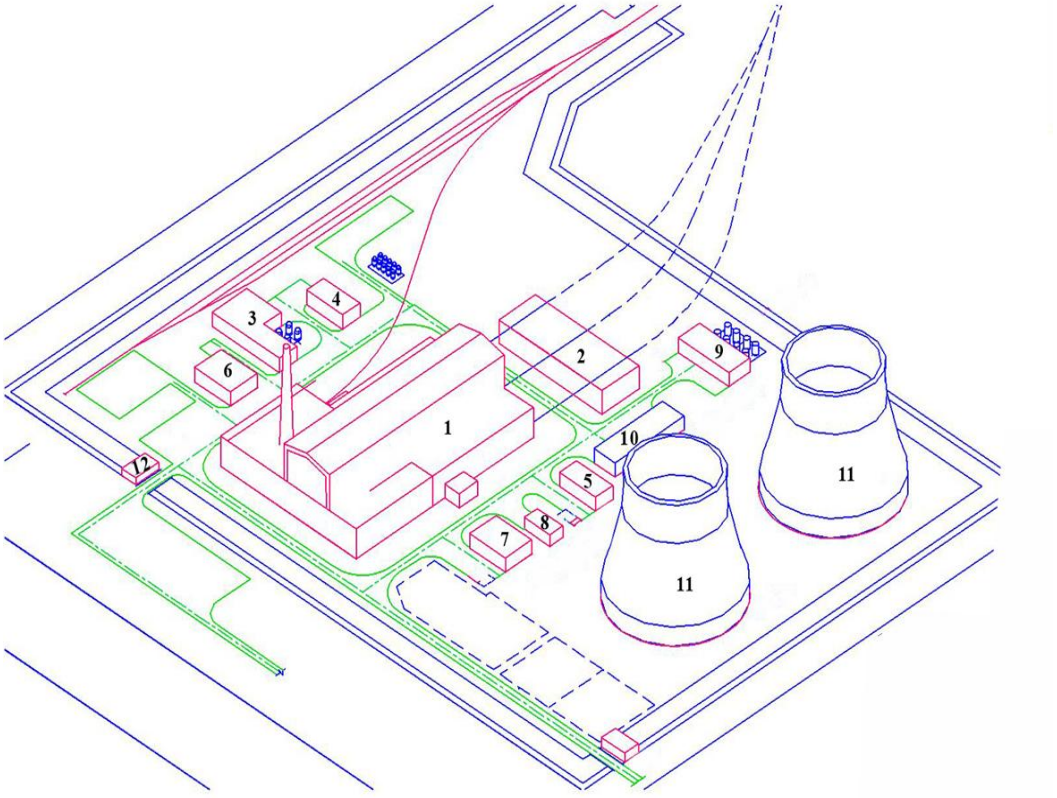

FIG. 3. "The most conservative" plant layout

On this figure one could see power plant`s main building (1) containing reactor`s and turbine`s compartments, service territories (2...10) and cooling towers (11).

Within rail-car size limitations "the most conservative" variant requires increased equipment for construction. On the Fig.4 reactor unit is shown:

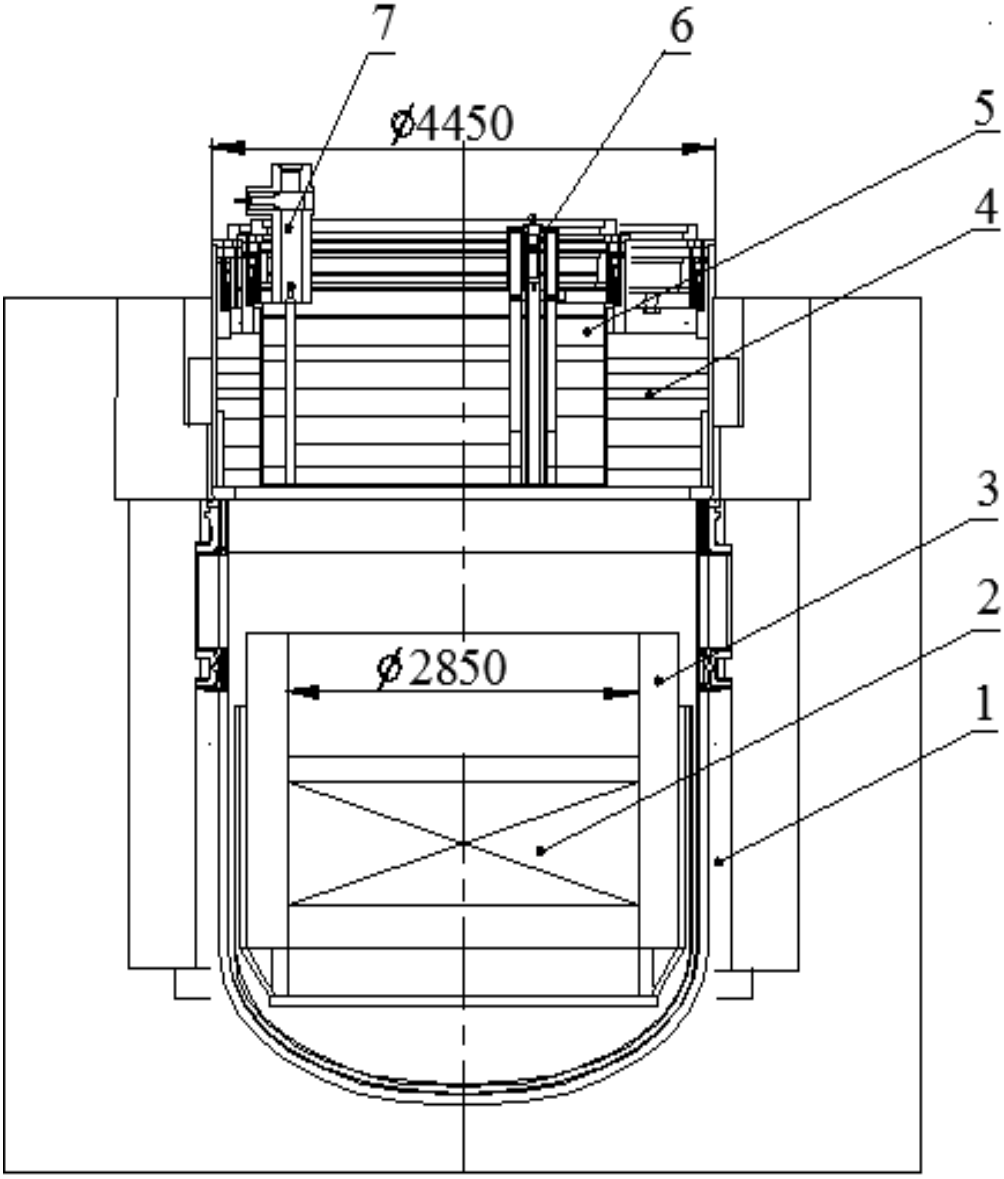

FIG.4 Reactor unit of "the most conservative" variant

Within external structures (1) reactor unit contains core (2) internal shields (3) and other required equipment (4...7).

By the results of 2007 year the Possible Owner was ensured that even in worst cases the first BN GT power plant would be more competitive than a serial VVER-1000 nuclear power plant.

5 The small power variant

One of the doubts of the Possible Owner was that reactor BN-600 could be treated as the technological prototype of BN GT-300 in any aspect except the gas turbine. To ensure the Possible Owner special project of BN GT demonstrating reactor was created. With power of 50 MWe BN GT-50 may be not only a prototype but a commercial power plant for remote territories.

6 The modern state of art

As the results of experience gained in 2001-2011 the improved version of BN GT-300 was created. Evolution of some owner-important parameters of single-unit BN GT nuclear power plant has shown in Table 1. For the purpose of comparison in the table data of serial water-cooled reactor VVER-1000 is shown too.

Table 1

	GN GT 2006	"The most conservative" variant 2007	BN GT 2011	VVER-1000 (B-392)
Unit`s electric power, MWe	300	250	300	1000
Unit`s efficiency, %	42	36	40	33
Main equipment`s relative metal consumption, t/MWe	5	15	11	18
Unit`s relative cost, $\$_{2007}$/kWe	–	2500	2000	3000

Currently achieved competitiveness estimates show significant commercial advantage of 300 MWe BN GT power plant in comparison with 1000 MWe water-cooled reactors.

7 Summary

The work done has sown high competitiveness of BN GT-300 reactor unit.

In modern state of art nuclear fuel recycling wasn`t included in the cost comparison and could give additional benefits.

References

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Status of Small Reactor Designs Without On-Site Refuelling, ANNEX XVIII TRANSPORTABLE MODULAR SODIUM COOLED REACTOR WITH GAS-TURBINE GENERATOR (BN GT-300), IAEA-TECDOC-1487, Vienna 2007