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New generation first-of-the kind unit – VVER-1200 design features

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Abstract

The paper is concerned with the commissioning of the new generation NPP-2006 power unit with the VVER-1200 reactor. A comparison is made between the characteristics of the new NvNPP II-1 and commercial VVER-1000 power units (B-320). Some design and circuit solutions used in the NPP-2006 project were described, which made it possible to increase the installed capacity of the power unit, which was achieved, in particular, by increasing the pressure of the primary circuit by 0.5 MPa and the pressure in the steam generators by 0.6 MPa, and also by increasing the capacity of the main circulation pumps by 2000 m^3/h.

The main differences in the equipment and composition of passive and active safety systems of the NPP-2006 power unit are considered. A brief description of the safety systems first applied at Russian power units is given, e.g., a two-channel structure of active safety systems with redundant emergency pumps in each channel, a double containment, a core melt localization device, a passive heat removal system, etc. Due to the increased number of BRU-Ks, it was possible to increase their performance from 15 to 3 s, which significantly improved the maneuverability of the power unit in abnormal conditions.

The structure of the APCS is considered, which is applied in the NPP-2006 project, using programmable technology based on the TELEPERM XS platform. The peculiarities of the power unit commissioning are analyzed, problematic issues that have arisen at various stages of the construction are revealed, some data on the tests carried out and the results of these tests are given.

Finally, an analysis is made of some design drawbacks revealed during the construction and commissioning of the power unit, an evaluation of the project was made, and proposals were formulated to finalize the VVER-1200 project for consideration in the subsequent NPP projects.
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Keywords: NPP-2006; Reactor; Steam generator; Power unit; Safety system; Accident; APCS; Operation; Equipment; Protective shell; Accumulator tank.

Introduction

The commissioning of Unit 1 at the Novovoronezh NPP II was one of the most important events in the nuclear power industry of Russia and the whole world.

The VVER technology [1] undoubtedly played a decisive role in the key stages of the formation and development of nuclear power in the Soviet Union and Russia. All the first-of-the-kind power units based on the VVER technology began their long life at the NvNPP site. The power units with VVER-210 and VVER-365 reactors were started up here. The NvNPP gave birth to the firstborns of the following VVER generations, i.e., the first VVER-440 and VVER-1000. The construction and operation of the first-of-the-kind power units at the NvNPP confirmed the technical feasibility of reliable and efficient industrial energy nuclear fuel sources, ensured the entrance of VVER technology to the international market of reactor technologies [2,3]. In the critical period after the accident at the Chernobyl NPP, it was the VVER reactors that ensured the stability of domestic nuclear power. The lat-

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Table 1
Characteristics of V-320 power unit and AES-2006 project.

Total number of	VVER-1000 (RoNPP, Unit 3)	VVER-1200 (NvNPP II)
Process systems	247	482
Pump units	339	779
Ventilation units	676	1600
Hosting devices	35	158
CPS CE drives	61	121
Motor-driven valves	4319	6175
FGC algorithms	34	154
Process protections and interlocks	3686	11,140
Measuring channels	6238	12,081
Tests at all stages of commissioning	1638	2231

est new-generation first-of-the-kind power unit based on the VVER technology was commissioned at the NvNPP site.

The NvNPP II is a new-generation nuclear power plant being constructed according to the NPP-206 project developed by JSC "Atomenergoproekt" using the VVER-1200 reactor plant (V-392M RP design) [4]. The characteristics of VVER-1000 and VVER-1200 reactor plants are compared in Tables 1,2.

Projects of improved light-water reactors have been actively developed in the last 25 years in two directions: (1) so-called evolutionary projects based on existing nuclear power plants with the addition of new technological improvements and modifications; (2) NPP projects characterized by a large number of differences from existing RPs, in which passive operational principles predominate, such as natural gravity or compressed gas pressure [5].

The purpose of the NPP-2006 project was to increase safety, economic competitiveness, consumer appeal as for reliability, maneuverability, and maintainability.

Improvements of the primary and secondary circuit parameters (pressure and temperature) and the performance of the main circulation pumps by 2000 m^3/h made it possible to increase the thermal capacity of the power unit and the reliability of heat removal from the reactor core (RC).

A significant part of the power unit systems and equipment has been designed, manufactured and commissioned for the first time. Compared with the serial NPP power units, the NvNPP II design includes additional security systems based on passive operational principles.

A number of design improvements have been made to the V-392 M RP design, including:

- Improved nuclear properties of the reactor core;
- Negative reactivity coefficients provided in a wider range of process parameters;
- New equipment monitoring and diagnostic systems;
- Improved RC neutron and radiation monitoring systems;
- Prolonged RP main equipment lifetime (up to 60 years);
- Increased maximum fuel burn-up (up to 70 MW-day/kgU);
- Reduced downtime and increased installed capacity utilization factor (ICUF).

The NvNPP-2 design implements a number of additional technical measures:

- Improved localization safety systems including a double containment with a ventilated gap;
- A device for retaining molten core materials to exclude the release of radioactivity into the environment in the event of an emergency;
- A steam generator passive heat removal system to cool down the reactor plant in the event of the power unit blackout;
- A core passive flooding system with secondary hydraulic accumulators.

Table 2
Comparative analysis of performance indicators and safety characteristics of NPPs with VVER-1000 and NPP-2006 [6,7].

Indicator	VVER-1000	NPP-2006.	Comment
Rated thermal power, MW	3000	3200	Increasing the parameters of the primary and secondary circuit media made it possible to increase the reactor thermal power, SG rated capacity and generator electric power
Rated electric power, MW	1000	1200	
Nominal primary pressure, MPa	15.7	16.2	
Nominal SG pressure, MPa	6.3	6.9	
SG rated steam capacity, t/h	1470	1602	
Safety systems (quantity of channels)	3	2	The cost of the unit is significantly reduced. The safety level is significantly increased due to an optimal compromise between active and passive systems. Each safety function is backed up by at least two different systems in each channel.
CPS CE system (quantity of drives, pcs)	61	121	Increased safety, deeper subcriticality after the core. The re-criticality temperature is less than 100 °C.
Main circulation pump (capacity, m^3/h)	20,000	22,000	Increased thermal power. The pump bearings are cooled with water. The oil system is located next to the electric motor.
SG blowdown water system (total flow rate, t/h)	40	140	Increased SG lifetime. A new scheme is used without SG blowdown flash tanks
Generator (cooling system)	Hydrogen- water	Air- water	Fire protection, decreased dimensions
BRU-K (quantity, pcs)	4	8	Increasing the number of BRU-Ks and decreasing their response time from 15 to 3 s made it possible to significantly the unit maneuverability in off-design modes.

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