

UDK 621.165

SIDORKIN I. D.¹, YEFIMOV O. V.²

ANALYSIS OF THE FEATURES OF TECHNOLOGICAL SCHEMES AND DESIGNS OF MODERN AND PROSPECTIVE REACTOR INSTALLATIONS OF NUCLEAR POWER PLANTS AND THEIR TECHNICAL AND ECONOMIC INDICATORS

¹ Ph.D. student, Chair of steam-generator Construction, NTU “KhPI”, Kharkiv, Ukraine.

² Sc.D. hab. (technic), Professor, Head of the chair of steam-generator Construction, NTU “KhPI”, Kharkiv, Ukraine.

Introduction. Nuclear energy is one of the key components of the energy system in many countries worldwide, meeting a significant portion of electricity demands. Its development is driven by the need to ensure energy security, minimize greenhouse gas emissions, and optimize electricity production costs. Modern trends in the design and operation of nuclear power plants (NPPs) aim to enhance the efficiency, reliability, and safety of reactor installations. Analyzing the features of technological schemes and designs of modern reactor installations helps identify key directions for their modernization and assess the potential of innovative solutions. This is especially relevant for Ukraine, given the ongoing public discussion on the prospects of constructing new nuclear power plant units at domestic NPPs: South Ukraine, Rivne, and Khmelnytsky.

The report includes an analysis of the main prevalent types and designs of reactors as well as an overview of innovative projects aimed at developing advanced water-water and small modular reactors.

Objective of the Study. To analyze the main features of technological schemes and designs of modern and prospective reactor installations of NPPs, as well as to evaluate their technical and economic indicators, which is a crucial step for the further development of nuclear energy and its adaptation to the challenges of the 21st century.

Main Body. Currently, reactors generate about 85% of global nuclear electricity. The primary design is the pressurized water reactor (PWR), where water in the primary cooling/heat transfer circuit is pressurized and heated to over 300°C, enabling steam generation in the secondary circuit. Less common boiling water reactors (BWR) produce steam in the primary circuit above the reactor core at similar temperatures and pressures. These designs are simpler but require heightened protection due to radioactivity in the primary circuit. Both types use water as a coolant and neutron moderator. A characteristic feature of these designs is the presence of a primary cooling circuit under very high pressure, passing through the reactor core, and a secondary circuit where steam

Тези доповідей XX Міжнародної науково-технічної конференції

«Енергетичні та теплотехнічні процеси й устаткування», 26–27 грудня 2024 р.

is generated to drive the turbine. Another common type is the pressurized heavy-water reactor (PHWR), which typically uses natural uranium (0.7 % U-235) as fuel in oxide form, requiring a more effective moderator—heavy water (D₂O). The moderator is located in a large reservoir called the calandria, intersected by hundreds of horizontal pressure tubes that serve as fuel channels. The fuel is cooled by heavy water flowing under high pressure (approximately 100 times atmospheric pressure) in the primary cooling circuit, where temperatures usually reach 290 °C.

Small Modular Reactors (SMRs) are modern nuclear reactors with a capacity of up to 300 MWe per unit, about one-third of the capacity of traditional reactors. SMRs can produce large quantities of low-carbon electricity and are compact, occupy significantly smaller areas than traditional nuclear units, and allow factory assembly of systems and components for transport as a single unit to installation sites. These characteristics make SMRs a promising solution for producing clean energy with lower construction and operational costs compared to traditional large reactors. Current prospects for SMR deployment include the following key players: Nuscale (USA) in 2029-2030, AP100 (China) in 2026, South Korean SMART around 2030, and BWRX-300 (USA) with the largest electrical capacity among SMRs at 300 MWe, slated for launch in 2035.

Conclusions. Nuclear energy remains an integral part of the global energy system, providing low-carbon electricity generation, energy security, and economic efficiency. An analysis of modern reactor technologies indicates that traditional water-water reactors (PWR and BWR), heavy-water reactors (PHWR), and prospective small modular reactors (SMRs) each have distinct advantages and areas of application. SMRs are of particular interest due to their compactness, flexibility in use, and reduced construction and operational costs, making them attractive for the future of nuclear energy. However, their implementation requires resolving technical, economic, and regulatory challenges, especially within Ukraine's energy system. Drawing on the experience of global leaders in nuclear energy and further adopting innovative solutions will enable Ukraine to adapt its energy policy to the challenges of the 21st century, ensuring stability in the energy sector and minimizing environmental impact.

References:

1. Reactors and Steam Generators of NPP Units: Schemes, Processes, Materials, Designs, Models / O. V. Yefimov, M. M. Pylypenko, T. V. Potanina, et al. ; ed. by O.V. Yefimov. – Kharkiv: V Spravi, 2017. – 420 p.
2. Reactors – Report of the Collaborative Project COOL of the International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO), IAEA-TECDOC-1696 (May 2013).
3. The NURECAB webinar 'Small Modular Reactors' / M. Ricotti, 23.12.2024.