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Advanced VVER-640 Development and Construction Programs

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ABSTRACT

The VVER-640 Nuclear Power Plant design is being developed within the frames of the Russian federal program "Ecologically Clean Energy" and based on "Safety Features Improvement For Operating VVER NPP Program". The new generation VVER program based on evolutionary developing VVER-440 and VVER-1000. Main VVER program vendors were not changed from first unit project to new projects. All materials used in manufacturing the reactor vessel are certified and substantiated by a long-term operating experience: above four hundred of reactor-years. The heightened interest in medium-power NPP is conditioned also by a possibility to apply such power units for power maneuvering in regions with relatively low-power grids. For regions with limited water resources a variant of dry cooling towers for turbine condenser cooling or desalination plant were considered.

LICENSING PROCEDURES AND MAIN EXAMINATIONS

Development of NPP new designs with improved technical characteristics and economic indices is an urgent necessity for progress in the nuclear power, being a part of the Russian Fuel-and-Power Complex, and a priority-oriented problem of the Russian Nuclear Power Ministry. The new generation NPP design completely meets the most stringent up-to-date safety requirements of the world and Russian codes and standards and ensures the competitiveness with the best world analogues as regards the technical characteristics and economic indices. Safety policy is based upon the well established deterministic methods, augmented by probabilistic methods using appropriate numerical targets and analysis.

VVER-640 NPP is designed as NPP equipped with enhanced safety VVER reactor of new generation. When elaborating the safety concept the evolutionary approach based on thorough analysis of operating NPP with VVER experience and design solutions. The analysis incorporated evaluation of advantages and weak points of operating NPP carried out within the framework of development of the concept of safety enhancement of the Units in question, which was implemented in line with domestic and international programs with participation of leading Russian companies (SPbAEP, OKB Gidropress, RSC "Kurchatov Institute") and foreign companies (GRS, Siemens AG) as well as IAEA.

Now in Russia the licensing procedure is introduced for activities in the nuclear power field. In compliance with the "Provision for the order of issuing the Gosatomnadzor of Russia tentative permits for construction of NPP power units for civil purposes" the design of the

NPP with VVER-640 is a first one to be subjected to the licensing procedure in this country practice. The international licensing standards, accepted and introduced in Russia, are intended to enhance the level and quality of safety estimate for certain NPP, subjected to this procedure, and hence enable to achieve greater confidence in nuclear power as a whole. The experience in licensing the new generation NPP with VVER-640 indicates a considerable increase of the developed design documentation nomenclature and scope, as well as of time for expert examination.

The VVER-640 NPP is at a stage of the detail design, including along with the technical and economic studies the "Preliminary Safety Analysis Report" and "Probabilistic Safety Analysis", allowing to carry out a full-scope procedure of the design qualification and licensing.

On the 25th of June 1996 Gosatomnadzor of Russia (Russian Nuclear Regulatory Commission) issued permit for constructing a forerunner of the power unit with VVER-640, being a part of the Scientific-Industrial Center of Nuclear Power in Sosnovy Bor. Prior to this permit the following main decisions were issued: Preliminary decision concerning the site from Gosatomnadzor of Russia, General Headquarters of Russian Armed Forces, Ministry of Emergency Situations, State Sanitary Inspectorate of Ministry of Health, State Fire Defense Department of Ministry of Internal Affairs, Summary Decision of Expert Commission of State Ecological Expert Board of Ministry of Nature, Department of State Projects, Expert Appraisal Board, Approval of Feasibility Study from Ministry of Nuclear Power, North - Western Regional Air Transport Board, Leningrad Region Highway Committee, Octjabrskaja Railway Board, Administration of Sosnovy Bor, Regional Department of Ministry of Fish Industry, Water Resources Committee, Government of Leningrad Region, Report of Utility, based on Feasibility Study documents, Expert Commission of "Kurchatov Institute", Decision of Scientific and Technical Council of Saint Petersburg Institute "Atomenergoproekt" (approved by Minister of Nuclear Power of Russia).

Apart from the review in the appropriate Russian supervisory authorities to confirm the correspondence of the accepted solutions to the world safety criteria and requirements, the design was subjected to a comprehensive examination by the leading expert company of Germany in the sphere of nuclear power - Gesellschaft fur Reaktorsicherheit mbH- (GRS), which positively appraised the presented documentation. US Department of Energy, Brookhaven National Laboratory, Raytheon Engineers and Constructors used VVER-640 design safety information for the report "Joint Parallel Nuclear Alternatives Study for Russia".

This design due to positive appraisals both in Russia and abroad attracts the attention of the world-known Western companies advising their co-operation within its frames. Nowadays such co-operation is being implemented in particular with Siemens AG in the field of development and delivery of Instrumentation & Control and Electrical systems for VVER-640.

The International Jury formed of experts from France, Germany, Sweden and Canada expressed their high appraisal of the design during the First St. Petersburg International Competition for the tender for construction of safe power units, where this design was named "recommended advanced design".

Public participation has been difficult at construction permit stage because many commissions need different details. It is solved for VVER-640. NPP VVER-640 standard design was used for application.

GENERAL PHILOSOPHY AND SAFETY CONCEPT

Safety concept used for VVER-640 NPP design is based upon application to maximum possible extent the engineering principles of defense-in-depth concept disclosed in valid IAEA regulations and upon usage of results of operating NPP with VVER safety analysis results.

The optimum combination of passive and active components in safety systems, use of equipment, assemblies and systems proved in Russian practice, application, for the first time, of such approaches as dual containment, reactor core cooling in a special pool, etc. make it possible to enhance appreciably the NPP safety, reliability and efficiency.

The features of the considered design made it possible for Russian Ministry of Nuclear Power to come to a decision to select it as a principal one among the base design for development of nuclear power in Russia for a period up to 2015. Principal reasons, explaining the selection of VVER-640 NPP, briefly presented below.

The VVER-640 concept has been under development during 8 years and principal design approaches have been adequately studied. As to its economic indicators the VVER-640 NPP is in line with the new generation power units, having an analogous power, of other Suppliers.

The NPP have 640 MW electrical power units and is intended for electrical energy generation under base-load conditions. The effective rated power hours of reactor operation make up 7000 effective hour/year. The NPP is conditioned also by a possibility to apply such power units for power maneuvering in regions with relatively low-power grids. The design lifetime of the NPP main equipment is 60 years. Refuelling is performed once per year. In the normal operation year an average duration of refuelling shutdown is 25 days. The NPP safety enhanced by passive systems for different accidental situations including the refuelling and repair work without any limitation in time, in principle.

The lower thermal power value for the VVER-640 core considerably enlarger the available departure from the nucleate boiling for coolant (2.77 and 1.85 at the rated power level for VVER-640 and VVER-1000 accordingly), thus new qualitative advantages are created as regards the reliability margins of this reactor. It is essential to emphasise a number of preferable features characteristic of the NPP with VVER-640, following from complete functionality of the emergency protection, which assures, with no regard to the action of the most effective absorbing rod in the control and protection system, having been stuck in the extreme top position, compensation of the summary influence, produced by the following factors: fuel temperature change at reactor power variation from 100% to 0% with subsequent fuel cooling down to 373 K and coolant mean temperature change from a rated one to 373 K with simultaneous unforeseen boric acid concentration lowering in the primary circuit down to 0.

The reduced specific loads, large reserves of the primary coolant and feed water in steam generators, layout, ensuring developed natural circulation in the circuits, removing heat from the reactor core to the ultimate heat sink, relative to the power rated level, when compared with a reactor plant of the NPP with VVER-1000, - all these factors create actual advantages of the VVER-640 reactor plant as regards its stable withstanding the power transients and assuring safe run of emergency conditions with coolant leaks. The controlled area in accordance with this design is located within the NPP site fence. Following the requirements of the Russian regulations determined were the radius of the controlled area and emergency planning area, they are 30 km and 1.5 km accordingly.

PLANT LAYOUTS AND CONSTRUCTION PROGRAM

The NPP power unit consists of the reactor plant and turbine plant. The primary circuit includes: thermal-neutron reactor VVER-640, four primary circulation loops, steam pressurizer and auxiliary equipment located inside the tight containment. The every loop comprises: horizontal steam generator, reactor coolant pump, primary circulation pipeline of stainless steel. The turbine plant is a tandem-compound steam turbine with a high-pressure cylinder, an intermediate pressure cylinder and two double-flow low-pressure cylinders. The last stage is fitted with a 1200 mm long titanium blade.

The NPP power unit includes: the reactor building, turbine building, auxiliary building, control building, complex of general-station auxiliary buildings. Layout of the power unit main buildings is presented in Figures 1 and 2.

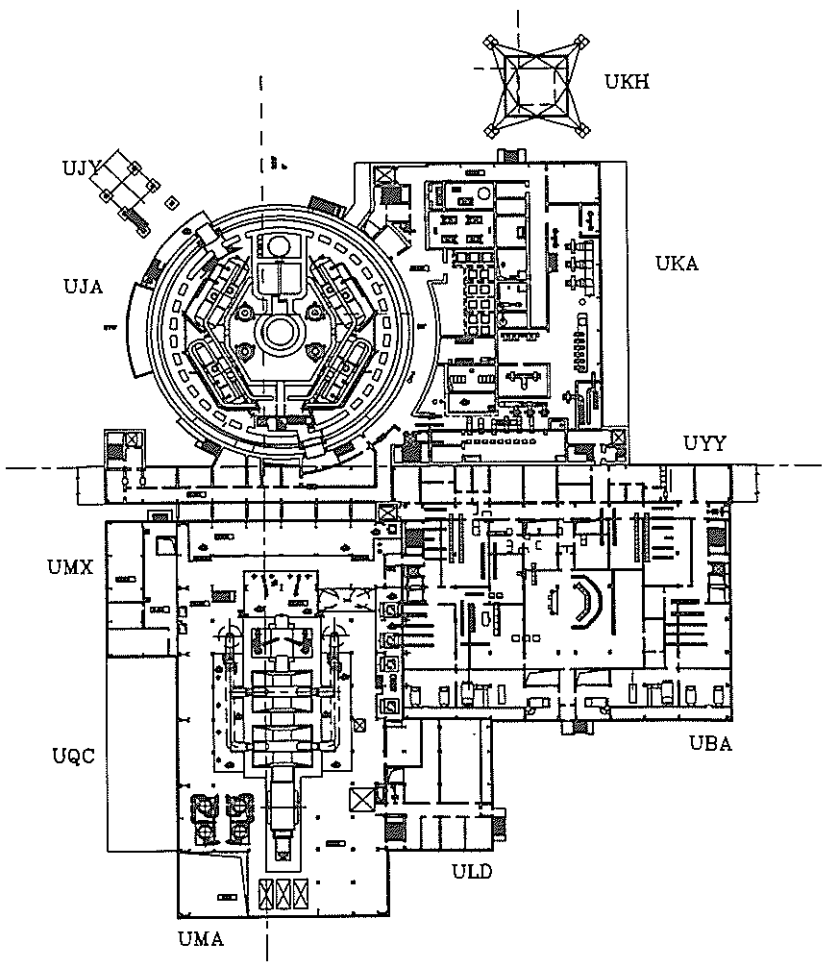

Fig. 1

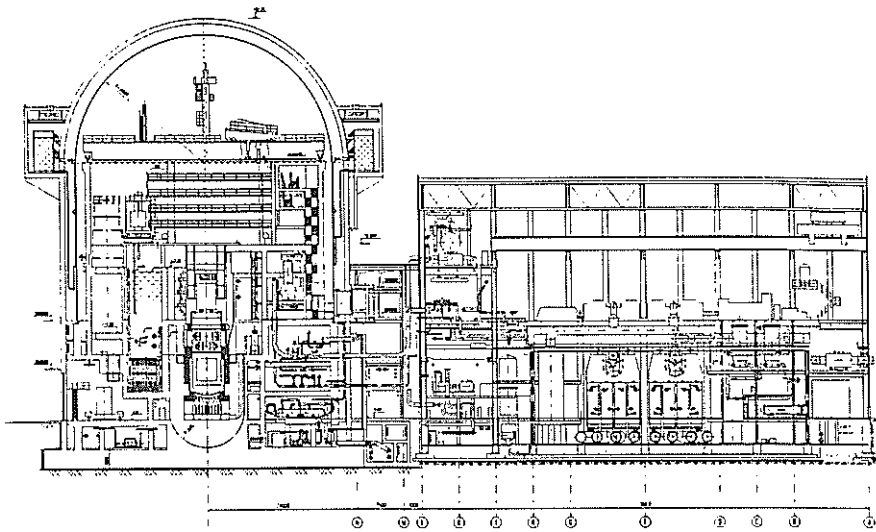

Fig. 2

The technical-and-economic indices analysis is based on the summary financial estimate, performed in the Standard VVER-640 NPP design and examined for real investment condition in the Kola-2 NPP. Commissioning terms for the power unit is accepted approximately 10 years after operation start-up.

The Russian companies and Suppliers working in the frame of the Standard VVER-640 NPP Project, Russian Ministry of Nuclear Power and Russian Government have made the Resolution to finished construction and start-up operating the power unit with VVER-640 in Sosnovy Bor in 2005 year. Second site in Murmansk Region named Kola-2 is available for same schedule. All in all now the Russian Federal and Local authorities have made the decisions aimed to construction of eight nuclear power units with VVER-640 on the territory of Russia (one unit in Sosnovy Bor, three units at the Kola-2 and four units at the Far East Part of Russia named Dalnevostochnaya NPP).

GENERAL TRENDS IN VVER-640 EXPERIMENTAL AND ANALYTICAL PROGRAM

NPP systems are based on the defence-in-depth principle. In accordance with it, in the design special attention is paid to reliability of safety-important normal operation systems, because on the one hand they ensure reliability of the product output and keep the safe operation limits, and on the other hand they ensure safety enhancement at carrying out of the post accidents measures and during the beyond design basis accidents. The residual heat removal is bringing about by normal operation systems, having standby electric power supply from the diesel-generator unit. These systems consist of trains, performed independent by the process connections, which was positively appraised by experts. Special attention for availability and reliability of normal operation systems were recommended as main project target. On this way all preliminary requirements for participants and subvendors were based due to utmost utilisation of experience in creation, manufacturing and operation of power units with VVER-440 and VVER-1000 reactors (more than 550 reactor-years).

In 1991 the main participants of the VVER-640 Project prepared to the Ministry of Nuclear Power budgetary offer to Research and Development Program for VVER-640 NPP.

That program have special part for increase equipment efficiency and create new equipment for ecological purposes and for different regions were medium power NPP have possibility to construction (dry cooling towers for turbine condenser or desalination plant etc.). Now main Russian manufacturers are ready to start working in frames the VVER-640 schedule.

Main function of safety systems, besides the unit shutdown, is that of residual heat removal from the core. That's why a great scope of researches is related to substantiation of the design approaches approved in design and the efficiency of systems ensuring the emergency reactor core cooldown and design basis events. In case of complete blackout (loss of auxiliary electric power supply and diesel-generators units) the passive heat removal systems are putting into operation to ensure the reactor plant cooldown. Experimental and analytical validation of passive heat removal systems have been carried out to define operating parameters over the whole range of specified conditions with the aim to justify the design solutions pertaining to passive heat removal system.

For accidents and design basis events were prepared the Experimental and Validation Program. That Program was approved and agreed by Gosatomnadzor of Russia. Some passive safety items have been insert on this Program. That Program has two main stages. First one was content preliminary calculations were made in frames of Preliminary Safety Analysis Report and based upon the carried out Safety Analyses and Probabilistic Safety Analysis results. Second one is content detailed calculations based on approved recommendation received with permit for start construction. Second stage is composed more detailed Probabilistic Safety Analysis, calculating different beyond basis events etc.

As the most important work forming a part of the Program the General-Designer of NPP consider the studies regarding the VVER fuel cycle characteristics, safety ensuring within the framework of radioactive fission product protection in depth and in particular, substantiation of the reactor core cooling efficiency during accidents.

The present-day regulatory and technical documents, issued by Gosatomnadzor of Russia, place stringent requirements upon NPP safety assurance. In compliance with these requirements, the VVER-640 NPP Standard Design meets the international trends in development of nuclear power as a whole and refers to the evolutionary designs with passive safety systems.