

**Project «Power units №3,4 of Khmelnytsky
NPP construction».
Safety enhancements
which are necessary for implementation.
Building Structure Inspection.**

Khmelnitsky NPP

An aerial photograph of the Khmelnytsky Nuclear Power Plant. The image shows a large industrial complex with several buildings, including two prominent blue cylindrical structures. Two orange arrows point from a rectangular orange box labeled 'Power units №3, 4' to these blue structures. The plant is situated near a large body of water on the left and is surrounded by greenery and infrastructure.

Power units №3, 4

Khmelnitsky NPP is situated in Slavutskiyi area of Khmelnytsky district, 100 km away in the north of city Khmelnytsky and 45 km away in the south-east of city Rivne. Town Neteshin is situated 3,5 km away in the north.

The history of Khmelnytsky NPP project implementation

- ❖ In March 1973 the decision on construction of Khmelnytsky NPP which should consist of 4 power units with total installed capacity of 4000 MW has been made;
- ❖ The beginning of construction of power unit №3 has been started in September 1985 and power unit №4 – June 1986;
- ❖ According to the moratorium the construction of Khmelnytsky NPP has been suspended in 1990;
- ❖ There has been created an infrastructure for KhNPP which is rated for 4 power units. It's under operation nowadays.

The history of Khmelnytsky NPP project implementation

.In 2008, an international competition was held to select the type of switchgear for the construction of KhNPP power units No. 3.4. The competition commission selected the VVER-1000 / V-392B project, which was submitted by ZAO “Atomstroyexport”, “Rosatom” State Corporation (RF).

.On June 9, 2010, the Cabinet of Ministers of Ukraine and the Government of the Russian Federation signed an Agreement on cooperation under construction of power units No. 3 and No. 4 of the Khmelnytsky NPP.

.The Cabinet of Ministers of Ukraine has approved a feasibility study (FS), Resolution No. 498-r of July 4, 2012.

.The Law of Ukraine dated September 6, 2012 No. 5217-VI “On the Location, Design and Construction of the Power Units No. 3 and 4 of Khmelnytsky NPP” was adopted.

The history of Khmelnytsky NPP project implementation

Verkhovna Rada of Ukraine adopted:

❖ The Law of Ukraine dated September 16, 2015 No. 696-VIII “On termination of Agreement between Cabinet of Ministers of Ukraine and the Russian Federation Government on construction of Khmelnytsky NPP power points №3, 4”;

❖ The Law of Ukraine dated September 16, 2015 No. 697-VIII “On annulment of the Law of Ukraine“ On Location, Design and Construction of Power Units No. 3 and 4 of Khmelnytsky NPP power points №3, 4”.

Existing building structures condition of Khmelnitsky NPP power units №3,4

At the moment of building halt in 1990:

Power unit №3 – 75% completed



Power unit №4 – 28% completed



- ✓In 2006-2007 technical state assessment and survey have been made to confirm the operation status of existing building structures.
- ✓The conclusion of the main expert organization in the construction area is as follows: a long term safe operating of existence buildings is confirmed with the condition of conducting the complex of repairing works.
- ✓To actualize examination results and reconfirmation of durability and reliability of building structures of Khmelnytskyi power units №3,4, in accordance with the current legislation SE NNEGC Energoatom in 2018 announced the competition to select the project performer. The additional examination of building constructions of KhNPP-3, 4 are scheduled in 2019-2020. The works are begun in March 2019. Examination summary and conclusions will be sent for state expertise on nuclear and radiation safety.

State of equipment which has been already installed at Khmelnytsky NPP power units №3, 4

The examination of equipment supplied for B-320 reactor type
Project is conducted



Monitoring and necessary measures are performed to maintain
constructions and equipment in an operable condition.

Examples of project implementation with the usage of previously constructed building structures

Completion of NPP construction with the usage of building structures which have been built in 1985-1990 is of the worldwide practice:

- Ukraine – power units №2 Khmelnytsky NPP and №4 Rivne NPP;
- Czech – Temelin NPP,
- Slovakia – Mohovce NPP,
- Romania – Chernovoda NPP;
- Russian Federation – Rostov NPP and Kalininsk NPP,
- USA - «Watts Bar» NPP.

Nowadays around the world more than 10 power units like these ones are under construction or commissioning.

Examples of project implementation with the usage of previously constructed building structures



Khmelnytsky NPP,
power unit №2, VVER-1000

Rivne NPP ,
power unit №4, VVER-1000



Examples of project implementation with the usage of previously constructed building structures

Rostov NPP, power units № 2, 3, 4 VVER-1000



Construction readiness when decision on construction finishing has been made in 2006.

After construction completion:
power start-up in March 2010



Examples of project implementation with the usage of previously constructed building structures

Kalininsk NPP, power units № 3,4 VVER-1000



After the construction completion:
commissioning in 2005.

Construction readiness after forced downtime in
1985-1997.



Examples of project implementation with the usage of previously constructed building structures

Mahovce NPP power units № 3, 4, VVER-440



General NPP view in 2009 when was made a decision on its construction finishing

Reactor hall of power unit №3 in 2016.



Examples of project implementation with the usage of previously constructed building structures



Temelin NPP,
power units №1, 2, VVER-1000.

Chernovoda NPP in 2006.
Power unit №1 - the only
functioning power unit (first
from the right). The 2nd power
unit was placed into
commissioning in 2007.



Examples of project implementation with the usage of previously constructed building structures

Watts Bar NPP Tennessee state, USA;
Two power units PWR-1200 (Westinghouse);

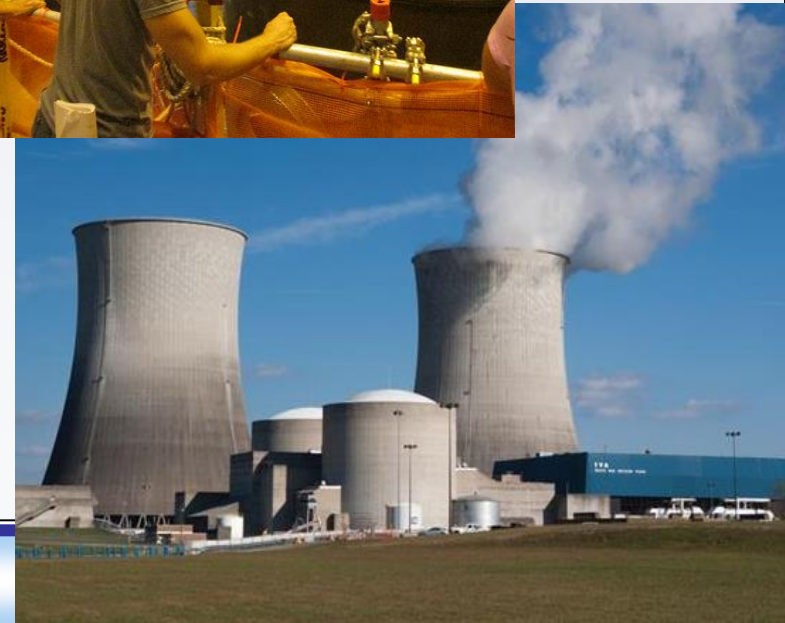
Construction has been started in 1972.
Construction suspended in 1985.

Power unit №1:

Construction was renewed in 1990;
Bringing into commercial operation in May 1996.

Power unit №2:

Construction readiness - 80%;
In 2007 has been made a decision to finish the construction;
In the end of 2015 NRC USA issued the permission for
commissioning.
Bringing into commercial operation in 2017





Khmelnitsky NPP power units №3,4 construction. Feasibility study revision.

The revision of «Feasibility study of Khmelnitsky NPP power units №3,4 construction» has been made because of:

- ❖ termination of the “Agreement between the Cabinet of Ministers of Ukraine and the Government of the Russian Federation on cooperation under the construction of power unit No. 3 and power unit No. 4 of the Khmelnytsky NPP”;
- ❖ replacement of the reactor technology VVER-1000 supplier;
- ❖ Implementation of safety improvement measures provided by the “Complex (Consolidated) Safety Upgrade Program of Power Units of Nuclear Power Plants” and “Additional Safety Requirements for New NPP Designs” and actions based on the analysis results of Fukushima accident
- ❖ Implementation of modified or enacted regulatory legal acts and regulatory documents in terms of the approval of feasibility study.
- ❖ Usage of equipment and systems which are qualified on external and internal influences (according to international requirements and national standards).



Khmelnitsky NPP power units construction state.

Feasibility study revision.

❖ Feasibility study revision has been made by Kiev Research and Design Institute "Energoproekt";

❖ Technical solutions that are not related to the changes correspond to the approved feasibility study for all objects and facilities of the complex of KhNPP power units No. 3 and 4.

❖ SE "Ukrgosstroyekspretiza" has carried out the complex state expertize of feasibility study for Khmelnsky NPP power units №3,4. Agreement conclusion № 00-2193-16/ПБ dated 29.05.2017 has been issued.

❖ The Cabinet of Ministers of Ukraine approved the Feasibility Study for the construction of power units No. 3 and 4 of the Khmelnsky NPP by Resolution No. 579 of 07.27.2018.

❖ The draft Law of Ukraine "On the location, design and construction of KhNPP power units No. 3 and 4" was submitted for consideration to the Cabinet of Ministers of Ukraine.

Technical and economical indicators

under Khmelnytsky NPP power units №3,4 construction project

Parameter	Measure	Indicator value		
		Total	I line	II line
Operation time	Years		50	50
Main technological equipment:				
• reactor	capacity, MW (thermal)	6 264	3 132	3132
• turbine facility, generator	capacity, MW (elect.)	2 178	1 089	1 089
Annual electricity production	Millions kW-hour	16 226,100	8 113,050	8 113,050
Annual electricity sales income (exc VAT)	Thousands (UAH)	10 009 930,582	5 004 965,291	5 004 965,291
Annual thermal energy sales income (exc VAT)	Thousands(UAH)	103 190,700	51 595,350	51 595,350
Total estimate cost of construction, including:	Thousands (UAH)	72 342 904,149	36 722 954,778	35 619 949,371
specific construction cost	UAH/kW	38 637	39 439	37 835
duration of construction	mounths		60	60
Payback period, calculated from Khmelnytsky NPP II line start up	Years		12	

Additional safety system requirements for Khmel'nitsky NPP power units №3,4

Feasibility study includes additional requirements for new NPP power units, which have been approved by the State Nuclear Regulatory Inspectorate of Ukraine for Khmel'nitsky NPP power units №3,4, namely :

- .[I] EU Council Directive No. 2014/87 / EURATOM of July 8, 2014;
- .[II] WENRA Safety Reference Levels for Existing Reactors (2014);
- .*[III] Safety Objectives for New Power Reactors (WENRA, 2009);
- .* [IV] Report on Safety of new NPP designs (WENRA, 2013);
- .[V] SSR-2/1 «Safety of Nuclear Power Plants: Design Specific Safety Requirements» with changes.

And also:

- .IAEA report: “Safety issues and its prioritization for nuclear power plants with VVER-1000/320 reactors type”, № IAEA-EBP-WWER-05;
- .“Complex (Consolidated) Safety Upgrade Program of Power Units of Nuclear Power Plants”;
- .Safety reassessment report of nuclear units located at the NPP site, in terms of the lessons learned of the accident at the “Fukushima-1” NPP.

*Currently “Khmel'nitsky NPP power units №3,4 construction” Project is considered as the completion of power units which previously were decided to suspend of their construction. All requirements of WENRA, relative to the operating units are taken into account, where it is achievable.

Additional safety systems of Khmelnitsky NPP power units №3,4

In the framework of implementation of the additional requirements for the new power the following actions are considered:

- **Providing a set of measures to preserve the functions of containment of the hermetic volume in case of accidents, including severe beyond design basis accidents with molten fuel:**
 - **Outer cooling system of reactor vessel;**
 - **Hydrogen control and removal system;**
 - **System of controlled (filtered) release of pressure from containment**
- **Decay heat removal from the reactor core and spent fuel pool using mobile units.**
- **Providing the parameter control in case of accidents using the post-accident monitoring system**

Technical decisions for prevention of severe accidents at Khmelnytsky NPP power units №3, 4

- **Complex (Consolidated) Safety Upgrade Program of Power Units of Nuclear Power Plants in Ukraine** provides the implementation of all actions for Khmelnytsky power units №3,4;
- Based on the “stress-tests” results for the power units (carried out according to the WENRA procedure) the implementation of the following actions for safety upgrade of NPP is envisaged:
 - Usage of a mobile diesel generator unit for power supply of 0.4 kV and 6 kV sections of the emergency power supply system under complete loss of power at the nuclear power plant. Additional mobile diesel generator units are provided for each of the power units and are designed for back-up power supply of the safety system equipment in the event of a complete electricity loss at the nuclear power plant and stand by diesel power plant failure;
 - Reactor core heat removal system through the second circuit to prevent the loss of the secondary circuit coolant by supplying coolant to the Steam Generator after pressure drop by connecting the mobile pumping units;
 - System for supplying water to the first circuit (after pressure relief), cooling pool and sump tank;
 - Connection of mobile pumping units located outside the reactor building, which provide water supply to all the necessary places - to the steam generator and to the primary circuit equipment (cooling pool, reactor or sump tank);
 - Providing technical water pools to responsible consumers from mobile units.

Reactor vessel cooling system (RVCS)

Purpose: the reactor vessel cooling system (RVCS) is designed to retain the core melt within reactor vessel during severe accidents due to :

- Long term residual heat removal from the RPV outer wall and bottom shell;
- Maintain RPV temperature below the meltdown temperature;
- Reducing pressure inside of RPV to ensure its integrity.

Goals: to fill the room under the RPV to secure RPV's long-term residual heat.

Cooling medium: the coolant is used from the reserves in the reactor compartment (the filled inspection cavities of internals and thermal control protective tubes), from external sources as well.

Control and start: are exercised from main or reserve control rooms.

Spurious actuation protection: special valves are provided to exclude RVCS spurious actuation in DBAs with no severe core damage. Valves are opened by operator from main or reserve control room only after identification of accident transition to severe condition.

Reserving: provided at least two ways to supply coolant under reactor bottom.

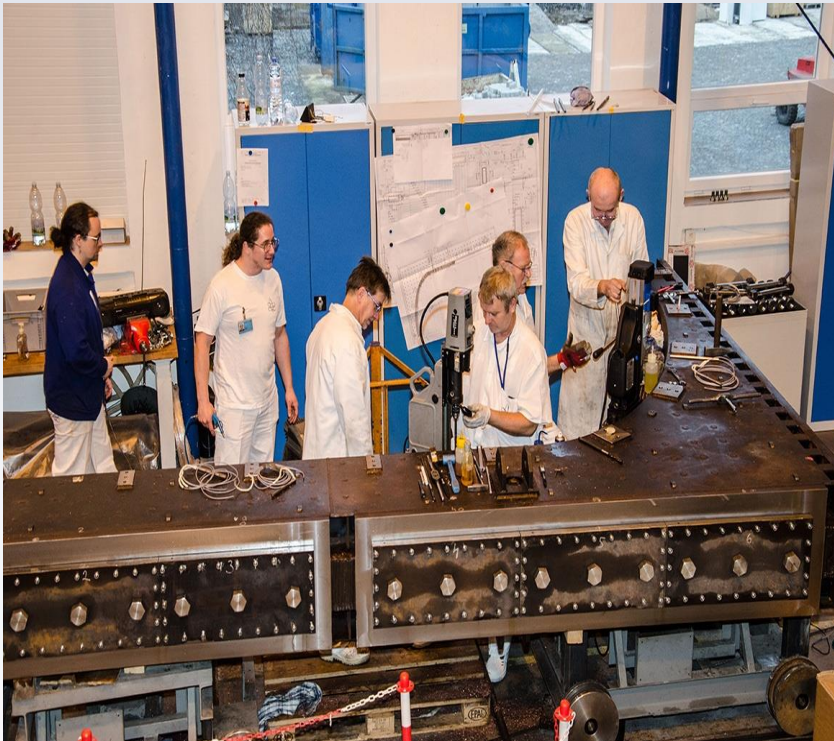
External coolant supply sources: passive part of the system is supplied from water tanks and active part of the system is supplied from mobile pumps.

Experimental Verification of RVCS

Possibility of external RPV cooling to prevent its destruction in conditions of severe core damage has been considered in different countries, including USA, China, Russian Federation, Czech Republic.

Calculation and experiments have been made worldwide to verify possibility of RPV external cooling strategy implementation.

The picture below shows a test bench of the “Big” experiment performed in the Řez Institute of Nuclear Research



Safety indicators of Khmelnytsky NPP power units №3,4

Level 1 &2 PSA results have been used to update the feasibility study. The full spectrum of initiating events for power unit #2 at all power levels and for the shutdown state was considered in view of CCSUP measures both implemented and planned for implementation in 2020 having impact on PSA results (basic model). With all this measures implemented for power units # 3 and # 4 probability of core damage frequency declined by 84.48% and large early release frequency declined by 96.46% (compared to basic model):

- **CDF** **1,89E-06 1/year;**
- **LERF** **1,21E-07 1/year.**

Predicted values of integral CDF and LERF of full spectrum of initiating events for power units reactors meet safety criteria for new NPP. Considering the fact of using equipment with better reliability specification for Units#3 & #4, better CDF and LERF indicators are expected

	Ukraine safety regulation (required)	Updated feasibility study (calculated for power units #3 & #4)
CDF, 1/year	1E-05	1,89E-06
LERF, 1/year	1E-06	1,21E-07



What are the improvements of RPV (reactor pressure vessel) and steam generator compared to those used in V-320 design reactor, in terms of structure, material, etc.? How will safety requirements stipulated in NS-R-1 IAEA «NPP safety: design»(2000) be fulfilled at Khmelnytsky NPP power units #3,#4?

KhNPP reactor design considers improvements used for the VVER-1000 reactor design. Also new solutions are applied to extend the RPV design life to 60 years:

- ❖ A new program of test specimen (placing the TS directly on the RPV wall);
- ❖ Limited nickel content in welds;
- ❖ Restriction of harmful impurities in the base metal and welds;
- ❖ Application of proven manufacturing technology.

Selection of base materials that are planned to be used in manufacturing of reactor installations of power units #3 and #4 will be based on the requirements of the approved standards, the materials will be suitable for operating conditions and comply with design performance. Any deviation will be substantiated by the designer. Structural materials should be tested and selected in accordance with the list of materials permitted for the use at NPPs.



Special requirements for selection of materials for reactor equipment

- ❖ The project and supply of materials /components, should include controlled test for lifetime, witnesses, archive metal and fast neutron flux zone inspection programs for RPV.
- ❖ For welded components in fast flux zones, material's retaining constant properties over time depends on its content of P, Cu, Ni, Mn, S, etc. Therefore, it is necessary to control and minimize the content of these elements within the steel and welded material grades.
- ❖ RPV metal degradation during operation shall be monitored.
- ❖ Modern technical supervision program shall be provided to monitor the metal degradation on the RPV flanges and the welds before the core during operation.
- ❖ All stainless steel welds shall be insensitive to intergranular corrosion (as far as possible).

With these requirements it is supposed to use 15X2NMFA grade1 steel, which is not a new material, for RPV manufacturing. This is a subtype of 15X2NMFA-A steel with a more compressed (narrowed) nickel range (1.0-1.3%) and a low copper content (not exceeding 0.08%), but within the limits of permitted chemical content. Such steel was used for RPVs at Kudankulam and Tianwan.



Required measures to increase steam generator reliability

Required measures to increase steam generator reliability:

- ❖ hydro rolling of heat exchange tubes (HET) in steam generator manufacturing;
- ❖ use of modernized SG feed and bleed system:
 - ✓ SG internals modernization;
 - ✓ retrofitting of feed water distribution headers;
 - ✓ installation of sleeveless attachments on a submersible perforated sheet;
 - ✓ reconstruction of SG level measurement system;
 - ✓ installation of partitions on and under the submersible perforated sheet;
 - ✓ installation of the “salt compartment” blowdown unit in the SG, the pipeline diameter being no less than 50mm.
- ❖ elimination of copper containing components in the condensate-feed system;
- ❖ application of modern density control methods of HET, during operation as well (N16);
- ❖ use of gaskets of thermally expanded graphite in flange connectors of the first and second circuits.
- ❖ additional reconstruction of the SG blowdown system:
 - ✓ separation of the blowdown of "pockets" and "ends" of steam generator by using electrically-driven valves;
 - ✓ modernization of the blowdown scheme of the SG “pockets” for sludge removal with installation of fittings;
 - ✓ automation of blowdown procedures;
 - ✓ leakage limiters dismantling on the purging lines of the SG “ends”;
 - ✓ increase the performance of the blowdown system and SWC-5(water treatment system) up to 80t/h.



Are there any design modifications in units #3,4 compared to #1,2 of KhNPP?

Compared to power unit #2, power units #3,#4 have following technological upgrades:

- ❖ Measures to ensure the integrity of the containment in severe accidents mitigating the radiological consequences of such accidents on the environment:
 - ✓ fast pressure decrease in the primary circuit in the event of core damage. The modification is intended to eliminate the effect of the melted core on the RPV wall at high pressure;
 - ✓ installation of new passive autocatalytic hydrogen recombiners for severe accident mode;
 - ✓ adjustable filtered containment pressure release as a measure preventing long static over-pressurization and a possibility of containment damage ;
 - ✓ additional implementation of external RPV cooling system in severe accidents. Currently computational and experimental studies, R&D and engineering are carried out. Achieved results make it possible with a high degree of probability to consider the possibility to implement this system in the configuration of KhNPP power units #3,4;
 - ✓ increased scope of control indicators to identify severe accidents and control their development;
 - ✓ full-scope simulator for staff training including severe accident management;
 - ✓ severe accident management guidelines application;
 - ✓ inclusion of equipment and systems for beyond the design basis accidents management which are implemented in operating units based on the results of stress tests (mobile and stationary additional sources of cooling medium and electricity);



Are there any design modifications in units #3,4 compared to #1,2 of KhNPP?

❖ Technical decision-based improvements:

✓ RPV guaranteed life time is 60 years and the possibility of RPV and RI equipment condition-based lifetime extension;

✓ “whipping” protection of pipelines with a high-energy medium (steam, feed water of SG) in the A-820 room in case of ruptures;

✓ increasing the volume of water in the containment, which can be used to cool the reactor in case of primary circuit leaks;

✓ upgrade the seismic hazard accounting requirements for the buildings of 1st category of seismic resistance, guaranteed seismic impact accounting- maximum horizontal acceleration at ground level - 0.1 g (in the part of the reactor installation the accountable seismic impact is 0.2 g);

✓ a modernized steam turbine, which requires a change in the foundation part of the building structures of power units No. 3,4 of the Khmel'nitsky NPP;

✓ using equipment which is qualified for external and internal impacts, according to the modern international requirements and national standards;

✓ using new generation I&C

❖ fuel cycle improvement, in particular through using RWFA



Are there any design modifications in units #3,4 compared to #1,2 of KhNPP?

Differences and improvements of turbine K-1000-60/1500-2M of power units #3,4 compared to the same serial turbine type:

- ❖ turbine provides for modernization of the HP turbine flow section, aimed to improve the efficiency and operational reliability of the turbine, to bring the HP turbine capacity to the flow rate corresponding to 3120 MW of reactor thermal power;
- ❖ turbine condensers will be of block-modular type with cooling tubes made of corrosion resistant steel;
- ❖ all LP heaters in low pressure regeneration system imply the heating surfaces of corrosion-resistant steel are provided to prevent erosion-corrosion damage of components operating in the wet steam area;
- ❖ main ejectors and seal ejectors will be made with a pipe system of corrosion-resistant steel;
- ❖ unloaded disk control valves are provided as control valves.



Taking into account the consequences of the accident at the “Fukushima – 1” NPP in Japan, the Council of the European Union made a statement about the need to review the safety of all nuclear power plants in the EU countries by performing a comprehensive risk assessment (using “stress tests”).

The European Nuclear Safety Regulators Group (ENSREG) and the European Commission set the scope and conditions for conducting such “stress tests” in the light of lessons learned from the accident at the Japanese nuclear power plant. Relevant analyses were performed by independent national authorities with peer reviews.

Results of analyzes and proposals for the implementation of the necessary measures were presented to the European Commission.



Additional target safety reassessment (“stress tests”) for extreme external natural hazards in view of “Fukushima – 1” NPP accident lessons for KhNPP

In accordance to SNRIU approved “Action Plan for the implementation of the extraordinary inspection and further improving the safety of Ukrainian NPPs taking into account the events at Fukushima-1” and the “Recommended structure and content of the report on the reassessment of nuclear facilities located at the NPP site, taking into account the lessons of the accident at the Fukushima-1 NPP, as part of this work, an additional reassessment of safety (“stress tests”) was performed for nuclear facilities located at the KhNPP site for extreme external natural hazards that can lead to the degradation of safety functions and the development of severe accidents. Such results are obtained:

Seismic impacts

The seismic resistance of the building structures of the power units # 1, 2, where safety important systems of 1 and 2 of PiN AE-5.6 (NPP codes and standards) are located, is provided for $PGA=0.1g$, which is substantially conservative to the design acceleration value of $0.05g$. The threshold value of seismic impact, which maintains the strength of the reactor containment, according to a conservative approximate estimate, is in the range of intensity 7-8 points and is approximately 7.7 points (which corresponds to PGA of $0.17g$).

Impact of tornado, extreme snow and extreme wind

Buildings and structures of category I according to the PiN AE-5.6 buildings are designed taking into account the impact of tornado, extreme wind and extreme snow defined for the NPP site.

In terms of impacts from the tornado, the reactor compartment design and the emergency DG have a margin of safety:

- adopted to justify the category of tornado above design values;
- These facilities are designed for external shock wave $\Delta P = 30$ kPa. In terms of static load on the frontal surface of the walls is significantly higher than the impact of a tornado.

The strength of the structure is ensured.



Additional target safety reassessment (“stress tests”) for extreme external natural hazards in view of “Fukushima – 1” NPP accident lessons for KhNPP

Flooding

Industrial site flooding stress analysis determined:

- ❖ Design maximum water levels in the Gorin and the Gniloy Rog rivers does not pose a danger to the structures and facilities of the KhNPP power units #1, 2, and therefore for the KhNPP power units # 3,4 either.
- ❖ The drainage systems of the buildings and rainwater sewage system on the site are calculated taking into account the extreme impacts typical for the NPP site.
- ❖ The layout of the industrial site was solved with a slope from the buildings to prevent flooding of the main buildings during the destruction of the dam of the NPP cooling reservoir.

External fire

The analysis showed that the influence of external fires on the NPP safety functions is absent.

Extreme temperatures

The analysis showed that safety functions are provided at extreme temperatures for the conditions of the KhNPP site.

Complex impact

Consideration of the external impacts combination has shown that an additional cumulative effect of influence does not take place. Implementation of additional measures that take into account combinations of impacts on the KNPP power units is not required.



**What design features and additional measures of preventing and elimination of the consequences of in management of severe accidents at Kozloduy NPP need to be applied at KhNPP power units #3, 4 ?
Is there a plan to plug the channels of the ionization chamber, like that at Kozloduy NPP 5,6 or will this issue be excluded by design changes?**

Phenomenon	Design features NPP Kozloduy	Additional measures for Kozloduy NPP to prevention and elimination	Additional measures at KhNPP power units No. 3,4
Core melt	Active medium and emergency injection of low pressure system; Passive hydraulic tanks emergency injection of low pressure boron	Additional diesel generators; Qualification of some systems to work as security systems; Water injection into the reactor core or SG using mobile fire-fighting equipment for extreme conditions.	Implemented during the design. As a technical solution is taken into account in the adjusted feasibility study. Will be clarified at the “Design” stage.
High pressure core melt	Primary circuit depressurization system; Safety valves; Sprinkler system.	Qualification of some systems to work as security systems	Implemented during the design. Technical solution accounted in the revised feasibility study. Will be clarified at the “Design” stage: designing an additional pressure line from the primary circuit; IPU KD qualified for water, steam and steam-water mixture will be used



Phenomenon	Design features NPP Kozloduy	Additional measures for Kozloduy NPP to prevention and elimination	Additional measures at KhNPP power units No. 3.4
RPV Failure	Hold inside the RPV (by injecting water into the RPV)	External cooling of the RPV with water	Implemented during the design. Technical solution accounted in the adjusted feasibility study. Will be clarified at the "Design" stage
External steam explosion	Missing. Dry vault.	Additional research is needed in the case of flooding the mine to keep the melt inside the RPV.	It is implemented during the design in the framework of the development of the RPV cooling system. Excess steam is discharged through the holes provided in the supporting structure of the RS (openings are organized during the manufacture of the support ring)
Through melting of the basis	Holding the melt inside the RPV by water injection.	Plugging the channels of the ionization chambers located in the walls of the reactor shaft; Outer shell events.	Implemented during the design. Through ionization chambers channels are excluded at the design and construction stage of KhNPP power units #. 3.4
Excess pressure in the containment shell	Containment sprinkler system (early phase); Increased free space of the containment shell.	Filtered dump (scrubber).	Implemented in the project as a regular system
Hydrogen detonation	Increased free space of the containment shell	Hydrogen recombiners; Long-term maintenance of the integrity of the containment (risk of release in the late phase).	Implemented in the project as a regular system



Phenomenon	Design features NPP Kozloduy	Additional measures for Kozloduy NPP to prevention and elimination	Additional measures at KhNPP power units No. 3.4
Containment bypass	Accident management (coolant leakage from the first circuit to the second using appropriate procedures).	Extracorporeal events (distribution of corium, cooling of corium using water); Long melt cooling.	It is implemented during the design in the framework of the development of the RPV cooling system.
Accident in cooling pool of spent fuel.	Water level and temperature control; Emergency water supply system.	Uniform distribution of heat in cooling pool of spent fuel. Water injection into spent fuel pool using mobile fire-fighting equipment for extreme conditions.	Implemented in the project by installing regulators on the pressure pipelines in the cooling pool and additional level gauges in the cooling pool to determine the reduced level, additional thermocouples are taken into account. The injection of water into the spent fuel pool using mobile fire-fighting equipment is provided by the project.

Thank you for attention!