National Action Plan based on the stress tests performed on the Belarusian NPP

System of measures intended to improve the safety level

The document includes an analysis of very severe natural phenomena and their combinations that could affect the NPP safety functions and result in a severe accident, and an assessment of safety margins of the power station and of the organisation of accident management. A plan of measures intended to improve the NPP safety level was developed. The plan was prepared based on an absolute priority to provide for safety assurance, taking into account the current stage of construction of the facilities at the NPP and with the support of the “intelligent ownership” of stress-tests results and their peer review.

Minsk 15.08.2019

The document was prepared by the Department for Nuclear and Radiation Safety of the Ministry of Emergency Situations of the Republic of Belarus (Gosatomnadzor) in cooperation with the "Joint Institute for Energy and Nuclear Research - Sosny" of the National Academy of Sciences of Belarus and the "Belarusian NPP" State Enterprise.

Table of contents

Symbols and Abbreviations

BES – Baltic Elevation System
BRU-A – Quick-acting Atmospheric Steam Dump Valve
CPS – Control and Protection System
CR – Control Rod
CSC – constructions, systems and components
D – Deaerator
DBA – Design Basis Accident
DiD – Defence in Depth
ECCS – Emergency Core Cooling System
ECR – Emergency Control Room
ENSREG – European Nuclear Safety Regulators Group
EPS – Emergency Power Supply System
ESAT – Emergency Standby Auxiliary Transformer
EU – European Union
FA – Fuel Assembly
HPC – High Pressure Cylinder
HPH – High Pressure Heater
IAEA – International Atomic Energy Agency
LPC – Low Pressure Cylinder
LPH – Low Pressure Heater
MCR – Main Control Room
MDG – Mobile Diesel Generator
MSIV – Main Steam Isolation Valve
NPC – Non-returnable Protective Containers
NPP – Nuclear Power Plant
OPN – Own Processing Needs
PEN – Electric Power Pump
PHRS – Passive Heat Removal System
PPR – Preventive Maintenance
PRT – Peer Review Team
PSA – Probabilistic Safety Analysis
RC – Reactor Compartment
RCP – Reactor Coolant Pipeline
RW – Radioactive Waste
SS – Safety System
SSE – Safe Shutdown Earthquake
TCCP – Technical Code of Common Practice
VKU – reactor internals
VVER -1200 – water cooled power reactor
WENRA – Western European Nuclear Regulators Association
ZO – Containment

Introduction

On 11 March 2011, an accident occurred at the Fukushima-Daiichi NPP (Japan) triggered by an earthquake and by the subsequent tsunami. Against the background of the above, nuclear power plant operators and regulatory bodies in all countries where NPPs operate faced the need for a detailed analysis of the causes which led to an accident of this magnitude and the consequences of this, and realised the necessity of learning lessons from what happened.

As a result of an assessment of aspects of the accident linked to nuclear safety, lessons learned as well as approaches to be taken and recommendation regarding the improvement of safety were described in the International Atomic Energy Agency (IAEA) comprehensive report on "Fukushima-Daiichi" [1]:

- The assessment of natural hazards needs to be sufficiently conservative. The consideration of mainly historical data in the establishment of the design basis of nuclear power plants is not enough to identify the risks of extreme natural hazards.
- The safety of NPPs needs to be re-evaluated on a periodic basis to consider advances in knowledge, and necessary corrective actions or compensatory measures need to be implemented promptly
- The assessment of natural hazards needs to consider the potential for their occurrence in combination, either simultaneously or sequentially, and their combined effects on an NPP.
- The defence in depth concept remains valid, but implementation of the concept needs to be strengthened at all levels by adequate independence, redundancy, diversity and protection against internal and external hazards. There is a need to focus not only on accident prevention, but also on improving mitigation measures.
- Instrumentation and control systems that are necessary during beyond design basis accidents need to remain operable in order to monitor essential plant safety parameters and to facilitate plant operations.
- Robust and reliable cooling systems that can function for both design basis and beyond design basis conditions need to be provided for the removal of residual heat.

- There is a need to ensure a reliable confinement function for beyond design basis accidents to prevent significant release of radioactive material to the environment.
- Comprehensive probabilistic and deterministic safety analyses need to be performed to confirm the capability of a plant to withstand applicable beyond design basis accidents and to provide a high degree of confidence in the robustness of the plant design.
- Accident management provisions need to be comprehensive, well-designed and up to date. They need to be derived on the basis of a comprehensive set of initiating events and plant conditions.
- Training, exercises and drills need to include postulated severe accident conditions to ensure that operators are as well prepared as possible. They need to include the simulated use of actual equipment that would be deployed in the management of a severe accident.
- In order to ensure effective regulatory oversight of the safety of nuclear installations, it is essential that the regulatory body is independent and possesses legal authority, technical competence and a strong safety culture.
- In order to promote and strengthen safety culture, individuals and organizations need to continuously challenge or re-examine the prevailing assumptions about nuclear safety and the implications of decisions and actions that could affect nuclear safety.
- A systemic approach to safety is necessary to consider the interactions between human, organizational and technical factors. This approach needs to be taken through the entire life cycle of nuclear installations."

These are exactly the lessons and approaches which form the base for the objective safety reassessment.

On 25 March 2011 the European Union announced that safety at European nuclear power plants should be reviewed based on a comprehensive and transparent risk assessment (stress tests). The essence of this assessment is to evaluate technical solutions that have been incorporated into NPP designs which would make it possible to confront very severe and unlikely natural phenomena. It will also include the assessment of systems of management and response to such events, at the plant and in the country, in order to determine if there are “safety margins”; the development, if necessary, of technical and organisational measures to “increase these margins”, making it possible to prevent serious accidents caused by such events, and to mitigate their negative impact on members of the public and the environment.

During the fifth review meeting of the contracting parties to the Convention on Nuclear Safety (April 4 to -14, 2011), the participants outlined the need to reassess NPP safety and to develop additional measures to improve NPP safety in their joint declaration on the NPP Fukushima Daiichi accident.

On May 13, 2011 the European Nuclear Safety Regulatory Group (ENSREG) and the European Commission agreed upon the technical requirements for stress tests on European nuclear power plants (ENSREG Declaration, Annex 1: EU stress tests specifications) [2]. In accordance with ENSREG, the technical requirements of these stress tests are an objective reassessment of nuclear power plants in the light of the events at NPP Fukushima-Daiichi. Stress tests should include a detailed analysis of very severe natural phenomena and any combinations that could affect the NPP safety functions and that can result in a severe accident.

In June 2011, the Republic of Belarus signed up to the Joint Declaration of the European Union and neighbouring states for comprehensive risk and safety assessments of nuclear plants (stress tests). Thus, it confirmed its commitment to carry out, on voluntary basis, stress-tests of the NPP under construction, considering specifications developed by the European Commission and ENSREG and availing of peer review of their results.

The effect of stress-tests performed is a country action plan on the increase of nuclear plants’ safety, taking into account lessons learned from the NPP Fukushima Daiichi accident.

The National Actions Plan is based on the stress tests performed in the Belarusian NPP, developed by Gosatomnadzor in cooperation with other interested parties, on the basis of the national report [3] and taking into account recommendations of the European Peer Review Report on the Results of Belarusian Stress Tests” [4], and on comments and suggestions of the Public Association “Ecodom” (letters No 46 of 18.05.2018 and No 130 of 10.12.2018), on the basis of the “intelligent ownership” principle recommended by European experts.

A description of this principle and its implementation in Belarus is given in Chapter 2.1 of this document.

Given the absence of safety deficits and, subsequently, the need for urgent action in the development of the Plan's measures and deadlines for their implementation the effect of increasing safety at the current stage of construction of the NPP was judged to be desirable.

1. General Information 7

1.1 Legal and Regulatory Framework

1.1.1 Establishing and Maintaining the Legal and Regulatory Framework for Nuclear Power Plant Safety Assurance

The Republic of Belarus has announced adoption of global nuclear safety procedures and commitment to the implementation of a nuclear power programme in compliance with international conventions and treaties [5-10], by ratifying them.

Nuclear safety activities are carried out in the Republic of Belarus in accordance with international practice and IAEA recommendations. Safety principles defined in IAEA Safety Fundamentals publication No. SF-1 “Fundamental Safety Principles” [11], as well as the general provisions of other IAEA safety standards are built into the basic Law of the Republic of Belarus “On nuclear energy use” and regulations of the Republic’s state administration bodies and other state organizations related to nuclear energy use.

As per the provisions of the Law of the Republic of Belarus “On nuclear energy use” [12] the Ministry of Emergency Situations of the Republic of Belarus

exercises state supervision for ensuring nuclear and radiation safety as well as physical protection of nuclear power facilities;

arranges and performs state supervision of spent nuclear materials management and radioactive waste management;

monitors compliance with nuclear and radiation safety legislation;

participates in organizing and performing activities for assessing equipment, products and technologies for nuclear power facilities;

provides for a functioning unified state accounting and control system for ionizing radiation sources and a state accounting and control system for nuclear materials in the Republic of Belarus;

arranges safety audits of the nuclear plant and/or storage facility, as well as of their design, including the involvement of independent experts.

Pursuant to the Decree of the President of the Republic of Belarus No. 756, dated 29.12.2006 “On certain issues of the Ministry of Emergency Situations" [13], the Department for Nuclear and Radiation Safety of the Ministry of Emergency Situations (Gosatomnadzor), was established within the structures of the MES to perform special functions in providing nuclear and radiation safety.

The principle of continuously increasing safety level, based on the greater knowledge and the implementation of new technologies, does not hinder or inhibit the implementation of the first nuclear project in the Republic of Belarus. It provides the basis for the functioning of the regulatory infrastructure. Therefore, Belarus took a decision to carry out a comprehensive safety assessment in connection with the NPP Fukushima Daiichi accident.

1.1.2 National Requirements and Regulations in the Sphere of Nuclear and Radiation Safety

The legal regulation of safety in the sphere of nuclear energy use in the Republic of Belarus features a hierarchical structure and provides for the subordination of lower legal force documents to the relevant requirements of the higher legal force documents, and is applied based on the Constitution of the Republic of Belarus and in accordance with:

laws of the Republic of Belarus;

normative legal acts of the President of the Republic of Belarus; resolutions of the Government of the Republic of Belarus;

normative legal acts of the Republic’s the state administration authorities executing regulation by the state of actions ensuring safety of use of nuclear power;

nuclear and radiation safety standards and regulations;

standard practice technical codes and other technical regulations.

Since a decision on the nuclear power program implementation in the Republic of Belarus was made in 2008, the regulatory framework in the sphere of nuclear and radiation safety has undergone significant changes. By 2019, top-level legislation (decrees of the President of the Republic of Belarus, laws of the Republic of Belarus, resolutions of the Government of the Republic of Belarus) had been fully established. It is based on:

The Law of the Republic of Belarus of 30 July 2008, No 426-3 “On the Use of Atomic Energy” [12];

The Law of the Republic of Belarus of 5 January 1998, No 122 “On Radiation Safety of the Population” [14];

Decree of the President of the Republic of Belarus of 1 September 2010, No 450 “On the Licensing of Certain Types of Activities” [15];

Decree of the President of the Republic of Belarus of 26 June 2012, No 332 “On Some Measures to Improve Control (Supervisory) Activity in the Republic of Belarus” [16];

Decree of the President of the Republic of Belarus of 16 February 2015, No. 62, “On Safety Assurance during the Construction of the Belarusian Nuclear Power Plant” [17].

The Law of the Republic of Belarus “On Radiation Safety to Members of the Public” defines fundamental legal regulations in the sphere of radiation safety for the members of the public and is intended to create conditions which ensure protection of people’s lives and health from harmful ionizing radiation exposure.

The Law of the Republic of Belarus “On Nuclear Energy Use” regulates matters related to the design, allocation, construction, commissioning, operation, performance constraints, extending operational life and decommissioning of a nuclear plant and/or storage facility, as well as any matters related to handling of nuclear materials in a nuclear plant and/or storage facility, spent nuclear materials and/or operational radioactive waste, and other matters in the area of nuclear power application.

The Decree of the President of the Republic of Belarus of 1 September 2010, No 450 “On the Licensing of Certain Types of Activities” regulates the licensing of activities related to nuclear energy and ionizing radiation sources; determines the powers of state administration authorities for issuing, suspending, terminating and renewing licenses as well as verifying compliance by licensees with licensing requirements and conditions; establishes general and specific licensing requirements and conditions in the sphere of nuclear power use.

The Decree of the President of the Republic of Belarus No 62, dated 16 February 2015 “On safety during the construction and operation of the Belarusian nuclear power plant” establishes a special procedure of control arrangement and implementation related to safety assurance during the plant construction and operation.

1.1.3 Licensing System

A system of licensing activities related to nuclear energy and ionizing radiation sources has been established in the Republic of Belarus. Basic regulatory requirements related to nuclear safety are determined by the Regulation on Licensing of Specific Types of Activities, approved by the Decree of the President of the Republic of Belarus No. 450, of 1 September 2010 “On Licensing of Specific Types of Activities” [15]. Activities related to nuclear energy and ionizing radiation sources are defined as licensed. The licensing authority is MES.

Major licensed activities include:

activities related to nuclear power use;

activities related to sources of ionizing radiation use;

activities related to radioactive waste management;

activities related to the design and manufacture of processing equipment for facilities using nuclear energy; design and manufacture of radiation protection equipment;

activities involving the examination of safety in using atomic energy and sources of ionizing radiation.

Activities related to nuclear energy use include the following work and/or services:

design, placement, construction, operation, and decommissioning of nuclear plants;

design, allocation, construction, operation, and decommissioning of nuclear materials storage facilities;

handling of nuclear materials, nuclear fuel, spent nuclear materials, spent nuclear fuel and operational radioactive waste;

performance of works and provision to operating organizations of services affecting safety, including construction of facilities.

Unlicensed implementation of these activities shall be illegal.

The functions related to the organisation of the licensing process of activities related to nuclear energy and ionizing radiation sources are performed by Gosatomnadzor [15].

The Government of the Republic of Belarus approved the examination procedure for the documents substantiating provision of nuclear and radiation safety when carrying out activities related to nuclear energy and ionizing radiation use [18].

Documents substantiating assurance of nuclear plant safety, including design, engineering, technological and operational documentation for a nuclear facility, to be submitted by the licence applicant to Gosatomnadzor, are subject to a nuclear plant safety examination. The safety examination which is requested by Gosatomnadzor, is carried out to determine the safety level of a nuclear facility by matching the design concepts adopted and their implementation results with the requirements of normative legal acts, including technical normative legal acts in the sphere of nuclear and radiation safety.

A license shall be issued only when the results of the nuclear facility safety evaluation are positive. At the construction stage of nuclear facilities, design concepts and measures taken to ensure safety are evaluated during the licensing process.

The issues addressed in stress tests are designed to assess safety margins over and above those statutory standards, with which compliance is verified through licensing procedures. Thus, it is an additional safety assessment: the licensing procedure does not include the consideration of stress tests issue, but the results of the stress tests demonstrate complementary assessment of plant parameters in the area of safety assessment, already validated under the licensing procedure.

The Belarusian NPP operating organization which has obtained, in line with established procedures, a license to operate in the field of use of nuclear energy in terms of construction is the Belarusian NPP State Enterprise, created by a Decree of the President of the Republic of Belarus No. 583, of 30 December 2013 “On the Reorganization of the State Institution Directorate for Nuclear Power Plant Construction”, and by the Order of the Ministry of Energy of the Republic of Belarus No. 1, of 10 January 2014, as a result of reorganisation of a state institution “Directorate for Nuclear Power Plant Construction” and its transformation into a Republic’s unitary enterprise.

In accordance with the law, the operator (operating organization) assumes all responsibility for safety during the entire life cycle stages of the Belarusian NPP [19].

1.1.4 Regulatory Control and Assessment System

Safety-related regulatory control is based on fundamental functions of safety assurance and defence-in-depth principles which correspond to up-to-date international practices in this area, as reflected in IAEA documents.

The Belarusian NPP is the sole facility in the country which corresponds to the definition in Article 2 of the Convention on Nuclear Safety. Special procedures for establishing and organizing safety control during construction and commissioning of the NPP [17] has been established at the construction site enabling supervising authorities to perform continuous monitoring/supervision in their spheres with application of sanctions and other measures. Its organisation and implementation procedure are established by the Government of the Republic of Belarus [20].

Overall coordination of the supervision over the Belarusian NPP construction is carried out by the MES through the Working group to coordinate supervision over the Belarusian NPP construction. The above-mentioned group is under the leadership of the Deputy Minister for Emergency Situations of the Republic of Belarus and includes representatives of all monitoring/supervisory authorities. The Working group authority is established by a Government resolution [21]. The above coordinating mechanism of monitoring and supervision of activities has been assessed as a “good practice” by the IAEA mission experts from the Integrated Regulatory Review Service (IRRS). The mission took place on 3 to 14 October 2016 in the Republic of Belarus.

Areas of nuclear and radiation safety provision to be assessed by the regulatory authority are based on established international practice as shown in the IAEA documents. They include: site characteristics for NPP construction, the NPP project, the operating organization management system, personnel competence, emergency planning and response, defence-in-depth concept, consideration of global best practices, etc.

The scope and contents of documents substantiating nuclear and radiation safety are subject to submission to the regulatory authority within the licensing procedure as defined in the terms of the legislation. The regulatory authority has enough powers to carry out expert assessment of the documents submitted in respect of nuclear and radiation safety issues. The current regulatory control and assessment system provides the regulatory authority with fairly extended powers both to implement the national report [3] provisions and the expert mission report [4] recommendations in the Belarusian NPP safety system, and to monitor the results of such implementation.

Safety of operation of potentially hazardous facilities is ensured within the framework of the state system of prevention and liquidation of emergency situations. National legislation provides the basis for the implementation measures aimed at increasing functional stability and security of the organizations/potentially hazardous facilities, operating in conditions of natural and man-made factors that could result in emergency situations [22].

The regulatory authority is empowered to develop and distribute to the organizations operating nuclear energy facilities mandatory proposals to improve the stability of such facilities [13].

1.1.5 Enforcement of Applicable Regulations and License Conditions

Pursuant to the Statute of Gosatomnadzor (approved by Decree No 756 of the President of the Republic of Belarus, dated 29.12.2006 [13]), Gosatomnadzor has the authority to monitor compliance with the nuclear and radiation safety legislation. Should any violations of the applicable legislation be discovered in the process of supervisory activities, an inspection report is drawn up based on the results of the inspection. Either a protocol on an administrative offence(s) can be issued regarding the facts of the detected violations and/or a ruling on the case of an administrative offence can be delivered. On the basis of the completed report, a judgment or a formal request shall be made for the elimination of violations which were discovered during the inspection. A judgment as well as a formal request arising from the inspection report shall be binding.

As provided for in the legislation, when violations constitute a threat to national security, inflict harm to human life and health, or to the environment, then a formal request shall be issued to suspend the activities of the inspected entity, workshops/production sites, equipment, operation of vehicles, manufacture and sale of goods/works, or services, on the day when the violation was discovered. This formal request should specify the time period of the suspension and the timing for informing the supervisory authority of elimination of the violations. When there are facts that indicate evidence of an offence, the supervisory authority is authorized to pass the inspection materials to the criminal prosecution authority.

The entity under inspection has the right to appeal against decisions of the supervisory authorities based on the inspection report as well as against formal requests for the elimination of violations, and challenge actions or inactions of inspectors.

Should violations of the licensing legislation, license requirements and conditions by the licensee (his employees of a separate subdivision) be discovered, the licensing or other regulatory/supervising authority shall issue the licensee, in line with established procedures, a formal request/improvement notice to eliminate the violations discovered and shall set a remedial period. This period cannot be longer than 6 months.

If the licensee has not eliminated the violations set forth in the formal request (improvement notice) on elimination of the violations discovered, or a written notice on elimination of the violations was not submitted to the licensing or other regulatory (supervising) authority, or licensing or other regulatory (supervising) authority discovered violation of special licensing requirements and conditions by the licensee (his employee and separate subdivision) within the set period, the licensing authority either on its own initiative or at the instance of another regulatory/supervising authority shall make a decision on suspending license for up to 6 months.

When the violations resulting in the license suspension are not eliminated by the licensee within the set period, or a written confirmation of elimination of the violations has not been submitted to the licensing or other regulatory/supervising authority, the licensing authority which issued the license shall decide on terminating the license.

Failure to comply with requirements of the legislation related to nuclear and radiation safety shall be subject to administrative accountability pursuant to the Code of the Republic of Belarus on administrative offences [23] or criminal liability under the Criminal code of the Republic of Belarus [28, 24]. Criminal liability will be incurred when facts indicating essential elements of offences stipulated in the Criminal Code of the Republic of Belarus are revealed during the inspection.

In addition, within the scope of licensing and permitting activities, there is a possibility to complement the licenses issued for activities related to nuclear energy use with specific licensing requirements and conditions for facilities using nuclear energy. These specific licensing requirements and conditions may include, among other things, actions targeted at improving safety which are developed as part of an analysis of stress tests results and peer review.

1.1.6 Transparency and Public Awareness

The MES and Gosatomnadzor provide information to the public on the safety performance of the radiation facilities, nuclear plants, and nuclear power facilities, as well as on regulatory activities in the field of nuclear and radiation safety. This work is considered to be one of the components that determine the quality of the main tasks in the field of nuclear and radiation safety regulation, as it is an integral part of supervision and licensing procedures, of the development of regulatory legal acts and others [25].

Following the principles of openness and transparency, the MES and Gosatomnadzor publish in the public domain on their Internet resources reports on the discharge of obligations under the Convention on Nuclear Safety, the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, reports of assessment missions and peer review reports, and other official documents.

Principles of openness and transparency are also implemented in relation to stress-tests of the Belarusian NPP by way of:

publication in the public domain of the national report on stress-tests of the Belarusian NPP on the ENSREG website and on the Internet resources of Gosatomnadzor; presentation to the general public of the national report and of key results of stress-tests through mass media by way of a press conference on 8 November 2017 in the information agency BELTA to which Belarusian and international journalists were invited;

providing interested parties (including the general public) with a possibility to ask questions in respect of the national report (centralised through ENSREG website), and publication of replies to questions received will be publicly available on the ENSREG website;

information coverage of activities carried out during the peer review of the results of the Belarusian NPP stress-tests (visits in Belarus of an authorised Peer Review Team of European experts from 12 to 16 March 2018 and of the Peer Review Board from 12 to 14 June 2018);

3 events involving coverage and presentation of the results of the peer review: on 3 July 2018 in Brussels, for the European public (organised by ENSREG), on 10 July 2018 in the BELTA press centre (Minsk), on 9 August 2018 in Gosatomnadzor, with the participation of the Peer Review Team Leader Mark Foy, representatives of state administration authorities, of the Belarus scientific and expert community, of Russian Federation organisations, of the Belarusian NPP State Enterprise, of public organisations and of mass media.

1.2 General Information on the NPP Site and General Characteristics of the Power Units

1.2.1 Brief Description of Characteristics of the NPP site

Administratively, the Belarusian NPP construction site is located in Ostrovets district in the North-East of Grodno region, 19 km North-East of Ostrovets town and 25 km east of the border with the Republic of Lithuania.

The geographical location of the Belarusian NPP site has the following coordinates: latitude 54°46', longitude 26°07'.

The site design absolute elevation is 174.5 to 182.7 m BES. The closest neighbouring states are: the Republic of Lithuania – 25 km, the Republic of Latvia – 110 km, the Republic of Poland – 200 km, the Russian Federation – 150 km and Ukraine – 320 km.

The nearest administrative districts of the Grodno region are: the Smorgon district – 12.5 km, Oshmyany district – 31 km; Minsk region: Myadel district – 16.5 km and the Postavy district of the Vitebsk region – 22.5 km.

In a 100 km area surrounding the NPP site there is one city with a population of over 100 thousand people. It is Vilnius (the capital of the Republic of Lithuania), located about 50 km away.

Geomorphologically, the NPP construction site is located in the area of central Belarusian uplands and ridges, a West-Belarusian sub-area within the Naroch-Vileika lowland and is part of the low-hilly and undulating Poozersky plain, at 140 to 180 m above sea level. The highest point of Ostrovets district, with an elevation of 309 m, is 30 km to the west of the NPP location site.

The hydrographic system includes the major river Viliya (5 km to the north) with its tributaries the Stracha (4 km) and the Oshmyanka (5.5 km); the Losha (9 km) which is a tributary of the Oshmyanka; the Gozovka, the Polpe and the Sorochanskie group of lakes (10 km); the Olkhovskoe reservoir (7 km), and finally shallow rivers and ditches. The Viliya river also flows through the territory of Lithuania (the Neris), into the Neman river. The following rivers are in the NPP surveillance area: the river Viliya (5 km to the north) and its 3 small tributaries which flow on the left: the Gozovka, 17 km long, Polpe, 9.3 km long, Losha, 9 km long.

The Vilia river is the process water source for the Belarusian NPP.

According to official sources, there are 595 settlements with a population totalling 46 097 in the 30 km zone around the Belarusian NPP.

1.2.2 Basic Characteristics of the Units

The NPP-2006 project is the basis of the Belarusian NPP project.

The Belarusian NPP is composed of two power units which are presently under construction, with thermal power of 3200 MW and electrical output of 1194 MW. The Belarusian NPP unit consists of a water-cooled water-moderated thermal neutrons reactor plant VVER -1200 and a turbine-generator plant. For conversion and transfer of energy from the reactor to the turbine generator the design provides for the two-circuit heat diagram. The basic specifications of the NPP power unit with VVER-1200 are shown in Table 1.

Table 1 -
Basic characteristic of the NPP power unit
with VVER-1200 [3, 33]

	Characteristics	**Value**
1	Power Unit's structure	Monoblock
2	Operation lifetime, years: - Power unit - Reactor plant	 50 60
3	Power unit's capacity, MW: - electrical (gross), under warranty conditions - thermal	 1194 3200
4	Power unit's heating power, MW	46.6
5	Utilisation factor of nominal capacity, relative units	0.9
6	Auxiliary power consumption (including recycling water supply cost and on-site costs), %	7.0
7	Unscheduled reactor's automatic shutdowns, min. 1/year	0.5
8	Average annual duration of scheduled shutdowns (reactor refuelling, routine	

	maintenance, PM), days, max.	25
9	Process-related manpower for the first Unit (specific), pers./MW	0.66
10	Number of FAs in the core, pcs.	163
11	Number of FAs in CPS CE, pcs.	121
12	Maximum fuel burnup, average across FA, MW·day/kgU	60
13	Fuel life time, year	3-4
14	Refuelling frequency, month	12
15	Fuel average enrichment with isotope U^{235}, %	4.79
16	Average fuel burnup in unloaded FAs for stationary refuelling mode, MW·day/kgU	55.5
17	Coolant basic parameters: *Primary circuit :* - - core inlet temperature, °C - - core outlet temperature, °C - - coolant heating across the core, °C - - coolant flow rate across the reactor, m^3/h - - core outlet pressure, MPa *Secondary circuit:* - - steam pressure at the SG outlet, MPa - - PG steam capacity, t/h - feed water temperature, °C - - steam humidity at SG outlet, %, max. - generated steam temperature at the SG steam header outlet, °C	 298.2 328.6 30.4 88000 16.2±0.3 7.0±0.1 1602+112 225±5 0.2 285.8±1 maximum allowable deviation
18	Turbine plant	K-1200-6.8/50
19	Turbine plant structural formula	2LPC+HPC+2LPC
20	Diagram of regenerative heating	4LPP + D + 2HPP
21	Number of main feedwater pumps, and type of drive Pumps.	Provisionally: 5 FEP. (electric drive)

22	Generator	T3B-1200-2
23	Type of generator cooling	Complete water- type
24	Turbine plant circulating water supply circuit	Recycling water supply with evaporative cooling towers
25	Industrial water supply circuit of safety-critical systems	Recycling water supply with spray cooling ponds
26	Fresh fuel and solid radioactive waste storage facility, including - fresh fuel storage facility - solid radioactive waste storage facility: - solidified liquid RAW (low-level and intermediate-level): - very low-level solid RAW - low-level solid RAW - intermediate-level solid RAW - high-level solid RAW	 499.32 m^2 777.5 m^2 (1st unit) 673.5 m^2 (2nd unit) 38 LTC containers (57 m^3) annually taking into account potential emergency situations Storage facility area of 194.0 m^2 is designed for 448 containers 27 drums (5.42 m^3) annually 161 drums (5.42 m^3) annually Storage facility area of 133.7 m^2 is designed for 1626 drums (including very low-level RAW) Storage facility area for length gauges is 28.5 m2 Temporary filter storage facility area 11.76 m^2 25 drums (2.5 m^3) annually Storage facility area of 54.6 m^2 is designed for 546 drums 0.5. m^3) annually Storage bay area is 18.6 m^2

27	Availability of spent fuel storage facility	There is a reactor wet spent fuel pool (storage pool)
28	Double containment of reactor building outer protective reinforced concrete containment - internal diameter, m - dome top elevation, m - thickness (cylindrical part /dome), m internal leak-tight reinforced concrete containment - internal diameter, m - dome top elevation, m - thickness (cylindrical part /dome), m - design overpressure, MPa - design temperature, °C emergency air cleaning system for the inter-shell area from radioactive leaks provides cleaning level not lower than: - elemental iodine, % - organic iodine, % - aerosols, %	 50.0 70.2 0.8/0.6 44.0 67.7 (68.5 including buttress) 1.2/1.0 0.4 150 99.9 99 99.99

The Belarusian NPP is designed taking into account extreme external loads, such as seismic hazards (maximum estimated earthquake – 7 points), aircraft impact (weight 5.7 tonnes, speed 100 m/s), shock wave, waterspouts (class 3.60 on the Fujita scale, etc.).

1.2.3 The safety systems and additional technical means for BDBA management

The Belarusian NPP design provides for a range of passive systems to overcome beyond design basis accidents, which fulfil basic functions of safety: a system of passive heat removal from the containment (PHRS C); a system of passive heat removal from the steam generators (SG PHRS);

a molten core catcher (JMR); hydrogen removal system from the containment;
double protective containment.

The safety systems and additional technical means for BDBA management are listed in Table 2.

Table 2.

Safety systems and additional technical means for BDBA management

No	Name	Number of channels and their efficiency
Protective, localizing, support and control safety systems		
1.	High- pressure safety injection system	4 x 100 %
2.	Low pressure safety injection system	4 x 100 %
3.	Emergency boron injection system	4 x 50 %
4.	Emergency feed water system and heat removal through BRU-A system	4 x 100 %
5.	Sprinkler system	4 x 50 %
6.	Residual heat removal system	4 x 50 %
7.	Intermediate cooling circuit to . safety related consumers	4 x 100 %
8.	Technical water system to safety related consumers	4 x 100 %
9.	SS ventilation systems	4 x 100 %
10.	Containment isolation valve system	2 x 100 %
11.	Borated water storage system	2 x 100 %
12.	Emergency gas removal system	2 x 100 %
13.	Primary circuit overpressure protection system	2 x 100 %
14.	Secondary circuit overpressure protection system	2 x 100 %
15.	Main steam lines cut-off system (MSIV)	2 x 100 %
16.	Protection system for emergency diesel generators	4 x 100 %
17.	Start-up system for safety systems	4 sensors/parameter, 4 4 logic channels each with 2/4 logic

		sensors/parameter, 4 sets of 2/4 logic at the 1st voltage level and 2 sets of 2/4 logic at the 2nd voltage level
Passive safety systems		
19.	ECCS accumulator tanks system	4 x 50 %
20.	Reactor containment system compartments	1 x 100 %
21.	Hydrogen removal system from the containment	1 x 100 % (1 subsystem)
BDBA control additional technical resources		
22.	System of passive heat removal via SG	(PHRS SG 4 x 33 %)
23.	System of passive heat removal from the containment fro m the volume	4 x 33 %
24.	Melt localization system	1 x 100 %
25.	Hydrogen removal system from containme nt	1 x 100 % 2nd subsystem)
26.	Chemical binding system for volatile iodine forms	1 x 100 %
27.	Ventilation system to maintain vacuum in the inter-shell space	2 x 100 %
28.	System of emergency water use from inspection shaft (JNB)	2 x 100 %

2. Targeted Security Reassessment Progress (Stress Test) of the Belarusian NPP

Stress tests represent a targeted reassessment of resistance to extreme external natural events and their combination against the background of the NPP Fukushima Daiichi accident. In carrying out stress tests the following points were assessed:
the presence of “safety margins” in relation to extreme natural events, specific for the region of the NPP site location, as well as adequacy of design and operational measures for successfully preventing a beyond design basis accident in the event of a complete loss of AC power supply and failure of the heat removal (water) system, and if it were to happen, to successfully overcome it.

When conducting a security review as part of the licensing process, there is an assessment of compliance with the level of nuclear and radiation safety provided by approved design solutions and the results of their implementation, with the requirements of the national legislation.

Technical and regulatory requirements for stress tests in the Republic of Belarus were introduced in 2015 by a Technical Code of Common Practice “Assessment of the frequency of severe damage to the reactor core (by external source events of natural and man-made nature)” [26]. Subsequently, in 2017, with the support of European experts under the European Union international technical assistance project, a separate document in the form of norms and regulations on nuclear and radiation safety “Requirements to stress tests (targeted safety reassessment) of a nuclear power plant” [27] was prepared and approved.

In 2015 ENSREG included an expert review of the targeted safety reassessment (stress tests) of the Belarusian NPP in its Work Programme for 2016-2019.

Self-assessment of the Belarusian NPP under stress tests took place in 2016 [28]. The consequences of such natural factors as earthquakes, floods, extreme weather conditions and their combination were forecast. The stability of the Belarusian NPP (taking into account design characteristics of seismic equipment, protection from floods, possibilities of operation under low/high temperatures, waterspouts, etc.) in the case of natural impacts of an **extremely** high level was assessed. The level of natural impacts adopted in the assessments significantly exceeds the parameters specific for the region of the NPP site location. Design and organizational solutions are assessed in respect of the management and reaction of the technical systems and personnel to the consequences of loss of NPP power supply and failure of the heat removal (water) system. The adequacy has been assessed of technical facilities provided for in the design, and to be used in the event of a hypothetical security failure, in order to provide protection from the impact of radiation on the population and the environment.

Representatives of the MES, the Ministry of Natural Resources, the Ministry of Health and the National Academy of Sciences were involved in the preparation of the national report on the targeted safety reassessment (stress tests) of the Belarusian nuclear power plant.

In April-June 2017 a State research institute “Joint Institute for Energy and Nuclear Research -Sosny” of the National Academy of Sciences of Belarus conducted an expert review “Report on the targeted safety reassessment (stress tests) of the Belarusian NPP”.

In June 2017, ENSREG established a Peer Review Board and in September 2017 a Peer Review Team (PRT) of experts to review the Belarusian national stress test report

In the period 28-30 August 2017 a seminar was held in Minsk entitled “Preparation of the national report on the targeted safety reassessment (stress tests) of the Belarusian NPP. Review of the national report: results, European Union experience, recommendations regarding its content, structure and completeness”, under the European Union international technical assistance project BY3.01/13 (BE/RA/08).

On the basis of the Report of the Belarusian NPP State Enterprise on the self-assessment, the national report on stress tests on the Belarusian NPP [3] was prepared. The Report was completed in September 2017. In accordance with the provisions of the documents [4, 27], the safety assessment was conducted in three key areas:

- Topic Area 1: External Hazards
- Topic Area 2: Safety System Loss
- Topic Area 3: Severe Accident Management

The national report also contained suggested actions to be carried out aimed at increasing the plant’s safety level.

On 27 September 2017 the report was approved by the interagency committee for coordinating and monitoring the implementation of the plan for key organisational steps for the construction of the nuclear power plant in the Republic of Belarus, headed by the Deputy Prime Minister of the Republic of Belarus.

The European Commission organised a peer review of the Belarusian national report, which was carried out on the basis of Practical Guidelines, agreed between the parties.

The national report on stress tests on the Belarusian NPP (English version) was submitted to the European Commission on 31 October 2017. Subsequently, it became publicly accessible in Russian on the Gosatomnadzor website www.gosatomnadzor.gov.by, and in English on the ENSREG website http://www.ensreg.eu. This procedure fully complies with the principles of openness and transparency.

The next steps were a desk review of documents by European experts, and questions on the national report were asked via the ENSREG website by experts and representatives of civil society. The Belarusian side prepared answers to all the questions. The questions and answers are publicly accessible on the ENSREG website.

An expert review of the national report of the Republic of Belarus was carried out from October

2017 to February 2018. In the course of this review authorised experts prepared and forwarded to the Republic of Belarus questions regarding the national report. More than 460 questions were asked by experts and public organisations from the Republic of Latvia.

The questions received were divided by area as follows:

- General – 62 questions;
- External Hazards – 155 questions;
- Safety System Loss – 132 questions;
- Severe Accident Management – 116 questions.

On 7 March 2018, in accordance with ENSREG procedure, Gosatomnadzor presented answers to all the questions asked by the authorised experts, and later it answered all the questions asked by public organisations.

A visit of European experts took place from 12 to 16 March 2018. The experts discussed the information presented in the national report with Belarusian and Russian specialists. They visited the construction site of the Belarusian NPP, and prepared a draft report on the peer review.

For the first time, under the stress-tests procedure, in performing the peer review of PRT, assessment criteria incorporated into the new IAEA 2016 [30] and WENRA 2014 [31] were used. This approach is noted in the PRT report [4].

The final version of the report was presented during the visit to Belarus of the Peer Review Board from 12 to 14 June 2018.

During a meeting of the European Nuclear Safety Regulators Group (ENSREG) on 2 July 2018, the Peer Review Report [4] was endorsed and, on 4 July 2018, it was published in the public domain on the ENSREG website.

Gosatomnadzor together with interested parties developed a road map for the preparation of the National Actions Plan based on the stress tests performed on the Belarusian NPP. In accordance with the road map, in March 2019 a system of measures was developed which are intended to further improve the safety level of the Belarusian NPP. In letter No 03-16/323 of 5 March 2019, Gosatomnadzor sent to the Belarusian NPP State Enterprise an instruction to implement measures based on the stress tests.

This document includes a descriptive part and information on the system of measures intended to further improve the safety level of the Belarusian NPP, which the operator and other national organisations accepted for implementation. An appropriate document format makes it possible for all interested parties to get acquainted with the actions undertaken as a result of the stress tests.

2.1 Approach to Implementation by the Republic of Belarus of the “Intelligent Ownership” Principle in respect of the peer review of stress tests of the Belarusian NPP

During the stress tests conducted on the Belarusian NPP and their peer review, a number of suggestions and recommendations were formulated how to increase safety margins of the Belarusian NPP in relation to extreme natural events and a combination thereof [3, 4].

In the Peer Review Report [4] a team of experts from the European Nuclear Safety Regulators Group (ENSREG) recommended that the Belarusian side Gosatomnadzor adopt an approach of “intelligent ownership" of recommendations issued, and in particular: "*in accordance with the principle of "intelligent ownership", identify the necessary safety improvements in response to the recommendations made in this report by the PRT and those by Gosatomnadzor itself [in the preparation of the national report on stress tests of the Belarusian NPP], and incorporate them into a National Action Plan containing all relevant safety improvement measures and associated implementation schedules. The National Action Plan should ensure timely implementation of the safety improvement measures in accordance with their safety significance.*"

In the development of actions of the Belarusian National Plan and deadlines for their implementation, Gosatomnadzor in cooperation with other interested parties analysed in detail each recommendation and subsequently accepted for execution specific activities and determined deadlines for their implementation, based on an absolute priority to provide for safety assurance.

The following was taken into account:

the absence of identified safety deficits in the Belarusian NPP and the focus of recommendations made in the Peer Review Report on a sustainable improvement of safety level of the Belarusian NPP;

the fact that the peer review was conducted in respect of a NPP under construction, and assessment criteria incorporated in the new recommendations IAEA 2016 [30] and WENRA 2014 [31] were used for the first time in respect of its design;

the ongoing licensing process for the operation of power block No 1 of the Belarusian NPP;

the need for real, temporary, human and financial resources for the implementation of additional measures to improve safety;

technical solutions of NPP-2006 design and its particularities.

As a result, the National Plan was developed based on the approach of "intelligent ownership" of recommendations issued, whose description is included in this document. Information is included in Annex 1 on recommendations issued by the peer review team (hereinafter PRT) and which were approved for implementation.

3. Belarusian NPP safety assessment as part of stress-tests

3.1 Measures taken on the basis of the results of the stress-tests procedure

Belarusian NPP design belongs to the 3+ generation and a number of new systems have been provided for from the beginning to manage and to overcome beyond-design-basis accidents. These systems are based on the passive principle of actuation, taking into account events similar to those which happened at the NPP Fukushima Daiichi. In the Belarusian NPP design which has been implemented since 2012, the safety criteria and design limits applied correspond to the requirements of the country which is to supply the technology, i.e. the Russian Federation, and to IAEA recommendations, applicable when the construction contract was signed.

The stress test results of the Belarusian NPP confirmed that the existing design measures for ensuring the safety of power units were adequate, taking into account events which took place at NPP Fukushima Daiichi. No safety deficits were identified, there is no need for additional measures to increase the safety level of the design . Safety margins are specified in respect of each of the extreme events which were examined.

Based on the results of the peer review, European experts noted examples of good practices in the Belarusian NPP, and recommended improving safety in some areas in accordance with the stress test procedure.

Taking into account the absence of safety deficits, immediate actions, involving modifying the fundamental design, are not necessary.

At the same time, following the safety priority principle, measures recommended on the basis of the results of the targeted safety reassessment and recommendations of the peer review team PRT will further improve the safety of the NPP in Belarus. Most of the measures are aimed at conducting feasibility studies in order to assess additional safety margins of the Belarusian NPP and they are of a long-term nature. At the same time, a number of pivotal and high-priority actions have been set for implementation.

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3.2 Topic Area 1: External Hazards

3.2.1 Seismic Hazards

The design basis of the Belarusian NPP provide for stability of the buildings and structures, as well as for process pipelines, other communications and engineering structures in the event of the following seismic impacts:

- The horizontal peak ground acceleration of the DBE level – 0.12 g (7 points as per the MSK-64 scale);
- The horizontal peak ground acceleration of the DBE level – 0.06 g (6 points as per the MSK-64

The seismic danger assessment under stress tests is performed taking into account seismic properties at the Belarusian NPP site and seismic category of construction of systems and components of the Belarusian NPP.

The area of the Belarusian NPP site is part of the Belarusian-Baltic seismotectonic region. The region examined is characterised by relatively week seismic activity. Under conditions of low seismicity, and also taking into account late development of instrumental seismometric observations, information on historical earthquakes is very important for the study of regional seismicity of the western part of the East European Platform. Earthquakes in the western part of the East European Platform are connected to specific, most active from the seismic point of view, fault zones, or their intersection zones.

The level of seismic danger for the NPP site within the near-field region is defined, generally, by seismicity of the Belarus platform territory.

In accordance with regulatory basis [32], in order to assess the level of seismic hazard of the region of NPP site location the map of the general seismic risk zoning of the North Eurasia GSZ-97-D with a scale of 1:10000000 was accepted. Design-Basis Substantiation for earthquake resistance of building structures provided for in the design, was prepared taking into account ground conditions at the Belarusian NPP site.

The peak (horizontal) accelerations (PHA) obtained as a result of field research (during seismic risk zoning) were < 0.1g (0.069g) (PHA of the site) [33]. At the same time according to NP-031-01 for the newly designed NPPs, irrespective of the site seismicity the accelerations corresponding with the SSE level should be minimum 0.1g. In IAEA recommendations of NS-G-3.3, item 5.26 and SSG-9, item 2.11., the recommended minimum level is also the horizontal peak ground acceleration 0.1g.

Taking this into account, in the design bases the PHA value is 0.12g (Design VVER-1200 Project, 2006).

There are no radiation consequences of DBE and SSE, and no additional improving measures are required. The assessment of the load-bearing capacity reserves available in the building structures (security of strength characteristics, reserves due to elastoplastic behaviour of the structures, etc.) showed that for the structures of seismic category I the reserve relative to the SSE level adopted in the design is not less than 4.9 times (0.62 g), and for the inner containment - not less than 4.3 times (0.51 g).

The main equipment of the reactor plant: reactor, steam generator, RCPS, reactor coolant pipeline, pressurizer, electrical connection block, connecting pipeline have the necessary reserves for load accommodation at 8-point SSE.

There is a 20% safety margin at the design SSE level for support stands of the racks of the spent fuel pool.

There is a 35% safety margin at the design SSE level for the emergency core cooling system.

For the equipment and piping of the NPP safety systems, the maximum permissible acceleration is 0.13g considering the accepted safety margin.

Thus, the determining factor in assessment of the horizontal peak ground acceleration is the failure of the safety systems pipelines. Based on the regulatory requirement regarding the minimum SSE level (0.1g), the seismic margin for the Belarusian NPP is 30%. As regards the actual SSE level determined for the site (0.069g), the seismic margin is 30%.

These results are presented in the national report [3] and noted by the European experts in the Peer Review Report.

In the meantime, when the activities involved in the peer review of the results of the Belarusian NPP stress-tests were carried out, safety audits started in October 2017 in respect of the application of the Belarusian NPP for license to operate the power unit No 1. In accordance with TNPA [34], PSA is included in the scope of the documents substantiating NPP unit’s safety.

PSA should take into account external hazards, caused by external natural and man-induced impacts, including seismic.

The peer review included a recommendation "*The regulator should consider the results of the PSA -2018 seismic survey in justifying the plant's safety standards and implementing measures to improve its safety. PSA results may require security concept updates in respect of seismic impacts in accordance with requirements of points F.1.1-1.2 WENRA» [31].*

The Action Plan includes the task "Review the results of seismic PSA-2018 in the assessment of NPP safety and determine any necessity to undertake relevant actions in order to improve safety (p. 2 Table 4). The deadline for its implementation falls within the licensing process for the operation of power block No 1 of the Belarusian NPP.

At the time when stress tests were carried out, overly conservative source data were used as the basis for calculating seismic parameters of the site and of the PSA-2018 prepared on their basis. They included:

– maximum magnitudes of possible earthquake source zones (PES) determined in accordance with the method based on the lengths of geological structures, without taking into account the actual activity of faults and sheer fractures. These assessments proved to be considerably overestimated. Reliability of such assessments is low and is not taken into account in the calculations, in the form of weighting coefficients;
– as the maximum magnitude of remote earthquakes from the East Carpathian (Vranch zone), the values 8.4 – 8.7 were selected. This significantly exceeds assessments based on scientific surveys of 7.8 – 8.0;
– the selection of expected directions of the ground motions was carried out for the seismically active areas and does not correspond to real geodynamic conditions of the territory of Belarus which on the whole is of a low-active nature;
– possible earthquakes with a magnitude lower than 4 were excluded from the review, while it is important for the territory of Belarus to keep this consideration in mind.

This has resulted in overestimated peak accelerations and response spectra, which significantly exceed deterministic estimate. As a result, overly conservative source data were obtained (calculated values of peak accelerations and calculated seismic hazard curves), which are not typical for the site with a low seismicity, as these values proved to be particular to seismically active regions. Consequently, seismic margins for elements of safety-critical systems, determined as a result of stress tests, must be refined taking into account the results of a site survey during the NPP construction, in order to eliminate the over-conservatism of generated results.

Against this background, Gosatomnadzor finds it necessary to prepare a more precise seismographic model, adequately corresponding to the geodynamic conditions of Belarus; to carry out additional studies on the drawing up of seismic hazard curves, taking into account a more refined seismotectectonic model, and also correct seismic impacts PSA for which initial data will come from adjusted seismic safety curves. Moreover, it is necessary to determine the necessity to perform a comprehensive assessment of seismic risk on the basis of more refined seismic hazard curves and existing equipment safety margins. Relevant tasks are included in the Action Plan (Table 4, point 1). Timeframe for work - December 2019

Based on the completion of the above-mentioned tasks, it is necessary to make an additional assessment of CSC (constructions, systems and components) and refine their seismic margins and how they operate in accident conditions (level 4 of the defence-in-depth). On the basis of results obtained using national standards and the IAEA recommendations, if necessary, relevant measures should be determined to increase safety (Table 4, point 3, deadline for implementation 31 December 2021).

The following recommendations of the peer review were taken into account: "A comprehensive margin assessment based on the hazard curve from the PSHA and fragility evaluations should be performed, to justify the adequacy of the margins of all SSCs with respect to the design basis and beyond for ensuring their integrity and function in accordance with their role in support of Defence-in-Depth (DiD) levels." and *"The regulator should ensure that the seismic resistances of SSCs credited for coping with accident conditions (DiD levels 3 and 4) induced by a seismic event are adequate to ensure their performance."*

Relevant seismic resistance margins regarding the SSE level of 3.7 points were identified on the basis of results of the Belarusian NPP stress-tests. The question of selection of SSE level was studied in detail during the peer review. The only point is that catalogues data regarding the area south-west from the Belarusian NPP site show the location of the epicentre of a historical and significant earthquake with intensity of 7 points on the MSK-64 scale. That earthquake occurred in 1908 near Gudogay village. This constituted the main reference criterion as the nearest fault structure to the seismic generating structure. However, taking into account information and results of assessments performed to date, the existence of that historical earthquake is doubtful. This was noted by the European experts from the PRT in the Peer Review Report on the Belarusian NPP Stress Tests Taking this into account, the PRT experts recommended performing an additional detailed study on this historical earthquake in 1908 in the Oshmiyansky fault area and to clarify its reliability. On the basis of results of the review, it was also suggested completing, if necessary, a review of the zoning and seismic catalogues. □

Thus, considering the importance of the question of the NPP seismic resistance, notwithstanding safety margins obtained in respect of SSE 7 points, the action plan based on the stress tests results provided for an additional study of historical sources, documents, and geophysical materials to establish whether the Gudogay earthquake of 1908 had actually taken place and to clarify its possible nature. Moreover, taking into account the results of the above-mentioned studies, as well as data from long-standing seismic monitoring in the period of surveying, designing and construction of the NPP, an update of the seismic events catalogue is planned for the region of the Belarusian NPP site location (point 4 of Table 4).

As part of stress tests, the question of seismic monitoring in the region of the Belarusian NPP site location was also examined.

For control of geodynamic stability in the region of the Belarusian NPP site location, seismic monitoring has been organised from 2008 until now, in the form of an observation network operating continuously (24/7). A number of survey works were carried out for this, it being necessary to select points for the seismic monitoring network. The network consists of 7 points of monitoring located 15-25 km from the site. It provides recording of seismic events within the required range of epicentral distances and energy.

Based on the results of the peer review, an additional analysis of the existing seismic monitoring network was recommended from the point of view of its resolution capacity, taking into account a possibility to control a potential geodynamic activity in the Oshmiyansky fault zone, linked to the Gudogay earthquake. Based on the results of the study, it is necessary to evaluate the need for increasing the accuracy of kinematic and dynamic parameters of possible earthquake source zones, and to identify the optimal location and number of observation points in the network (point 5, Table 4). The work is planned for 2020.

The above-mentioned work on the control of seismic monitoring of the geodynamic situation is carried out through a temporary observation network. A temporary seismic monitoring is provided for at the stage of preparation of design documents (as part of the survey), during development of the design documentation, and also at the stage of construction of the NPP. A permanent (fixed) local seismic monitoring network is to be arranged on the basis of stress tests results. The analysis of its resolution capacity at all stages of the life cycle of the Belarusian NPP will be taken into account. This monitoring network will be used to obtain information on changes in the geodynamic situation in the area of the facility location by detecting weak earthquakes which occur on activated tectonic structures; to obtain new data on the resonance properties of the soils at the NPP site for protection against future maximum earthquakes by introducing changes in the natural periods of oscillations of the facilities and essential structures in order to avoid the resonance effects; to obtain more precise and additional data for determining the quantitative parameters of a design basis earthquake (DBE) and safe shutdown earthquake (SSE) from local and remote seismically active areas in order to make more precise estimated accelerograms and response spectra; to obtain current data on the parameters of seismic impacts on buildings and essential structures during intense local and remote earthquakes in order to make decisions on the necessity of additional verification of reliability of facilities and equipment which have experienced significant seismic impacts; to obtain additional data for setting the parameters of the vibration protection sensors.

The implementation of these actions is provided for in the action plan based on the stress tests results (point 6, Table 4) and they are planned for implementation in 2020 – 2025.

Taking into account the implementation of the above-mentioned actions in the period of operation of the Belarusian NPP, a seismic observation network will be developed, providing for detailed information on the state of geodynamic parameters in the region of the Belarusian NPP site Statistical data obtained are of interest for scientific research. Therefore, taking into account peer review recommendations, the action plan includes a point whereby an access procedure to the data recorded by the seismic observation network is to be developed (point 7, Table 4).

3.2.2 Protection from Flooding

To initiate an event, i.e. flooding of the NPP site to the relative elevation of 0.00 (absolute elevation 179.3), the water level would need to rise from its absolute elevation of 127.8 (the Viliya river) by 51.5 m. Borders of the surrounding areas that could possibly be flooded with maximum water flows during spring floods of 0.01% confidence show that there is no possibility of access routes to the NPP and main roads being flooded, eliminating hampered or delayed access of the staff and equipment delivery to the NPP site.

In case of extreme precipitation, even if considering failure of the pump stations, the level of water on site can rise only 5.3 mm, which due to 150 mm perimeter pavement around the buildings eliminates the possibility of a design basis flood.

Stress tests results confirm that a "dry site" concept is adopted in the Belarusian NPP design. Protective measures adopted in the design are sufficient to prevent "extreme" flooding.

To protect the Belarusian NPP against surface water logging, the design provides for vertical layout of the site and its drainage. The drainage of storm water is organised through a closed drainage system to rainwater receivers, and further into the storm water drain system.

A design basis flood with water rising to site level is impossible. That is why the design does not specify any special measures to prevent floods.

As part of the peer review, experts recommended that consideration be given to the possibility/desirability of tightening the concept of a design basis flood, in terms of considering a possibility of ground waters rise up to lower basement elevations. *"Due to the current state of the construction during the plant visit, the PRT was not able to fully review the volumetric protection of plant safety related buildings against water ingress.*

Therefore, the PRT recommends the Regulatory Body to check that plant measures against water ingress into safety related buildings and underground galleries are robustly designed and implemented."

At the same time, the experts noted that protection measures against water ingress into buildings and special drainage measures provided for in the design, in case of flooding necessary access to the site, remains ensured, and mobile equipment stored on the site, necessary in case of severe accidents, remains accessible. Control and supervision of construction of buildings and structures on the site of the Belarusian NPP, including the foundation work, their waterproofing and waterlogging of building structures is performed on a systemic basis in accordance with the requirements of the codes of conduct SP 48.13330.2011 "Construction management" and SP 45.13330.2012 "Subsoil and foundation works, bases and foundations", requirements of the construction standards and regulations SNiP 12-04-2002 "Work safety in construction" [35-37]. At the stage of commissioning of the completed construction of the Belarusian NPP facilities, a comprehensive assessment of relevant buildings and structures is provided for. This includes their watertightness, design documents and TNPA requirements.

In the event of flood postulation, the reactor plant (RP) is transferred to a safe state in which it is maintained for 72 hours without the intervention of the operating personnel. With flooding of the NPP site postulated as an initiating event, and in order to increase the period of time when the NPP is in the safe mode, it is necessary to implement the following measures to improve resistance of the NPP to floods:

- in terms of heat transfer from RP, in 72 hours arrange feed
  of LCU tanks from the site (e.g. URR spray cooling pond, URX backup tank) and off-site (e.g. fire department tanks) water sources;
- in terms of removal of residual heat from the spent fuel pool:
  after 41 hours it is necessary to arrange for refilling the spent fuel pool. This can be done by connecting unconventional instruments (fire engine with 40 l/s pump and 100 m head). This will ensure feed of the cooling pool performed by operating staff after 41 hours have passed.

3.2.3 Extreme Weather Conditions

During the targeted safety reassessment, an analysis of the Belarusian NPP resistance to extreme weather conditions and also to some of their combinations was carried out. Table 3 shows values of extreme impacts used for the designing and for the Belarusian NPP site.

Table 3

Values of extreme impacts used for the baseline design and for the Belarusian NPP

Extreme impact	Value used in the Belarusian NPP design	Values of extreme natural impacts with a frequency of 1 time per 10 000 years according to PiN AE-5.6, specific for the Belarusian NPP site
Minimum temperature	–61°C	-50°C
Maximum temperature	+52°C	+37.4°C
Extreme snow load	4.3 kPa	3 kPa
Extreme wind speed	61 m/s	54 m/s
Tornado	Class F3.6	Class F2.5
maximum wind speed in the vortex	V_m=95 m/s	V_m=70 m/s
maximum subatmospheric pressure in the tornado eye	ΔP_{max} = 11.1 kPa	ΔP_{max} = 5.55 kPa
maximum wind pressure	P_{max} = 8.7 kPa	P_{max} = 3.2 kPa
flying objects	Considered	No flying objects

It has been concluded that extreme weather conditions have no influence on the safety of the Belarusian NPP.

The PRT considers that the plant demonstrates stability in respect of extreme weather conditions. During the visits of experts to the Republic of Belarus it was noted that operating procedures for extreme weather conditions are being developed.

Reliability of protection of the NPP against the impact of extreme weather conditions is also confirmed in the Peer Review Report by the PRT experts: "*in this respect the plant shows a high resistance".* The experts recommended to have all design solutions in terms of protection against the impact of extreme weather conditions in place after the construction is completed and to commission the NPP in accordance with specific operating procedures.

Extreme natural impacts on building structures and facilities constitute special load combinations. In accordance with the current regulations, requirements for building structures are imposed exclusively as of the first limit state (strength, stability).

After heavy rains, snowfall, hurricane winds, earthquakes and other natural phenomena, unscheduled general or partial technical inspections of buildings and electrical power units will be conducted in accordance with the regulatory requirements and provisions of the operating organization's internal documents. Objectives of technical inspection: gathering information about the environment in the working area of industrial buildings and structures; timely detection of structural defects and measures to eliminate them.

The survey should be carried out according to the developed and approved operating organization programme, using visual and instrumental methods.

A number of measures of emergency response are provided for in the "Plan of protective measures in case of a radiation accident at the Unitary Enterprise "Belarussian Nuclear Power Plant" (the external emergency plan).

Gosatomnadzor supervises the practical implementation of all design solutions. Under the licensing procedure, documents underpinning the safety of the Belarusian NPP are assessed by experts who review, among other things, operating documents including operating procedures in extreme weather impact conditions. Specific points in the Action Plan (Table 4) in respect of extreme weather conditions are not provided for.

3.3 Topic Area 2: Safety Functions Loss. Blackout and Final Heat Absorber Failure

The expert review of the "Report on the self-assessment of the Belarusian NPP shows that technical ENSREG conditions to protect against the loss of power supply and the loss of the ultimate heat sink are met. The diversification principle in terms of use of the active safety systems with passive ones, big water reserves stored inside the containment as well as other features provide stability and the necessary temporary framework in all emergency situations reviewed during the targeted safety reassessment.

At the same time, the PRT experts came to the conclusion that in particular, in order to extend design conditions, some issues regarding safety should be refined and improved.

The Belarusian NPP design is based on Russian regulatory documents developed before the NPP Fukushima Daiichi accident. These documents, International Atomic Energy Agency (IAEA) Standards, and in particular

SSR 2/1 requirements [30], dealing with the new concept of design extension conditions replacing the old BDBA concept, and the need to have mobile installations or to develop preventive measures. The construction of the Belarusian NPP started in 2013, based on the design developed in accordance with Russian regulatory documents in force at that time. They defined the measures for preventing dangerous conditions in the event of BDBA using mobile installations. The more recent IAEA approaches to the construction of nuclear power plants, published in 2016 (SSR 2/1 [30]), require providing for all necessary installations (including mobile) and to develop preventive measures for beyond design basis accidents. Recommendations of the PRT experts in terms of additional power supply sources and installations aim at increasing safety margins for uninterrupted operation of the NPP in a BDBA situation.

For the Belarusian NPP, loss of external power supply is a design basis condition analysed in the SAR on the Belarusian NPP.

The design provides for the following backup AC power supplies, constantly available for use, for each NPP Unit:

- an emergency backup transformer with a power of 16 MVA, seismic category I, voltage 110/10 kV, powered from the "Viliya" substation through a cable line laid in the ground;
- a Unit DG with a power of 6300 kW;
- 4 EPSS DGs with a power of 6300 kW each;

The equipment of the main power output system allows for cutting off the electrical equipment of Unit 1 and Unit 2. Therefore, the power supply system of one Unit is independent of the other Unit. Design accident management measures are independent of the operation of the other Unit.

In the event of loss of external power supply and design backup AC power supplies there is availability of power supply from the EPSS UPS for some valves (isolating valves of the sealed enclosure, BRU-A, MSIV) and I&C: availability of power supply from UPS of the system for power supply to the BDBA monitoring and management equipment (channel 7). In addition, an emergency backup AC power supply source in the form of MDG (Mobile Diesel Generator) is provided for, to be connected to the switchgear of the safety channel 7.

The presence of this set of power supply sources as well as passive safety systems stipulated in the design, make it possible to maintain NPP units in the safe mode for 72 hours without the intervention of operating personnel. This meets current IAEA recommendations for NPP safety. Moreover, with the diesel fuel stock on the site, a safe state of power units in the event of a loss of external power supply is secured for an unlimited time.

In the course of peer review by the PRT experts a recommendation was made to provide for a backup AC power source in order to secure an additional guarantee for working of passive safety systems for an unlimited time.

Taking into account the adopted concept of safety in the NPP-2006 design, it is necessary to carry out an assessment of the degree of safety increase for the Belarusian NPP with the implementation of the above-mentioned action (point 8 of Table 4) in order to take a decision to equip the Belarusian NPP with alternative stationary AC power sources for BDBA.

In the event of blackout and loss of the ultimate heat sink, taking into account design solutions, including systems based on the on the passive principle of actuation, the maintenance of power units in a safe state is secured for the time necessary for performing restoration works. In this regard, as part of the peer review conducted by PRT experts, considerable attention was paid to the study of designed passive safety systems and additional technical means for BDBA management and prevention. These systems and means are based on the passive principle of actuation and fulfil basic functions of safety.systems. As a result of stress tests and peer review, it was confirmed that with passive safety systems, in the event of loss of power supply and failure of the heat removal system, with non-interference (lack of action) of operators, and under the most adverse conditions, power units safety is secured for 72 hours. This temporary margin is sufficient for performing restoration works and meets current international safety standards.

In addition, technical facilities provided for in the design maintain for 72 hours the reactor plant (RP) in a safe state by maintaining water reserves in emergency heat removal tanks. Also damage of nuclear fuel in the spent fuel storage pool without operating personnel intervening does not occur for 41 hours. Maintenance and restoration of the water reserve is provided by a low-power high- pressure pump JNB50AP001 of the make-up system for the emergency heat removal tanks from LCU tanks. Powering of that pump is provided by connecting a mobile DG set required for the power supply channel 7 batteries. Provided these operations are performed, a safe state of the power unit is maintained for an unlimited time in the event of blackout and loss of the ultimate heat sink.

In these conditions the pump JNB50AP001 plays a key role in ensuring the operation of the PHRS longer than within 72 hours. Subsequently, the design provides for redundancy of the pump function (replenishment of the PHRS tanks and spent fuel pool) with the aid of fire engines. In this way, feeding of LCU tanks (followed by EHRT filling) can be done from any water sources on the NPP, using off-site mobile equipment.

The PRT team experts indicated vulnerability of this emergency feedwater system for the pump JNB50AP001 since off-site mobile equipment in emergency situations cannot be regarded as a reliable and unequivocally available means. Taking into account the above-mentioned and the fact that the design provides for only one pump JNB50AP001 per power unit is designed, the PRT experts recommended enhancing the reliability of the PHRS by installing an additional redundant pump.

This recommendation by the expert team is reflected in points 9 and 10 of the action plan following the stress tests results (points 9 and 10, Table 4). The Belarusian NPP must assess the impact which the installation of an additional pump will have on enhancing the reliability of the PHRS. If such measure is considered effective (increasing the level of safety), an additional pump will be installed.

The above-mentioned scenario of ensuring heat removal in emergency situations (after 72 hours) demonstrates that the mobile DG set (hereinafter MDG) is of key importance in ensuring power supply for the pump. Taking into account current concepts and approaches to safety WENRA and IAEA SSR2/1 recommendations “Safety of nuclear power plants. Specific safety requirements”, the PRT experts recommended that a permanent power supply should be used in the event of beyond design basis accidents.

As part of the action plan following the stress tests results (point 11, Table 4) each power unit of the Belarusian NPP is to be provided with a stationary connected DG set (2 DG sets per 2 power units). The deadlines for completion of this action are: unit No 2 - 1 January 2020, unit No 2 - 1 January 2021. It is necessary to prepare amendments to the design documents in 2019.

Auxiliary external power supply for the plant is provided by 7 different power lines. In the event of common-cause failure of all power lines (for example as a result of natural impacts), the design provides for an additional external power backup with an underground cable line from the “Viliya” substation to an emergency standby auxiliary transformer, seismic category I, with a power of 110/10 kV, constantly available for use.

The Plan provides for an additional assessment of the reliability of auxiliary power supply to safety related consumers, as well as for an assessment of the “Viliya” substation’s resistance to internal and external events, in line with the PRT experts recommendations (point 13, Table 4).

The results of an analysis of an accident with loss of all above-mentioned external AC power sources for the operational conditions of the RP power unit “power operation” and “cold” operating conditions of the Unit RP show that stabilization of the parameters and residual heat removal prior to restoration of the normal auxiliary power supply of the Unit is ensured.

The loss of an off-site power source is considered to be a design basis accident. The external power supply is backed-up by on-site power supply (as indicated above). The operating time of emergency diesel generating sets for emergency power supply can be secured for more than 72 hours without intervention by the operating personnel. The Power Unit can be in the safe mode for up to 7 days with active safety systems operating. This takes into account the use of an additional stock of diesel fuel stored at the site (at the diesel fuel central warehouse). The safety limits of the Unit are not violated in this mode.

Outside the 72 hours period and without intervention by the operating personnel (full black-out conditions) the design provides for ensuring reliable heat removal from the RP by means of the SG PHRS system.

The RP condition with a reduced level of coolant in the reactor may lead to the most adverse accident scenario. RP - decompressed and partially drained level of coolant. As a result, heat removal through the SG PHRS system is not available. The total time of the coolant boiling-off to the FA heads is 2.4 hours. This temporary reserve is regarded by the stress tests results as the most critical. For this situation to arise, a number of independent failures of all above-mentioned off-site and on-site energy supply sources would have to happen, in the course of specific maintenance works. This seems to be extremely unlikely.

The Action Plan (point 12, Table 4) provides for the development of measures for accidents management for shutdown states of power units, including those with the reactor head removed, to prevent severe accidents in the event of complete blackout. The ultimate goal of this activity is to ensure cooling of the reactor core.

Actions from chapter 3.3 are to be completed by 2024. For some of them it is necessary to carry out an assessment of their effective impact on the safety of the entire project before taking a decision on additional technical measures.

3.4 Topic Area 3: Severe Accident Management

The design of the Belarusian NPP provides for a number of normal operation systems and safety systems aimed at prevention of accidents, including severe accidents. If it is impossible to prevent a severe stage of an accident, the safety systems functions are backed-up by a number of passive systems designed to manage, overcome and mitigate the results of severe accidents.

The Belarusian NPP design provides for a range of passive systems to overcome beyond design basis accidents, which fulfil basic functions of safety: the system of passive heat removal from the containment (PHRS C); the system of passive heat removal from the steam generators (SG PHRS); molten core catcher (JMR); a hydrogen removal system from the containment; double protective containment. In addition, the design provides for a system for make-up of the SG PHRS and PHRS C, and the spent fuel pool whose operation is powered by mobile diesel generator, and a ventilation and filtration system for vacuum maintenance in annulus. These design basis systems ensure effective heat removal and integrity of the containment in the conditions of beyond design basis accidents.

The peer review experts noted the availability of these systems in the design of the Belarusian NPP. They described them as an example of positive experience. Their working capacity is confirmed by tests carried out on a similar project [45].

Stress tests results of the targeted safety reassessment of the Belarusian NPP confirmed the adequacy of existing design measures for safety assurance for power units, taking into account events which took place at NPP Fukushima Daiichi.

Taking into account the importance of preventing consequences of beyond design-basis accidents, the PRT team proposed a more detailed demonstration of strategy for eliminating in practice early or large radioactive releases, mitigating severe accidents in the spent fuel pool and accidents which may combine with the containment by-pass.

“Attention should also be devoted to the practical elimination of severe accidents in the spent fuel pool or severe accidents potentially combined with the containment by-pass”.

The Action Plan provides for an additional analysis of the adequacy of design solutions for the practical elimination of early or severe releases (point 14, Table 4).

Based on the results of the peer review, the PRT experts noted that the set of measures included in the design to be used in the event of severe accidents corresponds to European recommendations on stress tests. Taking into account contemporary approaches to designing new NPPs, the European experts suggested carrying out a review (analysis) of the stability of specific equipment to be used in a severe accident situation. The PRT experts paid special attention to equipment with a primary circuit-protection function against overpressure, in the conditions of beyond-design-basis accidents. This is due to the need to the severe stage of high-pressure accidents. The Plan provides for meeting this recommendation made by the PRT experts (point 16 of Table 4).

The design of the Belarusian NPP provides for a number of normal operation systems and safety systems aimed at preventing accidents, including severe accidents. If it is impossible to prevent an accident from entering a severe stage, the safety systems’ functions are backed up by a number of passive systems designed to manage, overcome and mitigate the results of severe accidents.

For severe-accident management the design provides for automatic equipment using power supply from the power supply system for severe accidents. Monitoring of operating parameters of the RP equipment and of the containment is performed from the main control room for beyond-design-basis accidents. During severe accidents, a separate set of I&C devices is used, independently of I&C (Instrumentation and Control devices). They can be used for normal operation, with anomalies, and for design-basis accidents.

I&C devices for severe-accident conditions include instrumentation for the control of:

- integrity of the SG with backup (using sensors status insulation, hatch tightness sensors, radiation monitoring dosimeters inside the containment, in annulus UJB, and on-site);
- level and temperature in the spent fuel pool;
- pressure, temperature, hydrogen and oxygen concentration in the containment;
- temperature in the molten core;
- temperature and level in the system of passive heat-removal tanks;
- parameters of operating conditions of different systems, etc.

The measuring range of I&C devices seems adequate for severe accidents.

Control and measuring devices and equipment necessary for containment integrity monitoring is of category 1 of seismic stability. The containment integrity monitoring sensors are designed for a wide range of parameters and are resistant to adverse impacts of BDBA.

Based on the results of the peer review, the European experts noted that design-based devices, equipment and I&C for the management of severe accidents are in compliance with the list of equipment recommended by European experts.

At the same time, the following recommendation was made: “Consideration should be given to the installation of independent means of reactor coolant system depressurization, or special attention should be given to reliable functioning of existing means under severe accident conditions.”

The Plan (points 17, 18 of Table 4) defines objectives in respect of the systems and measuring devices designed for severe accidents. The ability of measuring devices to perform their functions in severe accident conditions, within a relevant measuring range, is to be assessed, as well as the adequacy of technical devices envisaged for reducing pressure in the primary circuit in severe-accident conditions. If necessary, in view of the results of the assessment, additional measures will be taken.

Relevant activities take into account a proposal by the PRT experts to examine the possibility of installing autonomous means of pressure relief in the primary circuit. This PRT experts proposal is based on the IAEA (SSR-2.1, Rev.1) recommendation on the autonomy of the defence-in-depth protection levels.

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Taking into account new regulatory requirements of the Russian Federation NP-001-15 [39] it is planned to add to a list of actions under the management of severe accidents strategy, at the in-vessel stage, ensuring timely water supply to the SG in order to protect the integrity of the SG tubes and when it is necessary to ensure heat removal through the second circuit. Accounting work is necessary, as well as the development of a management strategy relevant to the severe accident scenario, envisaged by the Plan (point 15, Table 4).

Taking into account the technical and organizational measures for BDBA management, provided for in the design and aimed at maintaining the integrity and localizing functions of the double containment, the radiation effects of severe accidents will not lead to contamination of vast areas with radionuclides and mandatory introduction of protective measures affecting significantly the social and economic conditions and vital activity of the population, including evacuation and resettlement, is not required (does not exceed level 5 as per INES scale).

Provision is made for the personnel to be able to stay in the MCR/ECR to manage beyond design-basis accidents, including severe ones, and to bring the Power Unit to a safe state.

The main control room (MCR) is designed to support its operation under normal operating conditions of the power unit, anticipated operational occurrences, and accidents accounted for in the design. In case the MCR cannot function due to damage caused by an effect not considered in the design (such as sabotage, military actions, etc.), an emergency control room (ECR) is provided at a distance from the MCR. The MCR makes it possible to provide an independent monitoring and control of the most important functions that are necessary to carry out a shutdown and complete cooldown of the reactor, and confinement of radioactive substances.

The MCR / ECR life support system is equipped with a plenum air purification system on the basis of aerosol and iodine filters. The building structures of double containment and the management building UCB ensure a permanent stay of the personnel at the MCR / ECR.

The MCR (ECR), and the Personnel Life Support Systems of MCR (ECR), as well as their controlling and supporting systems are located in the management building, which is referred to Category I of seismic resistance in terms of nuclear and radiation safety.

The systems are protected by the building structures from external design-basis impacts, including flying items, shock wave, and seismic impacts.

The analysis shows that in case of severe accidents considered in the design, the personnel exposure in the MCR/ECR will not exceed the target limit of the effective equivalent dose of 25 mSv for the entire period of the accident and elimination of its effects.

Taking into account the clarifications provided in the course of the peer review, the PRT experts positively assessed the survivability and habitability of the MCR/ECR during a severe accident, combined with NPP blackout. At the same time, taking into account the importance of the personnel remaining in the MCR/ECR being able to manage the accident, the experts recommended the carrying out of an additional analysis to assess the necessity of ensuring an additional reliability of survivability in the main control room. The PRT experts proposed that special attention be given in the analysis to a combination of severe accident conditions and a long-time NPP blackout. The Action Plan following the stress tests results provides for a relevant work (point 19, Table 4).

As indicated above, the design provides for a double containment whose annulus is connected to a ventilation and filtration system. This system is designed to provide (maintain) vacuum and air cleaning in the containment annulus, and applies to systems designed to manage, overcome and mitigate the results of severe accidents. This is, however, an active system, not functioning in case of station blackout. Taking into account several times backed-up design-basis power sources, reliability of power supply for this system is, among other things, confirmed by stress-tests results. Taking into account the need for the practical elimination of early or severe releases, the PRT experts recommended to additionally review and evaluate the need for a ventilation system for annulus UJB to be in operation in an extremely unlikely event of severe accident in combination with NPP blackout. The Action Plan following the stress tests results provides for relevant actions (point 20, Table 4).

Part of the administrative measures for accident management on the Belarusian NPP include the development and implementation of the Instructions for Mitigation of Accidents (IMA), Beyond Design Basis Accidents Management Guideline (BDBA), and Severe Accidents Management Guidelines (SAMG). These manuals include the procedure and criteria of transfer from one guideline or instruction to the other, as well as the scopes of their application and mutual links

Taking into account contemporary approaches to accidents management, the PRT experts recommended to have emergency documentation (IMA, BDBA, including SAMG) in a symptom-based format (SBF) before commissioning of the NPP. Availability of these emergency instructions and manuals in a symptom-based format (SBF) is provided for in the Operating Organization during the plant commissioning. To ensure the preparation of this documentation, a “Programme for the preparation and implementation of emergency documentation in a symptom-based format (SBF)” was adopted. After its approval, this programme must be forwarded to Gosatomnadzor. The Action Plan provides for the implementation of these actions (point 21, Table 4).

3.5 Action Plan of Activities to Improve Safety of the Belarusian NPP

Actions intended to improve the safety level of the Belarusian NPP and developed based on the results of the targeted safety reassessment of the Belarusian NPP are shown in Table 4.

Table 4.

The Action Plan for implementing actions intended to improve the safety level of the Belarusian NPP based on the results of the objective safety reassessment of the Belarusian NPP

No	Activity	Deadlines for completion	Responsible for implementation
1.	To carry out additional studies on the drawing up of seismic hazard curves, to refine the construction margin for resistance, taking into account more refined seismotectonic model, To correct seismic impacts PSA for which initial data will come from adjusted seismic hazard curves, including the assessment of safety margins for elements of safety-critical systems. Moreover, it is necessary to determine the necessity to perform a comprehensive assessment of seismic risk on the basis of more refined seismic hazard curves and existing equipment safety margins.	31.12.2019	Unitary Enterprise Belarusian NPP, Centre of Geophysical Monitoring of National Academy of Sciences of Belarus
2.	Review the results of seismic PSA-2018 in the assessment of NPP safety and determine the necessity to undertake relevant actions in order to improve safety.	As part of review of documents substantiating safety submitted to obtain the license for the operation of Unit No 1	Gosatomnadzor, "Joint Institute for Energy and Nuclear Research -Sosny Belarusian NPP
3.	Based on the completion of the actions in point 1, to assess the characteristics of seismic stability of SSCs to ensure their function in an accident situation (levels DiD 3 and 4).	31.12.2021	Belarusian NPP
4.	Carry out research and development on the "Study of the nature of the Gudogay seismic event of 1908 and update	31.12.2022	"Centre of Geophysical

	the seismicity catalogue for the region of the Belarusian NPP location"		Monitoring of National Academy of Sciences of Belarus
5.	Carry out research and development on the "Assessment of the optimal location and resolution of the local seismic monitoring network in the region of the Belarusian NPP site location to control a possible geodynamic activity the Oshmiyansky fault zone". In accordance with the results of the research and development exercise, take the necessary measures with a possibility to increase the number of stations.	31.12.2022	Unitary Enterprise Belarusian NPP, Center of Geophysical Monitoring, Belarusian NPP
6.	To implement for the Belarusian NPP operation period a permanent .(fixed) local seismic monitoring network for control of stability of parameters for basics and for obtaining current objective information on changes in the geodynamical situation in the area of the facility location including: search for and selection of places (including 20-25 alternative ones) in a 30 km radius from the Belarusian NPP site for locating observation points, preparatory work; construction and auxiliary work (including designing on land parcels of selected places); purchase of the basic and ancillary equipment, its installation and set-up at the points of monitoring and in the data collection and processing centre. Organisation of buffer power connections, protective signalisation and other related works, preparation and debugging of software applications, putting the system (equipment) into operation.	01.01.2025 31.12.2020 31.12.2022 31.12.2024	"Centre of Geophysical Monitoring of National Academy of Sciences of Belarus Belarusian NPP"

7.	Carry out research and development on “Study of the international experience in securing scientific review of data recorded by the seismic observation network monitoring in the NPP location regions and development of technology and procedure of access to the Belarusian network data”.	31.12.2022	Unitary Enterprise Belarusian NPP, Centre of Geophysical Monitoring, Belarusian NPP

8.	Consider the desirability of equipping the NPP with alternative stationary AC power sources (for BDBA), taking into account the adopted safety concept for NPP-2006 design (taking into consideration the passive safety systems providing autonomy of operation).	31.12.2023	Belarusian NPP
9.	Assess the reliability of the passive heat removal system (SG PHRS) after installation of an another redundant pump in addition to JNB50AP001, compared with the characteristics of the existing system.	31.12.2023	Belarusian NPP
10.	In accordance with the results of assessment in point 9, carry out necessary organisational and technical actions.	01.01.2024	Belarusian NPP
11.	Undertake organizational and technical measures for stationary connection of one DG set to each NPP power unit.	Unit No 1 - 01.01.2020; Unit No 2 - 01.01.2021;	Belarusian NPP
12.	Develop for further implementation technical and organizational measures ensuring restoration of water supply in time necessary to prevent severe accidents arising in the open reactor condition in the case of a total loss of external and emergency power supply to the unit.	31.12.2023	Belarusian NPP
13.	Assess the reliability of auxiliary power supply to safety-related consuming sources, from an emergency standby auxiliary transformer SN (ARTSN) 110/10 KW, with a power of 16 MV A, which can be connected to a cable line 110 kV in the “Viliya” substation. Assess also “Viliya” substation’s resistance to internal and external events.	31.12.2023	Belarusian NPP, Belenergo

14.	Assess the adequacy of design solutions - for the practical elimination of early or severe releases; - the practical elimination of severe accidents in the spent fuel pool; - the practical elimination of the containment by-pass during severe accidents.	31.12.2024	Belarusian NPP
15.	To add to a list of actions under the management of severe accidents strategy, at the in-vessel stage, the assurance of timely water supply to the SG (in order to protect the integrity of the SG tubes and when it is necessary to ensure heat removal through the second circuit).	31.12.2024	Belarusian NPP
16.	Qualify the existing technical equipment with a primary circuit protection function against overpressure, in the conditions of beyond design basis accidents including the severe ones.	31.12.2023	Belarusian NPP
17.	Carry out a review confirming the adequacy of technical devices envisaged for reducing pressure in the primary circuit in severe accident conditions (in order to eliminate the damage resulting from high pressure).	31.12.2023	Belarusian NPP
18.	Carry out a review of the adequacy of technical measuring devices for the management of severe accidents. If necessary, additional measures will be taken.	31.12.2023	Belarusian NPP
19.	Review the necessity to equip management zones MCR (ECR) with additional systems ensuring survivability and habitability of the MCR/ECR.	31.12.2021	Belarusian NPP
20.	Review the desirability of ensuring the emergency ventilation system for annulus UJB to be in operation in the event of a severe accident in combination with a loss of external and emergency	31.12.2021	Belarusian NPP

	power supply to the power unit.		
21.	Prepare a programme of work on the development and implementation of symptom-oriented accident procedures.	01.03.2019	Belarusian NPP
22.	Develop and approve comprehensive measures (road map) for for the implementation of the points of the Plan.	30.01.2019	Ministry of Energy
23.	Carry out a review of the actual implementation of the points of the Plan and submit information on their implementation as well as proposals for amendments to the Plan: to the MES to the Government of the Republic of Belarus	annually by 1 February annually by 1 March	Ministry of Energy, MES

3.6 Good Practices

As examples of good practices for which the Belarusian NPP has a licence, PRT experts indicated the following technical and organisational solutions [4].

(a) The design of the Belarusian NPP includes several novel technical provisions including SG PHRS and PHRS C. Both systems are capable of operating passively even during station blackout conditions for at least 24 hours in a stand-alone mode. Moreover, at each power unit there is a core catcher capable of capturing, cooling down and stabilising the molten corium material preventing direct attack on the containment boundary.

(b) Experts noted that an example of good practice is the implementation of seismic PSA, on the results of which decisions will be taken on measures aimed at increase of safety.

(c) The training centre is equipped with a full scope simulator with capabilities to simulate even severe accidents, thus providing additional features for effective staff training.

(d) The Ministry of Emergency Situations of the Republic of Belarus has established for the needs of the NPP a strong fire brigade, well equipped with numerous mobile sources ready to respond to fires and other hazards at the NPP. It has at its disposal necessary transport means to react to severe accidents.

In addition, at the national level there is a radiation monitoring system which represents an important element for effective overall emergency response. The group of experts noted the necessity of ensuring coordination of on-site and off-site emergency response, and adequate interconnection with on-site monitoring as part of the national emergency response system.

(e) The results of analysis of potential recriticality presented in the national report show that for any possible configuration including premature melting of the control rods in the core there is always sufficient margin to the criticality.

(f) The design of the main components of safety systems, especially the steam generators whose design provides for a greater water inventory in the horizontal steam generators compared with Western style reactor designs, allows a “smooth” behaviour in case of transient processes.

(g) Close links were established domestically and internationally with designers organisations, scientific centres and supervisory organizations, WANO Moscow centre and other stakeholders in order to ensure long-term external support to safe operation of the Belarusian NPP.

4 Promising Actions

The current status of implementation of measures under the National Plan is presented in **Annex No 2.** Information on the implementation of the Plan will be regularly updated.

Implementation of the measures in the area of responsibility of the Belarusian NPP is being controlled by Gosatomnadzor. In turn, Gosatomnadzor, within timeline assigned, implements measures which are within its own area of responsibility. Implementation of the National Plan is fully controlled by the Government (points 22 and 23, Table 4) Thus, Close cooperation among all stakeholders has been established on the comprehensive implementation of the actions based on the stress tests performed in the Belarusian NPP and of the peer review based on recommended by the PRT principle of the "intelligent ownership".

As the National Plan is implemented by Gosatomnadzor, as recommended in the Peer Review Report [4], an approach will be defined to assess progress in its implementation.

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9. Convention on Nuclear Safety (since 1999).
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Annex 1

PRT recommendations put into implementation

№	PRT mission recommendations	Taken into account when drafting the National Plan
1	The regulatory body should review the results of the 2018 Probabilistic Safety Assessment in the beyond-design-basis plant safety evaluation, and should ensure that appropriate measures are taken in order to improve safety. Upon reviewing the Probabilistic Safety Assessment, it may be necessary to update the concept of seismic protection in accordance with the WENRA requirements, which were the standard used by the PRT.	Measure 2 in table 4
2	To carry out a comprehensive evaluation based on a hazard curve from a probabilistic seismic hazard analysis, in order to demonstrate that in the event of design-basis and beyond-design-basis accidents, all structures, systems and components have adequate safety margins to ensure their integrity and operation at the various levels of the	Measure 1 in table 4
3	The regulatory body must provide for the seismic safety characteristics of structures, systems and components to be such that they ensure their operation under accident conditions (levels 3 and 4 of the defence in depth) caused by a seismic event.	Measure 3 in table 4
4	The PRT is aware of the multiple interpretations of the 1908 seismic event published in seismological literature and catalogues. Given this situation, the inquiry into the 1908 seismic event should be concluded, so that its nature can be clarified and so that the examination of the seismics and zoning catalogue can be concluded.	Measure 4 in table 4
5	To increase the number of stations in the seismic conditions monitoring network, so that the zone of the Ashmyany quaternary fault is also covered.	Measure 5 in table 4
6	To ensure free access to the seismic monitoring network data for scientific purposes, which will make it possible to best define the seismotectonic model, taking into account the changes in the results of seismic probabilistic safety assessments.	Measure 7 in table 4

7	To perform the actions defined in Chapter 3.2.4. of the National Stress Test Report	As part of preparation for commissioning, seismic probabilistic safety assessment 1 has been drawn up (requirements under the licensing process). Currently, as part of the implementation of Measure 1 in table 4, the seismic probabilistic safety assessment 1 is being amended, and a seismic probabilistic safety assessment 2 is being drawn up. As part of commissioning, the seismic resistance of the design of systems and components vital to safety is being evaluated using the ‘Method for validating the dynamic characteristics of NPP power unit systems and elements which are vital to safety’. As part of the drafting of the seismic probabilistic safety assessment, the seismic resistance of equipment is being evaluated using the SMA methods set out in EPRI-NP-6041 and NS-G-2.13. Following the evaluation, to develop and implement measures for
8	The regulatory body should verify that measures for preventing water ingress into safety-related buildings have been developed and implemented. It must be ensured that the nuclear power plant site drains naturally through the surface by way of gravity.	Monitoring and oversight over the construction of the foundations, their waterproofing, and the flooding of building structures, is carried out systematically as part of oversight functions, in accordance with the requirements laid down in construction norms and rules. At the stage of acceptance of the completed Belarusian NPP buildings, a comprehensive evaluation of the conformity of buildings and equipment is planned, including their waterproofing, design documentation and the requirements of the Technical Normative Legal Acts (*Технические нормативные правовые*
8	The PRT recommends drawing up the instructions [on actions in extreme weather conditions][1] before the commissioning of the Belarusian NPP.	As part of licensing, the documents demonstrating the safety of the Belarusian NPP are analysed by experts. These documents include operational documentation comprising operational procedures in extreme weather conditions.
9	The PRT recommends providing for an alternative stationary electrical power supply source in order to ensure the necessary power supply in beyond-design-basis conditions. This alternative power supply must be equipped with the necessary connection points, in order to preserve the electric power supply system in the event of a simultaneous loss of the external power supply and the emergency	Measure 8 in table 4

[1] *Translator’s note*: The insertions in square brackets are there in the original Russian (they were not added by the translator).

10	The adequacy of the system and component safety margins capable of preventing large-scale emissions in the event of a severe accident caused by a beyond-design-basis earthquake must be evaluated again, taking into account the seismic probabilistic safety assessment, and, if necessary, their [the systems' and components'] resistance must be	Measures 1, 2 and 3 in table 4
11	The PRT recommends improving reliability by installing an additional standby pump.	Measures 9 and 10 in table 4
12	The PRT recommends implementing a suitable alternative solution to ensure the restoration of water supply within the time required in order to prevent damage to the core.	Measure 12 in table 4
13	The PRT recommends examining the external (off-site) electric power supply sources designed to supply electricity at levels 1 and 2 of the defence in depth, in order to demonstrate their reliability in seismic conditions.	Measure 13 in table 4
14	Since the design [of the Belarusian NPP] incorporates some advanced safety systems, the NPP's safety substantiation must depict in more detail the concept of practical elimination of radioactive material emissions at the early stage, or of large-scale emissions. Attention should also be paid to the practical elimination of severe accidents in the [spent nuclear fuel] storage pool, and of severe accidents which may be accompanied by a containment bypass.	Measure 14 in table 4
15	The possibility of installing autonomous means of pressure relief in the reactor cooling system should be considered. Alternatively, attention should be given to the reliability of operation of the existing means in severe accident conditions.	Measure 17 in table 4
16	Additionally to be considered is the prevention and reduction of the impact of severe accidents in conditions where the reactor is exposed, the SPOT PG heat exchangers are not working, and the lead time until damage to the core occurs is relatively short.	Measure 12 in table 4
17	The PRT recommends carrying out an analysis to demonstrate the reliability of external (off-site) sources of energy supplies in seismic conditions.	Measure 13 in table 4

18	Even though the option of staying in the control zones (main control room, emergency control room) in the event of a severe accident has been evaluated as satisfactory in the Safety Analysis Report, it is recommended that this issue be reviewed during the next evaluation and that the viability [of the control zones] be improved.	Measure 19 in table 4
19	In the event of an NPP blackout, the inter-shell space emergency ventilation system is not available. The requirement for the operational availability of the inter-shell space emergency ventilation system in the event of a severe accident combined with a complete blackout of the NPP must be fulfilled, or the system must be modified to ensure its availability.	Measure 20 in table 4
20	Given that symptom-based emergency procedures are necessary for issuing the [NPP] operating licence and that the timetable [of the Belarusian NPP's construction] is tight, it is recommended to have in place a clear programme of works for developing symptom-based emergency procedures; to verify and validate the procedures; and to carry out staff training before charging the core.	Measure 21 in table 4

Annex 2

Implementation of National Plan measures following the stress tests of the Belarusian NPP

№ (Table 4 of the Plan)	Measure	Implementation deadline according to the plan	Measure implementation status as at 15 August 2019
2.	To review the results of the 2018 seismic probabilistic safety assessment as part of the NPP safety evaluation and to determine the need for implementing appropriate measures to improve safety	As part of the expert analysis of safety-substantiating documents when licensing the operation of Unit 1	Materials from the full-scale level 1 and level 2 probabilistic safety assessments, including seismic probabilistic safety assessments, are being analysed by experts as part of the expert analysis of documents substantiating the safety of operation of Unit 1 of the Belarusian NPP. In accordance with the terms of reference for performing the expert analysis, the works should be concluded on 30 October 2019.
4.	To carry out an R&D project ‘Studying the nature of the 1908 seismic event in Gudogay and updating the seismic catalogue for the area where the Belarusian NPP is located’	31 December 2022	Gosatomnadzor and the Centre for Geophysical Monitoring at the Belarus National Academy of Sciences have concluded a contract for the performance of a research and development project entitled ‘Studying the nature of the 1908 seismic event in Gudogay’, with an implementation deadline of 15 December 2019.
21.	To prepare a programme of work for developing and implementing symptom-based emergency procedures	1 March 2019	The programme of work for developing and implementing symptom-based emergency procedures has been prepared. The operating organisation is implementing the programme measures.