

EU Peer Review Report of the Belarus Stress Tests

June 2018

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1 INTRODUCTION and BACKGROUND

On March 11th 2011, a magnitude 9.0 earthquake struck some 80 km off Japan's Tohoku coast. The ensuing tsunami and the subsequent accident at the Fukushima Dai-ichi Nuclear Power Plant (NPP) triggered the core melt of three reactors at the site. It was the worst emergency at a nuclear power plant since the Chernobyl disaster in 1986.

The analysis of the Fukushima accident revealed quite substantial, well-known and recurring technical issues: natural phenomena of a critical nature not being considered, faulty design, insufficient backup systems, failure to introduce safety improvements to operating reactors, human error, inadequate contingency plans, confusion in the response to a severe accident and poor communications. These points are clearly described in the International Atomic Energy Agency (IAEA) comprehensive report on Fukushima published in September 2015¹.

2 EU – STRESS TESTS AND FOLLOW-UP

2.1 Mandate

Against the background of Fukushima and based upon a mandate given by the European Council at its meeting on 24-25/03/2011, the European Commission (EC) – together with the **European Nuclear Safety Regulators Group (ENSREG)** – launched in 2011 EU-wide comprehensive risk and safety re-assessments of all EU NPPs (hereinafter referred to as "**Stress Tests**" (STs)).

The request of the European Council defined that the Stress Tests had to be performed first at national level and to be complemented by a European **Peer Review (PR)**.

2.2 Methodology

The European Council invited the EC and ENSREG to develop the scope and modalities for the Stress Tests with the support of the **Western European Nuclear Regulators' Association (WENRA)**. WENRA drafted the preliminary stress tests specifications. Consensus on these specifications, the so-called "**EU-STs specifications**", was achieved by ENSREG and the EC on 24/05/2011².

The specifications for the Peer Review of these EU-STs as well as a working paper on the transparency aspects of the STs³ were agreed later at the 11/10/2011 ENSREG meeting.

The EU-STs specifications, which were the basis of the safety track of the stress tests, **defined three main areas (topics) to be assessed: extreme natural events** (earthquake, flooding, extreme weather conditions), **response of the plants to prolonged loss of electric power and/or loss of the ultimate heat sink** (irrespective of the initiating cause) and **severe accident management**.

The assessments were organised in three phases:

- Self-assessments by nuclear licensees. Licensees were asked to submit STs reports covering all their Nuclear Power Plants (NPP) to the national regulators
- National review of the self-assessments. The National regulator reviewed the ST reports supplied by the licensees and prepared a **National Report (NR)**;
- European Peer Review of National Reports.

¹ <https://www.iaea.org/newscenter/news/iaea-releases-director-generals-report-on-fukushima-daiichi-accident>

² <http://www.ensreg.eu/node/289/>

³ <http://www.ensreg.eu/node/349/>

The peer review teams were composed of nuclear safety experts from EU Member States, Switzerland, Ukraine and from the Commission, with observers from three countries (Croatia, USA, and Japan) and the International Atomic Energy Agency (IAEA).

A considerable effort was made, in terms of human resources, to analyse the safety of all NPPs and spent fuel storage facilities of all 17 countries in a short time. In each of the 17 countries the review team conducted a NPP visit. The total number of reactor units on the sites visited during the originally scheduled visits in March 2012 was 43 (approximately 30% of all the units in operation). The plant visits confirmed the details of the prior analyses and in some cases have led to additional recommendations.

Additional visits were performed to eight reactor sites by the peer review teams in September 2012, in order to gain additional insight on different reactor types, to discuss implementation of the identified improvements and in order to alleviate concerns relating to installations in areas bordering other Member States. Thus, all operating reactor types in Europe have been visited by peer reviewers.

While the Stress Tests confirmed the high standards of nuclear safety in the EU, the reports also identified a number of improvements that could enhance safety. To ensure an appropriate follow-up, Member States developed National Actions Plans (NACPs) for the implementation of the identified recommendations.

2.3 Transparency and public involvement

In its meeting on 24-25 March 2011, the European Council mandated that the outcome of the Stress Tests and the information on any subsequent selected safety improvement measures should be provided to the public. Therefore, from the very beginning full transparency was a key issue of the EU-STs and its follow-up activities. The ability to become involved, by raising questions on the NRs and later the NACPs and to have public access to all reports of the reviews conducted, illustrates the extent of transparency achieved.

Several public meetings also took place in 2012 to present the process of the Stress Tests and the major outcomes.

All NRs and NACPs, as well as many licensee reports, are accessible to the public on the ENSREG website⁴.

2.4 Invitation to neighbouring countries to take part in the EU-STs

The events in Japan underlined the vital importance of nuclear safety, which should be addressed by the European Union (EU) and its neighbouring countries together as an absolute policy priority and the need to continuously re-evaluate nuclear safety.

On 23 June 2011 a meeting took place with Commissioner Oettinger, Deputy Ministers of Energy and senior representatives of the Ministries of Energy and national authorities responsible for nuclear energy of the Republic of Armenia, Republic of Belarus, Republic of Croatia, Russian Federation, Swiss Confederation, Republic of Turkey and Ukraine with the aim of inviting these countries to take part in the EU Stress Tests and improve the safety of their nuclear installations. The outcome of this meeting was that the attending countries, in cooperation with the EU⁵:

- Confirmed their willingness to undertake on a voluntary basis comprehensive risk and safety assessments ('stress tests'), taking into account the specifications agreed by the European

⁴ <http://www.ensreg.eu/EU-Stress-Tests>

⁵ https://ec.europa.eu/energy/sites/ener/files/documents/20110623_stress_test_joint_declaration_eu_neighbouring_countries.pdf

Commission and the European Nuclear Safety Regulators Group (ENSREG) on 24 May 2011. The need for a consistent approach towards nuclear safety by all countries making use of nuclear energy being reinforced by their shared vision that highlights the potential cross-border nature of nuclear accidents;

- Agreed to commit nuclear operators to self-assessments of their nuclear power plants, as well as to invite national regulatory bodies to present national reports, and to make use of a transparent peer-review system, enhancing credibility and accountability of the comprehensive risk and safety assessments;
- Agreed to engage on a multilateral level and with the IAEA in discussions on strong and common safety standards as well as international peer reviews.

Two countries **Switzerland and Ukraine** directly participated in the full process of the Stress Tests with the other EU countries in 2012 and contributed to the National Action Plan (NACp) peer reviews in 2013 and 2015.

Some neighbouring countries like Armenia, **Belarus** and Turkey expressed their interest in following the same peer review process at an appropriate point in the future. The EC has always indicated its willingness to support the peer review process in collaboration with ENSREG when the country indicates that it is ready to be subject to the peer review process. The Peer Review process took place in Armenia in 2015-2016 and this report documents the Peer Review that took place **in Belarus in 2017-2018**.

2.5 Follow-up

Member States developed National Actions Plans that were subject to the EU level peer review process. The 1st NACp peer review workshop was organised by ENSREG in April 2013. The workshop:

- Identified specific country actions and timescales for actions to improve nuclear safety in nuclear reactors
- Highlighted the importance of the principle of "Defence-in-Depth" whereby the safety of nuclear plants is assured in the case of an accident by a number of independent layers of safety actions
- Recognized the importance of Periodic Safety Reviews (PSR) for continuous improvement in the field of nuclear safety
- Highlighted the need to maintain "containment integrity" under severe accident conditions
- Committed to present an updated NACp report by December 2014 with a follow-up peer review workshop in April 2015

The 2nd NACp peer review workshop took place in April 2015, discussed the updated NACPs and the measures undertaken to improve the safety of nuclear power plants as well as changes in the schedules since the first reports. During the 2nd Workshop, special attention was devoted to the technical basis for any changes to the safety improvement measures proposed as well as the review of studies and analyses identified and completed since the 1st Workshop.

The workshop identified that an important number of actions listed on the NACPs have been completed under the oversight of the respective national regulatory authorities and concluded that most of the countries are adequately progressing the implementation of their NACPs, with all participating countries strongly committed to the full implementation of identified improvement actions in their respective NACPs, under the oversight of the regulatory authorities. Despite these positive improvements, **in November 2015 ENSREG issued a statement on this topic⁶** where it

⁶ <http://www.ensreg.eu/document/ensreg-statement-progress-implementation-post-fukushima-national-action-plans-nacps>

considered that *"the rate of safety upgrade implementation should be strengthened to target agreed implementation deadlines, taking into account other safety priorities and quality requirements"*.

As a follow-up to the completion of implementation of the pending actions contained in the NAcPs, **ENSREG members committed to update and publish periodically (every 2 years starting from 2017) a status report from each country** on the implementation of the NAcP, until completion of their respective NAcP. These updated NAcPs were published on the ENSREG Website in January 2018⁷.

⁷ <http://www.ensreg.eu/EU-Stress-Tests/Country-Specific-Reports>

3 BELARUS– CURRENT STATUS and STs PROCESS

3.1 Nuclear Power Plant in Belarus

On 17 September 2007, the President of the Republic of Belarus approved the Concept of Energy Security of the Republic of Belarus, which considers the introduction of a nuclear option into the national energy mix. The Concept assumes the construction of a nuclear power plant consisting of two reactors with total output electric capacity of 2000 MW before 2020.

In November 2007 a presidential decree defined the organizations responsible for preparing for the construction of the country's first nuclear power plant and budgeted money for engineering and site selection. The candidate sites were Krasnopolysk and Kukshinovsk (both in the Mogilev region) and Ostrovets in the Grodno region. Ostrovets/Astravets, 23 km from the European Union border and 55 km from Vilnius, was chosen in December 2008.

On 30 July 2008, the Law of the Republic of Belarus “On the use of atomic energy” was adopted. The Law sets up conditions and normative and legal bases for the safe development of the nuclear energy sector, and for the use of nuclear technologies in various sectors of the national economy, as well as for conducting research activities.

The design of the Belarusian NPP from type AES 2006 V-491 is the result of an evolutionary development process of the Russian VVER ((Vodo- Vodyanoi Energetichesky Reaktor) type Pressurized Water Reactor (PWR) family. The operating experience within the VVER-type plants amounts to about 1300 reactor-years, among them a great number of plants from the VVER-440 power plants in Russia and eastern Europe as well as the VVER-1000s operating in the Czech Republic, Bulgaria, China, India, Russia and Ukraine.

The later VVER-1000 NPPs of the type AES-91 operated in China (two units) can be seen as the reference plant for the development of the V-491. Currently, two units of this type are in the construction and commissioning phase at the Leningrad site in Russia. The project company for the Belarusian NPP project *JSC St. Petersburg Research and Design Institute ATOMENERGOPROEKT* took the units at the Leningrad site as reference units for the Belarusian NPP project. The two Nuclear Power Plants to be built on the Ostrovets (Astravets) site will have a unit power of 2×1194 MW. **The first unit is currently scheduled to go online in 2019.** A second unit of the same size is scheduled to enter service in 2020.

3.2 Mandate to perform a Stress Test Peer Review in Belarus

In the wake of the Fukushima accident in 2011, Europe took the lead in carrying out comprehensive risk and safety assessments ("Stress Tests") of Nuclear Power Plants (NPPs) to assess their ability to withstand extreme external events.

By joining the Joint Declaration on comprehensive risk and safety assessments of nuclear plants (stress tests) in June 2011, Belarus confirmed its willingness to undertake on a voluntary basis such assessments, taking into account the specifications agreed by the European Commission and the European Nuclear Safety Regulators Group (ENSREG) on 24 May 2011.

The European Commission and ENSREG have continually expressed their willingness to support any non EU country which would decide to undertake the same kind of peer review process and this support has been extended to Belarus.

3.3 Stress Tests in Belarus in compliance with the European STs process

Since June 2011 the European Commission services of DG ENERGY have been in regular contact with the Belarusian Ministry of Energy and the Belarusian Nuclear Safety Regulator to explain the EU

stress tests peer review process and ensure that the peer review process could be conducted in Belarus as soon as possible.

To ensure a smooth implementation of the process, the Commission initiated early detailed discussions with ENSREG to guarantee that sufficient resources would be available to perform the peer review process in a timely manner. In 2015, ENSREG included the Belarus peer review exercise in its Work programme for 2016-2019⁸.

In June 2017, in preparation for the peer review, the European Nuclear Regulators Safety Group (ENSREG) established a Board⁹ and in September 2017 a Peer Review Team (PRT) of experts to review the Belarusian national stress test report, the latter consisting of 17 nuclear safety regulators from nuclear and non-nuclear power EU Member States and the Commission.

During 2017 the Belarus nuclear regulatory authority (Ministry for Emergency Situation (MES) represented by its department Gosatomnadzor (GAN) worked to produce the host country national report for the stress test process and the Russian version of the national report was approved during an inter-governmental meeting on 27th September 2017. Belarus subsequently submitted the English version of its national stress tests report on the Belarusian Nuclear Power Plant to the EC and ENSREG for peer review on 31st October 2017.

To ensure consistency the EU Stress Test peer review process in Belarus adopted and followed the same technical specification prepared by ENSREG in May 2011 for previous applications of the process and was performed in full transparency according to the 'principle for openness and transparency' as embraced by ENSREG in December 2011. According to this principle, the Belarus national stress test report, the core element of the peer review, was published on the ENSREG website¹⁰ 8th November 2017.

To ensure the smooth implementation of the process, all practical details of the Peer Review were compiled in to a single document setting out the "Practical Arrangements"¹¹, which was agreed and approved by the Stress Test Board and by Belarus Counterparts.

The objective of the Stress Test peer review is to promote continuous nuclear safety improvements in Belarus, by providing an international, independent, and complementary assessment to ensure that no important issues have been overlooked on any of the topics within the scope of the Stress Test. Recognising the benefits of the conclusions of previous stress test reviews, the Peer Review Team also provided information to the Belarus national regulator and the licensee/operator/utility the areas for further improvement and good practice that were identified during the earlier peer review of national reports in 2012 or later¹² for their consideration.

3.4 Peer Review Board

The Board Composition was as followed:

- Chairperson: Marta Žiaková , Chairperson of the Nuclear Regulatory Authority of the Slovak Republic
- Deputy Chairperson: Sylvie Cadet Mercier, Commissioner, Nuclear Safety Authority, France

⁸ <http://www.ensreg.eu/document/ensreg-work-programme-2016-2019>

⁹ <http://www.ensreg.eu/news/minutes-34th-meeting-ensreg>

¹⁰ http://www.ensreg.eu/sites/default/files/attachments/belarus_stress_test_national_report-31.10.2017_0.pdf

¹¹ http://www.ensreg.eu/sites/default/files/attachments/practical_arrangements-31.10.2017_0.pdf

¹² <http://www.ensreg.eu/NODE/513>

- Peer Review Team Leader: Mark Foy, Chief Nuclear Inspector of the UK's Office for Nuclear Regulation
- Representative from non-nuclear EU MS: Andreas Molin, Head of Nuclear Coordination, Federal Ministry of Agriculture, Forestry, Environment and Water Management¹³, Austria
- European Commission representative: Massimo Garribba, Director, DG Energy – Nuclear energy, safety and ITER

The Board secretariat tasks were performed by Ghislain Pascal, European Commission, DG Energy, Team Leader International Relations.

The detailed roles and appointment process of the Board and PRT are described in the "Peer Review Practical Arrangements"¹⁴ that have been approved by the Belarus Nuclear Regulatory Authority the 18th October 2017.

Several meetings of the Board took place from September 2017 to June 2018 to ensure an efficient and transparent implementation of this peer review process.

3.5 Peer Review Team (PRT)

During the 34th ENSREG plenary Meeting in June 2017, the EC's Directorate-General for Energy asked ENSREG to seek nominations to form a Peer Review Team (PRT) of experts that would perform the peer review exercise for Belarus. Nominations were sought not only from ENSREG Members but also from Countries which have already participated to the EU Stress Test process in the past (e.g. Switzerland, Ukraine, etc.).

Based on proposals received, the Belarus Stress Test Board selected the team of experts. It comprised 1 Team Leader, 1 Deputy Team Leader, 1 Rapporteur, 1 leader for Topic 1 (Extreme external initiating events), 1 leader for Topic 2 (safety functions and design issues) and 1 leader for Topic 3 (Severe Accident Management) and experts for each of the topics. The PRT was composed in total of 17 experts from EU and non EU Member states (2 DE; 2 SE; 1 AT, 1 FR; 1 ES; 1 LT; 1 GR; 1 HU; 1 BG; 1 UK; 1 FL; 1 CH; 1 SK; 1 UA).

The PRT also included 2 representatives from the Commission, 1 expert from JRC and 1 rapporteur from DG ENERGY and 3 observers: 1 from the IAEA, 1 from the Russian Federation and 1 from Iran.

3.6 Independence

The Peer Review has been performed in an independent and structured manner by the selected experts in the PRT being experienced in such type of exercises.

The experts drew on information sources provided by a variety of different stakeholders (regulator, licensee, TSOs, Non-governmental Organizations (NGOs), etc.) supplementing by the core element of the peer review, i.e. the Belarus Stress Test National Report.

3.7 Questions of the Peer Review Team (PRT) to the Belarus National Report (NR)

The PRT began its work at the end of October 2017, with a desktop review of the Belarus NR. Each member of the PRT had access to the NR, and was asked to develop **written questions**. These questions were reviewed by the Topic leaders and by the Team and Deputy Team Leaders and **were subsequently submitted to Belarus Nuclear Regulatory Authority on 6th February 2018**. In total, **around 460 written questions** were prepared by the PRT, which were a combination of questions developed by the PRT, those from NGOs and others provided by Latvia. Prior to the visit to Belarus,

¹³ now Ministry Sustainability and Tourism

¹⁴ <http://www.ensreg.eu/document/belarus-stress-tests-practical-arrangements>

on 7th March, Gosatomnadzor provided written answers to all of the questions raised by the PRT and a response to all questions was provided on 7 March 2018. The full set of questions and associated answers have been published on the ENSREG website.

The questions were structured by the PRT according to the three topical areas of the ST:

- **General:** (62 questions)
- **Topic 1: Impact from extreme natural hazards** (155 questions),
- **Topic 2: Loss of safety systems** (132 questions), and
- **Topic 3: Severe accident management** (116 questions).

3.8 Belarus Peer Review process - timescale

The main activities and timeframe of the peer review exercise was:

- Belarus Stress Test Board appointed: 27th June 2017
- 1st Meeting of the Belarus Stress Test Board: 21st September 2017
- PRT established by the Board: 21st September 2017
- Belarus NR transmitted to the EC and ENSREG: 31 October 2017
- 2nd Meeting of the Belarus Stress Test Board: 19th December 2017
- Public Consultation on the Belarus Stress Test report on the ENSREG Website: open from Monday 13 November 2017 to Saturday 13 January 2018.
- Desktop review of the Belarus NR by the PRT (from November 2017 to end of January 2018). A template for the questions was provided to the PRT by the PRT secretariat.
- **A one-day pre-meeting** of the PRT was organized in **Luxembourg on 31 January 2018** to ensure an optimal preparation for the country visit to Belarus in March and review the questions prepared by the experts. A video conference with Gosatomnadzor was organized in the frame of this meeting.
- **Questions** prepared by the PRT were compiled by the rapporteur and **sent to Gosatomnadzor on 6 February 2018.**
- **Written replies from** Gosatomnadzor to the PRT questions were provided **6 and 7 March 2018.**
- **Written replies from** Gosatomnadzor to the remaining NGO etc. questions were provided the 28th May 2018.
- The PRT members completed the development of very early initial drafts of the chapters of the PRT report on 5 March 2018.
- A first preliminary draft of the PRT report was assembled by the rapporteur and sent to Gosatomnadzor on 7 March 2018, to give Gosatomnadzor the opportunity to comment on the early draft.
- **The country visit of the PRT (Country Review) to Belarus** took place **from 12 to 16 March 2018** (including a 1 day visit of BNPP on 14 March) during which the draft version of the PRT report was developed
- 3rd Meeting of the Belarus Stress Test Board to review draft report of PRT: 22nd March 2018
- 4th Meeting of the Belarus Stress Test Board to approve the Belarus PRT Report: 24th May 2018
- Belarus Stress Test Board visit to Belarus to present the PRT report: 12-14 June 2018

- Belarus Stress Test Board presents the results of the peer review to ENSREG: 2nd July 2018
- **Belarus Stress Test Board presents the results of the peer review to the public: 3rd July 2018**
- Belarus ST peer review report published on the ENSREG Website: 4th July 2018.

3.9 Transparency and public involvement

The PRT was conscious that full transparency, combined with the opportunity for wider civil society involvement, would significantly contribute to the Belarus ST process being recognised by the public and other stakeholders, as a reliable and trustworthy reference on the status and adequacy of nuclear safety in Belarus. Consequently, the EC and ENSREG, in close collaboration with Belarus Counterparts ensured that the PRT of the Belarus STs was guided from the beginning by the principles of openness and transparency, similar to those applied in Europe for the earlier STs and associated follow-up process.

Gosatomnadzor was informed about the EU transparency objectives and requirements and advised on how it might engage the public by organizing a structured and comprehensive information and public communications process. Transparency was further ensured by publishing key background and communication documents on the ENSREG Website¹⁵. A large effort was invested in regularly updating the information available on this website to ensure a comprehensive overview of the process was available for the public.

The goal of all these activities was to inform all stakeholders as objectively and comprehensively as possible on each aspect of the process and to facilitate collecting the views of stakeholders on the key nuclear safety related issues and how they were being dealt with in the course of the PR.

The Belarus national stress test report, the core element of the peer review, was published on the ENSREG website, remaining open for Public Consultation from Monday 13 November 2017 to Saturday 13 January 2018. During this Public Consultation comments/questions were received from 3 sources:

- The Ministry of Environmental Protection and Regional Development from Latvia
- Greenpeace Central and Eastern Europe
- Belarus NGO "Ecohome"

These questions/comments and associated responses were published on the ENSREG Website.

During the PRT mission in March, an opportunity was provided for the Belarus NGOs to have a meeting with several representatives of the PRT (TL, DTL and Topic Leaders) and the Belarus Nuclear Regulatory Authority. During this meeting the representatives of the Belarus NGOs sought clarity on the Stress Test scope and the peer review process. They were also advised that the full suite of questions (including those of the NGOs) arising from the review of the national report and the subsequent Gosatomnadzor responses will be placed on the ENSREG web site within a few weeks after the PRT mission. During the meeting, the representatives of the NGOs did not raise any issues of a technical nature with the PRT.

3.10 Peer Review Team report

The **main outcome of this peer review exercise** is this "**PRT report**". The structure of this report is similar to the structure of the reports published for the countries which participated in the EU STs in 2012. According to the 2012 ST template the report covers the following topics:

¹⁵ <http://www.ensreg.eu/EU-Stress-Tests/Country-Specific-Reports/EU-Neighbouring-Countries/Belarus>

- General Quality of national report and national assessment
- Plant assessment relative to earthquake, flooding and other extreme weather conditions.
- Plant assessment relative to loss of electrical power and loss of ultimate heat sink
- Plant assessment relative to Severe Accident Management

The PRT report presents further potential improvements or good practices that have been identified during the review exercise performed in Belarus with a view to ensuring continuous safety improvement.

4 GENERAL QUALITY OF NATIONAL REPORT AND NATIONAL ASSESSMENTS

4.1 *Compliance of the national report with the topics defined in the EU stress tests specifications*

In the opinion of the PRT the Belarus national report was drafted in accordance with the requirements of the EU stress Tests. Belarus's agreement to complete the EU Stress Test process in a relatively compressed timeframe is noted, particularly as it is an embarking country developing a new nuclear power programme and even for more established countries the process presents a sizeable challenge and learning process. The team was told that Gosatomnadzor had developed the national report mainly on its own, with limited external support.

Attempts to reduce the volume of its initial draft national report resulted in limited information in some parts, which led to a large number of additional questions being sent to Belarusian counterparts by the PRT and other stakeholders involved in Stress Test process. However, the PRT was impressed with how hard Belarusian counterparts worked to answer the questions raised by the PRT. Belarusian counterparts fully answered the questions and provided the answers translated into English to the PRT for consideration within 4 weeks, along with additional reference materials such as copies of parts of PSAR, project documentation, schemes, as further evidence to its given answers. Together with subsequent discussions with counterparts and the site visit in Belarus, these allowed the PRT to clarify all of its outstanding points.

Previous stress tests were undertaken on pre-existing reactor designs that were already operational and on NPPs under construction at the time in the EU. From the start, the experts from the PRT considered that highest safety standards should be taken into account during the stress test process for Belarus even though the construction licence for Belarus NPP was issued before WENRA approach was established for new reactor design.

The PRT acknowledges that the design of the NPP is intended to make the best of the evolutionary development process of the Russian VVER that has been developed and constructed in several east European countries as well as in Russian Federation, China and India.

The general view of the national report in each topic area was as follows:

Topic 1

The regulations presented for site investigations and evaluation as well as for design of the plant against the seismic hazards are limited. Short descriptions of the national requirements and regulations for nuclear and radiation safety don't include whole existing requirements against seismic hazards (including investigation and characterization of the site-specific hazards and design).

This assessment is also similar for other external hazards such as flooding and extreme weather: the regulatory basis is not detailed in the NR. The methodologies used for the screening and characterization of the hazards depending on their origin were partly presented in the NR. However, additional information was subsequently provided during the country visit.

Topic 2

The NR states that the legal framework is built in accordance with international norms as the IAEA Safety Standards. This legal framework relies on two laws enacted in 1998 and 2008 (as well as their related decrees) which are aiming at implementing international standards and rules. Applied technical requirements for the safety design of the BNPP needed to be discussed during the PRT mission. The NR makes DiD claims intended to meet IAEA safety standards, comprising five levels.

Topic 3

The regulatory specification setting out the scope of the stress tests and reporting of the results of the stress tests in the area of severe accident management is fully consistent with EU stress tests specification. The utility report has been developed in accordance with the regulatory specifications. The same is true for the national report, although an attempt to reduce the size of the national report has led to limited factual information, that resulted in a large number of additional questions being raised by international experts and other stakeholders involved in stress tests.

4.2 Adequacy of the information supplied, consistency with the EU stress tests specifications**Topic 1**

In general, the seismic design basis seems to be in line with current international practice, IAEA guidelines and the WENRA (2014) Safety Reference Levels. The procedure for definition of DBE is in accordance with Russian and Belarus regulatory requirements and standards, but it is different from the widely accepted methods implemented in EU and WENRA countries (references 2016).

In addition, the Belarus standard ТКП 263-2010 (02300) which is practically equivalent to NP-031-01 (in line with the IAEA Safety Guides NS-G-1.6 and taking into account the superseded IAEA documents 50-SG-D15 and 50-SG-S1) is not taken into account in the NR, relying instead on the Russian standard RB-019-01.

The NR provides insufficient information about the regulatory bases, technical background and the methodology used for screening and characterization of the flooding hazards, however additional information was provided during the country visit. The concept of Design Basis Flood (DBF) is not strictly used at the Belarus NPP. Using the methodology to screen and characterize flooding hazards, the maximum flooding level corresponding to a non-exceedance probability of 10^{-4} per year has been assessed taking into account Belarussian regulatory bases and IAEA recommendations., consistent with the EU stress tests specification.

Regarding extreme weather hazards, the NR doesn't provide full information about the regulatory bases, and methodology used for screening and characterizing such phenomena (heavy rain, etc.). It should be formalised in line with existing international standards. Nevertheless, with the information provided during the visit the PRT concluded that all relevant extreme weather events are taken into account.

Topic 2

The NR does not provide detailed information regarding the relevant technical specifications, and their application to the design of the Belarusian NPP, which required follow-up by the PRT to gain a clear understanding.

Topic 3

In general for severe accident management, information provided in the NR is consistent with EU stress tests specifications, although in several cases it was necessary to obtain more detailed information through the responses to the additional questions and also through the discussions held during the country visit. Typical areas where additional information was needed include specific legislation applicable for severe accident management, selected approach, status of development and plans for future implementation of EOPs and SAMGs, independence between design provisions implemented at different levels of defence, operational characteristics and functioning of novel design solutions, and more specific information about interfaces between the on-site accident management and off-site emergency planning.

4.3 Adequacy of the assessment of compliance of the plants with their current licensing/safety case basis for the events within the scope of the stress tests**Topic 1**

The PRT focused on the reliability of the current design basis earthquake of $I = 7^\circ$ MSK-64 and $PGA_H = 0.10 \text{ g}$ for the non-exceedance probability of 10^{-4} year. This was due to the fact that several earthquakes of $I = 7^\circ$ have been reported from the region and near-region around the NPP, this requires complementary analysis which are currently undertaken.

Compliance of the plant with their licensing basis for flooding has been found to be adequate.

The maximum values corresponding to a non-exceedance probability of 10^{-4} per year for most relevant extreme weather scenarios were given. If historical, local and regional data are limited, the WENRA 2014 SRLs Issue T4.2 allows a non-probabilistic estimation of the event. A practical procedure for a justification could be a comparison of requirements in neighbouring countries.

Topic 2

The description of the general safety concept ensured by the active and passive safety features in order to take into account European objectives and requirements as formulated by WENRA seem to be met. This concept is intended to address safety related aspects coming from the lessons learned of the Fukushima Daichii accident.

Topic 3

Safety features of the plant relevant for the management of severe accidents ensure full compliance with the licensing basis of the country of origin (Russian Federation) as well as applicable regulatory documents of Belarus. In addition, there is a report on comparison of Belarusian, Russian, IAEA Safety Standards and WENRA Reference Levels and Safety Objectives concluding that there are no significant contradictions between these reference documents. Nevertheless, it is taken into account that since the plant design there has been significant progress in updating the safety requirements, in particular the Russian regulations and IAEA Safety Standards. The most significant modifications to these standards are the main source of the suggestions made by the peer review team for further safety enhancements.

4.4 Adequacy of the assessment of the robustness of the plants: situations taken into account to evaluate margins**Topic 1**

The reported analysis on seismic resistance gives a basic overview of the margins expected on several equipment's, such as high-pressure components. This does however not apply for all the equipment's (see ECCS) and the expected margins are rather different.

Comfortable margins of the plant design in respect to flooding have been demonstrated for river overflow and dam rupture. As groundwater rising up to lower basement level cannot be excluded, basement of buildings have been made watertight against groundwater ingress and special drainage arrangements have been put in place.

For extreme weather cases, some margins have been taken into account. The exceedance frequencies and the corresponding values for precipitation were presented during the country visit. For lightning the design requirements were given, which corresponds to other countries.

Topic 2

The PRT found that the assessment work performed regarding loss of off-site power (supplement power transmission line), on-site power supply, station blackout or heat removal is generally satisfactory. However later in this report the PRT highlights further assessment work in a number of areas it considers necessary to enhance the robustness of the design.

Topic 3

The national report highlights design features of the Belarusian NPP that form a good basis for the robustness of the plant for coping with severe accident conditions including:

- double containment,
- multiple means for the reactor coolant system depressurization,
- hydrogen mitigation system,
- passive containment heat removal system
- core catcher for molten corium stabilization.

Suggestion for future enhancements are mainly associated with post-Fukushima safety requirements, such as enhanced independence between different levels of defence in depth, demonstration of practical elimination of early and large radioactive releases, adequate margins in

design of selected systems against natural external hazards more severe than design basis events and specific use of mobile sources in the plant design.

4.5 *Regulatory treatment applied to the actions and conclusions presented in NR*

4.5.1 General aspects

The national report highlights a limited number of measures to improve the safety of the Belarus NPP. Examples of the identified measures to improve safety include:

- Installing additional anti seismic supports to improve the seismic resistance of the ECCS and Pressurizer System
- Installation of stops to the racks of the spent fuel pool, limiting rack horizontal movement and improving seismic resistance
- Improving the seismic resistance of the RCPS anti-seismic fixation rod
- Arranging permanent, fixed local seismic monitoring network to obtain geodynamic data
- Improving the tie in arrangements to improve the make-up capability to the spent fuel pool to maintain water levels and hence heat removal capability
- Reviewing the options to recharge the UPS
- Provision of 2 mobile DG sets (one set per NPP) to improve NPP stability in the case of a loss of power supply and UHS to both NPPs at the same time.

This list is not exhaustive. However, the PRT considers that adopting the recommendations made by the PRT later in this report would provide greater safety benefits than some of the measures proposed by Gosatomnadzor.

4.5.2 Periodic Safety Review (PSR)

The Belarus NPP is under construction and no specific PSR has been considered or performed. However, responses to the PRTs written questions confirm that there is a requirement in the legal provisions for a PSR to be undertaken after 10 years.

5 PLANT(S) ASSESSMENT RELATIVE TO EARTHQUAKES, FLOODING AND OTHER EXTREME WEATHER CONDITIONS

The plant under review in Belarus is a new NPP under construction. Consequently, the experts from the PRT considered that highest safety standards should be taken into account during the stress test process for Belarus. WENRA¹⁶ stipulates that for new NPP designs *“accidents with core melt which would lead to early or large releases have to be practically eliminated”¹⁷*. WENRA further specifies, *“For that reason, rare and severe external hazards, which may be additional to the general design basis, unless screened out (...), need to be taken into account in the overall safety analysis.”* It is further said that *“Rare and severe external hazards are additional to the general design basis, and represent more challenging or less frequent events. This is a similar situation to that between Design Basis Conditions (DBC) and Design Extension Conditions (DEC); they need to be considered in the design but the analysis could be realistic rather than conservative.”*

These safety expectations require a broader and more extensive consideration of external hazards in the plant design and the consideration of events with occurrence probabilities below 10^{-4} per year in the safety demonstration.

5.1 Description of present situation of plants in country with respect to earthquake

5.1.1 Design Basis Earthquake (DBE)

5.1.1.1 Regulatory basis for safety assessment and regulatory oversight

The presentation of the Belarus national regulations for site investigations and evaluations as well as the plant design against seismic hazards is rather scarce in the National Report (NR). National requirements and regulations for nuclear and radiation safety are summarized in chapter 1.2 of the NR. The relevance of these documents for the safety requirements with respect to seismotectonic hazards and for the investigation and characterization of the site-specific hazards and design against hazard, effects could not be judged.

During the country visit, the PRT received a full list of the regulatory documents relevant for securing seismic safety. Regulations are based on both, Belarus and Russian documents. It was clarified that the main basis of the regulation regarding investigation and characterisation of the seismic hazard is the Russian normative document NP-031-01¹⁸. This standard has been developed taking into account the recommendations of the now superseded IAEA guidelines 50-SG-D15¹⁹ and 50-SG-S1²⁰. The NP-031-01 defines two levels of earthquake:

¹⁶ WENRA, 2013. Report safety of New NPP designs. <http://www.wenra.org/publications/>

¹⁷ In this context, the possibility of certain conditions occurring is considered to have been practically eliminated if it is physically impossible for the conditions to occur or if the conditions can be considered with a high degree of confidence to be extremely unlikely to arise.

¹⁸ NP-031-1: Standards for Design of Seismic Resistant Nuclear Power Plant

¹⁹ IAEA 50-SG-D15: Seismic Design and Qualification for Nuclear Power Plants, 1992 (outdated)

²⁰ IAEA 50-SG-S1: Earthquakes and Associated Topics in Relation to. Nuclear Power Plant Siting, 1979 (outdated)

1. The Safe Shutdown Earthquake (SSE) as an event with 10.000 years return period (0.5% exceedance probability in 50 years) and
2. the Operating Basis Earthquake (OBE) as an event with 1.000 years return period (5% exceedance probability in 50 years).

The SSE complies with international practice²¹. Due to a translation error from the Russian to the English version the NR addresses the OBE as the design basis earthquake (DBE). Correctly, the SSE should be labelled as DBE.

Regarding the site seismicity, the NP-031-01 standard refers to the Maps of General Seismic Zoning of North Eurasia (GSZ-97)²². The maps in the scale of 1 : 10.000.000 include the Belarus territory. The seismic intensity presented in these maps is described as the numerical value on the Medvedev-Sponheur-Karnik scale 1964 (MSK 64). The scientific studies for the maps were performed from 1991 to 1997. The Belarus standard TKP 45-3.02-108-2008²³ adopts the concept of NP-031-01 and provides in its Appendix B the map of isoseismic zones for Belarus that is based on the map GSZ-97-D for the Russian Federation from 2002. The map GSZ-97-D is applicable for the design of nuclear power plants, since the MSK-64 intensity is given for 0.5% exceedance probability in 50 years, which corresponds to an average recurrence interval of 10.000 years.

The NP-031-01 defines the minimum value of maximum horizontal peak ground acceleration for the SSE (PGA_H) with 0.1 g, which is in line with the IAEA Safety Guides NS-G-1.6 and SSG-9.

In the NR the Russian standard RB-019-01²⁴ is cited as a basis for the site-specific seismic hazard assessment.

The seismic design of the structures, systems and components (SSC) of the Belarus NPPs follow NP-031-01 and the Russian standard NP-064-05²⁵. The Belarus standard ТКП 263-2010 (02300) that is practically equivalent to NP-031-01 is not cited in the NR. Seismic qualification of the electrical equipment and I&C follows the Russian standards GOST 17516.1 and GOST 16962.2.

The PRT concludes that the Russian codes and standards have been used by the designer/supplier in cases where no comprehensive Belarus regulation existed. The laws of Belarus approve this.

²¹ WENRA Safety Reference Levels for Existing Reactors (2014) require to consider events with exceedance frequencies not higher than 10^{-4} per year for the design basis. IAEA NS-G-1.6 (Seismic design and qualification for nuclear power plants) notes that the OBE is usually not associated with safety requirements but is related to operational requirements only. The SSE should be adopted for the design of safety classified items. The minimum level should correspond to a peak ground acceleration of 0.1 g.

²² V. N. Strakhov, V. I. Ulomov, and L. S. Shumilina, 1998, New Maps of General Seismic Zoning of North Eurasia *Izvestiya, Physics of the Solid Earth*, Vol. 34, No. 10, pp. 872–876.

²³ TKP 45-3.02-108-2008: High-rise buildings – Design buildings rules

²⁴ RB-019-01: Seismic assessment of the regions of location of nuclear and radiation hazardous sites on the basis of geodynamic data

²⁵ NP-064-05: Accounting of External Natural and Man-Induced Impacts on Nuclear Facilities

A Belarus regulatory document exists for assessment of core damage frequency due to natural and man-made external hazards (ТКП 566-2015 (33130)). These regulations have been applied in the Stress Tests of Belarus NPP (see page 8 of NR). However, there is no indication of the use of this regulatory document in the Section 3 of the NR (except of the heading of the sections).

5.1.2 Derivation of DBE

Information on the DBE provided in the NR (p. 40-41) is inconsistent and difficult to understand. After receiving extensive information during the country visit, the PRT concludes the following:

According to NP-031-01 the seismic hazard map GSZ-97-D²⁶ has been used to derive the Design Basis Earthquake (DBE correctly SSE)²⁷. The map GSZ-97-B was used for the definition of the Operating Basis Earthquake (OBE). Taking into account the map in the Belarus standard ТКП 45-3.02-108-2008, the following ground motion values were selected for the Belarusian NPP:

DBE (exceedance frequency 10^{-4} per year) (named SSE in the NR): Intensity 7° MSK-64 = 0.10 g PGA_H

OBE (exceedance frequency 10^{-3} per year) (named DBE in the NR): Intensity 6° MSK-64 = 0.05 g PGA_H

The NP-031-01 correlates the maximum horizontal acceleration to the intensity grades for the medium soil conditions and defines the standard design response spectra²⁸. It is said that the design accounts for the soil conditions at the site. However, detailed information on the site conditions is not provided in the NR.

An alternative determination of the DBE hazard level using an approach taking into account the seismogenic zoning and local conditions at the NPP site revealed:

DBE (exceedance frequency 10^{-4} per year) = 0.069 g PGA_H

This ground motion value was not accepted as it is below the minimum level of 0.1 g suggested by IAEA, as a consequence the NR states the **DBE** = 0.10 g PGA_H

However, Atomenergoprojekt, the designer of the Belarus NPP, set the value of 0.12 g as the engineering basis of design, which corresponds to the general basic design of the VVER-1200, 2006 reactor.

Although the performance of external hazards PSHA seems to be a requirement according to ТКП 566-2015 (33130), a seismic hazard curve is not presented in the NR. Information about ground motion values with occurrence probabilities $< 10^{-4}$ are therefore not available. During the country visit, it was explained and shown that site-specific hazard curves have recently been calculated as the basis for seismic PSA.

Design basis values for other seismotectonic hazards (liquefaction, dynamic compaction) are not developed. It is mentioned in the NR that the soil at the site is not susceptible to liquefaction without providing supplementing information on how the hazard was screened out. The answers to the PRT

²⁶ Уломов В.И. Сейсмичность // Большая Российская Энциклопедия (БРЭ). Том 1. 2004. С.34-39

²⁷ In the English version of the NR the OBE is erroneously translated as DBE.

²⁸ The Belarus standard ТКП 45-3.02-108-2008 correlate 1 m/s² (~0.1g) maximum horizontal acceleration to intensity 7° MSK-64.

questions inform that these hazards are addressed in the SAR. During the country visit, the Belarus counterpart granted access to the technical report 37/3-307-1579 (14.03.2014) that excludes soil liquefaction for the site.

Site investigations to screen out the hazard of surface faulting (fault capability) are not mentioned in the NR. During the country visit, the PRT was informed that dedicated geological and geophysical investigations addressed the identification and assessment of faults. The only Quaternary fault identified (Oshmanski fault, 0.3 m displacement in 2 ma) is located at a distance of 22 km from the site.

External flooding of the site due to the earthquake exceeding the design basis level can be excluded (dry site concept).

5.1.2.1 Main requirements applied to this specific area

National regulatory requirements for seismic safety are not presented in the NR. During the country visit, the Belarus counterpart presented a full set of norms and standards applicable for seismic safety. The requirements for the derivation of the seismic design basis are given in the Russian standard NP-031-01 and associated Russian regulatory requirements and standards, as well as in the Belarus standard TKP 45-3.02-108-2008, Appendix B.

SSCs important to safety are said to be seismically qualified for PGA_H of 0.12 g. The value envelopes the ground motion determined for the design basis earthquake ($PGA_H = 0.1$ g). The value corresponds to the basic design of the VVER 1200, 2006 reactor type. The seismic classification of SSCs for the plant design has been developed on the principles and definitions given in the Russian standard NP-031-01. A Safe Shutdown Equipment List (SSEL) comprising of 72 individual SSCs is included in Table 3.1.2.1 of the NR.

5.1.2.2 Technical background for requirement, safety assessment and regulatory oversight (Deterministic approach, PSA, Operational Experience Feedback)

The original selection of vibratory ground motion values for the DBE uses three different and partly independent approaches: (1) non-site specific normative seismic zoning maps from the Russian Federation, (2) probabilistic and (3) deterministic seismic hazard analyses.

(1) The seismic hazard of the region is defined based on macroseismic intensity maps included in the standard TKP 45-3.02-108-2008 (map GSZ-97-D). Since the site is located within a zone of intensity 7° MSK-64, the DBE was defined according to Appendix 2 of NP-031-01. The design basis is therefore selected with $I = 7^\circ$ MSK-64 which is equal to $PGA_H = 0.1$ g.

(2) The micro-zoning approach led to the assessment of the DBE with $PGA_H = 0.069$ g. Since NP-031-01 defines the minimum applicable $PGA_H = 0.1$ g, the site-specific ground motion value is bounded by 0.1 g (in line with international practice).

(3) The micro zoning as per NP-031-01 has been supplemented by a site-specific seismic hazard assessment, which follows the Russian regulation RB-019-01²⁹ and NP-064-05³⁰. Chapter 3.1.1 of the NR provides information about some details of the procedure. Analyses include the compilation of an earthquake catalogue for the period 1602-2007, the identification of geodynamic active zones and possible earthquake sources (PES zones), and the selection of maximum magnitudes (M_{\max}) for both, active zones and earthquake sources. The NR does not provide information on the ground motion prediction equations (GMPEs) or “attenuation functions” used to develop the hazard model. The method used for SHA is also not mentioned in the NR. DBE hazard levels were apparently calculated for a “scattered seismic activity model” resulting in intensity of 6° MSK-64 for the DBE and average soil conditions, and a “structured seismic activity model” resulting in intensity of 7.2° MSK-64 for the DBE (SSE) and average soil conditions. The SHA therefore led to practically the same intensity for DBE (SSE) as the values deduced from NP-031-01 and GSZ-97-D (i.e., 7° MSK-64).

In the seismic hazard analysis, the PRT notes five main issues which are regarded important for the reliability of the hazard results:

- (1) Hazard results are highly sensitive to the chosen maximum earthquake magnitudes (M_{\max}). The NR states that for the possible earthquake sources (PES zones) M_{\max} was selected from the magnitude of the strongest observed earthquake, apparently without adding a margin. This approach is not conservative. For the Oshmyany, Daugavpils and Kaliningrad-Lithuanian seismogenic zones maximum magnitudes of $M_{\max} = 4.5$ and $M_{\max} = 4.0$ are assumed. These values appear unrealistically low when compared to the other international seismic hazard studies covering the same region (e.g., the 2013 European Seismic Hazard Model ESHM13 uses M_{\max} between about $M_w = 6.5$ to 7).
- (2) The assumption of very shallow hypocentre depths of 5 km for Oshmyany zone or 8 km for Kaliningrad-Lithuanian seismogenic zone seems unreasonably small given that the region is located in thermally old (1.5-0.6 Ga) and 45 km thick continental crust. It should be noted that GMPEs are sensitive to hypocentre depths.
- (3) In several paragraphs of chapter 3.1.1 the NR refers to hazard values for “average soil conditions” suggesting that the results of quantitative analyses of soil conditions (e.g., determination shear wave velocity v_s) were not accounted for. Such data, however, appear important, as the NPP site is located on thick Quaternary sediments with low or very low shear wave velocities that may lead to an amplification of the ground motion.
- (4) Chapter 3.1.1 of the NR suggests that hazard levels were calculated for two scenarios named „scattered seismic activity model” and “structured seismic activity model”. This procedure is not comparable to modern PSHA, which adopts a logic tree approach to capture the epistemic uncertainty of the input data.
- (5) Hazard assessments, which are based on macroseismic intensity, are not state of the art in ENSREG and WENRA countries. This is due to the large uncertainties that arise from the conversion of macroseismic intensity into ground motion values. It is common practice in EC countries to base SHA on earthquake data expressed in moment magnitude (M_w) and use adequate GMPEs to relate ground motion parameters (PGA, spectral acceleration etc.) to earthquake magnitude and distance from the seismic source. The PRT, however, takes notice that macroseismic intensity based hazard assessments are Russian practice.

²⁹ RB-019-01: Seismic assessment of the regions of location of nuclear and radiation hazardous sites on the basis of geodynamic data

³⁰ NP-064-05: Accounting external, natural and man-induced impacts on nuclear facilities

During the country visit, the PRT was informed about a new probabilistic seismic hazard assessment (PSHA 2018), which was performed to develop a seismic PSA.

The study was carried out by The Schmidt Institute of Physics of the Earth of the Russian Academy of Sciences (Report 01/2018-02-10³¹) for the designer. At the time of the country visit the draft report has not been approved. It includes an up-to-date probabilistic seismic hazard assessment (PSHA) adopting a logic tree approach. The geological-geophysical database of the PSHA is based on extensive surveys (including reflection seismic) covering the near-region of the site (Geology Report 2013³²). It accounts for a number of faults in the near-region including the Oshmyanski active fault for which a Quaternary displacement of 0.3 m was identified. The fault is located at a distance of 22 km from the site. The PSHA is based on the seismotectonic model resulting from the Geology Report 2013, recent GMPEs, site-specific soil conditions (v_s , v_p velocities determined from boreholes), and maximum magnitude values close to those used in ESHM13 hazard model.

The PSHA developed hazard curves and spectral accelerations ranging to frequencies well below 10^{-4} . The used methodology accounts for reservations of the PRT described above and seems to conform to the current state of science and technology. The PRT, however, was unable to perform a comprehensive review of the study.

The hazard curves calculated in the PSHA show PGA_H values for the occurrence probability of 10^{-4} to 10^{-10} for different soil conditions (v_s velocities) and confidence levels (most important mean hazard value and 84% confidence interval). Results for the design basis earthquake with the occurrence probability of 10^{-4} per year are 0.10 g for the mean hazard value. The PRT recognizes the on-going work in this area. The impact of the ground motion values derived by the PSHA 2018 now need to be considered, including those for rare and infrequent probabilities below 10^{-4} .

5.1.2.3 Periodic safety reviews (regularly and/or recently reviewed)

The Belarus NPP is a new plant under construction; no periodic safety review has been performed.

5.1.2.4 Conclusions on adequacy of design basis

Defining the design seismic basis for a return period of 10.000 years is in agreement with current international practices, IAEA guidelines and the WENRA 2014 Safety Reference Levels. Setting the minimum peak horizontal acceleration at 0.1 g is also in line with international practice. However, information on uncertainty of the value as highlighted by WENRA 2014 is not provided

The procedure for the definition of DBE is in accordance with Russian and Belarus regulatory requirements and standards, but it is different from international guidelines (IAEA-SSG³³; WENRA,

³¹ PSHA 2018: "Topical Report Belarus NPP Calculation of seismic hazard curves based on the parameters and configuration of the zones of possible seismic sources and GMPEs" (No. 01 / 2018-03-10),

³² Energoprojecttechnologia Academy of sciences, Report Nr. BLR1C. 752.&&&&&&&&&&.002.HG.0001. Technical report. Belarus NPP consisting of 2 Units. Updating of the seismotectonic conditions for the region and for the site of the Belarus NPP and preparation of documents for the PSAR - Book 1. Seismotectonic features and seismicity of the region and the vicinity of the site of the Belarus NPP.

³³ IAEA, 2010: Specific Safety Guide No. SSG-9. Seismic Hazards in Site Evaluation for Nuclear Installations

2014³⁴; WENRA, 2015³⁵; WENRA, 2016³⁶) and the widely accepted PSHA methods practised in WENRA countries.

The information available in the NR does not allow judging the adequacy of the DBE. The PRT, however, notes that the DBE is challenged by the fact that earthquake catalogues for the East Baltic region (e.g., the European SHEEC catalogue) show that several earthquakes with epicentral intensity $I_0=7^\circ$ should have occurred in about the last hundred years within the area, which according to the maps TKP 45-3.02-108-2008 and GSZ-97-D is characterized by an occurrence probability of 10^{-4} per year for such events. The closest $I_0=7^\circ$ earthquake listed in the SHEEC catalogue occurred at a distance of only 25 km from the NPP site (Oshmyansky 1908).

The National Academy of Sciences of Russia indicated its confidence that the existence of these events is doubtful. At the time of the PRT visit it was undertaking an analysis of the relevant events and on completion of this work a review of the zoning and seismic catalogue will need to be undertaken..

The DBE appears to be confirmed by the PSHA 2018 which reveals higher ground motion values for the design basis earthquake. The methodology used by the Geological Study 2013 and the PSHA 2018 is in line with the cited WENRA and IAEA reference levels and guidelines and provides comprehensive information on uncertainties.

After approval of the PSHA 2018 by the regulator the results of the study should replace the older assessments. The 2018 results should be used for any further considerations of seismic safety. The regulator should consider the results in the safety evaluation of the plant and implement appropriate safety upgrading measures where this is shown to be necessary.

5.1.2.5 Compliance of plant(s) with current requirements for design basis

According to the NR the plant design fulfils the design basis requirements. The plant is designed for a maximum horizontal ground acceleration of $PGA_H=0.12$ g (see page 41). However, depending on the PSHA results and their acceptance by the regulator, an update of the seismic design basis may deem necessary to conform with WENRA safety requirements, which were taken as a reference by the PRT.

In case of a new plant, the design procedure, the design and qualification (testing) standards used are the basis of assessment of the compliance with design basis requirements. The starting point of the adequate design is the seismic classification that complies with the NP-031-01. The seismic classification of SSCs is presented in the table 3.1.2.1 of the NR. The seismic design is made in compliance with Russian codes NP-031-01 and PNAE G-002-86³⁷. The building structures are designed in accordance with standard SP 14.13330.2011 (an updated version of SNiP II-7-81 "Construction in Seismic Areas"). The containment is designed in accordance with ASME BPVC-ASME Boiler and Pressure Vessel Code, Part III, Division 2. These are adequate normative documents.

³⁴ WENRA, 2014: Report WENRA Reference Levels for Existing Reactors

³⁵ WENRA, 2015: Guidance Document Issue T: Natural Hazards Head Document on Natural Hazards

³⁶ WENRA, 2016: Guidance Document Issue T: Natural Hazards Guidance on Seismic Events

³⁷ PNAE G-002-86: Equipment and pipelines strength analysis norms for nuclear power plants

According to table 3.1.2.1 of the NR SSCs can have functions in several plant conditions, i.e. normal operation (NO), anticipated operational occurrences (AOO), design basis accidents (DBA) and beyond design basis accidents (BDBA), or otherwise these SSCs have functions related to different levels of defence in depth. During the country visit, it was explained that the design basis for all SSCs including those, which have safety functions under BDBA, is 0.12 g (PGA_H).

The scenarios after an earthquake above OBE level and up-to SSE level are presented in the Tables 3.1.2.2 and 3.1.2.3 of the NR for power operation and cold shutdown condition, respectively. According to these tables, the fundamental safety functions for the reactor and the SFP are ensured.

During the country visit it was explained that it is currently unclear whether the functionality of SSCs that have safety functions in BDBA conditions caused by earthquake is ensured by sufficient margins.

According to table 3.1.2.2 of the NR fire fighting systems are only classified as seismic category II and III. Gas-based fire fighting systems inside the containment are classified as seismic category I. It is unknown if the availability of these systems is required by the protection concept in case of a design basis earthquake or in cases of earthquakes exceeding the DBE, and/or internal fire induced by such earthquakes.

5.1.3 Assessment of robustness of plants beyond the design basis

5.1.3.1 Approach used for safety margins assessment

The assessment of safety margins is based on the comparison of the ground motion value derived for the design basis earthquake $PGA_H = 0.10$ g and the value selected as the basis for the general design of the VVER-1200, 2006 reactor (0.12 g).

In addition, seismic margins were assessed by an analysis of the design calculation to identify conservatisms in the design. This calculation was made during the Stress Tests process.

The design features of the reactor system and anchorages of the main coolant system SSCs is presented in the NR sections 3.2.1.1 and 3.2.1.1. The design margin of passive structures and components are assessed and briefly summarised in the NR. The method of assessment of the design margin is rather simple: the stresses or deformations due to DBE effects (loads) are compared to the allowable or ultimate stresses or deformations and corresponding factors of safety. For the analysis, the design standard PNAE G-002-86 is used as a reference. The damping and ductility values accounted in the seismic design are also compared to those accepted in the Seismic Margin Assessment (SMA) procedures trying to justify the obvious conservatism of the design.

Regarding the design of the containment structure the NR is referring to the standard SP 14.13330.2011. For the justification of the design, some comparison of the Russian code is made to the IBC-2000 "International Building Code" and UBC-97 "Uniform Building Code".

Although the design margin of safety and seismic class 1 SSCs with respect to the DBE (SSE) seismic effects are assessed, a systematic and state-of-the-art seismic margin assessment is not presented in the NR.

In the report, some non-precise hints and comparisons are made to the international practice and accepted methods for evaluation of seismic margin. For example, some considerations of the EPRI-NP-6041 "A Methodology for Assessment of Nuclear Power Plant Seismic Margin" are arbitrarily used

in Section 3.2.2 of the NR to justify the conservatism of containment design. The design is apparently obviously conservative.

The NUREG/CR-0098 response spectra is compared to the Belarus NPP design basis earthquake spectra, neglecting the fact that the method for definition of the NUREG/CR-0098 response spectra is differing from the method for definition of the spectra for Belarus NPP. There are also non-precise comparisons to some Western standards (e.g. BPVC Section III-Rules for Construction of Nuclear Facility Components-Division 2-Code for Concrete Containments is mentioned with regard to "equipment and tanks" page 62, or IBC-2000 "International Building Code" and UBC-97 "Uniform Building Code", page 63 of the NR).

The seismic margin in the EPRI Code "Deterministic-Failure-Margin (CDFM)" methodology is defined as: High Confidence of Low Probability of Failure (HCLPF) proportional to the total load bearing capacity of failure minus permanent loads. The result of this has to be divided by the seismic load.

The information given in the NR in respect to seismic margin does not follow this calculation concept. The margin values given in the NR represent only a more or less approximation of the above mentioned HCLPF. To have qualified information about the margins the PRT suggests to perform the margin assessment in accordance with the EPRI methodology.

Furthermore the PRT suggests the performance of a qualified seismic PSA and a rigorous seismic margin assessment. In the seismic PSA the mean hazard curve of the seismic PSHA 2018 (if approved) should be used. The regulatory body should consider the results in the course of the NPP safety evaluation and ensure that safety upgrading measures are completed where needed.

It is rather difficult to guess what will be the total probability of the failure now.

5.1.3.2 Main results on safety margins and cliff edge effects

Independent from the determination of the design basis earthquake with the $PGA_H = 0.1$ g the Belarus NPP is designed for the value of 0.12 g. The value was selected by the designer and corresponds to the general basic design of the VVER-1200, 2006 reactor.

The analysis of the design calculation to identify conservatisms in the design revealed a seismic resistance of 0.13 g for the design of the weakest safety-relevant SSCs. The NR therefore quantifies the seismic margin of the plant with $PGA_H = 0.13$ g which is 0.03 g higher than the ground motion value derived for the site-specific design basis earthquake (DBE=SSE).

For the building structures of seismic category I, the earthquake with $PGA=0.6$ g can result in imminent damage (page 63). Particularly, loss of containment integrity is assessed at $PGA=0.51$ g.

According to the NR the seismic resistance of the reactor, steam generators, primary loops, pressurizer, mean circulating pumps and structure of the electric connection unit correspond to intensity 8° MSK-64³⁸. According to NP-031-01 the maximum horizontal acceleration corresponding to intensity 8° is $PGA_H = 0.2$ g. It means that the listed SSCs have a margin of 0.1 g when compared to the design basis earthquake. During the PRT visit to Belarus the PRT was advised that the seismic margin analysis was done on the basis of the horizontal design peak ground acceleration $PGA_H = 0.12$ g.

³⁸ The assessment is justified in a document entitled "Analysis of seismic resistance of the main equipment of the reactor unit of units 1,2 of Belarusian NPP at 8-points MDBE"

The above mentioned margin is not valid for the emergency core-cooling system (ECCS), injection and discharge pipelines, pressurizer system, the reactor upper unit, the SFP, and the RCPU anti-seismic fixation rod. According to the NR some of these SSCs have 35% margin above the design of 0.12 g. The reactor upper unit has a seismic resistance of 0.13 g (10% margin above 0.12 g). The racks in the SFP have a margin of 20% above 0.12 g. According to the NR, the seismic resistance of safety system pipelines does not exceed 0.13 g.

The safety systems have active parts and electrical and I&C subparts. The design and qualification of active systems is not presented in the NR.

The NR concludes that the seismic resistance of “safety-system piping and pipelines”, which is limited to $PGA_H=0.13g$, is the determining factor for limiting the safety margin of the Belarus NPP. The NR does not provide information on the accident conditions, which are expected to result from events leading to $PGA_H > 0.13 g$.

The occurrence probability of events with $PGA_H > 0.13 g$ is not specified in the NR. The PSHA 2018 assigns occurrence probabilities of about 10^{-4} to 10^{-5} to events with $PGA_H = 0.13 g$. The PRT therefore considers that the margin of 0.03 g is not sufficient to demonstrate the practical elimination of accidents leading to early or large releases, a WENRA Safety Objective for new nuclear power plants. The practical elimination of such accidents requires the demonstration that the conditions leading to the accidents can be considered with a high degree of confidence to be extremely unlikely to arise. Consequently, the seismic margins should be specified for all safety-relevant SSCs and their adequacy to ensure continuous safety of the plant should be confirmed, with the expectation that they confirm the practical elimination of core melt accidents that would lead to early or large releases.

5.1.3.3 Strong safety features and areas for safety improvement identified in the process

The PRT acknowledges the following strong safety features:

- The passive safety systems of the VVER-1200, 2006. It should be ensured that these systems are also available in BDBA conditions subsequent to BDB earthquake.
- High seismic resistance of the containment
- Seismic observation network
- Dedication to perform and complete a modern PSHA and a seismic PSA.

5.1.3.4 Possible measures to increase robustness

The PRT suggests reviewing the seismic robustness of all SSCs, mobile equipment, and buildings housing such SSCs or used as storages for mobile equipment, which are required for coping with DB and BDB accidents, including DB and BDB earthquake. The provided demonstration of conservatism of the seismic design of passive safety systems is not sufficient for the justification of sufficient margin.

Analyses should ensure the functionality of SSCs in different levels of defence in depth. The need for measures to increase the robustness of the plant can be identified by a state-of-the-art seismic margin evaluation of the plant or seismic PSA. The analyses may lead to the evidence that SSCs required to cope accidents induced by earthquakes exceeding the design basis need upgrading.

Attention should be given to the upgrade of the fire extinguishing system, which is currently not seismically resistant.

5.1.3.5 Measures (including further studies) already decided or implemented by operators and/or required for follow-up by regulators

The measures and future actions identified in the Section 3.2.4 of NR are adequate and urgent. Measures include the development of seismic PSA and a re-assessment of the seismic margins for SSCs of seismic category I using a SMA methodology as specified in EPRI-NP-6041 and NS-G-2.13.

During the period of the Stress Tests Atomergoprojekt was conducting a seismic PSA, which includes a re-assessment of seismic hazards with an up-to date PSHA methodology. The PSHA was already completed at the time of the country visit. The complete results of the study are expected for July 2019.

During the country visit it was explained that the temporary seismic observation network shall be replaced by a permanent one which will be integrated into the existing Belarus national network. The network will be operated by the National Academy of Sciences of Belarus.

5.1.4 Peer review conclusions and recommendations specific to this area

Initially, the PRT focused on the reliability of the current design basis earthquake of $I = 7^\circ$ MSK-64 and $PGA_H = 0.10$ g for the non-exceedance probability of 10^{-4} year. This was due to the fact that several earthquakes of $I = 7^\circ$ have been reported from the region and near-region around the NPP. The National Academy of Sciences of Russia indicated its confidence that the existence of these events is doubtful and at the time of the PRT visit was undertaking an analysis of the relevant events. On completion of this analysis, the PRT recommends that a review of the zoning and seismic catalogue is undertaken by the academy of Belarus and updated as necessary.

However, the PRT's hesitations to accept $PGA_H = 0.10$ g for the design basis earthquake were addressed by the comprehensive PSHA conducted by Academy of Sciences of Russia which were presented during the country visit (PSHA 2018). It reveals ground motion values of 0.10 g for the mean hazard value for the design basis earthquake with the occurrence probability of 10^{-4} per year which is acceptable to the PRT.

The review of the seismic classifications of SSCs required by the protection concept revealed that all SSCs are equally designed for $PGA_H = 0.12$ g irrespective of the fact that SSCs have functions related to different levels of defence in depth. The fact that the function of some SSCs is also required for coping with beyond design basis accidents (BDBA) is neither reflected by higher design requirements, nor have adequate margins been proved for such SSCs.

A systematic assessment of the seismic margins for all SSCs important to safety is currently not available. Although most of the SSCs required by the protection concept appear to have some or even significant margins of their seismic resistance above the DBE, pipes and pipelines of some safety systems are only resistant up to $PGA_H = 0.13$ g. The accident conditions that may arise from failure of the SSCs with the smallest seismic margin are currently unknown. The PSHA 2018 assigns occurrence probabilities of about 10^{-4} to 10^{-5} to events with $PGA_H = 0.13$ g.

The PRT therefore considers that the margin of 0.03 g is not sufficient to demonstrate the practical elimination of accidents leading to early or large releases as required in WENRA Safety Objective. The practical elimination of such accidents requires the demonstration that the conditions leading to the accidents can be considered with a high degree of confidence to be extremely unlikely to arise. The

seismic margins should be specified for all safety-relevant SSCs and their adequacy to ensure continuous safety of the plant should be confirmed, with the expectation that they confirm the practical elimination of core melt accidents that would lead to early or large releases.

To further strengthen the seismic robustness of the Belarusian NPP the PRT therefore recommends that:

- The regulator should consider the PSHA 2018 results in the beyond design basis safety evaluation of the plant and ensure the implementation of appropriate safety upgrading measures. The results of the PSHA may require an update of the protection concept with respect to seismic impacts to conform with WENRA safety objectives for new nuclear power plants which were taken as a reference by the PRT.
- 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.
- 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.
- The PRT is aware of the different interpretations of the 1908 seismic event published in seismological literature and catalogues. Keeping this in mind, the PRT recommends performing a study on this seismic event to clarify its nature and completing a review of the zoning and seismic catalogues.
- Extend the number of stations of the seismic observation network to also cover the Quaternary Oshmiyansky fault.
- Provide free access to the data recorded by the seismic observation network for scientific purpose to profit from research results that better constrain the seismotectonic model for future updates of the PSHA.
- Implement the measures and actions defined in the Section 3.2.4 of the NR.

5.2 Description of present situation of plants in country with respect to flood

5.2.1 Design Basis Flood (DBF)

5.2.1.1 Regulatory basis for safety assessment and regulatory oversight (national requirements, international standards, licensing basis already used by another country...)

The regulatory basis for flooding (codes, guides and standards applied in Belarus for the flood evaluation and design) is not detailed in the NR. However, it was clarified during the country visit that the Belarussian Technical Code of Practice TCP-263-2010 "Accounting of external natural and man-induced impacts on nuclear facilities" covering external hazards, TCP 45-4.01-30-2009 "Water intake structures - Design construction norms", TCP 45-4.01-31-2009 "Water preparation structures - Design construction norms" were used as well as the Russian codes SNiP 2.04.02-84 "Water supply - Pipelines and portable water treatment plants", SNiP 2.06.04-82 "Loads and impacts on hydraulic structures (from wave, ice and ships)" and SNiP 2.06.15-85 "Engineering protection of territory from flood and water ingress". The methodologies used for the screening and characterization of the hazards of flooding depending on their origin are not presented in the NR. An assessment of the

potential flood sources was performed, taking into account atmospheric precipitation, dam or water reservoir rupture, flash floods, melting of snow, groundwater ingress and drains directed towards the site.

The report mentions that the design basis for rainfall was calculated based on Soviet standards (2012 updated edition of SNiP 33-01-2003). Catchwater ditches have been put in place to prevent site flooding by external floods and rainfall, in accordance with "Norms of Structural Design of Nuclear Power Plants with Reactors of Different Types" (PiN AE-5.6) and SP 58.13330.2012 "Hydraulic Structures - Basic statements - Updated edition of SNiP 33-01-2003".

5.2.1.2 Derivation of DBF

The concept of Design Basis Flood (DBF) is not strictly used at the Belarus NPP. There is not a formalized reference DBF level provided for the site.

The topography of the Belarus NPP site near Ostrovets makes it a "dry site" (dry site concept). The site is slightly graded and the absolute elevation is between +174.5 and +182.7 m BES. All rivers and water basins existing near the plant site are located more than 50 m lower than the elevation of the plant site.

The following potential sources of flooding have been assessed:

- **River flood (Viliya river).** The long term average level of the Viliya river at the level of the plant water intake is estimated to be +117.40 m BES. The maximum level of the Viliya river corresponding to a non-exceedance probability of 10^{-3} per year, is estimated to be +125.70 m BES and the maximum level corresponding to a non-exceedance probability of 10^{-4} per year is +127.80 m BES. These estimations were made using a one-dimensional hydrodynamic model and are based on historical data recorded since 1925. The elevation of the pumping station is +130.30 m BES.
- **Dam rupture (Vileyka reservoir).** The NR states that the highest water level would be caused by a break of the Vileyka reservoir which is located about 150 km upstream (Malye Sviryanki). Calculations were made in 1972 by the Central Research Institute for Complex Use of Water Resources and the Institute of Hydrodynamics (Siberian department of the USSR Academy of Science, Novosibirsk). These estimations were made based on a one-dimensional hydrodynamic model. Although the calculations were initially made in 1972, the known changes in the region that could affect the spread of water since the construction of the dam of the Vileika reservoir are expected not to have a significant impact on the calculated level in the river (RUE TSNIKIVR, 2013).
The NR does not provide the maximum flood level in case of rupture of the Vileyka reservoir, but it was clarified during the country visit that the estimated wave height is expected to be lower than 6 meters at a distance of 50 km downstream of the dam. As the water intake of the Belarus NPP is about 150 km downstream of the dam, the possible additional flood level would be lower.
- **Groundwater ingress.** The elevation of the aquifer around the Belarus NPP site is estimated to evolve between +157.18 and +162.67 m BES. Regardless of these values, to protect the foundation and to prevent possible flooding of the underground basements, the design includes stratum drainage. The NR states that groundwater cannot reach the bottom of the foundation. During the observation period beginning in 2008, there have been no clear abnormalities in dynamics of ground waters, and there is no significant evolution of the

groundwater level. The deepest basement of Belarus NPP is at elevation +165.6m BES. As groundwater rise to higher elevations cannot be excluded (also because of the short observation period), basement of buildings have been made watertight against groundwater ingress.

- **Heavy rain (flash flood).** This scenario is covered under the chapter 5.3 (extreme weather) of this report.

5.2.1.3 Technical background for requirement, safety assessment and regulatory oversight (Deterministic approach, PSA, Operational Experience Feedback)

Technical background has been provided in chapter 5.2.1.2.

Taking into account the topography of the site, the flooding due to nearby river overflow and dam rupture is excluded by the dry site concept.

5.2.1.4 Conclusions on adequacy of design basis

The NR provides little information about the regulatory bases, technical background and the methodology used for screening and characterization of the flooding hazards; however, the necessary information was provided during the country visit. The concept of Design Basis Flood (DBF) is not strictly used at the Belarus NPP. There is no formalized reference DBF level provided for the site.

The following can be concluded:

- The methodology to screen and characterize flooding hazards is formalised. Using this methodology, the maximum flooding level corresponding to a non-exceedance probability of 10^{-4} per year has been assessed taking into account Belarussian regulatory bases and IAEA recommendations.
- Because of the topography of the site, the flooding due to nearby river overflow and dam rupture can be excluded (dry site concept).
- As groundwater rise up to lower basement elevations cannot be excluded, basements of buildings have been made watertight against groundwater ingress and special drainage measures have been implemented below safety relevant buildings.
- In case of flooding, the necessary access to the site remains ensured.
- Mobile equipment necessary in case of severe accident stored on the site remain accessible in case of flooding scenarios.

5.2.1.5 Compliance of plant(s) with current requirements for design basis

The NR states that the NPP complies with the regulatory requirements regarding protection against floods. To confirm the compliance of the Belarusian NPP with the license requirements, inspections are conducted by:

- Gosatomnadzor,

- other governmental bodies ensuring compliance with requirements in the field of construction, industrial, sanitary and fire safety,
- the general contractor to ensure compliance with the requirements of technical documents and the design,
- the operating organization to ensure compliance with the regulatory requirements, quality assurance programmes, as well as design, technical and operation documents.

During plant operation, stipulated periodic surveillance tests and maintenance are used to ensure operability of the systems and to monitor performance of components.

The NR states that no deviation from the licensing basis has been observed.

5.2.2 Assessment of robustness of plants beyond the design basis

5.2.2.1 Approach used for safety margins assessment

A calculation of the maximum level of the Viliya river up to a non-exceedance probability of 10^{-4} per year was completed by the Central Research Institute for Complex Use of Water Resources (see "Report on the conduct of a targeted reassessment of safety (stress tests) of the Belarusian NPP" BL-11752). Estimated water levels have been calculated using mathematical modelling of the water regime and cross-sections of the Viliya basin measured by the Central Research Institute for Complex Use of Water Resources and Belgiprovodkhoz in 2008-2012.

A conservative deterministic analysis of the consequences of a flooding on safety-related SSCs located below +0.0 m (absolute elevation +179.3 m BES) has been performed to identify possible cliff-edge effects.

5.2.2.2 Main results on safety margins and cliff edge effects

The maximum level of the Viliya river corresponding to a non-exceedance probability of 10^{-4} per year is estimated to be +127.80 m BES. This result shows that flooding by river can be practically eliminated (more than 50 meters of margin between the Belarus NPP site and the river). The NR also states that access routes to the NPP and main roads cannot be flooded by the Viliya river, eliminating hampered or delayed access of the staff and equipment delivery to the NPP site.

The calculations also showed a margin of about 50 m in case of the dam rupture.

The margin for groundwater ingress has not been quantified and water could rise up to lower basement; therefore basement of buildings have been made watertight against groundwater ingress and special drainage measures have been put in place below safety relevant building basements.

A conservative deterministic analysis of the consequences of a flooding impacting SSCs located below +0.0 m (absolute elevation +179.3 m BES) has shown that it could lead to a loss of the following critical safety functions:

- transfer of heat from spent nuclear fuel (loss of FAK and JMN systems),
- transfer of heat from the primary circuit (loss of JNG, JNA, KAA, KAB systems),
- coolant inventory maintenance (loss of JND system),
- the primary circuit feed (loss of JND system).

In case of water accumulation inside plant buildings, the water is evacuated gravitationally through the sump system.

Fire trucks are available on site and can be used to pump water from the site.

5.2.2.3 Strong safety features and areas for safety improvement identified in the process

The topography of the Belarus NPP site makes it a "dry site" preventing external flooding from river water, which is a robust passive safety feature.

5.2.2.4 Possible measures to increase robustness

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.

5.2.2.5 Measures (including further studies) already decided or implemented by operators and/or required for follow-up by regulators

The NR states that as flooding of the site is impossible, no additional potential measures to prevent flooding are needed. However, in application of the defence in depth concept, some measures are proposed to increase the time during which the reactors and the spent fuel pool remain safely cooled in case of site flooding. These measures are not specific to flooding and are described in the chapters of this report addressing loss of electrical power and loss of ultimate heat sink.

5.2.3 Peer review conclusions and recommendations specific to this area

The topography of the site of the Belarus NPP, which is located some 50 metres above the nearest river, adequately protects against river flooding and impact from dam rupture. This is regarded a strong safety feature.

The NR provides little information about the regulatory bases, technical background and the methodology used for screening and characterization of the flooding hazards, however during the country visit the necessary information has been provided.

The concept of Design Basis Flood (DBF) is not used at the Belarus NPP.

Using the methodology to screen and characterize flooding hazards, the maximum flooding level corresponding to a non-exceedance probability of 10^{-4} per year has been assessed and is in line with the EU stress tests recommendations.

Groundwater rising up to lower basement level cannot be excluded, basements of buildings have been made watertight against groundwater ingress and special drainage measures have been implemented.

Nevertheless, because the PRT was not able to fully review the volumetric protection due to the current state of construction, the PRT recommends that the Regulatory Body should check that plant measures against water ingress into safety related buildings and underground galleries are robustly designed and implemented.

In case of flooding, the necessary access to the site remains ensured and mobile equipment necessary in case of severe accidents stored on the site remains accessible.

5.3 Description of present situation of plants in country with respect to extreme weather

5.3.1 Design Basis Extreme Weather

5.3.1.1 Regulatory basis for safety assessment and regulatory oversight (national requirements, international standards, licensing basis already used by another country...)

National requirements for extreme weather conditions are not mentioned directly in the NR. However, it can be concluded, that the basis for the Probabilistic Safety Assessment (PSA) and for the NR of the EU stress tests related to extreme weather are the requirements of TCCP 566-2015 "Assessment of the frequency of severe damage to the reactor core (for external source events of natural and man-made nature)" and the requirements of the IAEA Safety Guide No. SSG-3. For protection against flooding and heavy rainfall PiN AE-5.6 "Norms of Structural Design of Nuclear Power Plants with Reactors of Different Types" and SP 58.13330.201 are mentioned

One of the key recommendations from ENSREG following the completion of the European stress tests in the aftermath of the TEPCO Fukushima Dai-Ichi accident was to develop the WENRA Safety Reference Levels (SRLs) specific to Natural Hazards (Issue T) and a corresponding Guidance Head Document issued 2014. The corresponding Guidance Head Document contributes to a consistent interpretation of the SRLs and provides insight into the considerations that led to their formulation. Another international basis to evaluate the protection of a NPP in respect to extreme weather is the IAEA Safety Guide No. SSG-18 "Meteorological and Hydrological Hazards in Site Evaluation for Nuclear Installations", issued in 2011.

Therefore the assessment of the Belarus Stress test peer review is based on WENRA 2014 SRLs Issue T specific (Natural Hazards) and the IAEA Safety Guide No. SSG-18.

For the review process, the definition of a design basis accident of the WENRA 2014 SRLs Issue T (T4.2) is used:

The exceedance frequencies of design basis events shall be low enough to ensure a high degree of protection with respect to natural hazards. A common target value of frequency, not higher than 10^{-4} per annum, shall be used for each design basis event. Where it is not possible to calculate these probabilities with an acceptable degree of certainty, an event shall be chosen and justified to reach an equivalent level of safety.

5.3.1.2 Derivation of the design bases for extreme weather loads

As part of the EU-stress tests the following dangerous meteorological phenomena were analysed. A reliable exceedance frequency was not given for any of the events. Reasons were the limited historical data. The events were covered in part by other design base events described in the NR such as:

- strong winds (instantaneous speed > 25 m/s) but covered by tornado and extreme wind speed,
- squalls (short-term wind speed increase up to 21 – 35 m/s, (exceedance frequency probably once per ~40 years) covered by tornado;
- large hail (diameter > 20 mm) (exceedance frequency probably once per ~40 years) covered by flying object during a tornado and aircraft impact;
- dust storms exclude, but would be covered by extreme wind and the design of the plant against minimum temperature for the safety systems (closing of air intakes);

- strong snowstorms (with wind speed of 15 m/s ;exceedance frequency once per 3 to 6 years); but would be covered by extreme wind and the design of the plant against minimum temperature for the safety systems (closing of air intakes)
- heavy snowfalls (precipitation> 20 mm within 12 hours or less); covered by extreme snow load
- thick ice coating and hard rime (diameter> 20 mm); covered by extreme snow load and loss of off site power;
- heavy fogs (visibility – less than 100 m) no direct impact to the plant;

However, most of the external meteorological hazards corresponding to an exceedance probability of 10^{-4} /year, in line with WENRA 2014 SRLs Issue T (T4.2), were assessed (Table 5.2.1.1 of the NR).

As shown in the table below, the NPP design can cope with the following external events corresponding to an exceedance frequency of 10^{-4} /year.

Recurrent extreme effects	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, typical for the Belarusian NPP site
Minimum temperature	-61 °C	-50 °C
Maximum temperature	+52 °C	+37,3 °C
Extreme snow load	4.3 kPa	3 kPa
Extreme wind speed	61 m/s	54 m/s
Tornado	Class F3,6	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	$\Delta P_{\max} = 11.1$ kPa	$\Delta P_{\max} = 5.55$ kPa
-maximum wind pressure	$P_{\max} = 8.7$ kPa	$P_{\max} = 3.2$ kPa
- flying objects	Considered	No flying objects
Precipitation (question & answers given during the country visit)	150mm elevating of the safety related buildings	5.3 mm flood level at plant site (160 mm/day)

The combination of events listed in the NR in table 5.1.2.1 –“Analysis of Combinations of External Effects” was part of the PSA-1, which include beyond design basis accidents.

The following open items were explained during the country visit:

In respect to heavy rain (precipitation > 50 mm within 12 hours or less; exceedance frequency once per 1 to 2 years) additional information was given. It was explained, that the precipitation of 150 mm/day has an exceedance frequency of once in 10000 years, which leads to a flood level at the plant site of 5,3mm. This is covered by elevating the safety related building 150 mm above the plant site. The site was still under construction, so the PRT could not confirm the final civil work of the site. It is recommended that the regulator observes this issue.

Lightning by and in the area of the power lines is mentioned in the NR. No exceedance frequency was given for the lightning considered in the design of the plant (impact in power lines, buildings and other structures). During the country visit it was explained that the protection against lightning was in accordance with the IEC 62305 and the Russian Standard GOST R IEC 62305.

5.3.1.3 Technical background for requirement, safety assessment and regulatory oversight

The basic principles for analysing external events are based on general recommendations specified in the IAEA SSG-3 Development and Application of Level 1 Probabilistic Safety Assessment for Nuclear Power Plants. During the country visit it was stated that the national requirements of the Russian Federation were applied (NP-064-05 "Accounting of external natural and man-induced impacts on nuclear facilities", AE-5.6, SP 20.13330.2011 "Loads and Impacts", SP 58.13330.2012 "Hydraulic Structures Basic statements»). In addition, the national requirements of the Republic of Belarus TCCP-263-2009 was used («The list of external effects of natural and human induced events for Nuclear Power Plants» and TCCP 566-2015 "Assessment of the frequency of severe damage to the reactor core for external source events of natural and man-made nature"). As described above, historical data are limited.

5.3.1.4 Conclusions on adequacy of design basis

The conclusions of the EU Stress Tests and the WENRA 2014 SRLs require the definition of design basis events for exceedance frequencies not higher than once per 10 000 years. It can be concluded, that all analysed events in the NR fulfil the requirement of WENRA 2014 SRLs Issue T4.2 with exceptions: for precipitation (heavy rain) and lightning the information in the NR are not sufficient.

Nevertheless, during the country visit, the necessary information was given for precipitation. Available data for meteorological phenomena in the past (for example heavy rain) were limited. An extrapolation to an exceedance frequency to once in 10'000 years results in a high degree of uncertainty.

For example regarding lightning, the WENRA 2014 SRLs Issue T4.2 allows a non-probabilistic estimation of the event: "Where it is not possible to calculate the probabilities of the event with an acceptable degree of certainty, an event shall be chosen and justified to reach an equivalent level of safety".

A practical procedure for a justification could be a comparison of requirements in neighbouring countries. The given standard for protection against lightning is acceptable.

5.3.1.5 Compliance of plant(s) with current requirements for design basis

The PRT has no evidence that the plant does not comply with the current national requirements.

For heavy rain (precipitation) and lightning, the information in the NR was not sufficient, but the necessary information was given during the country visit.

In the NR protective measures against flooding of the site due to heavy rain (such as catchwater ditches and storm-water drains) to ensure normal operation of safety category I-III structures according to PiN AE-5.6 "Norms of Structural Design of Nuclear Power Plants with Reactors of Different Types" are described. The storm water treatment and drainage systems at the site are designed for normal operation conditions. In case of electric power failure, the storm water treatment and drainage systems will not operate. The perimeter pavement around the safety relevant buildings are 150 mm high and the buildings have waterproof walls in their underground sections, such precipitation will not affect the equipment in the buildings. According to the NR, the NPP complies with the regulatory requirements regarding protection from precipitation/floods, which is confirmed by inspections of Gosatomnadzor and other governmental bodies. During the plant visit, the site was still under construction, so the PRT could not confirm the final civil work of the site. It should be ensured that the plant site could be drained via the surface by gravity (Streets, catch water ditches). It is recommended that the regulator observe this issue.

5.3.2 Assessment of robustness of plants beyond the design basis

5.3.2.1 Approach used for safety margins assessment

The safety assessment of the plant includes PSA of external events as part of the full scale PSA-1.

The NR presented the result of an analysis of the combination of external events in table 5.1.2.1, which can be categorized as beyond design basis accidents or as Design Extended Conditions (DEC). In table 5.2.1.1 main extreme weather conditions are listed with the design values and their value of an exceedance frequency of once per 10 000 years. It was mentioned in the NR, as a result of a threshold analysis, that the maximum values of extreme climatic conditions, determined for the site are much lower than those used in the design. This design values cover the events for extreme weather conditions with an exceedance frequency of once in 10000 years.

5.3.2.2 Main results on safety margins and cliff edge effects

In the NR it was shown that the design has margin to the design basis accident conditions for extreme weather. However, exceedance frequencies for these design extended conditions were not given. Lightning and precipitation were identified by the PRT as open items in the NR. During the country visit, it was explained that the protection against lightning was based on IEC 62305 and the Russian Standard GOST R IEC 62305.

The design of the plant has taken precipitation already into account by elevating the pavement around the buildings 150 mm higher than the surrounding area. The design base event for precipitation was given during the country visit. The PRT inspected the plant during the country visit.

During the country visit the regulator confirmed that the plant area has a continuous slope and dangerous roof ponding can be excluded by the design. The area around the building is flat to drain the site via the surface even if the storm water treatment and drainage systems would fail. The safety related buildings have no direct connection to the metrological draining systems, so that the buildings cannot be flooded via these systems backwards.

The PHRS-System is designed to work also under extreme low temperature conditions. Analyses and a full-scale facility test was used to prove operation for more than 20 days at -61°C. (Report NO-0-0-22-T-002 "Evaluation of the serviceability of PHRS and PHRS30 in the condition of extremely low

temperature of external air). The PHRS has enough water to operate for 72h autonomously. Furthermore, demineralised water is foreseen for 7 days. Even the water of the spray ponds would be available to feed the PHRS under extreme low temperature conditions due to heating and their depth. The PRT concluded, that only a part of the inventory of the spray ponds ($4 \times 20\,000 \text{ m}^3$) would be enough to remove the decay heat for months. The water in the spray ponds is also available for the PHRS when a layer of ice is assumed at the surface.

The PRT concludes that there is no risk of cliff edge effects associated with extreme weather.

5.3.2.3 Strong safety features and areas for safety improvement identified in the process

During extreme weather conditions, the PHRS is protected in the reactor building and ensures the decay heat removal from the primary system and the containment, even if the emergency diesel generators failed during the first 24 hours of an accident.

Only minor features and areas for safety improvement were identified.

For high air temperature a maximum design value of 52 °C is given. It is assumed from the PRT, that this is the design limit of the cooling/refrigeration systems. The limiting effect or the relevant SSC is not described in the NR. It is assumed, that the given limiting high air temperature is valid for the safety systems as a whole. In general, the installation of instrumentation and control systems are sensitive to high temperatures. From the physical point of view, the PHRS has no limiting high air temperature as long as the system has a reliable and controlled water supply. It was confirmed that the PHRS is able to operate manually and if necessary to refill using mobile pumps after 72h.

Some extreme weather conditions need a reasonable time to develop such as high and low temperature, snow, snowstorm (clogging air intakes of the emergency diesel generator) and high snow loads on the roofs. To consider the weather forecast and to implement a clear process (operating procedures for extreme weather conditions) additional staff can be called in early to the site to assist with corrective operator actions (shovelling snow, plant walk down) in time. After Fukushima, the operating procedures for extreme weather conditions were significantly improved in European countries. For a nuclear power plant under construction, it is recommended to develop such plant specific operating procedures early to have them in place already during first start up.

5.3.3 Peer review conclusions and recommendations specific to this area

As part of the stress tests the Belarus nuclear power plants have been analysed in respect to extreme weather conditions and necessary combinations of them.

The report provides little information about the screening process for the selection of analysed extreme weather phenomena. During the country visit the necessary information was provided.

In respect to the extreme weather phenomena, the plants show a high resistance.

It was stated during the country visit that operational procedures for extreme weather conditions are under development. The PRT recommends having specific operating procedures in place before commissioning of the Belarusian NPP.

During the plant visit, the site was under construction, so the PRT could not confirm the final civil work of the site and the adequacy of the drainage arrangements. It should be ensured that the plant site can be drained via the surface by gravity (streets, catch water ditches).

6 PLANT(S) ASSESSMENT RELATIVE TO LOSS OF ELECTRICAL POWER AND LOSS OF ULTIMATE HEAT SINK

6.1 *Description of present situation of plants in the country*

6.1.1 **Regulatory basis for safety assessment and regulatory oversight (national requirements, international standards, licensing basis already used by another country)**

The design of the Belarusian NPP from type AES 2006 V-491 is the result of an evolutionary development process of the Russian VVER (Vodo- Vodyanoi Energetichesky Reaktor) -type Pressurized Water Reactor (PWR) family. According to the commonly international applied category, this concept could be assorted into the modern designs regarding to safety concept and implemented safety features. The operating experience within the VVER-type plants amounts to about 1 300 reactor-years in several countries.

Nowadays, the advanced VVER-1000 NPPs from the type AES-91 operated in China (two units) can be seen as the reference plant for the development of the V-491. Currently, two units from this type are in the construction and commissioning phase at the Leningrad site in Russia. The project company for the Belarusian NPP project *JSC St. Petersburg Research and Design Institute ATOMENERGOPROEKT* took the units at the Leningrad site as reference units for the Belarusian NPP project.

As presented in the NR, the legal framework in Belarus is built in accordance with the international agreed and applied norms issued by the IAEA. It is mentioned in a general statement, that further provisions laid down in the associated standards which itemize the IAEA Safety Standards are implemented in national regulations.

As expressed in the NR, the construction as well as the future commission and operation of the Belarusian NPP is based on the *Law of the Republic of Belarus of July 30, 2008 "On the Use of Atomic Energy"* as well as the *Law of the Republic of Belarus of January 5, 1998 "On Radiation Safety of the Population"*, implementing international standards and rules and, the associated Presidential Decrees, itemizing the laws regarding to the licensing procedure and the procedures and activities for review and assessment of the safety related documents describing the conceptual design.

The NR doesn't contain any information regarding applied technical requirements requested and applied in Belarus for the safety design of the Belarusian NPP. Also, no information are given, whether and if yes, in which mode the requirements stipulate in IAEA SSR 2/1, Rev. 1 and SSR 2/2, Rev. 1 are implemented in Belarusian regulations and standards for design, commissioning and operation of the Belarusian NPP.

During the discussion Gosatomnadzor informed the PRT, that in the Republic of Belarus two IAEA missions were carried out connected with regulatory infrastructure and legal framework assessment regarding the application of international agreed standards.

In a letter dated 23 November 2011, the Permanent Mission of the Republic of Belarus to the International Organizations in Vienna requested the IAEA to carry out an Integrated Nuclear Infrastructure Review Mission (INIR). The Republic of Belarus (hereafter Belarus) also provided their self-evaluation report (in Russian and English) entitled: Report on the Assessment of the National Nuclear Infrastructure of the Republic of Belarus. INIR mission were held in from 18 to 29 June 2012. By the results of INIR mission National Action Plan to Carry Out the Recommendations of the

International Atomic Energy Agency (IAEA) Mission for the Integrated Nuclear Infrastructure Review (INIR) of the Republic of Belarus was approved and implemented.

On invitation of the Government of the Republic of Belarus from 2 till 14 October 2016 in Belarus there was held an Integrated Regulatory Review Service (IRRS).

The mission experts studied the previously prepared by the Republic of Belarus self-assessment materials, held interviewing with the representatives of the state administrative bodies and organizations, took part in the inspections at the Belarusian NPP construction site, SSE "Joint Institute for Power and Nuclear Research - Sosny" of the Academy of Sciences of Belarus, JSC "Isotope Technologies", CUE "Ecorez", SE "Republican Clinical Hospital of Medical Rehabilitation".

The group of experts came to the conclusion that in Belarus there is the regulatory infrastructure in place and in course of the mission there was demonstrated a strong commitment to the principles of nuclear and radiation safety, high order of alignment with the IAEA safety standards.

Based at recommendations and suggestions of IRRS mission there were prepared an action plan on improvement of the regulatory infrastructure of nuclear and radiation safety of the Republic of Belarus.

As a result of the discussion Gosatomnadzor informed the PRT that the following Belarusian and Russian legal requirements and norm and standards are applied:

- "Regulations on the Licensing of Certain Types of Activities" approved by the Decree of the President of the Republic of Belarus of September 1, 2010 No. 450;
- Resolution № 1781 of December 7, 2010 "On Approval of the Clause about the Procedure of Examining Documents Ensuring Nuclear and Radiation Safety in the Sphere of Atomic Power Use and Ionizing Radiation Sources";
- Decree of the Ministry of Emergency Situations of the Republic of Belarus No. 72 of December 30, 2006 "On Approval of Normative Legal Acts in the Field of Nuclear Security Assurance" (together with the "Rules for the Arrangement and Safe Operation of the Executing Mechanisms of the Reactivity Regulators", "Safety Requirements for Storage and Transportation of Nuclear Fuel at Nuclear Facilities";
- TCP 170-2009 (02300) "General provisions of safety of nuclear power plants (GPS NPP)", approved by the Order of the Ministry of Emergency Situations of the Republic of Belarus of February 17, 2009 No.14;
- TCP 171-2009 (02300) "Nuclear safety rules for NPP reactors", approved by the Order of the Ministry of Emergency Situations of the Republic of Belarus of February 17, 2009 No.14;
- TCP 294-2010 (02300) "Content Requirements for Safety Case Report for Nuclear Power Plant with VVER Type Reactor", approved by the Decree of the Ministry of Emergency Situations of the Republic of Belarus of December 27, 2010 No. 68;
- TCP 294-2010 (02300) " Content Requirements for Safety Case Report for Nuclear Power Plant with VVER Type Reactor ", approved by the Decree of the Ministry of Emergency Situations of the Republic of Belarus of December 27, 2010 No. 68.

Additionally in accordance with the legislation of the Republic of Belarus the legal acts of Russian Federation in the area of nuclear safety are valid in case if there no regulations of the Republic of Belarus in this area.

According to the item 3.10 of the Decree of the President of the Republic of Belarus of November 23, 2017 No. 7 "On the Development of Entrepreneurship" the technical standards of "USSR in the area of atomic energy use" are applicable in the legislation of the Republic of Belarus.

6.1.2 Main requirements applied to this specific area

NPP safety is achieved by a comprehensive implementation of the principle of defence-in-depth (DiD) based on the application of a system of measures composed by off-site and on-site power systems, physical barriers and different level of ultimate heat sink.

Criteria for composition and function of the respective safety systems are mentioned in the NR. They are structured in accordance with recognised international practices and comprise single failure criterion, redundancy, physical separation, electrical isolation, consideration of common cause failures and diversity.

Passive safety features such as the "*Steam Generators Passive Heat Removal System - SG PHRS*" are implemented in the safety design. For beyond design conditions, Belarus recognises these systems provide adequate residual heat removal from the fuel elements to assure the long-term integrity of the barriers retaining the radioactivity as part of its DiD approach.

The detailed requirements such as codes and standards, norms and practices of other country, specific requirements of systems' designer or license holder are not presented in NR.

6.1.3 Technical background for requirement, safety assessment and regulatory oversight (Deterministic approach, PSA, Operational Experience Feedback)

The NR states, that the Probabilistic Safety Analysis (PSA) is applied as a constitutive part of the safety assessment to be conducted in the frame of the licensing procedure for the Belarusian NPP. Pertaining to the Safety Analysis Report, PSA level 1 and 2 are under development by the applicant. These Analysis bases on Russian technical norms normally intended to be used for application in Russia. Average values of core damage frequency are formulated in the PSA level 1. The highest Core Damage Frequency (CDF) for internal events estimated in the PSA level 1 is reported with 7.7×10^{-7} per year for reactor in operation.

In the IAEA safety standard SSG 3 reference was made to theoretical basics of achievable CDF'S for new reactor concepts considering the longstanding experiences with the design and operation of nuclear power plants. In this document also an internal IAEA document, INSAG 12, was quoted, where as an objective for the CDF to be achieved for new plants, the numerical value of in maximum 1×10^{-5} per reactor-year for have been proposed for a full scope PSA Level 1 (all operational modes, all potential initiating events and potential hazards). Moreover, the current state of PSA Level 1 and the results of PSA Level 2 are not presented in the NR.

Regarding Deterministic Safety Analysis (DSA) no special description is contained in the NR. The National Report contains the results of the deterministic safety analysis of the NPP with regard to the stress-tests. Since, DSA is an international applied standard procedure for the safety analysis of nuclear facilities, the execution and implementation of DSA into the respective chapters of the Safety Analysis Report is supposed by the PRT.

6.1.4 Compliance of plants with current requirements

The technical concept of the AES 2006 V-491 design has been already assessed and reviewed in detail in the frame of the licensing procedure for the two units at the Leningrad site in Russia (regulatory reviews performed, construction and operation license issued). The design concept was checked against international and national Russian requirements for nuclear safety.

The NR doesn't contain any information regarding applied technical requirements requested and applied in Belarus for the design of the Belarusian NPP.

6.2 Assessment of robustness of plants

6.2.1 Approach used for safety margins assessment

The assessment of the robustness of the plant to cover the issues SBO and loss of UHS was conducted according to the requirements set in the EU-STs specifications from May 2011. For both cases the required levels of actions set in the specifications were considered and assessed. Actions and countermeasures were described and safety margins were defined generally as well as cliff edge effects and related time periods up to their occurrence expressed.

The approach is based on an assessment of technical and partially administrative measures that enable the plant to cope with the consequences of a total failure of power supply which is termed as station black out (SBO) and loss of ultimate heat sink (LUHS). This includes losses of power from the national grid, after the reactor scram and an immediate or subsequent failure of the alternative power supplies. For the LUHS, an assessment of the sufficiency of residual heat removal from the reactor to avoid a core damage event was undertaken.

6.2.2 Main results on safety margins and cliff edge effects

The review of Topic 2 of the Belorussian NR concluded that the ENSREG specification developed for the EU stress tests was followed in the process of assessment in the area of loss of electrical power supply and loss of heat sink.

Based on the text of the NR supplemented by the discussions of the review team with the Belarusian counterparts coming from the regulatory body and the operator as well as with Russian experts from the project organizations designing and constructing the NPP, it can be considered, the design is appropriate to cope with the stress test requirements.

Since the NPP is under construction currently, no comparison between the statements in the NR as well as the discussion and the realization in the plant systems and components was possible. So, the demonstration of sufficient robustness and time margins for all relevant accidents considered in the EU stress tests planned to be achieved by the diversification of the active safety systems with passive ones, big water reserves stored inside the containment as well as other features was rendered theoretical only.

Loss of off-site power (LOOP)Off-site Power Supply Features

The Belarusian NPP is planned to be connected to the national grid on a voltage level of 330 kV. In the shutdown mode, when a station supply cannot be provided, power supply will be realized by means of two transformers (main and standby) transforming the grid voltage of the 300 kV down to the operational voltage level of 10 kV as well as the respective transmission lines, circuit breakers and auxiliary systems.

The equipment of the main power output system allows for cutting off the electrical equipment of Unit 1 and Unit 2 with 330 kV circuit breakers of the units, therefore the power supply system of one unit is independent of the other unit.

As an additional unclassified off-site power source, if the 330 kV national grid isn't available, the "Viliya" substation with an output voltage level of 110 kV would serve the site via an underground transmission line. In the case of demand, the substation should feed a so called "emergency backup transformer" with a power of 16 MVA, and a voltage of 110/10 kV. This transformer is intended to supply power to one Emergency Power Supply System (EPSS) channel of each Unit. Standard feeds from 110/10 kV substation are provided for all 10 kV sections of the unit power supply system for normal operation.

On site power supply

A back up power on-site power supply system is installed at each unit feeding the Emergency Power Supply Channels (EPSS) is installed. These channels provide energy to the safety relevant consumers which are needed for ensuring the operability of the safety functions such as core residual heat removal and maintenance of the plant integrity.

Each power unit comprises a Diesel Generator (DG) system of four 10.5 kV of emergency power supply system diesel-generators with power capacity of 6300 kW each, which provide energy to the Emergency Power Supply System of each of the four safety train power channels (EPSS channel).

A fifth diesel generator called as "unit DG" is planned to be installed in a separate building devoted to serve as an internal power source for the reliable power supply to normal operation auxiliary consumers important for safety and integrity of the main equipment.

The four EPSS EDG's are hard wired connected and dedicated to feed one of the four redundant safety trains comprising all safety related systems and components to bring and maintain the unit in a safe mode in case of loss of off-site power supply. Therefore they are directly assigned to one of the four safety trains and the safety trains acts independently from each other.

The NR states, that the operation of the unit with power supply from EDG's is guaranteed for more than 72 hour by the EDG system. According to Russian standards applied for the design of the safety systems at the Belarussian NPP, an operational time of 53 hours for EDG is ensured by the supply tank of the respective EDG (5 h) and a directly assigned storage tank, in the NR called as intermediate warehouse (48 h). Additional available fuel stock is stored in separate on-site storage facility, in the NR called as "Open diesel fuel warehouse", which comprises fuel amount for the operation of one EDG per unit for a period of 5 days with nominal power.

The four EDG`DG`S are housed in a building in four physically separated compartments. Each EDG`s has auxiliary systems for the control and an internal water cooling circuit which is cooled by air coolers located on the roof of the EDG building.

If necessary EDG intermediate fuel reservoirs can be refilled by tank trucks which will deliver the required diesel fuel from the Main fuel and lubricant warehouse of the NPP or from the nearest oil depot to the respective EDGs fuel storage facilities.

Alarms for levels in the supply tank and the storage tank are displayed on the control panel. According to the NR the oil system is designed to provide such oil inventory to ensure independent operation for at least 240 hours.

Station Blackout (SBO)

The EU-STs specifications define the SBO as a loss of all permanently-installed AC power sources on and off site. In the case of Belarussian NPP, it is the loss of the external national grid as well as the loss of all four EDG`s per unit. In this case also additional unclassified power transmission line with 110/10 kV from the “Viliya” substation feeding the “emergency transformer” is lost. Since the unit DG isn`t connected to the EPSS of the four safety trains, it cannot take credit from them as a back-up power source for providing power to the safety trains in case the four EDG`s are lost.

This event generates a failure of all active safety components. Heat removal from the core cannot longer be provided by the cooling systems used for normal operation conditions, AOO conditions or DBA conditions. According to the NR, this status is seen as beyond design basis condition/accident (BDBA) and the respective technical features come into operation and organizational sequences come into force.

The spent fuel cooling in the spent fuel pool is also lost.

Energy needed for the category 1 consumers will be supported by the uninterruptable power supply fed by accumulators (EPPS UPS). These consumers include special devises as valves and general I&C systems. The EPPS UPS is designed for two hours operation without battery recharge, after this time power supply to components will be stopped which leads to the loss of their function and the loss of safety related I&C systems, valves, switches and measuring devices. In this situation, the SG PHRS valves automatically open and the SG PHRS operates autonomously within at least 24 hours.

When all AC stand-by safety power sources (EDGs) are lost (SBO condition), the station batteries, associated to each safety bus, which provide uninterruptible power supply to the safety and safety related loads, will be discharged within 2 hours (calculated value). Although during the SBO event the heat removal from the reactor is ensured by the SG PHRS, losing the DC power system, if not recharged before battery depletion time, will cause a complete loss of equipment (e.g. I&C and control power to manage switching operations, lighting, heating and ventilation systems, DEC equipment ensuring the MCR and ECR habitability, Ra filtration system in annulus).

The only available power source will be the 7th channel, which is intended to serve as a BDBA power source with limited functionality. The 7th channel batteries supply power with a capacity of 24 hours, and can be recharged by a mobile diesel generator with a power of 500kW. Therefore systems and components dedicated for DEC, and that may be required to maintain habitability functions and switching operation while restoring power supply will be unavailable. However, the National Report highlighted the survivability and self-sufficiency of the main control room for 72 hours.

Monitoring features and equipment devoted to maintain the reactor safety underbdba conditions will be powered by a special power “channel 7”. As stated in the NR, the accumulators supporting this channel with a capacity of 2030 Ah will be discharged after 24 hours latest, which leads to the termination of operation. For recharging these accumulators a special mobile diesel generator for each NPP unit (power 500 kW) to be connected to the “channel 7” switchgear from an access point outside the safety building is intended.

The NR states that the concept to manage an SBO event when the reactor is at power is the heat removal via SG PHRS as described in the next paragraph. This system acts autonomously, is passive and does not require power supply, except for opening of the valves (only once at the moment of the NPP blackout).

When an SBO event occurs during the refuelling period; specifically when the reactor is drained to the 550 mm below the main reactor flange, the heat removal is interrupted and boiling in the reactor pressure vessel will occur soon. The respective time will be discussed below in the paragraph “Time margins until „Cliff Edge Effects“”.

Heat removal in case of SBO

In the case of a SBO, the heat removal from the reactor core and based on this, the retention of the barrier system functionality is maintained only by the JNB-system *Steam Generator Passive Heat Removal System* (SG PHRS).

The system consists of four independent channels (4x33%) – one for each steam generator - which operates based on natural convection circuits. Each circuit includes one water tank with a volume of approx. 540 m³, sixteen heat exchangers, pipelines of the steam-and-condensate path with large and small start-up, control and isolating valves. The heat removal is performed through the chain *Reactor – Steam Generator – SG PHRS – Atmospheric Air (heat sink)*. Heat is removed to the atmosphere by evaporation of water from the SG PHRS tanks. Large motor operated and small solenoid start-up valves are installed in parallel in the condensate path which open in the case of demand and ensure the automatic start of the connection in the channels in the respective cooldown mode.

First after a SBO and closing of the turbo generator stop valves, the pressure in the secondary circuit arise and actuate the BRU-A valves on the SG`S, which are fed by the uninterruptible power supply.

The SBO leads also to an activation of the SG PHRS, which reaches the full design capacity within 80 seconds. Operation of the SG PHRS channels decreases pressure in the steam generators in accordance with the SG PHRS performance parameters, so the BRU-A on all the steam lines of the SG`s are closed, loss of boiler feed water in the steam generators is stopped and the level is stabilized.

Three channels of the SG PHRS with the assigned water inventory in the respective SG PHRS tank ensure the design operability of this safety feature and the adequate heat removal from the fuel elements for conservatively estimated 24 hours. Based on best-estimate evaluation, this time can be extended to 72 hours using the water inventory of the fourth SG PHRS tank. For this purpose the four tanks can be interconnected among each other.

As stated in NR the heat removal via SG PHRS constitutes an autonomous system. The SG PHRS valves are powered from the batteries of the 7th channel and open automatically at the signal of the

NPP blackout; afterwards, the system continues operation in the autonomous mode and does not require power supply from the batteries.

The PHRS tanks are also devoted to remove heat from the inner atmosphere of the containment in case of a primary leakage with steam intake into the reactor building. Heat is transferred by natural circulation from the PHRS C condensers (C PHRS) (JMP 4 x 33%) to the SG PHRS tanks.

Consequently the SG PHRS tanks have a dual use and fulfil the heat removal from the primary-secondary circuit side as well as from the containment under special accident conditions.

Spent fuel pool cooling under SBO conditions will be performed by means of boiling water in the spent fuel pool and evaporation of water above the level of the fuel assemblies.

Time margins until „Cliff Edge Effects“

As stated in the NR, the Loss of off-site power supply (LOOP) is seen as a DBA, to be handled by the alternative onsite power supply. For various LOOP scenarios, the availability of specific systems to prevent a core damage accident demonstrates time margins within which a sufficient core cooling as well as cooling of the spent fuel pool of units 1 and 2 can be maintained.

The NR describes, that an operational time of the EDG's supporting the EPSS (safety trains) systems can be assured for a time period of more than 72 h without external support or aid. According to NR statement, sufficient fuel amount is stored at the site, which can be delivered to the EDG'S by tank vehicles. Only a very general statement is given, how the ability of the EDG auxiliary systems for the stated operational time of 240 hours is assured.

Therefore, significant for the assessment of possible "cliff edge effects" as stated in the EU STs specifications including the respective time margins, the SBO as postulated BDBA condition should be considered mainly. This issue may lead without countermeasures (beyond the period of 72 hours from the initiating event) to the loss of the barrier integrity.

It was reported that the cliff edge effects might occur after 72 hours (realistic estimate), if all four PHRS water tanks are available. Conservatively, a refill of the PHRS water tanks is required within 24 hours, which is considered by the design. If all four PHRS water tanks are available, the refill process has to start after 72 hours at the latest. After the respective times without a refill, SG PHRS operation stops, which leads to an increase of the parameters in the secondary circuit up to the set points for opening of the safety valves of all the SGs. Deterioration of heat removal by the secondary circuit (due to level decrease in the SGs) causes an increase in the primary circuit parameters up to the set points for actuation of the pressurizer control valve.

Later, continuous leakages of the primary circuit coolant, operation of the pressurizer control POSV, lack of supply from the Emergency Core Cooling System (ECCS) hydro accumulators can lead to dehydration of the fuel assembly upper part, as well as fuel heating and melting. Time allowance substantiated by the thermohydraulic analysis prior to the start of heating is about 310 000 sec (86 hours).

Mass yield of the primary circuit coolant through leakages after 72 hours is approximately 41 tons. Mass of steam discharged through the steam dump devices of the second circuit during the considered time interval is about 210 tons.

To avoid the previous described cliff edge effect a refill of the SG PHRS tanks is needed. For this purpose a water make-up system is installed.

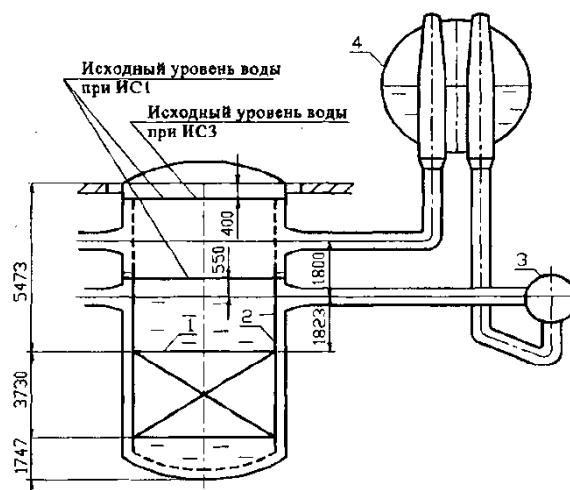
Making-up of the SG PHRS tanks is provided by low-power high- pressure pump JNB50AP001 - designed as a single device- belonging to the make-up system for the emergency heat removal. The SG PHRS tanks are made up by low-power high-pressure pump JNB50AP001 made as a single unit and which is a part of the system for making up the emergency heat removal systems. This air cooled pump is located in the steam chamber (building UJE) and is connected to the tanks of system LCU (LCU 01, LCU 02, LCU 03 and LCU 04), each with a capacity of 700 m³. If necessary, pump JNB50AP001 can be fed from any of the LCU01-04 tanks by switching over the respective valves from the BDBA I&C

The pump JNB50AP001 is powered from the BDBA power supply "channel 7". For this purpose the mobile 500-kV diesel generator must be connected to the channel 7 switch gear to provide sufficient energy for the pump operation. As a second cliff edge effect, the loss of spent fuel cooling in the spent fuel pool has to be considered. A SBO leads to the failure of the spent fuel pool cooling system (FAK) and the alternative standby cooling channels. In this case at a first stage, cooling of spent nuclear fuel in the fuel pool is performed by heating up of the water inventory in the spent fuel pool and the following evaporation of the water into inner containment atmosphere.

As stated in the NR, the calculations performed for time estimation of water evaporation time before fuel uncovering show two options. The first option considers the full unloading of the core into the spent fuel pool, taking into account fresh spent fuel assemblies as well as the availability of spent fuel assemblies for 10 years of operation. The second option implies only fuel elements stored for long-term radioactivity decay. The start time for water boiling is in option 1 approx. 4 hours and in option 2 approx. 16 hours. As stated in the NR, the total time of the spent fuel pool boiling-off to the fuel assembly heads from the beginning of the accident will be at least 41 hours in option 1 and 89 hours in option 2.

The command situation to be treated for avoidance of cliff edge effects in the spent fuel pool is the option 1, when a complete core of irradiated fuel assemblies is unloaded and slightly spent fuel assemblies are stored in the spent fuel pool. In this case boiling will start after a time period of nearly 4 hour. If no counter measures are taken the top of the fuel element will be uncovered after 41 hour. In order to avoid uncovering of fuel assembly heads, a refill of the spent fuel pool is necessary. This is intended to be done also by the make-up system fed by the LCU tanks and operated by the JNB50 pump.

As a special case for a possible cliff-edge effect, the unlikely event, that a SBO occurs during the preparation activities for refueling, has also to be considered too. When this event occurs; specifically when the reactor is drained to the 550 mm below the main reactor flange (see the figure below), the heat removal is interrupted and boiling in the reactor pressure vessel will occur soon.



The time to reach the top of fuel assembly (TFU) is about 2.4 hours, if no countermeasures. In order to cope with this situation, the water supply of 10.5 kg/s has to be provided within 2 hours. Alternatively, it is possible to use hydro accumulators by energizing and opening the isolation valve(s). Owing to the short time period during which the power has to be recovered to restore the inventory and cooling, this has been identified as a cliff edge effect. Currently, the plant does not have any alternate power source which would be diverse to stand by AC power sources and which would be aligned in a time period to prevent cliff edge effect during the refuelling as well as ensure continuity of DC power supply by charging at least one station battery.

Loss of ultimate heat-sink (LUHS)

Heat sink for normal operation

At the Belarus in NPP, the heat sink in normal operation mode is composed by the cooling towers (counter-flow natural draft cooling tower) and associated systems (PA system) as well as by the Essential Service Water System (ESWS) here called as PE system. The PE systems composed of four independent channels (4x50%) with cooling water pumps, pipelines, distribution chambers and channels which are connected to two spray ponds acts as heat sink in the normal operation mode as well as in the mode of AOO and DBA.

Primary Ultimate Heat sink

The ultimate heat sink for removal of residual heat from the fuel elements in the reactor core is composed of the SG's BRU-A system and the PE System with the spray ponds. Also for the essential consumer necessary for the continued provision of the safety functions, the PE system and the spray ponds serve as ultimate heat sink.

Using the ultimate heat sink, residual heat from the fuel elements in the reactor will be removed first via the chain *Reactor - Primary Circuit – Secondary side of SG's – BRU-A valves – Atmospheric Air*. Through the BRU-A the steam will be released from the secondary SG site into the atmosphere (feed & bleed).

Losses of water in the secondary side of the SG through evaporation will be made up by pumping water with the emergency feed water system EFWS (LAR/LAS 4 x 100) to the steam generators.

When the parameters of the primary circuit are decreased by means of the BRU-A and the operating parameters are achieved in system JNG1/JNA, they are connected to the primary circuit, and afterwards the residual heat is removed by the residual heat removal system through the planned and emergency cooldown heat exchanger JNG10-40AC001-002 (in the cooldown mode, JNA-JNG1, 4 x 50%) to the intermediate component cooling circuit (KAA, 4 x 100%); from KAA to system PE (4 x 50%), and from system PE to the spray ponds from which the heat is released into the atmosphere due to water spraying. Also the safety related components such as heat exchangers and pumps are cooled by the PE system.

Two spray ponds are provided for the four redundancies of the PE system, which means one spray pond for two redundancies.

The heat removal from the spent fuel pool in normal operation as well as under AOO and DBA conditions is performed by spent fuel pool cooling system (FAK), which is also connected to PE system via the intermediate circuit cooling system (KAA, 4 x 100%). If one of the channels of dual-channel system FAK fails in the event of a complete emergency unloading or malfunction of the FAK system equipment in both channels in other modes, heat can be removed through the second or third channel of the sprinkler system (JMN), through the heat exchanger of the low pressure emergency injection system (JNG1) heat is transferred to the intermediate component cooling circuit (KAA, 4 x 100%); from KAA to systems PE (4 x 50%), and from systems PE to the spray pools.

Loss of primary ultimate heat sink (PE System with Spray ponds)

In case of loss of the spray ponds of the PE system which is seen as a BDBA condition, the heat removal from the reactor core and based on this, the retention of the barrier system functionality, is maintained by alternative measures initiated either by the system parameters automatically or by operating staff actions.

The alternative ultimate heat sink is represented by BRU-A and the *Steam Generator Passive Heat Removal System* SG PHRS. Immediately reactor shutdown and closing of the turbo generator stop valves, the pressure in the secondary circuit arise and actuate the BRU-A valves on the steam generators, which operate in the SG pressure maintaining mode. Losses of water in the secondary side of the SG through evaporation will be made up by the emergency feed water system EFWS (LAR/LAS 4 x 100) to the steam generators. Pumps are located in UJE building. The pumps are self-cooling designed, using the conveyed medium.

After closing the BRU-A valves, SG PHRS operation starts, activated automatically by the system parameters. Structure and function of this system is already presented above.

The SG PHRS reaches the full design capacity within 80 seconds. Since, the operation of the SG PHRS channels decreases pressure in the steam generators in accordance with the SG PHRS performance parameters, the BRU-A on all the steam lines of the SG's will stay closed and loss of boiler feed water in the steam generators is stopped. Therefore, the level of boiler feed water in the steam generators after some reduction resulting from steam discharge through BRU-A is stabilized and no significant additional feed water for refill the SG is needed.

The operation of three channels (33.3%) of the SG PHRS with the assigned water inventory in the respective SG PHRS tank ensure the design operability of this safety feature and the adequate heat removal from the fuel elements for 24 hours. This time can be extended to 72 hours using the water inventory of the fourth SG PHRS tank. For this purpose the four tanks can be interconnected among each other.

In the event of a loss of the ultimate heat sink (PE), it becomes impossible to remove heat from the SF pool through the heat exchangers of the SF pool cooling system (FAK). Heat is removed from the spent fuel by evaporating water from the SF pool. Subsequent to its visit to Belarus, the PRT was advised that to prevent uncovering of the fuel in this mode, SF pool FAB50BB001 is made up from sump tank JNK10(40)BB001 by pumps FAK10(40)AP001 as per the standard scheme or as per the redundant scheme by pumps JMN20(30)AP001 through the safety system header, however formal corroboration of this was not obtained.

Loss of ultimate heat sink and alternate ultimate heat sink

The SG PHRS is a passive safety feature which operates after actuation without energy and active control for a period of 24 or 72 hours. Therefore, a failure of the SG PHRS and as a consequence a loss of alternate ultimate heat sink is extremely unlikely. In this special case severe accident measures according to the actions dealt with in chapter 7 have to be set in force.

Time margins until „Cliff Edge Effects“

As stated in the NR, the capacity of each spray pond ensures the operation of the PE system as ultimate heat sink without making-up for a time not less than 8 days. During this period technical measures for supply of make-up water must be arranged. Water make-up can be performed by three possible flow paths:

- the cooling tower reservoir,
- the treatment plant
- the turbine reservoirs.

So a long term residual heat removal via the design features for normal operation can be assured.

In the case of loss of ultimate heat sink, heat removal will be executed by the BRU-A and the SG PHRS. In this case the same situation has to be covered as already described for SBO. Also the same times for the development of cliff edge effects can be assumed.

As described above loss of ultimate heat sink requires also alternative measures for the spent fuel pool cooling. After loss of heat sink, at a first stage, cooling of spent nuclear fuel in the fuel pool is performed by heating and evaporation of water above the fuel assembly level. Conditions and timeframe till a cliff edge effect can occur and which counter measures have to be implemented, have already been presented above in the subchapter "SBO".

Loss of UHS with SBO

The combination of both SBO and loss of ultimate heat sink may lead without counter measures to the same situation as already described in the paragraph dealing with the SBO. Since it will be considered as a BDBA too, the same measures as described above will be implemented. Therefore it can be assumed, that the same "cliff edge effects" and respective time margins will emerge.

6.2.3 Strong safety features and areas for safety improvement identified in the process

The design concept of the AES 2006 V-491 bases in general on the current international approaches for modern reactor designs and considers internationally agreed and applied in general standards as from the IAEA. The concept considers safety related aspects coming from the lessons learned of the Fukushima Daichii accident. LOOP and Loss of the main ultimate heat sink are declared as incidents to be handled on the DiD level 2 and 3 (AOO and/or DBA).

Both events SBO and the Loss of alternative ultimate heat are categorized as DiD 4 (BDBA) incidents according to the DiD level scale described in the chapter 2.3.2.1 of the NR. Technical safety features

and organizational measures are implemented to mitigate these situations. The installed safety systems seem to be appropriate to deal with both events.

The SG PHRS is a new safety feature never previously installed, in this special form, except in the new Leningrad-2 NPP reactor. The PRT was advised that at the Leningrad-2 NPP, the system was successfully tested in autumn 2017 during the commission phase. The NR only quoted calculations which were conducted for the assessment of the functionality and the respective operational parameters of the SG PHRS. No information is presented in the NR, if the calculations were validated by experiments.

Since, as stated in the NR, the *Steam Generator Passive Heat Removal System* (SG PHRS) and the *Containment Passive Heat Removal System* (C PHRS) combined with the emergency make-up system for refill the SG PHRS tanks as well as the spent fuel pool builds the ultimate technical safety feature to ensure the heat removal from the core as well as from the spent fuel pool, special attention has to be paid for the operability of this safety system and its availability in BDBA conditions subsequent to BDB earthquake. This includes also the reliability of the water make-system for both systems.

6.2.4 Possible measures to increase robustness

As stated in the NR, the Belarusian regulatory body identified the need for action regarding the procedures stipulating staff activities to assure the appropriate structured approach in case of active control activities of or suitable monitoring of automatic action of the active or passive safety features.

To mitigate the consequences of accidents with a complete loss of power supply, the following organizational and technical measures are provided:

- Operational procedures for preparation of operation and commissioning of a mobile DG in case of complete loss of AC power supply;
- Operational procedures and instructions for preparation of operation and commissioning of the emergency standby auxiliary 16 MVA 110/10 kV transformer, including procedures for the possible use of an additional 110/10 kV source, serving the essential loads of a second 10 kV section (including EPSS);
- Operational procedures creating the power supply from the neighboring unit via 10 kV assemblies of 330/10 kV standby transformers connected together with cable jumpers
- Operational documentation for additional personnel in a SBO event as
 - strengthening the monitoring of the Unit process parameters;
 - strengthening the monitoring of the safety-related systems operation;
 - preparation for operation and commissioning of the designed safety systems;
 - preparation for operation and commissioning of the mobile DG set.

To assure a reliable heat removal from the spent fuel pool during a SBO event the Regulatory Body requests to implement an additional connection for non-standard facilities (e.g. fire engine with a pump unit) to two process ports of JNB50 system, located on the outside of the safety building for ensuring the make-up line for the SG PHRS tanks in case the JNB 50 pump fails.

In accordance with the recommendations resulting from development of the Stress Test Report (target reassessment of safety) for Belarusian NPP, two mobile DG sets (one per NPP Unit) with a

power of 500 kW were requested by the Regulatory Body. This mobile DG set has to be delivered to the point of its connection, prepared for operation and connected to the switchgear of BDBA “channel 7” within a time of 24 hours.

6.2.5 Measures (including further studies) already decided or implemented by operators and/or required for follow-up by regulators

No information about decisions with regards to possible measures for the enhancement of the plants robustness was given in the NR or during the discussions.

6.3 *Peer review conclusions and recommendations specific to this area*

The review of Topic 2 of the Belarussian NR concluded that the ENSREG specification developed for the EU stress tests was strictly followed in the process of assessment in the area of loss of electrical power supply and loss of ultimate heat sink. Robustness and time margins were theoretically demonstrated for all relevant accidents considered in the EU stress tests due to the diversification of the active safety systems with passive ones, big water reserves stored inside the containment and other features.

Nevertheless, the PRT concludes, that some issues regarding the safety especially under design extension conditions (DEC) need clarification and enhancement.

It has to be considered, that the design is based on Russian standards developed before the Fukushima accident. These standards define measures supported by mobile equipment to be taken for the prevention of hazardous conditions in a case of a BDBA.

Given the nature of conducting the Stress Test on a new NPP under construction in Belarus, the PRT considered it appropriate to make comparison against the new IAEA standards especially the IAEA Specific Safety Requirement SSR 2/1, Rev. 1 “Safety of Nuclear Power Plants: Design”, dealing with the new concept of design extension conditions replacing the old BDBA concept, and the need to have permanent installations carrying out or supporting preventive measures under these DEC.

Considering the crucial function of the JNB-50 pump for meeting the requirements for DEC, the PRT recommends that a permanent power supply should be installed to improve the availability of the pump in SBO situation.

The PRT recommends that an alternative permanent power source to supply the necessary power in design extension conditions should be provided. This alternative AC power supply should include necessary connecting points, to protect electrical power systems against the simultaneous failure of off-site and emergency AC power supplies. AC power sources should be used that are diverse in design and are not susceptible to the events that caused the loss of on-site and off-site power sources. The necessary switching operation to connect the alternate power source should be consistent with the depletion time of the battery. Extending the battery discharge time by e.g. load shedding may also be considered. This recommendation considers international agreed and applied

requirements described in Requirement 68 of the IAEA Specific Safety Requirement SSR 2/1, Rev. 1 “Safety of Nuclear Power Plants: Design”.

Additional recommendations to meet safety requirements above are laid down in the Specific Safety Guide SSG 39 “Design of Instrumentation and Control Systems for Nuclear Power Plants”.

The PRT identified vulnerability in the design of the JNB system. Despite the autonomy of the passive heat removal system (PHRS) which is designed to cope with SBO scenarios the SG PHRS, the C PHRS tanks and the spent fuel pool are refilled with water using a single low -pressure pump JNB50AP001 (only 1 pump per unit is designed), transporting demineralized water coming from the LCU Tanks, which is fed by the channel 7. Owing to the importance of ensuring the functionality of SG PHRS in SBO, the PRT recommends enhancing the reliability by installing an additional redundant pump.

When an SBO event occurs during the refuelling period; specifically when the reactor is drained to the 550 mm below the main reactor flange, the heat removal is interrupted and it is only a short period before boiling in the reactor pressure vessel occurs. Time to reach the top of fuel assembly (TFU) is about 2 hours, if no countermeasures are applied. Owing to the short time period during which the power has to be recovered to restore the inventory and cooling, this has been identified as a cliff edge effect by the PRT. The PRT recommends a suitable alternative solution is implemented to ensure that restoration of water supply is achieved within necessary time to prevent core damage.

The NR considers the so called substation “Viliya” as an additional technical solution for the provision of energy supplies to safety related consumers. From this substation an additional “emergency transformer” with a capacity of 16 MVA on a voltage level 110/10 kV will be fed, as an additional source for providing energy to one safety train of both units. Since the off-site power supply is the source for energy provision on DiD level 1 and 2, the PRT recommends that analysis is undertaken to demonstrate the reliability of these off-site powers sources in seismic conditions.

In the NR no information was given regarding the evidence of the efficiency and reliability of the new passive safety systems as the SG PHRS and C PHRS. During the discussion the PRT requested information based on experimental data and commissioning test in similar plants. No additional evidence was available during the review mission. Nevertheless, Gosatomnadzor stated, that comprehensive tests, proving the efficiency and functionality of new systems have to be carried out as a part of the commissioning procedure and were requested in the licensing procedure.

7 PLANT(S) ASSESSMENT RELATIVE TO SEVERE ACCIDENT MANAGEMENT

7.1 Description of present situation of nuclear power plants in Belarus

7.1.1 Regulatory basis for safety assessment and regulatory oversight (national requirements, international standards, licensing basis already used by another country)

According to the national report, the basis of the legislative and regulatory framework relevant to nuclear energy is formed by several legislative documents, which have been developed since the decision to build a NPP was taken in 2008. In addition to the law “On the use of nuclear energy” of 2008 the legislation includes regulations related to the design, siting, construction, commissioning, operation, operational safety limits, plant lifetime extension and decommissioning of a nuclear power plant. Decree of the President of the Republic of Belarus No. 450, dated September 1, 2010 “On the licensing of specific types of activities” covers issues related with the licensing and establishes general and specific licensing requirements and conditions for nuclear power use. Licensing procedure is further stipulated in Decree No 1781 “On approval of the Regulations on the procedure for the examination of documents substantiating the provision of nuclear and radiation safety in the implementation of activities in the field of the use of atomic energy and sources of ionizing radiation. Severe accident management area is regulated based on the relevant Russian regulations and guidance documents.

As provided in the national report, an on-site emergency plan shall be developed and submitted to the supervisory authority for granting the operating license. Although the contents of the plan seem, in general, to be relevant to selected elements of severe accident management, the link of this plan with the development and validation of the operator’s accident management programme, including development and validation of EOPs and SAMGs, was not comprehensively described. As explained in the response of Belarus to the questions raised and in the discussion during the country visit, the development of the plant’s accident programme is ongoing based on the most recent relevant Russian guidance (RB-105), including symptom-based EOPs and SAMGs. These procedures will be subject to regulatory review and approval prior to commissioning of the plant.

Belarus has ratified and adopted several international conventions and, as stated in the national report, is committed to the implementation of the nuclear programme in compliance with these conventions. As provided in Belarusian legislation, IAEA Safety Standards shall be taken into account in preparation of the national legislation and in the supervision of the NPP. As stated in the responses to relevant questions, the IAEA Safety Guide NS-G-2.15 “Severe Accident Management Programmes for Nuclear Power Plants” has been taken into account in the development of the severe accident management programme; it is noted that the Guide is in the advance stage of the updating by the IAEA. As concerns the latest WENRA recommendations for new reactors these have not been considered, because, as claimed by Belarus, the plant was already under construction when the latest recommendation were issued, and Belarus has only a position of the observer in WENRA. Nevertheless, Belarus has available a study with assessment of the level of compliance of its regulations with IAEA and WENRA requirements confirming a good level of consistency between those reference documents.

7.1.2 Main requirements applied to this specific area

Information related to the requirements directly applicable to the issue of beyond design and severe accidents is not explicitly provided in the national report. Some relevant, general information is found in different parts of the report. As it is mentioned, the safety objective for the Belarusian NPP implies that the radiation exposure in case of beyond design basis accidents is limited to acceptable values. As explained during the visit, compliance to an upper limit for core damage frequency lower than 10^{-5} per year, for a large release (more than 100 TBq of Cs-137) a frequency lower than 10^{-7} per year is required by the current regulations. In accordance with the new regulatory requirements, compliance with the above criteria shall be verified by PSA Level 2 studies based on full-scope PSA Level 1 results. The whole body effective dose beyond 3 km from the plant shall be less than 5 mSv/year. Additional design acceptance criteria in relation to beyond design basis and severe accidents, are also listed in the national report.

7.1.3 Technical background for requirement, safety assessment and regulatory oversight

According to the national report, PSA studies and Safety Analysis Reports (SARs) are required by the Belarusian legislation to be submitted in different stages of the plant licensing. Regulatory documents containing the requirements applicable to the development of PSA Level 1 and Level 2 are listed in the national report. As claimed during the visit, severe accidents are covered by the deterministic accident analysis in the SAR. It was also clarified that PSA Level 1 for external and internal events is presently under development scheduled to be completed until the end of 2018. Available quantitative results of PSA Level 1 for the reactor core damage frequency due to internal events and total frequency for damage of fuel in the spent fuel pool were provided in the national report. PSA Level 2 is being also developed based on the results of the PSA Level 1 and, as claimed, the results of it will be used in the development of the severe accident management program.

According to the national report, a training centre with necessary simulators, techniques and training materials for staff training in emergency situations has been established at the Belarusian NPP. The scope of the training and the simulator covers all plant states, including beyond design accidents and severe accidents.

As stated in the report and the provided responses, a Safety Enhancement Programme of the NPP will be developed as part of the efforts for continuous safety improvements. No measures were explicitly specified for the improvements in the area of the severe accident management.

7.1.4 Compliance of plants with current requirements (national requirements)

As provided in the national report, on-site emergency plan shall be developed and submitted to the supervisory authority during the stage of licensing for operation, together with symptom based EOPs and SAMGs. EOPs and SAMGs shall be completed, validated and approved by Gosatomnadzor prior to commissioning of the plant. During the visit it was clarified that compliance of the plant with the current requirements, including the accident management programme, will be reviewed in the upcoming stage of licensing for commissioning and operation.

7.2 Assessment of robustness of plants

7.2.1 Adequacy of present organizations, operational and design provisions

Organization and arrangements of the licensee to manage accidents

The Belarusian NPP is under construction. Organization of emergency planning and response covering the on-site/off-site coordination has been developed prior to the NPP construction. Significant role in this coordination belongs to the Ministry for Emergency Situations (alongside with other governmental bodies, in cooperation with the operator). Gosatomnadzor is one of the departments of the Ministry for Emergency Situations.

Regarding the on-site radiation protection of the site personnel, this is covered by the on-site emergency plan which is under responsibility of the operator among other conditions for the operator to get an operational license. The operator is also responsible for the public safety in close vicinity of the NPP. According to the requirements, training and emergency response drills have to be carried out for prevention and mitigation of accidents, medical assistance, use of protective equipment, interaction between different teams (e.g. fire-fighting and medical teams) etc.

Regarding the accident management inside the NPP itself, emergency situations should be manageable by the emergency response of the plant staff. Emergency response is controlled by the shift supervisor, chief engineer or general director of the plant, depending on their availability in a given time. There is also the Commission for Emergency Situations of the NPP. Members of the Commission support the emergency response team by identification of causes of the accident, assessment of the plant status, forecast of potential radiological consequences and determination of actions towards recovery. There is a link between the plant emergency response team and the State Emergency Prevention System (under coordination of the Ministry for Emergency Situations), which can provide necessary external assistance in emergency situations. In case of the need for external support, the NPP can contact the regional office of the Ministry, which is responsible for making arrangements for adequate external support. There are redundant communication channels between the plant and the relevant ministry, regulatory authorities and permanent management bodies.

The national report also refers to the “Action Plan for the Protection of Personnel in the Event of Accidents at the Belarusian NPP” and “Protective Measures against the Radiation Accidents at the State Company Belarusian NPP”. It is indicated that these documents represent the on-site and external (off-site) emergency plans. However, there is a lack of clarity within the national report over the status and scope of these documents.

In response to the additional questions and during discussions the position was clarified. It was reported that the on-site and off-site (external) emergency plans remain under development but that they will be required prior to the shipment of fuel to the NPP. In particular the role of the Ministry of Emergency Situations of the Republic of Belarus was explained and the roles of a number of other state bodies (e.g. Ministry of Health). It was explained that the Ministry of Emergency Situations (MES) existed before the decision was made to construct the Belarusian NPP and acts as National Regulatory Authority (NRA) in the area of prevent and response to different (not only radiological) emergency situations. MES is in charge of development of external emergency plan of Belarusian NPP. At the same time, MES is NRA in the area of nuclear and radiation safety. After decision-in

principle to construct Belarusian NPP, the Department for Nuclear and Radiation Safety was created in the structure of MES as a special unit focused on this particular area.

It should also be mentioned as an important component of the external support that in 2015 Belarus has signed an agreement with the WANO Moscow crisis centre on overall support in case of the emergency.

Procedures and guidelines for accident management

The national report states that the Emergency Operating Procedures (EOPs), Beyond Design Basis Accident Management Guidelines (BDBAMGs) and Severe Accident Management Guidelines (SAMGs) are under development. The national report outlines the process for development of the EOPs, BDBAMGs and SAMGs in four stages with the final stage being their agreement and approval.

As stated in the national report, a symptom-based approach should be used for the development of EOPs and SAMGs. It was explained that symptom-based SAMGs are not required by Belarusian legislation for granting of the operation licence, but NRA included such a requirement as obligatory license condition. The current progress regarding EOPs and SAMGs development and the specific stage of the licensing was not clearly provided in the national report.

Through the responses to questions raised by the peer review team and discussions during the visit it was explained that symptom-based emergency procedures are being developed in accordance with the IAEA guide “NS-G-2 15 Severe Accident Management Programmes for Nuclear Power Plants” and with the Russian regulatory guide “RB-102-15 Safety Guide on the use of Atomic Energy”.

It was confirmed in the discussion that the procedures should be presented to NRA before a licence to operate is granted and that this is a regulatory requirement. NRA demanded that verification and validation of this should be done prior to fuel being loaded in the reactor. It was also confirmed that the regulator together with the TSO, will cover the emergency procedures as part of the safety review.

During the discussions it became clear that the timescales for the development of the emergency procedures and their verification and validation and training is very challenging. The intention is that the procedures will be finalised prior to commissioning of the plant, however there did not appear to be a clear programme of work to ensure this. It is therefore recommended that such a programme is established.

With respect to emergency training the national report states that the NPP has a training centre equipped with simulators and training materials for training and exercising of personnel for accidents. It is also stated that programmes for emergency response training of operational personnel is under development.

Further clarification of the status of the training centre and training was requested through peer review team questions and during discussions during the visit. It was explained that a simulator has been manufactured and is subject to comprehensive testing by the manufacturer. The simulator will be under trial operation until the end of 2018 and will then be used for personnel training at the NPP.

It was also explained that personnel will be trained in accordance with the training schedule stated in “The common-plant set of programs of emergency response training for operating personnel” which is planned for completion by the beginning of May 2018. In response to the additional questions it

was confirmed that all operating modes of the Belarusian NPP can be simulated (normal operation mode, transient mode, anticipated operational occurrences, design basis accidents and beyond design basis accidents). Severe accidents can also be simulated including core melt, heating up and destruction of the reactor bottom and interaction of the molten material with the core catcher. This was confirmed during the plant visit.

It was also reported that training of operating personnel is currently being performed according to a general training schedule with employees of the Belarusian NPP being on probation at the 6th power unit of Novovoronezh NPP-2 of the Russian Federation.

Hardware provisions for severe accident management

The systems of the NPP for management of postulated initiation events and accident scenarios are in general designed in accordance with the concept of defence in depth. There are a number of normal operation systems and safety systems aimed at prevention of accidents and in particular of severe accidents. Specifically, the active safety systems (including emergency boron injection, high and low pressure ECCS, containment spray system, SG emergency feedwater system, essential service water system, emergency power supply system) have either 4x100 % or 4x50% redundancy, depending on vulnerability to their failure due to an initiating event.

The NPP design further considers a number of stationary (active and passive) and mobile means for beyond design basis accidents (design extension conditions- DECs), aimed to prevent and mitigate severe accidents, with focus on ensuring the integrity of the containment and performance of safety functions so that to comply with the radiation acceptance criteria for severe accidents. These means are primarily intended to prevent a progression of an accident into a severe accident. In case of a failure of prevention, there are specific means to manage the severe accident and to mitigate its consequences. These means include:

- System of passive heat removal from the containment (C PHRS system), capable to remove residual heat from the containment including conditions of severe accidents without any human action for at least for 24 hours
- System of passive residual heat removal via steam generators (SG PHRS) designated mainly to prevent progression into a severe accident, but with capability for certain residual heat removal also after core melting, capable to remove residual heat through steam generators and including failure of one train of the system without any human action for at least 24 hours with large margin (nearly 50 hours)
- Pilot operated safety valve (POSV) of the pressurizer with a possibility of their opening from the control rooms (main control room or emergency control room) in case of a severe accident for fast reduction of primary circuit pressure (in case when the capacity of SG PHRS is not sufficient to reduce the pressure)
- Emergency steam and gas removal system (KTP) from the reactor, steam generator collectors and the pressurizer as an additional means for fast reduction of the primary circuit pressure
- Ventilation and filtration system to maintain vacuum in the containment annulus, which is however an active system, not functioning in case of station blackout

- System of passive autocatalytic recombiners for hydrogen removal (JMT); 44 recombiners are installed in the containment internal volume with sufficient capacity for hydrogen removal in case of a severe accident
- Melt localization system – core catcher (JMR), implemented to capture, cool down and stabilize molten core and reactor internals without excessive mechanical impact on the reactor cavity and without direct attack of the containment boundary by the corium
- The system for making up the tanks of the SG PHRS and C PHRS, as well as for making up the SFP, using a single high-pressure make-up pump, powered by a mobile 500 kW DG
- Internal inspection shaft water emergency use system (JNB90); the system provides coolant for flooding the core catcher as well as spent fuel pool make-up.

For electric power supply there is a dedicated system of power supply (7th train of the power supply, with partial redundancy provided by 8th channel]) that includes two sets of 24-hour batteries in each unit, a mobile DG 500 kW (one DG for each unit), which recharges the batteries and powers the common pump which supplies coolant to the heat exchangers of the passive heat removal systems from the LCU storage tanks. As stated in the NR, the mobile DG in case of a need within 24 hours needs to be transported to the point of its seismically resistant connection. If the transport of the mobile DG is impossible, connection can be provided from the original position of the DG using special switching equipment and additional cables. During the discussion with the counterpart it was stated, that the improved design will ensure permanent connection of the mobile (transportable DG) to the relevant consumers.

The design also provides for special instrumentation for severe accident conditions. This instrumentation includes redundant monitoring of containment integrity (by a number of sensors for isolation status, air locks tightness, radiation monitors inside the containment, in the containment annulus and at the site), level and temperature in the spent fuel pool, redundant monitoring of containment pressure, temperature, hydrogen and oxygen concentrations, temperatures in the core catcher, temperatures and levels in the tanks of passive heat removal system, various parameters indicating operating status of various systems, etc. The instrumentation has the measurement range sufficient for severe accidents.

When comparing available NPP means with the European stress test recommendations it can be concluded that the list of recommended hardware measures is consistent with the NPP design. In addition the stress tests recommendations explicitly mentioned containment filtered venting to avoid over-pressurization of the containment. In the Belarusian NPP such system is not considered, because other systems, in particular a passive containment heat removal system, passive autocatalytic hydrogen recombiners, core catcher and the robust containment with large volume are designed to ensure efficient heat removal and integrity of the containment.

Evaluation of factors that may impede accident management

Although the Belarusian NPP is comparison with existing NPPs is equipped with a number of advanced hardware features designed to cope with severe accidents, there are certain factors that may impede accident management.

In the new reactor designs differently from existing plants there should be (in accordance with updated IAEA Safety Requirements SSR-2/1 Rev.1), stable systems for coping with DEC, while mobile means are not considered as a part of the design due to potential difficulties with their timely connection.

Implementation of SAMG after 24 hours from the beginning of the accident requires certain on-site human actions, in particular transport and connection of the mobile DG to a dedicated connecting points. However, harsh radiological situation in case of a severe accident could impede or complicate this action (although calculations included in the safety analysis report indicate that the conditions will be acceptable).

Human actions to be performed within implementation of SAMG are supposed to be executed either from the MCR or ECR. The national report states that the both control rooms provides for their habitability in case of radiation accidents on the given or other unit as well as in appearance of toxic substances. Habitability is ensured by means of shielding, ventilation systems with filtration, radiation protection systems and fire protection systems. For the short term access, personal protective equipment will be available. However, in case of prolonged station black-out when the ventilation/filtration system is inoperable, habitability of the control places could be impeded.

The national report presents high margins of the plant civil structures against external hazards, in particular against beyond design basis earthquakes. However, it is not clear if the equipment inside the civil structures including instrumentation has the similar resistance. Further on it is not clear what could be the scope of damage of the plant surroundings and its wider infrastructure which could complicate the recovery activities.

Accident management for events in the spent fuel pools

Differently from several other new PWR designs, in Belarusian NPP the spent fuel pool is located inside the containment. Therefore, even in case of fuel damage taking place in the pool there would no direct pathway for dispersion of radioactivity from the pool into the environment. While structural resistance of the spent fuel pool against earthquakes seems to be high enough, its cooling systems do not look equally robust for DEC.

The SFP can be cooled down by the SFP cooling systems (FAK) or the spray system (JMN). If both channels of FAK system fail, heat can be removed through the second or third channel of the spray system (JMN). If all these systems fail, under DEC conditions pump JNB50 is used.

The cooling system (FAK) was designed to remove residual heat from the pool under all plant states from normal operation up to DBAs and DEC. Similarly, the spray system is assumed to be used in both DBAs and DEC. It means that the same systems are used for several levels of defence contrary to the principle of independence of levels of defence. In the case of prolonged (more than 41 hours) loss of SFP cooling by FAK and JMN systems due to station black-out, the loss of coolant starts which should be compensated by a high-pressure make-up pump (the same pump as one for feeding the heat exchangers of SG PHRS) which is powered by a mobile DG. In addition, it is possible to use a mobile high pressure fire pump to make up the spent fuel pool.

It is clear that very reliable measures for compensation of the loss of coolant need to be implemented in order to exclude damage of the fuel in the pool. The need for strengthening of cooling options for the spent fuel pool is further underlined by the fact that effectiveness of the hydrogen mitigation system can be also impaired due to lack of oxygen needed for recombination in case of additional hydrogen from the spent fuel or from decomposition of the pool concrete. Large amount of hydrogen could represent the risk in the case of penetration of hydrogen to spaces outside the containment.

7.2.2 Margins, cliff edge effects and areas for improvements

Strong points, good practices

The design of the Belarusian NPP includes several novel provisions designated for the fourth level of defence in depth aimed to prevent severe accidents, manage severe accidents and mitigate their consequences, which are essential for elimination of early or large radioactive releases from the containment.

The strengths of the project include in particular a passive residual heat removal system through the steam generators (SG PHRS) and passive system for heat removal from the containment atmosphere (PHRS C). Both systems are capable to operate passively and automatically even during station black-out conditions at least for 24 hours in the stand-alone mode. Further on there is a core catcher capable to capture, cool down and stabilize the molten corium without direct attack of the containment boundary.

The training centre is equipped with the full scope simulator with rather unique capabilities to simulate also severe accidents, thus providing additional features for effective staff training.

The Ministry for Emergency Situations has established for the needs of the NPP strong fire brigade, well equipped with numerous mobile sources ready to respond to fires and other hazards at the plant. In addition, at the country level there are other necessary sources such as heavy machines and transport means available under the same Ministry. Well-developed countrywide radiation monitoring system represents an important element for effective overall emergency response, if adequately interconnected with on-site monitoring including coordination of on-site and off-site emergency response.

Significant efforts need to be made to maintain and strengthen close links with the designers (the General Designer, the Designer of the reactor plant, etc.), as well as scientific supervisory organizations, WANO Moscow centre and any other stakeholders, both domestic and foreign, in order to ensure long-term external support to safe operation of the NPP. A number of national research programmes are on-going and planned to further enhance availability of qualified manpower and knowledge basis.

The issue of potential recriticality for various configurations including severely damaged core or various corium configurations in the core catcher have been analysed in the national report. It came out from the analysis, that for any possible configuration including premature melting of the control rods in the core there is always sufficient margin to the criticality. This analysis can be considered as a good practice.

Weak points, deficiencies (areas for improvements)

In spite of significant advanced design features there are a number of issues that require further more convincing justifications or improvements.

Due to the current status of the development and implementation of symptom based EOPs and SAMGs and the need to have the process completed before fuel loading it is realized that the process is delayed and the acceleration of the process should be addressed as an urgent matter.

There are several systems envisaged to operate at both level 3 and level 4 of defence in depth: a) Pilot operated safety valve (POSV) of the pressurizer, b) Emergency steam and gas removal system

(KTP), c) Ventilation and filtration system of containment annulus, d) Spent fuel pool cooling system (FAK). Such design solutions are not fully consistent with the principle of independence in particular between levels 3 and 4 of defence, as required by IAEA Safety Requirements (SSR-2/1 Rev. 1) for new reactor designs. Special considerations are needed to ensure functioning of the systems in case of severe accidents or different design solutions should be implemented.

Due to implementation of several novel passive design solutions, plant autonomy is ensured for at least 24 hours. As stipulated by the design, after 72 hours (24 hours - in the event of an unlikely failure of one of the four emergency heat removal tanks) the make-up of the tanks of the SG PHRS and C PHRS will be performed by a single make-up pump JNB 50. Although in the case for the safety features for the DEC's the redundancy is not explicitly required by the IAEA Safety Requirements, due to the dual use of a single (not redundant) pump this limitation could be considered as a challenge for successful execution of accident management actions.

Owing to the importance of ensuring the functionality of SG and C PHRS in SBO, the PRT recommends enhancing the reliability by installing an additional redundant pump.

It is noted that the civil structures needed to prevent large radioactive releases (including containment, control rooms, spent fuel pool) are robust with large margins against external hazards. However, these margins need to be confirmed by the Probabilistic Safety Assessment of seismic impacts. In addition, attention should be paid to adequate resistance of the technological equipment (cooling systems) ultimately needed for prevention of large releases in case of a severe accident.

The issues associated with mitigation of severe accidents taking place during shutdown operational regimes were not specifically addressed in the national report. On the other hand such regimes represent an increased risk of occurrence and mitigation of severe accidents, since under such conditions the heat exchangers of the SG PHRS are disabled and time margin to uncovering of the fuel in the reactor is rather short (about 2.4 hours).

There is an active emergency ventilation system to maintain vacuum and ensure filtering of the annulus between the primary and secondary containment. However, the system is not operable in case of a severe accident (resulting from LOCA in combination with station black-out). Although location of the spent fuel pool inside the containment could be considered as comparative advantage to other designs, the possibility of severe fuel damage (fuel melting) in the spent fuel pool should be practically eliminated, since the design does not include provisions for reaching safe stable conditions following such accident.

Habitability of control areas (main control room, emergency control room) during a severe accident combined with long-term station blackout (more than two hours) resulting in switching-off the ventilation system of these control places is questionable. Although there is no obvious driving force for penetration of potentially contaminated outside air, habitability of the control places should be given further attention.

The need to transport and connect a mobile DG to the relevant connecting point under potentially harsh radiation conditions following a severe accident is not in compliance with the updated IAEA Safety Standards (SSR-2/1, Rev. 1). During the PRT discussion it was stated by the plant designer, that in order to address this issue the mobile DG will be permanently connected to the relevant consumers. Nevertheless, considering implementation of a permanent power source with sufficient capacity not only for recharging the batteries and powering the make-up pump, but also for providing power to ventilation of the main control room and ventilation of the containment annulus would significantly enhance robustness of the design. At the same time it is underlined that the

additional use of mobile means should be further considered as a valuable component of operational accident management.

7.2.3 Possible measures to increase robustness

In the following text the areas for further safety enhancements of the NPP identified by the peer review team are listed.

1. While it is recognized that several advanced safety features are implemented in the design, the overall concept of practical elimination of early and large releases should be more explicitly reflected in an updated plant safety case,. 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 (such as accident with an open containment, or uncompensated primary to secondary accidents potentially resulting in severe accident).
2. 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.
3. The adequacy of margins of SSCs for beyond design basis earthquakes of the plant equipment ultimately needed for prevention of large releases in case of a severe accident should be reconsidered and the robustness of the systems increased, if necessary, based on the results of seismic PSA under preparation.
4. Further consideration should be given to the prevention and the mitigation of severe accidents under open reactor conditions, when heat exchangers of the SG PHRS system are disabled and time margin to core damage is rather short.
5. The implementation of a redundant make-up pump JNB 50 for the dual purpose of providing coolant to the PHRS heat exchangers and to the spent fuel pool is recommended.
6. Although habitability of control areas (main control room, emergency control room) during a severe accident in combination with station black-out has been assessed in the SAR as satisfactory, it is still advised that this issue be further assessed and habitability enhanced.
7. In the event of NPP blackout the emergency ventilation system of the annulus is not available. Whether there is a need for the system to be in operation in the event of severe accident in combination with station blackout should be further investigated. And, if necessary, the emergency ventilation system of the containment annulus should be modified.
8. Noting that symptom-based emergency procedures (EOPs and SAMGs) are required before a licence to operate is granted and the challenging timescales, it is recommended that there is a clear programme of work in place to develop the symptom-based emergency procedures; to verify and validate the procedures; and to train personnel before core load.

7.2.4 New initiatives from operators and others, and requirements or follow up actions (including further studies) from regulatory authorities: modifications, further studies, decisions regarding operation of plants

Upgrading programmes initiated/accelerated after Fukushima

In the time of Fukushima accident the NPP design was in its active stage, and the additional lessons learned were implemented in the designs. Examples of such improvements include proper location

and resistance of fixed connecting points for transportable means and enhancement of the robustness of the PHRS systems.

Further studies envisaged

There are several research and development projects aimed at further enhancement of availability of qualified manpower and future continuous safety improvements of the plant. The current national research project (2009-2020) is devoted to the support to the NPP construction, and another project is under preparation aimed at supporting plant operation. There is an EU project (financed through INSC) and another IAEA technical cooperation project, aimed at human resource development in Belarus. A number of intergovernmental agreements have been signed with several EU countries on cooperation and exchange of information in the area of nuclear safety.

Decisions regarding future operation of plants

The BNPP has available advanced features for prevention and mitigation of severe accidents as required for new reactor designs. Nevertheless, it is advisable that adequate attention be devoted to further safety enhancements presented in this peer review report.

7.3 Peer review conclusions and recommendations specific to this area

The peer review concluded that the BNPP belongs to the new generation of NPPs, with significantly enhanced hardware capabilities for prevention and mitigation of severe accidents, including availability of redundant active safety systems, redundant passive safety features for residual heat removal through the steam generators and from the containment and various other safety features for DECAs aimed at elimination of challenges to containment integrity.

Nevertheless there are possibilities for further increase of the robustness of the design, in particular by means of replacement of mobile DG by a stable source of electricity, installation of a dedicated system for the reactor coolant system depressurization and enhancement of capability for residual heat removal from the spent fuel pool, for ventilation of the main control room and for ventilation of containment annulus in DECAs. In view of recently determined site seismic level the adequacy of margins of certain SSCs for beyond design basis earthquakes may be an issue. Overall approach to practical elimination of early or large releases, including elimination of severe accidents in the spent fuel pool, should be further developed and explicitly demonstrated.

It is further underlined that also in the case of significantly enhanced hardware provisions there is a need to have effective EOPs and SAMGs in place. On-going programme for development of procedures and guidelines should be completed as soon as possible. Sufficient time and resources should be provided for validation of procedures and guidelines, and for training all groups of staff involved in accident management.

It should be also taken into account that the whole area of severe accident management is still evolving internationally. It is thus recommended to follow this development and to contribute to this development by own Belarusian studies.

8 MAIN CONCLUSIONS OF THE PEER REVIEW TEAM

Introduction

Following the Fukushima accident in Japan in March 2011, the European Commission (EC), together with the European Nuclear Safety Regulators Group (ENSREG), mandated and completed comprehensive risk and safety re-assessments of all EU NPPs, termed Stress Tests (STs).

The Stress Tests were completed against a common EU-STs specification that defined 3 topic areas for assessment:

- extreme natural events (earthquake, flooding, extreme weather conditions),
- response of the plants to prolonged loss of electric power and/or loss of the ultimate heat sink
- severe accident management.

The request of the European Council defined that the Stress Tests had to be performed at national level and be complemented by a European Peer Review (PR).

At the time of the EU-STs, some neighbouring countries like Armenia, **Belarus** and Turkey expressed interest in following the same peer review process. They confirmed their willingness to voluntarily undertake a comprehensive risk and safety assessments in accordance with the stress tests specifications agreed by the European Commission and the European Nuclear Safety Regulators Group (ENSREG) on 24 May 2011, at an appropriate point in the future.

The Russian version of the host countries national report for the stress test process was approved during an inter-governmental meeting on 27th September 2017. Belarus subsequently submitted the English version of its national stress tests report on the Belarusian Nuclear Power Plant to the Directorate-General for Energy of the European Commission and ENSREG for peer review on 31st October 2017, and the PRT immediately began its review.

In total, around 460 written questions were subsequently submitted to Belarus Nuclear Regulatory Authority, which were a combination of questions developed by the PRT, those from NGOs and others provided by Latvia. Prior to the visit to Belarus, on 7th March, Gosatomnadzor provided written answers to the questions raised by the PRT.

The Peer review took place in Belarus from 11th to 16th March. The PRT consisted of 17 experts from EU and non EU Member States that had been nominated by ENSREG. The PRT included 2 representatives from the Commission - 1 expert from JRC and 1 rapporteur from DG ENERGY. 3 observers were also present during the country visit: 1 from the IAEA, 1 from the Russian Federation and 1 from Iran.

Peer Review Team's general comments on the Belarus National Report

Previous stress tests were undertaken on pre-existing reactor designs that were already operational and on NPPs under construction at the time in the EU. From the start, the experts from the PRT considered that highest safety standards should be taken into account during the stress test process for Belarus even though the construction licence for Belarus NPP was issued before the WENRA approach for new reactors was established.

In the opinion of the PRT the Belarus national report was drafted in accordance with the requirements of the EU stress Tests. Belarus's agreement to complete the EU Stress Test process in a relatively compressed timeframe is noted, particularly as it is an embarking country developing a

new nuclear power programme and even for more established countries the process presents a sizeable challenge and learning process.

Attempts to reduce the volume of its initial draft national report resulted in limited information in some parts, which led to a large number of additional questions being sent to Belarusian counterparts. However, the PRT was impressed with how hard Belarusian counterparts worked to answer the questions raised by the PRT. Belarusian counterparts fully answered the questions and provided the answers translated into English to the PRT for consideration, along with additional reference materials such as copies of parts of PSAR, project documentation, schemes, as further evidence to its given answers. The PRT recognise and commend the open and transparent way in which Gosatomnadzor and the licensee sought to address these during the review. Together with subsequent discussions with counterparts and the site visit in Belarus, these allowed the PRT to clarify all of its outstanding points.

Topic 1: ASSESSMENT RELATIVE TO EARTHQUAKES, FLOODING AND OTHER EXTREME WEATHER CONDITIONS

Earthquake

Initially, the PRT focused on the reliability of the current design basis earthquake of $I = 7^\circ$ MSK-64 and $PGA_H = 0.10$ g for the non-exceedance probability of 10^{-4} year. This was due to the fact that several earthquakes of $I = 7^\circ$ have been reported from the region and near-region around the NPP. The National Academy of Sciences of Russia indicated its confidence that the existence of these events is doubtful and at the time of the PRT visit was undertaking an analysis of the relevant events. On completion of this analysis, the PRT recommends that a review of the zoning and seismic catalogue is undertaken by the academy of Belarus and updated as necessary.

However, the PRT's hesitations to accept $PGA_H = 0.10$ g for the design basis earthquake were addressed by the comprehensive PSHA conducted by Academy of Sciences of Russia which were presented during the country visit (PSHA 2018). It reveals ground motion values of 0.10 g for the mean hazard value for the design basis earthquake with the occurrence probability of 10^{-4} per year which is acceptable to the PRT.

The review of the seismic classifications of SSCs required by the protection concept revealed that all SSCs are equally designed for $PGA_H = 0.12$ g irrespective of the fact that SSCs have functions related to different levels of defence in depth. The fact that the function of some SSCs is also required for coping with beyond design basis accidents (BDBA) is neither reflected by higher design requirements, nor have adequate margins been proved for such SSCs.

A systematic assessment of the seismic margins for all SSCs important to safety is currently not available. Although most of the SSCs required by the protection concept appear to have some or even significant margins of their seismic resistance above the DBE, pipes and pipelines of some safety systems are only resistant up to $PGA_H = 0.13$ g. The accident conditions that may arise from failure of the SSCs with the smallest seismic margin are currently unknown. The PSHA 2018 assigns occurrence probabilities of about 10^{-4} to 10^{-5} to events with $PGA_H = 0.13$ g.

The PRT therefore considers that the margin of 0.03 g is not sufficient to demonstrate the practical elimination of accidents leading to early or large releases as required in WENRA safety objectives for new reactors. The practical elimination of such accidents requires the demonstration that the

conditions leading to the accidents can be considered with a high degree of confidence to be extremely unlikely to arise. The seismic margins should be specified for all safety-relevant SSCs and their adequacy to ensure continuous safety of the plant should be confirmed, with the expectation that they confirm the practical elimination of core melt accidents that would lead to early or large releases.

To further strengthen the seismic robustness of the Belarusian NPP the PRT therefore recommends that:

- The regulator should consider the PSHA 2018 results in the beyond design basis safety evaluation of the plant and ensure the implementation of appropriate safety upgrading measures. The results of the PSHA may require an update of the protection concept with respect to seismic impacts to conform with WENRA requirements which were taken as a reference by the PRT.
- A comprehensive margin assessment on basis of the hazard curve from the PSHA and state-of-the-art fragility evaluations should be performed to justify the adequacy of margins of all SSCs with respect to the design basis and beyond for ensuring their integrity and function in accordance with their tasks in different Defence-in-Depth (DiD) levels
- 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.
- The PRT is aware of the different interpretations of the 1908 seismic event published in seismological literature and catalogues. Keeping this in mind, the PRT recommends performing a study on this seismic event to clarify its nature and completing a review of the zoning and seismic catalogues.
- Extend the number of stations of the seismic observation network to also cover the Quaternary Oshmiyansky fault.
- Provide free access to the data recorded by the seismic observation network for scientific purpose to profit from research results that better constrain the seismotectonic model for future updates of the PSHA.
- Implement the measures and actions defined in the Section 3.2.4 of the NR.

Flooding

The topography of the site of the Belarus NPP, which is located some 50 metres above the nearest river, adequately protects against river flooding and impact from dam rupture. This is regarded a strong safety feature.

The NR provides little information about the regulatory bases, technical background and the methodology used for screening and characterization of the flooding hazards, however during the country visit the necessary information has been provided.

The concept of Design Basis Flood (DBF) is not strictly used at the Belarus NPP.

Using the methodology to screen and characterize flooding hazards, the maximum flooding level corresponding to a non-exceedance probability of 10^{-4} per year has been assessed and is in line with the EU stress tests recommendations.

Groundwater rising up to lower basement level cannot be excluded, basements of buildings have been made watertight against groundwater ingress and special drainage measures have been implemented.

Nevertheless, because the PRT was not able to fully review the volumetric protection due to the current state of construction, the PRT recommends that the Regulatory Body should check that plant measures against water ingress into safety related buildings and underground galleries are robustly designed and implemented.

In case of flooding, the necessary access to the site remains ensured and mobile equipment necessary in case of severe accidents stored on the site remains accessible.

Extreme Weather

As part of the stress tests the Belarus nuclear power plants have been analysed in respect to extreme weather conditions and necessary combinations of them.

The report provides little information about the screening process for the selection of analysed extreme weather phenomena. During the country visit the necessary information was provided.

In respect to the extreme weather phenomena, the plants show a high resistance.

It was stated during the country visit that operational procedures for extreme weather conditions are under development. The PRT recommends having specific operating procedures in place before commissioning of the Belarusian NPP.

During the plant visit, the site was under construction, so the PRT could not confirm the final civil work of the site and the adequacy of the drainage arrangements. It should be ensured that the plant site can be drained via the surface by gravity (streets, catch water ditches).

Topic 2: ASSESSMENT RELATIVE TO LOSS OF ELECTRICAL POWER AND LOSS OF ULTIMATE HEAT SINK

The review of Topic 2 of the Belarussian NR concluded that the ENSREG specification developed for the EU stress tests was strictly followed in the process of assessment in the area of loss of electrical power supply and loss of ultimate heat sink. Robustness and time margins were theoretical demonstrated for all relevant accidents considered in the EU stress tests due to the diversification of the active safety systems with passive ones, big water reserves stored inside the containment and other features.

Nevertheless, the PRT concludes, that some issues regarding the safety especially under design extension conditions (DEC) need clarification and enhancement.

It has to be considered, that the design bases on Russian standards developed before the Fukushima Accident. These standards define measures supported by mobile equipment to be taken for the prevention of hazardous conditions in a case of a BDBA. The new IAEA standards especially the IAEA Specific Safety Requirement SSR 2/1, Rev. 1 "Safety of Nuclear Power Plants: Design", dealing with the new concept of design extension conditions replacing the old BDBA concept, requests for having permanent installations carrying out or supporting preventive measures under these DEC. Considering the crucial function of the JNB-50 pump for meeting the requirements for DEC, the PRT

recommends that a permanent power supply should be installed to improve the availability of the pump in SBO situation.

The PRT recommends that an alternative permanent power source to supply the necessary power in design extension conditions should be provided. This alternative AC power supply should include necessary connecting points, to protect electrical power systems against the simultaneous failure of off-site and emergency AC power supplies. This needs AC power sources that are diverse in design and are not susceptible to the events that caused the loss of on-site and off-site power sources. The necessary switching operation to connect the alternate power source should be consistent with the depletion time of the battery. Extending the battery discharge time by e.g. load shedding may also be considered. This recommendation considers international agreed and applied requirements described in Requirement 68 of the IAEA Specific Safety Requirement SSR 2/1, Rev. 1 "Safety of Nuclear Power Plants: Design".

The adequacy of margins of SSCs for beyond design basis earthquakes of the plant equipment ultimately needed for prevention of core melt should be reconsidered and the robustness of the systems increased, if necessary, based on the results of seismic PSA under preparation.

The PRT identified vulnerability in the design of JNB system. Despite the system autonomy of the passive heat removal system (PHRS) which is designed to cope with SBO scenarios the SG PHRS, the C PHRS tanks and the spent fuel pool are refilled with water using a single low -pressure pump JNB50AP001 (only 1 pump per unit is designed), transporting demineralized water coming from the LCU Tanks, which is fed by the channel 7. Owing to the importance of ensuring the functionality of SG PHRS in SBO, the PRT recommends enhancing the reliability by installing an additional redundant pump.

When an SBO event occurs during the refuelling period; specifically when the reactor is drained to the 550 mm below the main reactor flange, the heat removal is interrupted and it is only a short period before boiling in the reactor pressure vessel occurs. Time to reach the top of fuel assembly (TFU) is about 2 hours, if no countermeasures are applied. Owing to the short time period during which the power has to be recovered to restore the inventory and cooling, this has been identified as a cliff edge effect by the PRT. The PRT recommends a suitable alternative solution is implemented to ensure that restoration of water supply is achieved within necessary time to prevent core damage.

The NR considers the so called substation "Viliya" as an additional technical solution for the provision of energy supplies to safety related consumers. From this substation an additional "emergency transformer", having a capacity of 16 MVA on a voltage level 110/10 kV, will be fed as an additional source for providing energy to one safety train of both units. Since the off-site power supply is the source for energy provision on DiD level 1 and 2, the PRT recommends that analysis is undertaken to demonstrate the reliability of these off-site powers sources in seismic condition.

In the NR no information was given regarding the evidence of the efficiency and reliability of the new passive safety systems as the SG PHRS and C PHRS. During the discussion the PRT requested information based on experimental data and commissioning test in similar plants. No additional evidence was available during the review mission. Nevertheless, Gosatomnadzor stated, that comprehensive tests, proving the efficiency and functionality of new systems have to be carried out as a part of the commissioning procedure and were requested in the licensing procedure.

Topic 3: ASSESSMENT RELATIVE TO SEVERE ACCIDENT MANAGEMENT

In relation to severe accident management, the PRT makes the following recommendations for further safety enhancements of the NPP:

While it is recognized that several advanced safety features are implemented in the design, the overall concept of practical elimination of early and large releases should be more explicitly reflected in an updated plant safety case. Attention should be also devoted to the practical elimination of severe accidents in the spent fuel pool or severe accidents potentially combined with the containment by-pass (such as accident with an open containment, or uncompensated primary to secondary accidents potentially resulting in severe accident).

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 adequacy of margins of SSCs for beyond design basis earthquakes of the plant equipment ultimately needed for prevention of large releases in case of a severe accident should be reconsidered and the robustness of the systems increased, if necessary, based on the results of seismic PSA under preparation.

Further consideration should be given to the prevention and the mitigation of severe accidents under open reactor conditions, when heat exchangers of the SG PHRS system are disabled and time margin to core damage is rather short.

The implementation of a redundant make-up pump JNB 50 for the dual purpose of providing coolant to the PHRS heat exchangers and to the spent fuel pool 3 is recommended to increase reliability.

Although habitability of control areas (main control room, emergency control room) during a severe accident in combination with station black-out has been assessed in the SAR as satisfactory, it is still advised that this issue be further assessed and habitability enhanced.

In the event of NPP blackout the emergency ventilation system of the annulus is not available. Whether there is a need for the system to be in operation in the event of severe accident in combination with station blackout should be further investigated, and, if necessary, the emergency ventilation system of the containment annulus should be modified.

Noting that symptom-based emergency procedures (EOPs and SAMGs) are required before a licence to operate is granted and the challenging timescales, it is recommended that there is a clear programme of work in place to develop the symptom-based emergency procedures; to verify and validate the procedures; and to train personnel before core load.

Good Practices

Particular strengths of the Belarusian NPP include a passive residual heat removal system through the steam generators (SG PHRS) and passive system for heat removal from the containment atmosphere (PHRS C). Both systems are capable to operate passively and automatically even during station black-out conditions at least for 24 hours in the stand-alone mode. In addition, there is a core catcher capable of capture, cool down and stabilize the molten corium preventing a direct challenge to the containment boundary.

The completion of the seismic PSA is recognised by the PRT as a good practice that will inform the decision for further appropriate safety measures.

The training centre is equipped with the full scope simulator with rather unique capabilities to also simulate severe accidents, thus providing additional features for effective staff training.

The Ministry for Emergency Situations has established strong NPP fire brigade, well equipped with numerous mobile sources ready to respond to fires and other hazards at the plant. In addition, at the country level there are other necessary sources such as heavy machines and transport means available under the same Ministry to respond to severe accidents. Well-developed countrywide radiation monitoring system represents an important element for effective overall emergency response, if adequately interconnected with on-site monitoring including coordination of on-site and off-site emergency response.

The issue of potential recriticality for various configurations have been analysed in the national report. This analysis highlighted that for any possible configuration, including premature melting of the control rods in the core, there is always sufficient margin to the criticality.

The design of the main components allows a “smooth” behaviour in case of transients, especially the steam generators (greater water inventory in the horizontal steam generators compared with Western style reactor designs).

The significant effort to establish close links domestically and internationally with the designers, scientific supervisory organizations, WANO Moscow centre and other stakeholders in order to ensure long-term external support to safe operation of the NPP is commended.

Future outlook

The PRT recommends that Gosatomnadzor in accordance with the principle of "intelligent ownership", should identify the necessary safety improvements in response to the recommendations made in this report by the PRT and those by Gosatomnadzor itself, and incorporate them into a National Action Plan containing all relevant safety improvement measures and associated implementation schedules. It should also include, as appropriate, recommendations and suggestions from the review of the European Stress Tests³⁹. The NAcP should ensure timely implementation of the safety improvement measures in accordance with their safety significance. In consideration of the practice adopted by the EU MS, the PRT further recommends that the National Action Plan be subject to a future review, the approach to a meaningful review being determined by Gosatomnadzor.

³⁹ <http://www.ensreg.eu/NODE/513>

9 List of acronyms

AC	Alternating Current
BCC	Back-up Crisis Centre
BCP	Back-up Control Panel
BDB	Beyond Design Basis
BDBA	Beyond Design Basis Accident
BZOV	Demineralised water tank
CDF	Core Damage Frequency
CDFM	Conservative Deterministic Failure Margin
CSNO	Coolant System of Normal Operation
CSS	Containment Spray System
DAR	Additional emergency cooling system
DB	Design Basis
DBA	Design Basis Accident
DBE	Design Basis Earthquake
DBF	Design Basis Flood
DC	Direct Current
DG	Diesel Generator
DGS	Diesel Generator Station
DOE	Department of Energy
EC	European Commission
EDG	Emergency Diesel Generator
ENSREG	European Nuclear Safety Regulators Group
EOP	Emergency Operating Procedure
ERG	Emergency Response Guidelines
ERT	Emergency Response Team
ESWS	Essential Service Water System
EU	European Union
FSA	Fault Sequence Analysis
g	standard value of the gravitational acceleration (9,81 m/s ²)
HCLPF	High Confidence Low Probability of Failure
HPP	Hydroelectric Power Plant
IEP	Internal Emergency Plan
I&C	Instrumentation and Control
IAEA	International Atomic Energy Agency
INSC	Instrument for Nuclear Safety Cooperation
ISFSI	Independent Spent Fuel Storage Installation
LOCA	Loss of Coolant Accident
LOOP	Loss of Off-Site Power
LTE	Life Time Extension
LTO	Long Term Operation
MCC	Main Crisis Centre
MCP	Main Circulation Pump
MCR	Main Control Room
MNPP	Metsamor Nuclear Power Plant
MRZ	Russian abbreviation for the maximum design earthquake (~ Safe Shutdown)

MSK	Medvedev–Sponheuer–Karnik
NACP	National Action Plan
NPP	Nuclear Power Plant
NR	(Stress Test) National Report
PAMS	Post Accident Monitoring System
PGA	Peak Ground Acceleration
PHRS	Passive Heat Removal System
PNAE	Russian nuclear standard
PR	Peer Review
PRT	Peer Review Team
PSA	Probabilistic Safety Assessment (also known as PRA)
PSHA	Probabilistic Seismic Hazard Analysis
PSR	Periodic Safety Review
PWR	Pressurised Water Reactor
PZ	Russian abbreviation for design earthquake
RA	Republic of Armenia
RCC	Regional Crisis Centre
RCPS	Reactor Coolant Pump Set
RLE	Review Level Earthquake
SAM	Severe Accident Management
SAMG	Severe Accident Management Guideline
SAR	Safety Analysis Report
SBO	Station Blackout
SEC	Second Emergency Cooling
SFP	Spent Fuel Pool
SG	Steam Generator
SNiP	Russian civil code
SPSA	Seismic Probabilistic Risk Assessment
SSC	Structures, Systems and Components
SSEL	Safe Shutdown Equipment List
ST	Stress Test
TH	Turbine Hall
TSO	Technical Support Organization
UHS	Ultimate Heat Sink
US	United States
US NRC	United States Nuclear Regulatory Commission
VSN	Temporary Russian civil code
VVER	Water Water Energetic Reactor
WANO	World Association of Nuclear Operators
WANO MC	World Association of Nuclear Operators Moscow Centre
WENRA	Western European Nuclear Regulators Association
WOG ERG	Westinghouse Owners Group Emergency Response Guidelines