New Safety Requirements Addressing Feedback From the Fukushima Daiichi Accident

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ABSTRACT

It is well known that regulatory body activities are constantly aimed at improving the safety of the supervised nuclear facilities. These generally include amending safety requirements, implementation of licensing and periodic safety reviews (PSRs), and inspections, and this was common practice of many states prior to the Fukushima Daiichi NPP accident (hereinafter – F-D accident). The F-D accident experience has revealed a wide range of new areas for safety improvement, most of which are applicable also to research reactors (RR), especially those, subjected to extreme external events. It was proposed that the RR safety regulations should be supplemented with new safety requirements which addressed among others: increasing of the original beyond design basis accident groupings; strengthening emergency preparedness and response (EPR) infrastructure; ensuring effective communication procedures. Rostechnadzor is making improvements ranging in scope from significant to minor changes in its day-to-day processes. A number of amendments to the regulatory framework have already been made or are in progress, including requirements for PSRs. There is a need to improve arrangements on emergency exercises, which so far have involved preferably local emergency services with minimal involvement of external response organizations. The supplementary safety assessments based on lessons learned from the F-D accident showed the need to strengthen role and capabilities of the regulatory body in EPR, and this has been done as a part of the overall improvement of EPR system at the national level. It has also been recognized that application of the graded approach to safety and safety assessments is reasonable and appropriate, but there is a need in practical guidance on grading performance. The main aspect of using the graded approach in safety requirements is the classification process for reactors, systems, structures and components (SSCs), facility modifications, and procedures. The paper will focus on new safety requirements for research reactors in the regulatory framework of the Russian Federation, which have been developed in consistence with the provisions of the Code of Conduct on the Safety of Research Reactors and the IAEA Safety Report Series No. 80 (SRS-80).

1. Introduction

In the Russian Federation the key areas important for strengthening the national nuclear regulatory framework in light of the lessons learned from the accident at the Fukushima Daiichi nuclear power plant (the F-D accident) were addressed through implementation of the IAEA Action Plan [1], Action Programme of Russian Authorities and Organizations [2], and Rostechnadzor[1] Action Plan [3] that has been implemented not only for nuclear power plants but also for safety enhancement of ***nuclear research facilities (NRF)***. Following a good international practice the Russian Federation has performed supplementary safety assessment (reassessment) of NRF safety. The main results of Rostechnadzor review of NRF safety reassessments, including the regulatory aspects were reported earlier to the international society of research reactors [4-6]. Moreover, the IAEA summarized the international experiences in Safety Reports Series № 80 [7], which defines that the F-D accident experience has revealed a wide range of areas for safety improvement applicable to research reactors. In a global manner the survey of safety enhancements resulting from the research reactor safety reassessments was given in [8].

[1]The Federal Environmental, Industrial and Nuclear Supervision Service (Rostechnadzor) is the state regulatory authority in the field of atomic energy use in accordance with international conventions.

This paper focuses on improving of the regulatory framework in the Russian Federation. In light of feedback from the F-D accident the relevant regulatory aspects of the NRF safety were addressed to:

- reviewing reports of the NRF safety reassessments performed by operating organizations in compliance with a programme of State Corporation "Rosatom" for the most powerful facilities and a programme of Rostechnadzor for all other NRFs and its spent fuel storages;
- revision and updating of NRF safety requirements, development of new safety regulation on arrangements for notification, prompt information transfer in emergency situation at NRF;
- revision of licensing procedures, licensing conditions for NRF siting and operation, updating of licensing conditions for NRFs in operation;
- improvement of ***Emergency Preparedness and Response (EPR)*** including development of Rostechnadzor ***Information and Analysis Centre (IAC)*** and emergency exercises on its basis, implementation the concept of ***technical support center (emergency center)*** in organizations operating NRFs.

It has been recognized that there is a need to clarify the safety reference basis for "***test reactors" ("small modular reactors" - SMR)*** in future regulatory activities.

2. Feedback from Reassessments of the Research Reactors Safety in the Russian Federation

The International Conference, held 11-15 April 2016 in Vienna, Austria, summarized the general observations after the F-D accident, as well as the challenges faced by regulatory bodies in the world. It stressed the following observations, challenges and considerations for maintaining a high level of safety and security:

- continued use of facilities will require sustaining improvements globally;
- need to sustain strong regulatory systems in order to maintain nuclear safety and security, and public trust;
- need to harmonize national regulatory requirements with the IAEA safety standards;
- need to encourage research on ageing to support the licensing;
- need to improve the interface between nuclear safety and nuclear security;
- need to develop an integrated management system to promote safety culture.

The International Conference, held 19–23 October 2015 in Vienna, Austria, provides recommendations on actions to be implemented by regulators, operators, and national organizations for continuing improvements of EPR including lessons learned from the F-D accident. It stressed the need for strengthening EPR infrastructure, including effective communication procedures and management of interface between safety and security.

Rostehnadzor reviewed the supplementary NRF safety reassessments based on the international activities (stress tests) and the national programmes of the supplementary NRF safety assessment. Most facilities did not identify a need for updating, but the results of the safety reassessments revealed recent progress in the NRF safety improvement. Moreover, a need in additional mobile equipment at some NRFs was identified (for example, at site of JSC «SSC RIAR»).

The Rostechnadzor review highlights the following general observations:

- the existing safety requirements provide a high level of NRF nuclear safety;
- Rostechnadzor revealed no significant areas of weakness in safety regulations and confirmed that the existing safety requirements generally cover the lessons learned from the F-D accident;
- a small set of amendments were proposed to strengthen safety assessment taken into account research reactors with potential core damage (melting) and off-site consequences.

Reviewing of safety reassessments shows that in many cases facility blackout including emergency electric power supplies has not been assessed. The loss of off-site electrical power supply was analyzed when backup an electrical power supply system was available. For some NRFs of high hazard categories, the safety analysis should be expanded for a prolonged and total loss of electrical power supply (off-site, diesel generators, batteries) that will lead to the loss of forced cooling of the core as well as to the loss of the controlling parameters. So, additional safety requirements should be implemented to provide operation of systems important to safety in case of blackout by means of emergency mobile power supply (diesel generators) or highly reliable back-up batteries).

Revision of NRF EPR shows that there is a need to review organizational aspects including the role and responsibility for taking decisions, the communication with off-site authorities and technical support organizations, and the role of the regulatory body in case of emergency.

3. Update of Safety Requirements. New Safety Regulation

One of the main functions of Rostechnadzor is implementation of the state policy in the field of nuclear and radiation safety and development of regulations for nuclear and radiation safety, nuclear and radioactive material accounting and control, and their physical protection. Rostechnadzor developed the draft of concept of improvement of safety regulation [9]. In this regard, self-assessment of status of regulatory framework is key to sustaining improvements to maintain a reasonably practical and achievable level of NRF safety and security in a timely manner.

Although the NRF safety reassessments did not identify any significant areas of weakness in safety requirements, it has revealed areas for updating and implementation of new safety requirements. Feedback from operator's safety reassessments has demonstrated the needs to ensure the following updates in existing safety requirements:
Design requirements:

- expand groups of beyond design basis accidents (BDBAs, in SSR-3 [10] the concept BDBA is replaced by concept design extension conditions - DEC),
- consider combination of natural hazards;
- updating seismic analyses,

EPR requirements:

- harmonization between the existing safety regulations for incident/accident investigation, planning of emergency protection of the NRF personnel.

Moreover, a need to develop a new regulation on announcement and communication in emergency has been revealed.

The survey of major amendments in the safety requirements and new safety regulation is given below in shortly manner.

In the Russian Federation the general safety objectives, principles, criteria and safety requirements for NRFs are established in the safety regulation "General NRF Safety Regulations", (NP-033-11). The regulation is mandatory for all types of research reactors, critical, subcritical stands, and accelerator driven systems (ADS).

The specific safety requirements for specific type of facility are reflected in the following nuclear safety regulations:

- Rules on Nuclear Safety of Research Reactors (NP-009-17);
- Rules on Nuclear Safety of Critical Stands (NP-008-16);
- Rules on Nuclear Safety of Subcritical Stands (NP-059-05);
- Rules on Nuclear Safety of Pulse Reactors (NP-048-03).

The listed safety regulations include the core design, structures, systems and components (SSC) important to safety, extent of the cooling requirements, structures for confining radioactive substances, handling with nuclear fuel and materials, requirements to experimental facilities and works, requirements to management system and personnel responsibility.

The specific "Rules on Nuclear Safety" might be developed for the other types of NRFs if needed. For example, it was discussed a reasonability of specific nuclear safety regulation for homogeneous solution reactors, as well as for the ADS facilities.

In addition to the mentioned above, the safety reference basis of NRFs includes the following specific regulations:

- Requirements to the Content of NRF Safety Analysis Report (NP-049-03);
- Provisions on Investigation and Reporting on Anticipated Operational Occurrences and Accident at NRFs (NP-027-10);
- Requirements to the Action Plan for Personnel Protection in Emergency at NRF (NP-075-06);
- Periodic Safety Review of NRF (NP-092-14);
- Safety Rules on Decommissioning of NRFs (NP-028-17).

The relevant feedback from the F-D accident was taken into account as it is shown below. The measure of defence-in-depth and improvements of the capabilities to withstand beyond design events were revised.

The revision NP-009-04 → NP-009-17 (put in force in 2017). The additional/updated safety requirements have been implemented to:

- Clarification of the external impacts:
  - ✓ all ***specific for the research reactor site external impacts*** of natural origin and human induced shall be taken into consideration ***(updated)***;
  - ✓ the design and operational documentations shall include analysis of response of important to safety systems on internal and external impacts of natural origin and human induced ***taking into account their combination along with the impact of other interdependent processes (new)***.
- Obligatory reviewing of BDBAs (DEC):
  - ✓ the design and operational documentation shall include the list of initial events of design basis accidents (DBAs) and a list of BDBAs ***(including research reactor blackout, loss of ultimate heat sink, the aircraft crash)***, as

well as the results of DBAs and BDBAs analysis and their consequences ***(new)***;

- Emergency electrical power supply:
  - ✓ the reactor design shall provide the technical means for ensuring reactor nuclear safety including ***(updated)***:
    - ***redundant power supply*** of systems and elements used for planned shutdown and subsequent cooling of the reactor core in case of failure of the main (working) electric power supply;
    - ***emergency electrical power supply***, providing operation at least two channels of the reactor power level control, work of the position indicators of control rods, the temperature control of the reactor core and spent fuel storage, emergency cooling of the reactor core, and operation of the supplementary control room while emergency.
- Cooling of the reactor core:
  - ✓ the design shall provide as much as possible for type of reactor ***the natural circulation of coolant*** when an emergency cooling regime happened ***(new)***.

The revision NP-008-04 → NP-008-16 (put in force in 2016). The additional/updated safety requirements have been implemented to:

- Clarification of the external impacts:
  - ✓ all ***specific for the NRF site external impacts*** of natural origin and human induced shall be taken into consideration ***(updated)***;
  - ✓ the design (operational documentation) shall include analysis of response of the control and other systems important to safety on ***combined impact of natural origin and human induced factors*** specific for site of the critical stand ***(new).***

The revision NP-049-03 → NP-049-XX (in progress)**.** The safety regulation defines the scope and content of information that should be submitted in SAR NRF, including the features of initial design, results of modifications, current state of SSC, results of an adjustment and testing of systems, the component examinations, results of facility criticality and power starting-up, the changes of the design, a management programme, safety analysis of DBA and BDBA (DEC) and other. This safety regulation extends for all NRFs. The draft is based on experience accumulated at national level and the IAEA safety recommendations [10, 11].

The additional/updated safety requirements concern analysis of extreme external events, their impact, their combination and consequential events including:

- values of seismic impact requiring facility scram ***(new)***;
- response of the SSC ***to impact of combination*** of external natural and human induced origin events specified for facility site ***(updated)***:
- ***expanded list*** of initial events of DBAs and expanded groups of BDBA (DEC) ***(updated)***:
- accidents involving unauthorized insertion of positive reactivity due to the superposition of a number of human errors or hardware failures causing ***core damage*** and fuel melting ***(updated)***;
- accident in which initial event of DBA is accompanied by a complete failure of reactor safety system and accompanied by failure of any one element of confining system or human error in control of this system ***(updated)***;

- loss of off-site power accompanied by failure of any one element of confining system or human error in control of this system (***updated***);
- facility ***blackout*** including emergency power supplies ***(new)***;
- loss of coolant accompanied by failure of one element of confining system or human error in control of this system ***(updated)***;
- loss of ultimate heat sink ***(new)***;
- accident caused by the simultaneous effect of ***several external factors of maximum values (new)***;
- accidents caused by the ***personnel inability*** to implement emergency measures during the initial events of DBA ***(new)***;
- description of systems and components including a special technical equipment (means) using to mitigate emergency in BDBA ***(new)***;
- description of ***ageing management programme (new)***;
- results of ***periodic safety review (new)***.

At present the application of a graded approach for different type of NRFs (research reactors, pulse research reactors, critical stands, subcritical stands ect.) in the NP-049-XX is being discussed.

The revision NP-075-04 → NP-075-XX (in progress)**.** The safety regulation applied to all type of NRFs during commissioning, operation or decommissioning. The action plan for personnel protection shall be agreed by all stakeholders responsible for NRF EPR. Action plan for personnel protection shall be implemented for each NRF at the site and shall be coordinated with action plan for protection of the population.

The additional/updated safety requirements concern:

- calculation of the size of the emergency planning zone ***(new)***;
- criteria to identify scenarios "Emergency preparedness" and "Emergency situation" ***(updated)***;
- templates of information (tables, forms ect.) that should be implemented in emergency ***(new)***;
- plan of emergency planning zone ***(updated)***;
- communication with technical support structure at the site in emergency ***(updated)***;
- managing the ***interface between safety and security(new)***.

New NP-XXX-XX "Provision on Arrangements for Notification, Prompt Information Transfer in Emergency Situation at NRF" (in progress). The draft of safety regulation is developed based on national legislation taking into account the IAEA recommendations [12, 13] and includes the following safety requirements:

- criteria for notification "Emergency preparedness" and "Emergency";
- requirements for operation of technical support center (emergency center) and its functions;
- requirements for prompt notification and information transfer in emergency situation including:
  - ✓ classification the emergency within 15 minutes and notification local authorities within 15 minutes after classification;
  - ✓ procedures determined communication and information exchange with notification point and mass media,
- requirements for urgent assistance to NRF personnel in emergency situation;

- management between safety and security.

For the safety regulation ***NP-092-14*** (put in force in 2014) revision is planned in compliance with the IAEA Specific Safety Guide № SSG-25 [14]. The safety regulation applied to all type of NRF.

The revision NP-028-01 → NP-028-16 (put in force in 2017) was done in compliance with the IAEA Safety Standards GSR Part 6 [15]. The safety regulation is applied to all types of NRFs and takes into account requirements to ensure safety in decommissioning that shall be implemented at stages of facility siting, construction, commissioning and operation.

4. Improvements of Licensing Procedures and Licensing Conditions

The F-D accident happened at the licensed facility, and it highlights challenges in licensing system. Licensing of activities at a nuclear facility is one of the principal functions of a regulatory system. The licensing process stipulates implementation of conditions providing proper level of safety and security. The improvement of licensing procedures is on-going process relevant to changes of legislation. The self assessment of the regulatory activity did not find out any gaps in licensing procedures for NRFs. The main regulatory observation of licensing at the stage of siting activity was found out the absence of safety regulations for NRF siting as well as requirements for content of NRF feasibility study report in the Russian Federation.

The licensing conditions (validity conditions) are an integral part of the licence. General requirements to the structure and contents of licensing conditions were included in Administrative Regulations [16]. Licensing conditions for NRF in operation include details of activity time period, current restrictions of activity, additional requirements in the framework of national legislation and regulations, related to:

- safety reference level (including SAR, technical specifications, technical regulations and operating instruction, quality assurance programmes, plan for personnel protection in emergency);
- nuclear and radiation safety;
- accounting and control of nuclear material, radioactive substances and radioactive waste;
- insuring physical protection.

The revision of the licensing conditions for NRFs in operation did not highlighted any gaps, but identified a need ***to add procedures for announcement of the resident inspectorate*** about planning and performing of nuclear hazardous and other specific work important to safety.

In addition to the requirements mentioned above, in the licensing conditions for the critical stands the operating organization shall timely inform Rostechnadzor's region inspectorate about the physical start-up after facility modification.

The challenges faced by regulatory body are directed to implementation of the methodology of a grade approach application taking into account different factors which impact on NRF potential hazard.

5. Strengthening of Rostechnadzor's System for Control Over NRFs in Emergency

Based on the mandate, Rostechnadzor plays a key role in the regulatory framework and overseeing for adequate emergency management within the Unified System for Prevention and Management of Emergencies. Rostechnadzor should ensure control over nuclear facilities in case of an accident. As a feedback from the F-D accident the following actions to improve Rostechnadzor EPR role in compliance with the IAEA recommendations [13] are in progress:

- harmonization of the existing hazard categorization of facilities, established by national regulations, with the emergency preparedness categorization for facilities and activities (this issue concerns the changes of mature Russian system for categorization of radiation objects and currently is not supported by responsible authorities of the Russian Federation);
- harmonization of emergency notification timing;
- the criteria for announcement of "Emergency preparedness" and "Emergency situation".

Rostechnadzor has its own IAC. To improve data exchange between Rostechnadzor and State Corporation "Rosatom" in case of emergencies at facilities the agreement on information exchange was signed (2014) and administrative regulations for information exchange between the Crisis Center of SC "Rosatom" (CC of Rosatom) and the IAC of Rostechnadzor has been agreed on (2017). The fast speed fiber-optic channel has been set up between the IAC of Rostechnadzor and the CC of Rosatom.

The emergency exercises at NRFs are considered in the action plan of the IAC. Data automatic transfer systems, video-conferencing systems, models and computer codes for express-assessments should be developed.

The webinars between Rostechnadzor Headquarter and Rostechnadzor's Region Offices are regularly carrying out since 2016 to discuss observations, challenges and considerations for improvement of regulatory activities.

6. Safety Requirements for Test Reactors

The Government of the Russian Federation approved (2010) the Federal Target Programme (FTP) "New Generation Nuclear Power Technologies in 2010-2015 and up to 2020" that envisage development of new technologies and construction of the reactors to demonstrate closed nuclear fuel cycle for new generation of nuclear power plants. In accordance with the FTP two new projects of "test reactors" (SMR) are in progress at present in the Russian Federation:

- Innovative project of experimental-demonstration complex consists of fast reactor BREST-OD-300 with lead coolant, electric power 300 MW, module for fabrication of mixed uranium-plutonium fuel, and module for processing spent nuclear fuel.

- Innovative project of experimental-demonstration complex SVBR-100 consists of fast reactor with lead-bismuth coolant, electric power 100 MW. The SVBR project reflects intention to use submarine reactors technology for nuclear power industry and currently is under design.

The mentioned above test reactors will use equipment for generation of heating and electricity to demonstrate abilities of new technologies for implementation at the nuclear power plants of new generation. There are some other examples of new test reactors.

These facilities do not meet safety requirements for NPPs, because they use new technologies and non-approved equipment. From the other hand the IAEA does not extend the research reactor safety standards and regulations to such type of facilities. Moreover, neither the Convention on Nuclear Safety nor the Code of Conduct on the Safety of Research Reactors do not cover the facilities like “test reactors” (SMR).

In light of the lessons learned from F-D accident, the future new reactor projects should prevent the occurrence of accidents involving a large release of radioactive material. If the IAEA safety standards and regulations are the global reference for achieving a highest level of safety these documents must clarify, which international legal instruments on nuclear safety (the Convention on Nuclear Safety, the Code of Conduct on the Safety of Research Reactors, etc.) should be applied for safety assessment and regulation of the “test reactors”.

in past in the Russian Federation applied a graded approach in licensing of demonstration facilities that implemented heating and electricity generation. Among them “The First in the World NPP” (now it is research reactor “AM-1, 5 MW, in decommissioning), demonstration boiling reactor BK-50 (200 MW, in operation), test fast reactor BOR-60 (60 MW, in operation), and multipurpose fast research reactor MBIR (100 MW, in commissioning).

In light of the lessons learned from F-D accident the preventive actions should be made for future new projects.

7. Conclusion

Post F-D accident general observation shows that challenge faced by regulatory body in the Russian Federation and the issues for future consideration ongoing as following:

- categorization of the NRFs including “test reactors”(“small modular reactors”);
- improvement of methodology for implementation of a graded approach to enhance efficiency of safety regulation (safety assessment, licensing, inspection, EPR of NRFs);
- clarification of safety reference for test reactors.

8. References

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