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ON THE NECESSITY TO ENHANCE GENERAL SAFETY REQUIREMENTS FOR NUCLEAR POWER PLANTS

Based on the lessons learned of the accident at Fukushima Daiichi nuclear power plant it is proposed to enhance the General Safety Requirements for Nuclear Power Plants in Ukraine concerning the classification of emergencies, deterministic vs. probabilistic safety criteria, and requirements to computer modeling tools and guidelines for severe accident management.

Keywords: safety, general requirements, nuclear power station, emergency.

According to recommendations of IAEA and leading nuclear countries regulating authorities Ukrainian NPP service providers (National Nuclear Energy Generating Company of Ukraine "Energoatom" (NNEGC "Energoatom") and State Nuclear Regulatory Inspectorate of Ukraine (SNRI)) developed a Plan for further improvement of nuclear power safety considering lessons of heavy emergency at Fukushima Daiichi NPP (further on — the Plan). The first short-term phase of the Plan was carrying out of stress-tests for safety analysis [1] with main goal to determine additional actions for the Complex (composite) program for safety increase (CxPSIU-2010) considering lessons and conclusions of the heavy emergency at Fukushima Daiichi NPP.

One of the important focus areas of the Plan in [1] was determined as the necessity for re-considering the legal and technical guidelines that regulate NPP safety. During the Plan implementation in 2013 a draft for fundamental legal document "General requirements for nuclear power stations safety" (GRS) was developed to replace the "General statements on nuclear power stations safety" (GSS-2008) [2]. The importance and fundamental level of these legal documents determine active dialogue and many proposals on their improvement.

Further we propose our commentaries to different statements of the GRS which are not justified enough or are contradictory considering lessons of Fukushima emergency.

Terminology for the emergencies. The GRS draft introduces a term of 'emergency with multiple failures' (practically replacing 'beyond-design emergency' term of GSS-2008) which is determined as an emergency with additional (comparing to design emergencies) system failures and staff faults.

Concerning such approach to emergency classification it is necessary to stress the following:

1. The terms 'design emergency' and 'emergency with multiple failures' practically do not 'cover' a group of emergencies with beyond-design initial events but without 'multiple failures'. E. g. Fukushima Daiichi NPP emergency [3] was a result of a beyond-design earthquake (with magnitude of about 9 in the epicenter) and tsunami (about 15 m high at the coast) which were not foreseen by the power units design (a beyond-design initial event). Due to multiple flaws in the power units design it lead to 'multiple failures'. But we can imagine a better situation — due to a beyond-design initial events (not foreseen by the design) a single failure takes place that would be specific to design emergencies.

2. On the other hand, the development experience of guidelines / instructions on control and liquidation of the emergencies shows [3] that the algorithms of design and beyond-design emergencies control are almost identical (in case no critical safety functions failure cause nuclear fuel damage). Therefore it is more efficient to classify the emergencies in two groups: emergencies without nuclear fuel damage and heavy emergencies with nuclear fuel damage.

The boundary condition for these two emergencies groups are system failures (including staff faults) that provide critical safety function to prevent nuclear fuel damage.

Probability criteria for the safety. The GRS draft 'preserved' the probability criterion-based approach to regulating nuclear safety accepted in GSS-2008 [2]:

heavy emergencies frequency is $<10^{-4}...10^{-5}$ year^{-1};

maximal emergency radiation release frequency is $<10^{-6}...10^{-7}$ year^{-1}.

Such approach corresponds to generally-accepted world practice of nuclear regulation in 'pre-Fukushima' period. However, it contradicts to lessons of Fukushima Daiichi NPP emergency:

1) all the power units corresponded to such safety criteria until the emergency (including justification on prolongation of the power units operation period a month before the emergency);

2) the emergency events and their sequence didn't violate conditions of safety probability criteria.

I. e. Fukushima emergency lessons revealed that probability indexes of heavy emergencies and maximal radioactive release cannot be the basic safety criteria. The priority should be given to alternative deterministic criteria which should more adequately reflect the nuclear power units safety state.

Sufficient qualification of the equipment, systems, constructions in conditions of emergency situations and emergencies may be proposed as one of such deterministic safety criteria. The qualification means justification of operability and / or reliability of carrying out the designated functions by experimental and calculation methods.

We should stress that even in 'pre-Fukushima' period IAEA developed and recommended guidelines on implementing programs for equipment and systems qualification (including 'hard' operation conditions).

The measures on qualification of equipment and systems of PWR are successfully implemented in Ukraine. That is why introduction of qualification safety criterion into the GRS does not require development of new programs and guidelines. On the other hand it is a deterministic alternative to probability criteria which is insufficient for safety estimate.

Efficiency of qualification safety criterion may be hypothetically demonstrated on example of Fukushima emergency. It is known that one of the main reasons for complete loss of stationary electric supply at emergency power units (initial event for heavy emergencies) was flooding of diesel-generators at lower levels of turbine rooms through trenches of cabling and pipeline [3]. In case the before-the-fact and thorough qualification of the buildings for the 'hard' flooding conditions had been made and corresponding compensating measures taken, then the heavy emergency might had never happened and wouldn't cause catastrophic environmental consequences.

Safety analysis requirements. The GRS draft determines the requirements to safety analysis methods and approval of the used means. Concerning this a note should be made:

1. Legislation document of such level, in our opinion, should not specify the methods for safety analysis, which are constantly being improved and expanded. Particularly one of the reasons for wide application of probability safety analysis methods is caused by limited possibilities of deterministic methods. However, contemporary scientific-and-technical development of methodological basis and computing technologies improvement may lead in future to full dominance of deterministic methods for safety analysis.

2. There are no sufficiently justified and reliable criteria for approval of software for modeling the emergency processes. E. g. at present due to "Fukushima events" numerical qualification of equipment and systems sustainability during beyond-design seismic events became more actively developed based on contemporary software. Its guidelines may differ from 'obsolete' but current norms for sustainability estimation [4].

The same situation arises for so-called code of heat-and-hydraulics and neutron physics methods [5].

Such situation may lead to subjectivity of the software approval by SNRI experts, and inadmissible consequences at safety regulation: hidden 'backstairs influence', interdependence of regulating and operating organizations, etc. We should remind, that Japanese government officially stated (not justified enough in our opinion) that one of the main specific causes of the heavy emergency at Fukushima Daiichi NPP was absence of necessary independence between regulating and operating organizations of TEPCO [3].

Therefore we consider the statements of GRS concerning specific methods of safety analysis and approval of software to be inappropriate.

The requirements of GRS should reflect the necessity of adaptation, verification, validation of the software used and analysis of uncertainties of numerical modeling to the safety analysis reports and / or technical safety justification.

Requirements for guidelines on heavy emergencies control. The root reasons for heavy emergencies at Fukushima Daiichi NPP were flaws in power units design in determination of relatively low-probability beyond-design events and also insufficient readiness of the staff to controls such emergencies. That is why IAEA recommendations, committees of European authorities and stress-tests results [1] pay a special attention to necessity of adequate guidelines on heavy emergencies control (GHEC) development.

The major GRS draft demand to GHEC is the necessity of considering all potential sources of radioactive release and influence of extreme external events. To some extent these requirements consider lessons of Fukushima disaster: the GHEC known in 'pre-Fukushima' period were generally oriented at internal and external (considering the reactor shell) phases of the heavy emergencies. But the measures on control of heavy emergencies, e. g. in cooling pool for 'fresh' spent nuclear fuels were either not prescribed, either were insufficiently considered. Also not enough attention has been paid to organizing control of heavy emergencies under extreme environmental conditions like during heavy emergency at Fukushima Daiichi NPP [3].

However, the lessons of Fukushima emergency in our opinion must determine other fundamental requirements to GHEC which should determine efficient strategies of heavy emergencies control (SHEC) considering initial emergency events and current state, accessibility and working capacity of the systems providing control for:

prevention of safety protection barriers destruction;

stabilizing and returning under control the fuel-containing masses (FCM).

The native GHEC projects (e. g. see [3]) determine SHEC as measures on prevention of separate effects of heavy emergencies (e. g. “pressure reduction in hermetic volume”, “cooling of the damaged fuel”, “prevention of hydrogen explosion” etc.). Such approach has obvious limitations, because it is inadmissible e. g. to implement pressure reduction strategy without cooling of the FCM and / or prevention of the steam-and-gas explosions. SHEC must implement all the array of efficient measures to reach the main goal: to prevent destruction of the protective safety barriers and stabilization of FCM. The list of SHEC must be mainly determined by the history of heavy emergency and access and work capacities of the critical safety function systems.

Conclusions

Considering the Fukushima Daiichi emergency lessons in the new version of General requirements for nuclear power stations safety we propose:

1. Classification of emergencies into two groups: emergencies without nuclear fuel damage; heavy emergencies with nuclear fuel damage.

The boundary condition for these two emergencies groups are system failures (including staff faults) that provide critical safety function to prevent nuclear fuel damage.

2. In addition to probability safety criteria, the deterministic safety criteria of sufficient equipment, systems qualification in conditions of emergency situations and emergencies (qualification safety criteria) must be applied.

3. Specification of methods and software for safety analysis are inappropriate. The requirements should reflect only necessity for their verification, validation and analysis of uncertainties in the numerical modeling.

4. Additional requirements for guidelines on heavy emergencies control should determine the necessity for efficient heavy emergencies controls strategies considering initial events and also access and work capacity of the system that enables control of emergency processes to prevent destruction of safety barriers and stabilizing the fuel-containing masses.

List of references

1. National report on results of implementation of the “stress tests” / State Nuclear Regulatory Inspectorate of Ukraine. — 2012. (Russian)
2. *NP 306.2.141-2008*. General statements on nuclear power stations safety (GSS-2008). (Ukrainian)
3. *Skalozubov V. I.* Analysis of reasons and consequences of accident at Fukushima NPP as a factor of prevention of severe accidents at tank reactors. / V. I. Skalozubov, A. A. Klyuchnykov, V. N. Vascshenko, S. S. Yarovoy. — Chernobyl : Institute for Safety Problems of Nuclear Power Plants of Ukraine, 2012. — 280 p. (Russian)
4. Rules and norms in nuclear power-7-002-86. Norms of calculation of equipment and pipelines durability. (Russian)
5. *Skalozubov V. I.* Basis for control of beyond-design emergencies at NPPs with PWR / V. I. Skalozubov, A. A. Klyuchnykov, V. N. Kolykhanov. — Chornobyl : Institute for Safety Problems of Nuclear Power Plants of Ukraine, 2010. — 400 p. (Russian)

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