REASSESSMENT OF NUCLEAR POWER SAFETY IN VIEW OF LESSONS OF FUKUSHIMA-DAIICHI ACCIDENT

Head of Department of NPPs Safety Analysis of Institute for Safety Problems of Nuclear Power Plants of National Academy of Sciences of Ukraine

Head of Branch of NPP Chair of National Academy of Sciences of Ukraine, Doctor of Engineering, Professor

Skalozubov Vladimir Ivanovich

The main directions

The main directions of reassessment of nuclear power safety in view of lessons of FUKUSHIMA-DAIICHI accident.

- 1. Recommendations of IAEA and requirements of European regulators in regard to reassessment of nuclear power safety in view of lessons of FUKUSHIMA-DAIICHI accident.

  Basic lesson: review of the relationship to the rare events.

- 2. The Ukrainian stress tests on the safety reassessment have used not well founded methodological support in case of joint impact of external extreme effects.

Projects proposed in 2016 on «REASSESSMENT OF NUCLEAR POWER SAFETY IN VIEW OF LESSONS OF FUKUSHIMA-DAIICHI ACCIDENT»

1. Improved methods to substantiate severe accident management strategies in view of lessons of FUKUSHIMA-DAIICHI accident.
2. Independent analysis of possibility of flooding of NPP sites and storages of spent nuclear fuel affected joint extreme natural phenomena in view of lessons of FUKUSHIMA-DAIICHI accident.
3. Enhanced diagnostics of fuel assembly state of PWRs/VVERs.
4. Optimization of tests of the NPP safety related systems by using non-PSA methods.

Improved methods to substantiate severe accident management strategies in view of lessons of FUKUSHIMA-DAIICHI accident

Some lessons of Fukushima-Daiichi accident:

- Lack of attention to the rare accident events,
- Lack of effectiveness of current strategies for the prevention and management of severe accidents,
- Multiple failures (including passive safety systems and control systems),
- Lack of attention to risk of steam explosions.
- Lack of analysis of the possibility to use the "non design" nuclear fuel (MOX-fuel, Unit 3).

Objective of Project

To develop and improve the methods to substantiate severe accident management strategies taking into account the lessons of the accident at NPP Fukushima-Daiichi.

Main Tasks

- To analyse the draft severe accidents management guidelines (SAMG) for VVER taking into account the lessons of the accident at the NPP Fukushima-Daiichi.
- To develop symptom-informed method to form effective SAMGs for PWR.
- To develop a thermodynamic method to determine conditions for the occurrence of steam and gas explosions during severe accidents.
- To develop criteria based method of express analysing of nuclear safety for reactors with the "non design" nuclear fuel.

Expected Results

- Improved methodology of VVER SAMGs to form effective strategies of severe accident management based on symptom-informed approach.
- The effective strategy to prevent steam and gas explosions during severe accidents in reactors and containments.
- The criteria based method of express analysing of nuclear safety will allow to solve the following problems:
  - To assess operatively the restrictions of using of "non design" nuclear fuel;
  - To reduce significantly the scope of computational modelling and analysis of accident processes.

Independent analysis of possibility of flooding of NPP sites and storages of spent nuclear fuel affected joint extreme natural phenomena in view of lessons of FUKUSHIMA-DAIICHI accident

Substantiation of Project

Flooding of Fukushima-Daiichi site by a tsunami caused beyond design basis earthquake (MSK magnitude 9 at the epicentrum) was an initial event of Fukushima accident in March 2011.

Under the IAEA aegis nuclear states came to an unambiguous conclusion about need to revalue ecological safety of all operating and designing NPPs taking into account extreme natural phenomena.

During the "post-Fukushima" period, the operator of Ukrainian NPPs (NNEGC "Energoatom") and State Nuclear Regulatory Inspectorate of Ukraine (SNRIU) developed and accepted to implementation the improvement plan for NPP safety taking into account lessons of Fukushima-Daiichi accident.

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Institute for Safety Problems of Nuclear Power Plants

The stress tests on safety revaluation were the first step of plan implementation. These tests did not reveal possibility of flooding of Ukrainian NPP sites affected by extreme natural phenomena. However, procedures of stress tests did not consider dynamic nature of flooding at NPP sites and joint impact of beyond design basis extreme natural phenomena over water volumes near the plant.

Thus, the independent (from the operating and regulating organizations) expert assessment of possibility of flooding of NPP sites taking into account joint influence of beyond design basis extreme natural phenomena is actual.

Main Objective and Tasks of Project

The main objective of the project consists in an independent expert assessment of possibility of flooding of NPP sites under the joint exposure of beyond design basis extreme natural phenomena and development of practical recommendations to improve ecological safety of nuclear power engineering.

The project is performed according to recommendations of IAEA and the European union of regulators of nuclear and radiation safety (WENRA).

Main objectives of the project are:

a) To collect, to analyse and to systematize geophysical and constructional and technical data to model possible flooding of an NPP site under the joint exposure of beyond design basis extreme natural phenomena (the pilot NPP as an example),

b) To develop a methodology for hydrodynamic modelling of flooding of an NPP site under the joint exposure of beyond design basis extreme natural phenomena and "hard" external conditions,

c) To verify hydrodynamic model of flooding of an NPP site using information about Fukushima-Daiichi accident in 2011,

d) To analyse results of deterministic modelling of flooding of a pilot NPP site under the joint exposure of beyond design basis extreme natural phenomena,

e) To substantiate practical recommendations about improving of ecological safety of nuclear power engineering under beyond design basis extreme natural phenomena.

Enhanced diagnostics of fuel assembly state of PWRs/VVERs

Substantiation and Relevance

The phenomenon of thermoacoustic instability (TAI) of the coolant is connected with appearance of the high-frequency (meet the propagation velocity of acoustic disturbances) high-amplitude (up to 50% of stationary values) self-oscillatory modes.

A two-phase flow with essential non-equilibrium is necessary condition of appearance of TAI into the heat equipment (for example, a surface boiling of the subcooled coolant following by intensive steam condensation in a "cold" flow).

The phenomenon of TAI is known for a long time in the general heat engineering (the early pilot studies were conducted in the middle of last century), however possibility of appearance of the coolant TAI in reactors was not considered in nuclear power. The basic reasons of this are following.

1. The technical substantiations of reactor designs have not included methodical bases of definition of conditions and boundaries of appearance of the coolant TAI in the reactor core.
2. The engineering designs of reactors have not included corresponding diagnostic systems of the coolant state concerning TAI. Implementation of additional control systems for diagnostics of TAI in the reactor (for example, high-sensitivity sensors of pressure pulsations of the coolant) was always limited by obvious reasons. Implementation of systems of noise diagnostics allows to solve problems of diagnostics of TAI of the coolant in principle, but also has certain restrictions (for example, to enhance the signals "responsibling" for TAI from a noise spectrum).

At the same time diagnostics of TAI of the coolant in reactors WWER, PWR is the extremely actual due to the following basic reasons.

1. The pressurized reactors like WWER, PWR are able to realise the necessary conditions of TAI in transitional (start-up/shutdown) or emergency operation – surface "boiling" of the subcooled coolant.
2. High-frequency and high-amplitude pressure fluctuations of the coolant provided TAI lead to considerable cyclic loads on fuel claddings in the reactor core and consequently to inadmissible for safety damages. So, for the long-term operation of power units with WWER the damages of fuel claddings that are relevant for external cyclic loads were revealed during fuel loadings. Of course, it is impossible to claim unambiguously that TAI of the coolant was the cause of these damages, but to exclude its influence there are no sufficient bases.

Thus, to develop and implement of the on-line diagnostic system of TAI in the reactor core is the topical problem for WWER, PWR. This system has to define a reactor state concerning TAI and to carry out timely effective actions of operators to eliminate the dangerous modes with TAI of the coolant based on indications of regular monitoring and measuring systems (temperature and pressure of the coolant, power level, etc.) without additional diagnostic systems.

Main Objectives and Tasks of Project

The main objective is to substantiate and develop the operative system of TAI diagnostics in WWERs/PWRs. Based only on regularly registered parameters of reactor (without additional systems of intrareactor control) this system will allow to on-line estimate the reactor core state concerning TAI and to assume effective actions for elimination of the dangerous modes.

To achieve this objective it is necessary to solve the following main tasks.

1. Adaptation of methodology of diagnostics of conditions and boundaries of appearance of the coolant TAI in a core of WWERs/PWRs.
2. Verification of methodology of an operative system of TAI diagnostics based on data of experimental stands.
3. Adjustment and approval of an operative system of coolant TAI diagnostics in a core of WWER/PWR.
4. Development and approval of the application instruction of an operative system of coolant TAI diagnostics in a core of WWER/PWR.

Optimization of tests of the NPP safety related systems by using non-PSA methods

Relevance

Long-term operating experience of NPPs confirms need to review the existing design strategy of tests of safety-related systems (SRS) during reactor operation at power, and scheduled repairs. To change test strategy it is need to develop scientific and program and methodical base for test optimization during the overhaul period and repairs of NPP power units. Now this base is absent in fact. Therefore, the development of new schedules of SRS tests by the NPP operating organization and adaptation of recommendations of other nuclear states on scheduling of SRS tests are not enough correct without adequate scientific substantiation.

The risk-informed methods are the most effective approach to optimize SRS tests at NPPs with VVER. The choice of objective risk functions depends on the optimization purposes and sensitivity of risk factors to parameters optimized. The previous researches showed that risk factors of the probabilistic safety analysis are not enough sensitive to change of SRS test frequency.

It is reasonable to use probabilistic assessments of integral reliability factors of safety function fulfilment as an objective risk function for optimization of SRS test scheduling.

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Dependence of an extremum of an integral reliability factor on SRS test frequency has obvious interpretation: to reveal the hidden failures/defects during standby mode of SRS it is necessary to increase number of tests, on the one hand; but on the other hand, the excessive increase in number of tests leads to unreasonable decrease in a reserve of system channels, wear of the equipment and essential influence of human errors.

Thus, now strategy of SRS test scheduling changes based on either a subjective expert judgment or not enough reasonable methods that do not consider the major factors effecting SRS reliability or methods that are not enough sensitive to SRS test scheduling changes. The approach considering reliability factors of system elements, conditions and the modes of operation, quality of maintenance, test efficiency and safety effects is perspective for optimization methods of SRS tests.

Main Objective and Tasks of Project

The main objective is to develop optimization methods of scheduling of SRS tests, maintenance, and repair to improve safety and efficiency of NPP operation.

Main objectives of the project are:

a) To generalize, analyse and systematize modern methods, approaches and experience of optimization of SRS test scheduling to improve safety and efficiency of NPP operation,

b) To develop methods, techniques and the software to optimize test scheduling of the safety systems and SRS during the overhaul period,

c) To develop methods, techniques and the software to optimize scheduling of tests, maintenance and repair of safety systems and SRS during repair of the power unit.

Expected Results

- New techniques and software to optimize scheduling of SRS tests, maintenance and repair,
- Estimated optimum periodicity of tests, maintenance and repair for selective number of SRS of power units with PWRs.