WENRA APPROACH WITH RESPECT TO DESIGN EXTENSION OF EXISTING REACTORS

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Abstract

In 2014, the Western European Nuclear Regulators Association (WENRA) published a revised version of the Safety Reference Levels (RLs) for existing reactors developed by the Reactor Harmonisation Working Group (RHWG). The objective of the revision was to take into account lessons learned of the TEPCO Fukushima Dai-ichi accident.

A major update of the RLs was the revision of Issue F "Design Extension of Existing Reactors" introducing the concept of Design Extension Conditions (DEC).

The revised RLs clearly distinguish DEC not involving a severe accident (DEC-A) and involving a severe accident (DEC-B). They clarify how DEC are to be addressed in safety analysis and provide explicit goals of DEC analysis as well as attributes of the safety analysis of the selected DEC. They address adequate qualification and operability of (mobile) equipment used to manage DEC. The revised RLs also address sites where several reactors are collocated and emphasize the safety of spent fuel storage in DEC. They require independent and diverse heat removal means, one of them being effective after events involving natural hazards more severe than the one used for design basis, and address the availability of I&C, electric power and control room to manage DEC.

This conference contribution discusses WENRAs view on the DEC concept for existing reactors, including the selection process for the design extension conditions and the requirements for ensuring the safety functions, in particular with respect to heat removal and emergency power.

1. INTRODUCTION

With the view to increase harmonization within the countries of the Western European Nuclear Regulators Association (WENRA), WENRA published in 2006 a set of Safety Reference Levels (RLs) for existing reactors. The RLs were updated in 2007 and 2008. The RLs are developed in consensus within the Reactor Harmonization Working Group (RHWG) and approved by the WENRA members. They reflect international safety standards and expected practices in the WENRA countries. It is expected that the RLs are transposed in national regulations and implemented in the nuclear power plants.

In 2014, WENRA published a revised version of the RLs, developed by RHWG [1]. The objective of the revision was to take into account the lessons learned of the TEPCO Fukushima Dai-ichi accident. For this purpose RWHG reviewed the whole set of RLs, taking into consideration recommendations and suggestions published by ENSREG as a result of the complementary safety assessments (“stress tests”) performed in Europe following the TEPCO Fukushima Dai-ichi accident as well as IAEA safety requirements being under updating at that time for the same reason and the conclusions of the 2nd Extraordinary Meeting of the Contracting Parties to the Convention on Nuclear Safety.

As a consequence, a new Issue (Issue T), dedicated to natural hazards, has been established. Issue E (Design Basis Envelope for Existing Reactors) and Issue F (Design Extensions Conditions of Existing Reactors) have been changed significantly. Furthermore, for approximately half of the remaining Issues, there have been limited changes.

The concept of design extension in Issue F has been enhanced and the term design extension conditions (DEC) has been introduced for consistency with the IAEA SSR-2/1 safety standard [2]. The revised Issue F clarifies how DEC to be addressed in safety analysis will be identified and defines explicit goals of DEC analysis as well as attributes of the safety analysis of the selected DEC. Furthermore, new expectations have been formulated for several specific points in Issue F.

In order to provide explanations of the intent of the RLs of Issue F, to contribute to a consistent interpretation and to permit insights into the considerations which have led to their formulation, RHWG developed a Guidance Document for Issue F which was also published by WENRA in 2014 [3].

The RL Issue F is divided in five sections. This division is reflected in the five parts of the following section of the paper.

2. MAIN INNOVATIONS IN THE 2014 VERSION OF ISSUE F OF THE WENRA RLS

2.1. Objective of Design Extension Conditions (DEC)

Occurrence of conditions more complex and/or more severe than those postulated as design basis accidents (DBA) could not be neglected in safety analysis. These conditions shall be investigated as Design Extension Conditions (DEC) so that any reasonably practicable measures to improve the safety of a plant are identified and implemented. Regarding the treatment of DBA and DEC, there are a number of clear and basic differences concerning the methodology of analysis; technical acceptance criteria and radioactive releases tolerated could also differ, depending on the category of DEC.

The RLs define two categories of DEC:

- DEC A for which prevention of severe fuel damage in the core or in the spent fuel storage can be achieved; and
- DEC B with postulated severe fuel damage.

Special efforts shall be implemented with the goal that a severe accident in a spent fuel storage becomes extremely unlikely with a high degree of confidence, since measures for sufficiently mitigating the consequences of a severe accident in spent fuel storages could be difficult to realize.

Extreme unlikeliness with a high degree of confidence is an element of the concept of “practical elimination”. The term “practical elimination” has not been used in the RLs. It is usually applied almost exclusively in the context of severe accidents leading to large or early releases. To demonstrate extreme unlikeliness with a high degree of confidence, probabilistic and deterministic elements both are required.

2.2. Selection of DEC

The RLs stipulate that a set of representative DEC shall be derived and justified based on a combination of deterministic and probabilistic assessments as well as engineering judgment. DECs are selected and analysed for the purpose of further improving the safety of the nuclear power plant.

The events which are considered in the selection of the representative DEC should cover a wide range of scenarios, from less demanding to more demanding.

A wide scope of events and combinations of events exceeding the design basis are to be considered at the beginning of the selection process for DEC A – those events, and combinations of events, which cannot be considered with a high degree of confidence to be extremely unlikely to occur, and which may lead to severe fuel damage.

Events occurring during the defined operational states of the plant shall be covered, including events resulting from internal and external hazards, and common cause failures. A non-exhaustive listing of initiating events for DEC A is provided in the Guidance Document for Issue F, including external hazards.

For DEC B, a set of representative severe fuel damage scenarios has to be identified, covering the different situations and conditions which can occur in the course of a severe accident. There will usually be a very large number of possible scenarios which cannot all be captured at the start of a selection process.

2.3. Safety analysis of DEC

The selected DEC are subject to DEC analysis. The purpose of this analysis can be

(1) to review whether the fundamental safety functions can be guaranteed by existing equipment, or

(2) to identify reasonably practicable measures for enhancing safety.

For (1), conservative or best estimate approaches may be used. In case of (2), best estimate methodology should be preferred to avoid missing reasonably practicable improvements due to an unduly conservative approach. In any case, uncertainties and their impacts have to be taken into account.

Within the analysis of DEC, cliff-edge effects should be identified and a sufficient margin to avoid such effects should be demonstrated wherever applicable. Different kinds of margins may have to be considered, depending on the nature of the DEC. For example, for multiple failure events, the margin could be seen as the capacity of required SSCs to achieve functional capability beyond their design basis, or as the number of additional failures for which it remains possible to avoid severe fuel damage. For certain multiple failures like total SBO, the margin could be expressed in terms of the period of time available for counter-measures. For events related to reactivity or loss of coolant, the margin could be expressed in terms of fuel temperature or enthalpy release. For external hazards within DEC, margins could be expressed in terms of frequency of severity.

When analysing a sequence in the framework of DEC, an end state should be defined and justified for the analysis. For DEC A, this defined end state could be a “safe state” according to IAEA SSR-2/1. In case of DEC B, it is unlikely to reach such a safe state and the defined end state could be a “controlled state after severe accident”. Such a state is characterized by ensured decay heat removal, stabilization of damaged fuel, prevention of re-criticality and confinement ensured to the extent that release of radionuclides is limited.

2.4. Ensuring safety functions in design extension conditions

In DEC A, it is the objective that the plant shall be able to fulfil the fundamental safety functions (control of reactivity, removal of heat from core and spent fuel and confinement of radioactive material).

In DEC B, the objective is that the plant shall be able to fulfil confinement of radioactive material. The other fundamental safety functions are of importance insofar as they are required to support the confinement function. Severe accident management actions to prevent the irreversible loss of confinement which are leading to limited and controlled releases are not considered a loss of the confinement function if they are temporary, associated with specific predefined requirements (e.g. filtering of the releases) and do not lead to unacceptable off-site consequences.

SSCs used for DEC shall be adequately qualified to perform their functions for the appropriate period of time. Plant management under DEC may rely on mobile equipment. Permanent connecting points, accessible under DEC, shall be installed to enable the use of this equipment.

For multi-unit sites, a systematic process shall be used to review all units relying on common services and supplies, to ensure that common resources of personnel, equipment and materials expected to be used in accident conditions are effective and sufficient for each unit at all times.

The NPP shall be autonomous regarding supplies supporting safety functions, for a period of time until it can be demonstrated with confidence that adequate supplies can be established from off site. External hazards exceeding the design basis and related potential damage to infrastructure have to be taken into account.

2.4.1. Heat removal functions

Regarding the removal of the residual heat from the core and the spent fuel, there shall be sufficient independent and diverse means available, including necessary power supplies. At least one of these means shall be effective after events involving external hazards more severe than design basis events.

Either an alternative ultimate heat sink (including a complete chain of systems providing a link to it) or a chain of independent and diverse systems for using the primary ultimate heat sink (if the primary ultimate heat sink is available for all events within the DEC involving external hazards) should be in place. If there is an alternative ultimate heat sink, it should be independent as far as practicable from the primary ultimate heat sink.

The alternative ultimate heat sink or the chain of diverse systems should be able to secure the cooling of core and spent fuel for an extended period of time.

2.4.2. Confinement functions

The reference levels on confinement should also be applied to the spent fuel storages, in case severe spent fuel damage has not been demonstrated to be extremely unlikely with a high degree of confidence.

Isolation of the containment shall be possible in DEC. For the shutdown states, special attention needs to be given to situations with an open containment. In this case, timely containment isolation should be guaranteed, or measures to prevent core damage with a high degree of confidence made available. Also, in case of events leading to containment bypass, severe core damage shall be prevented with a high degree of confidence.

The previous version of the RLs already contained the expectations, in Issue F, that pressure and temperature as well as the threats due to combustible gases shall be managed, that containment shall be protected from overpressure, that high pressure core melt scenarios shall be prevented and containment degradation by molten fuel shall be prevented or mitigated as far as reasonably practicable.

A new expectation states that if venting is to be used for managing containment pressure, adequate filtration shall be provided. For multi-unit sites, conditions at other units should be taken into account.

Finally, for the confinement functions, a new RL has been introduced stipulating that in DEC A, releases shall be minimised as far as reasonably practicable. In case of DEC B, any release to the environment shall be limited in time and magnitude as far as reasonably practicable in order to allow sufficient time for protective actions in the vicinity of the plant and to avoid long-term contamination of large areas. These radiological objectives are in line with principles 1 and 2 of the Vienna Declaration on Nuclear Safety [4].

The delay of releases in DEC B can also be important for the implementation of additional measures in the plant (or neighbouring units) to delay releases further or to prevent them altogether.

2.4.3. Instrumentation and control for the management of DEC

New expectations concern adequately qualified instrumentation which shall be available for DEC for determining the status of the plant (including spent fuel storage) and safety functions as far as required for making decisions (on-site as well as, in case of DEC B, off-site).

The instrumentation should be able to perform its safety-related functions in DEC environmental conditions. Instrumentation for key parameters should also be able to perform it function for a sufficient period of time in case of total SBO.

An operational and habitable control room (or another suitably equipped location) shall be available during DEC. The other suitably equipped location could be a supplementary control room or a local control panel, if they are adequately equipped and protected.

2.4.4. Emergency power

This new section of Issue F stipulates that adequate power supplies during DEC shall be ensured to support the fundamental safety functions. The timeframes defined in the DEC analysis have to be considered and external hazards taken into account.

Furthermore, DC power supply shall be provided with adequate capacity until recharging of batteries can be established or other means are in place.

2.5. Review of the design extension conditions

Regular assessment of the overall safety of an NPP is required in the Issue “Safety Policy”, in the (new) RL A2.3. A new RL in Issue F emphasizes that this regular assessment has to include the design extension conditions. Furthermore, the design extension conditions shall be reviewed, when relevant, as a result of operating experience and significant new safety information.

The review shall use both a deterministic and a probabilistic approach as well as engineering judgment to determine whether the selection of design extension conditions is still appropriate. Based on the results, needs and opportunities for improvements shall be identified and relevant measures shall be implemented. In accordance with RL A2.3, reasonably practicable measures for improvement which have been identified shall be implemented in a timely manner.

CONCLUDING REMARKS

WENRA is committed to the improvement of nuclear safety. Bearing this in mind, the WENRA Safety Reference Levels have been significantly updated and expanded taking into account the lessons learned from the TEPCO Fukushima Dai-ichi accident, with the purpose of further improving the safety of nuclear power plants.

Issue F of the RLs (Design Extension of Existing Reactors) is of high importance in this context. Safety considerations for existing reactors need to reach beyond the limitations of the initial design basis, in every respect, including for external hazards.

Furthermore, Issue F emphasizes that the regular assessment of the overall safety of a nuclear power plant, as required in RL A2.3, has to include the design extension conditions. Reasonably practicable measures for improvement which have been identified shall be implemented in a timely manner, in accordance with RL A2.3.The main criterion for the implementation of improvements is reasonable practicability. What is reasonably practicable may change over time. Hence, there also is the need for a regular review of DEC.

Finally, it should be noted that there are significant interactions between some of the Issues of the RLs. Hence, each Issue should not necessarily be considered as self-standing. The RLs need to be considered as a whole set. In particular, the connections between Issue F and Issues E (Design Basis Envelope for Existing Reactors) and T (Natural Hazards) need to be taken into account.

REFERENCES

[1] WENRA-RHWG, WENRA Safety Reference Levels for Existing Reactors – update in relation to lessons learned from TEPCO Fukushima Dai-Ichi Accident, Report, 24 September 2014

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[4] Vienna Declaration on Nuclear Safety, INFCIRC/872, IAEA, Vienna, 18 February 2015