IMPLEMENTATION DESIGN EXTENSION CONDITIONS (DECS)
WITHIN THE SCOPE OF RISK MANAGEMENT REGULATORY FRAMEWORK

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Abstract

How to balance the approach for DEC consideration between NRC and European? It is benefit for the design approach for the design and assessment of new nuclear power plant to form the common agreement about DEC. West European Nuclear Regulation Association (WENRA) considered the DEC and assessed those conditions by deterministic analyses method as well as the updated version of SSR2/1[1] did. According to the requirement of EUR, the off-site release targets for DEC(complex sequences) should meet the acceptance criteria relevant to Design basis category 4 condition(DBC). Meanwhile, American NRC made a decision to maintain the existing regulatory framework, not plan to establish a formal design basis extension category, for the nuclear power reactor safety program area on March 9, 2016 as SE CY-15-0168[4]. The category is still considered by implementation of a risk management regulatory framework. For example, the selected events such as SBO, ATWS are considered in the deterministic approach, other DECs(complex sequences) and severe accidents are analyzed using the probabilistic approach. Although the requirements relate to DEC is different from SSR-2/1, the DECs could also be fully evaluated following the US NRC regulatory framework. The current risk management regulatory framework can meet the requirement of DEC with a little improvement according to the assessment.

1. BACKGROUND

Nuclear safety especially severe accidents risks are of great concerns of nuclear power plant. Design consideration of severe accident prevention and mitigation is generally required by various nuclear safety authorities worldwide. However, those requirements related to severe accidents consideration are somewhat different from country to country. Recently the International Atomic Energy Agency (IAEA) updated and published a safety code on Specific Safety Requirement of Nuclear Power Plant Safety: Design (SSR-2/1)[1]. Meanwhile the Chinese National Nuclear Safety Administration (NNSA) also revised and updated the safety code on Requirement of Nuclear Power Plant Safety in Design (HAF102)[2]. In these two codes, both IAEA and NNSA established some new requirements, among which two are of great concern, one is Design Extension Conditions (DEC) for consideration of those conditions traditionally called Beyond Design Basis Accidents(BDBA) in design of nuclear power plant, another is requirement of practically elimination of large release of radionuclide.

In the other hand, improvement activity 1 in SECY-13-0132[3] recommended that the NRC adopt a new term – “design-basis extension”—to define and describe the events and requirements for nuclear power plants that have typically been characterized as “beyond-design-basis” events and accidents. But the NRC staff determined that a new category of events should not be established in SE CY-15-0168[4].

Some new design nuclear power plants are being designed by SNERDI and their documentation was prepared mainly in accordance with US NRC RG-1.206[5] (Combined License Applications for Nuclear Power
Plants). This Guide does not use the concept of DEC. So a gap analysis between current safety documentation and the requirements of DEC is being carried out.

2. **THE REQUIREMENTS OF IAEA TECDOC-1791**

IAEA TECDOC-1791\(^6\) was issued in 2016. This document is to provide insights and approaches in support of the practical application of the new crucial requirements introduced in SSR-2/1\(^1\) and subsequently reinforced in SSR-2/1\(^0\). According to this document, the requirements of DEC mainly include following elements:

- Definition of DECs
- Determination of DECs
- Acceptance criteria for DECs

2.1. **Definition of DECs**

According to SSR-2/1\(^1\), DECs are: “Postulated accident conditions that are not considered for design basis accidents, but that are considered in the design process for the facility in accordance with best estimate methodology, and for which releases of radioactive material are kept within acceptable limits. Design extension conditions comprise conditions in events without significant fuel degradation and conditions in events with core melting.”

TECDOC-1791\(^6\) also points out “DECs are those conditions not included in the DBAs, and which have a frequency of occurrence that cannot be neglected and in some cases comparable with the frequency of some DBAs.”

Although current documentation does not include DEC, analyses have been provided in the current safety documentation for the conditions exceeding DBAs which is similar to DEC. This will be discussed in the next section.

2.2. **Determination of DECs**

The DECs can be divided into DECs without significant fuel degradation (DEC-A) and DECs with core melt (DEC-B) according to SSR-2/1\(^1\).

For DEC-A, at least three types of DECs can be considered according to the postulated assumptions:

- Very unlikely events that could lead to situations beyond the capability of safety systems for DBAs.
- Multiple failures (e.g. CCFs in redundant trains) that prevent the safety systems from performing their intended function to control the PIE.
- Multiple failures that cause the loss of a safety system while this system is used to fulfill the fundamental safety functions in NO.

Typically, it may include:

- ATWS
- SBO
- Loss of core cooling in the residual heat removal mode;
- Extended loss of cooling of fuel pool and inventory;
- Loss of normal access to the ultimate heat sink;
- Total loss of feed water;
- LOCA plus loss of one emergency core cooling system (either the high pressure or the low pressure emergency cooling system)
- Loss of the component cooling water system or the essential service water system (ESWS)
- Uncontrolled boron dilution;
- Multiple steam generator tube ruptures (MSGTR) (for PWRs);
- Steam generator (SG) tube ruptures induced by main steam line break (MSLB) (for PWRs);
- Uncontrolled level drop during mid-loop operation (for PWRs) or during refueling.

In fact, all of these DECs are analyzed in current risk management regulatory framework. For example, ATWS, identified in 10 CFR50.62\(^2\), usually is presented in chapter 15.8 of preliminary/final safety analysis
report (P/FSAR). The other example is that SGTR induced by MSLB is considered in PSA, which was included in chapter 19. So does SBO.

In addition, some plant specific initiating events such as spurious operation of automatic depressurization system, which was induced in some passive NPPs, are also included in the analysis, which can be treated as DECs too.

For DEC-B, it is necessary to select a representative group of severe accident conditions to be used for defining the design basis of the mitigatory safety features for these conditions. In general, it is similar to the severe accidents in current risk management regulatory framework.

Current risk management regulatory framework has included a detail analysis for severe accidents. PSAR chapter 19.2 of an example NPP is shown as follows:

(a) The sub-section of chapter 19.2 presents the selection of significant accident sequences. The accident progressions of these significant accidents are analyzed using severe accident analysis code, including in-vessel and ex-vessel melt progressions. Key events evaluated for the in-vessel melt progression are core recovery, core damage, molten core relocation to lower plenum, hydrogen combustion, in-vessel steam explosion and RPV failure. Key events evaluated for the ex-vessel melt progression are MCCI, DCH, ex-vessel steam explosion and long-term containment pressurization. The severe accident mitigation measures are described in sub-section of chapter 19.2, including in-vessel retention (IVR) of core debris, hydrogen control, mitigation of high-pressure core melt ejection (HPME), containment pressurization from decay heat, molten core concrete interaction (MCCI) and steam explosion.

(b) A more specific example is given below. The evaluation of hydrogen control is described in another sub-section of chapter 19.2. Hydrogen generation and mixing are analyzed for typical severe accident classes with igniters unavailable, in order to determine probable regions of hydrogen risk. In order to validate the effect of hydrogen control system, a bounding case, initiated by large break LOCA with failure of accumulator, generating the most hydrogen is selected and analyzed also. 100% cladding of active fuel is oxidized, which is mainly occurred during reflooding. According to the analysis results, igniters can control hydrogen concentration effectively, thus the design of hydrogen control system is effective.

As mentioned above, current risk management regulatory framework has included almost the DECs should be considered although the concept of DEC is no appeared.

2.3. Acceptance criteria for DECs

SSR-2/1\(^{(1)}\) sets out the general requirement for DECs (Reg.20) where it states that “A set of design extension conditions shall be derived on the basis of engineering judgment, deterministic assessments and probabilistic assessments for the purpose of further improving the safety of the nuclear power plant by enhancing the plant’s capabilities to withstand, without unacceptable radiological consequences, accidents that are either more severe than design basis accidents or that involve additional failures”.

Base on this, the Appendix 2 of TECDOC-1791\(^{(6)}\) gives examples of acceptance criteria, as TABLE 1 shown.

In addition, safety features for DECs shall as far as is practicable be independent of safety systems and the integrity or operability of equipment for DECs shall be justified under the DECs environmental conditions. In current risk management regulatory framework, the severe accidents with the phenomena challenging the containment integrity are analyzed in chapter 19 of safety analysis report.

PSAR chapter 19.2 of an example NPP is shown as follows: Sub-section 19.2.2 of chapter 19.2 provides the principles and methods for sequence selecting together with 12 accident categories, and different scenarios are determined for different purpose by combination of the probabilistic and deterministic and the engineering judgment. The hydrogen risk and the effectiveness of the hydrogen control system were assessed. The qualitative analysis of each category are exhibited and the results is that the containment cooling system provides well mixing in the containment for the open compartment and the hydrogen risk is restricted in the confined compartment because of the high steam concentration. Additionally, the hydrogen control system is evaluated by the amount of hydrogen that generated from the 100% active Zirconium oxidation, and the results show that the ignition system can effectively eliminate the hydrogen risk. The containment pressurization analysis without containment cooling system water cooling was performed, and the result shown that the failure
probability in the 24h is less than 0.01% and the vent setpoint is reached in 37h, there is at least 4h left for the operator to consider before it reaches 5%. The MCCI analysis without water circulation was performed for the consideration of basement melt-through challenge and pressurization threaten challenge. The results are that in the first 24 hours, the cavity basement penetration or containment over-pressure will not occur, and the containment integrity will not be challenged with plenty margin. All the above evidence shows that the containment will keep integrity under the conservative condition after accident in 24h or longer and can reasonably deduce that it can maintain in the long term.

Moreover, the assessment of severe accident equipment survivability, which is required by risk management regulatory framework, is similar to those of DECs.

Based on the above explanations, the risk management regulatory framework is similar to those of DECs. Furthermore, if the frequency of the single selected severe accidents causing large radioactive release is lower than 1E-7/y, these conditions can be treated as “practically eliminated” conditions.

In general, the analysis of current risk management regulatory framework almost covers the acceptance criteria for DECs. But something should be done to indicate that the requirements of DECs have been considered:

— Give an explicitly description about compliance to DEC acceptance criteria in the safety analysis report.
— Make sure that all of the equipment for DEC is qualified based on the equipment survivability assessment during severe accidents.

3. CONCLUSIONS

In the future, the design of Chinese nuclear power plants should consider the requirement of DECs in SSR2/1[1] and HAF102[2] but it is not necessary to make a big change to current risk management regulatory framework because most contents of DECs have been covered by PSA or SA. The requirement of DECs can be met through supplementing some contents about compliance to DEC acceptance criteria and DEC equipment qualification.

4. TABLES

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5. REFERENCES
