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DEC (Design Extension Conditions) Analyses in Kozloduy NPP

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Abstract. It is clear from the IAEA publication - Safety of Nuclear Power Plants: Design, SSR-2/1 (Rev. 1) that the classification of the initiating events for safety analyses is changing. New groups appear, using a new term – design extension conditions (DEC). In 2016 Bulgarian Nuclear Regulatory Agency (BNRA) substantially changed the content of "Regulation on ensuring the safety of nuclear power plants" and a new classification of the initiating events appeared too. In this document one of the sub-categories of events is postulated multiple failure events. Although the IAEA uses the term DEC analyses (without fuel melting) and the BNRA – analyses of postulated multiple failure events, the two terms essentially mean the same thing.

Keywords: analyses, DEC, safety, severe accidents.

1 Introduction

The issue of design extension conditions (DEC) has been considered by the Institute for Nuclear Research and Nuclear Energy (INRNE) in Bulgaria, NPP Kozloduy and Risk Engineering (Bulgaria) in 2015 after stress tests as a result of the event in the Fukushima Daiichi NPP [1]. According to the IAEA publication SSR-2/1 (2016) [2], the accident conditions are:

- Normal operation;
- Anticipated operational occurrences;
- Design basis accidents;
- Design extension conditions (without significant fuel degradation or with core melting).

In this document there is a new term – design extension conditions (DEC), which is new for IAEA classification of the accident conditions. In the same year Bulgarian Nuclear Regulatory Agency (BNRA) substantially changed the content of Regulation on ensuring the safety of nuclear power plants [3] and a new classification of the initiating events appeared:

- Normal operation;
- Anticipated operational occurrences;
- Accidents without melt of the fuel (postulated single initial events or multiple failure events);
- Accidents with melt of the fuel.

There is again a new term - multiple failure events. Figure 1 shows the comparison between IAEA classification and BNRA classification.

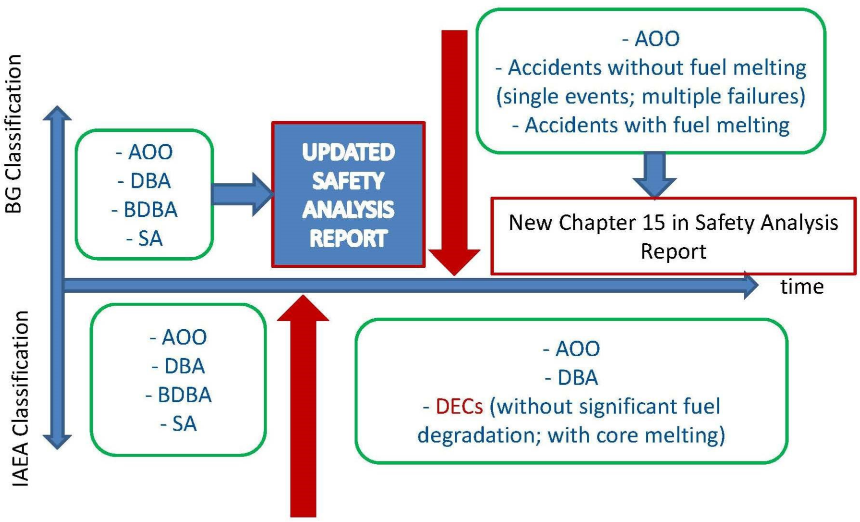

Figure 1. Plant condition categories.

2 Main Definitions Connected with DEC Analyses

The main functions of multiple failure events analyses are [3]:

- to confirm the capability of the design;
- to deal with common cause failures;
- to determine the need for additional measures;
- to prevent the melting of nuclear fuel;
- to demonstrate sufficient margin to the occurrence of cliff-edge effects.

Analyzing these events, the following general rules shall apply:

- use moderately conservative or realistic assumptions, hypotheses and arguments that are reasonable for the purpose of analysis;
- use the conclusions and results of the probabilistic safety analysis;
- consider failures and events that may occur in all operating states;
- consider the geographic and spatial location of the NPP, the capacity and diversification of the SSCs performing safety functions, and the feasibility of implementing the actions envisaged for accident management;
- adequately consider the uncertainties and their impact on the end.

It shall be demonstrated that accidents with nuclear fuel melting that lead to large or early releases of radioactive substances into the environment have been practically eliminated. Analyses of accidents with fuel meltdown and the radiological consequences thereof shall be made using a realistic approach and reasoned assumptions, applying the following requirements to:

- consider scenarios which may occur in all operational states;
- consider successful actions of the personnel and the accident management teams;
- use the conclusions and results of the probabilistic safety analysis levels 1 and 2, and the applicable experimental data;
- consider the characteristics of the phenomena arising from severe accidents and the associated uncertainties;
- determine the possibilities for interaction with other nuclear facilities on the site.

According to the IAEA SSR-2/1 [2], Design Extension Conditions are defined as: 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. In the same document, at the end of Requirement 20 is written that these design extension conditions shall be used to identify the additional accident scenarios to be addressed in the design and to plan practicable provisions for the prevention of such accidents or the mitigation of their consequences.

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. The most plausible reason for the failure of safety functions (such as reactivity control and core cooling) is the occurrence of dependent failures that may cause the failure of redundant trains simultaneously. Common cause failures (CCFs) are a predominant group that are given high attention and provisions are implemented in the design either to eliminate them or reduce their likelihood to the extent possible or to cope with their consequences. Systematic analysis of dependences between structures, systems and components (SSCs) important to safety is a good practice to conclude whether CCFs have been adequately considered.

As it is written in IAEA TECDOC- 1791 [4], DEC analyses are:

- Very unlikely events that could lead to situations beyond the capability of safety systems for DBAs. The regulatory body may accept a demonstration based on best estimate analyses that the safety systems are indeed capable of and qualified for mitigating the event under consideration. In general however, the inclusion of specific safety features for DEC is necessary;
- Multiple failures (e.g. CCFs in redundant trains) that prevent the safety systems from performing their intended function to control the postulated initial events. An example is loss of coolant accident (LOCA) without actuation of a safety injection system. The failures of supporting systems are implicitly included among the causes of failure of safety systems;
- Multiple failures that cause the loss of a safety system while this system is used to fulfill the fundamental safety functions in normal operation. This applies to those designs that use, for example, the same system for the heat removal in accident conditions and during shutdown.

As general we can say that DEC analyses with core melting are using to:

- select the additional scenarios to be considered in the design;

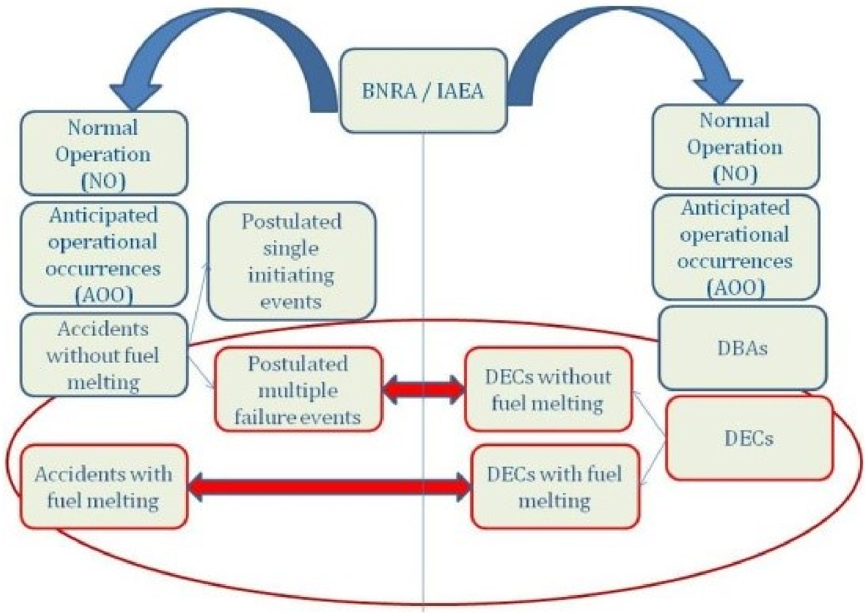

Figure 2. Links between BNRA and IAEA categorization.

- define and design the features credited for the design extension conditions with core melting so that these features have the requested performances to meet the relevant safety requirements;
- help in establishing and validating severe accident management guidelines;
- provide the environmental conditions in which systems called in DECs should be capable of performing;
- help in SSCs safety classification as appropriate;
- provide input for emergency planning.

Comparing the definitions and requirements for DEC, multiple failures and accidents with melting of the fuel we can conclude that the accidents with melting of the fuel and DEC analyses with melting of fuel are inherently the same and that the postulated multiple failures can be equated to DEC without melting the fuel. This is demonstrated in Figure 2.

3 Examples for DEC Analyses in Kozloduy NPP

The concept of DEC is not completely new for the nuclear plant in Kozloduy. Some multiple failures of safety systems have been considered and took part in the Updated Safety Analysis Report (update of the original Safety Analysis Report). The classification of the initiating events was made according to the BNRA. These multiple failures were analyzed and were put in subchapter beyond design basis accidents (BDBA). Such analyses are:

- Anticipated transients without scram (ATWS);
- Station Blackout;
- Small LOCA in coincidence with a total loss of medium pressure safety injection pumps and so on.

BDBA were analyzed using a special methodology for analyses of BDBA that is different from the methodology for analyses of design basis accidents (DBA). The acceptance criteria for DBA were kept. According to the definitions in [2] now these analyses can be called multiple failure events analyses. In the scope of the project in Kozloduy NPP: "PHARE Project BG 01.10.01 Phenomena investigation and development of SAMG" there were analyzed scenarios leading in same cases to severe accidents. According to SSR-2/1 [2] these can be DEC with core melt.

In 2009 Kozloduy NPP started a project of power uprate (104%). This involved new safety analyses with higher initial thermal power. All the imitating events were calculate again, but in addition, according to new document SSR-2/1 [2] there were made more analyses specially to demonstrate DEC. It is important to be remarked that CCFs must be considered very precisely.

In the framework of project for using a new type of fuel – TVSA-12 there were prepared new safety analyses. All the analyses in Chapter 15 of the Safety Analysis Report (SAR) were recalculated taking into account work with new type of fuel on higher thermal power. On the ground of this in 2019 Kozloduy NPP started a project for updating Chapter 15 of SAR with new safety analyses and implementation the new categorization from BNRA requirements [3].

After updates, Chapter 15 of SAR contains the following analyses of postulated multiple failure events and accident with fuel melting:

1. ATWS:
   - uncontrolled withdrawal of a control rod group during start-up;
   - uncontrolled withdrawal of a control rod group during power operation;
   - loss of main feed water;
   - loss of on- and off-site power;

- loss of condenser vacuum;
- inadvertent opening of turbine (control or by-pass) valves;
- inadvertent actuation of auxiliary pressurizer spray;
- trip of two reactor coolant pumps;
- maximal decrease of the feed water temperature.

2. Total loss of electrical power supply (total station black out);
3. Multiple steam generator tube ruptures (equivalent diameter 100 mm);
4. Total loss of feed water;
5. Loss of primary ultimate heat sink;
6. Small break LOCA (100 mm) with a total loss of medium and low pressure safety injection pumps;
7. Boron dilution;
8. Uncontrolled level drop of reactor during refueling or stopping;
9. Total loss of the component cooling water system;
10. Loss of required safety systems in the long term after a postulated initiating event;
11. Analyses of the phenomena of severe accidents in spent fuel pool;
12. Assessment of the radiological situation in the main control room or emergency control room during severe accidents.

4 Conclusions

Although the IAEA uses the term DEC analysis and the BNRA – analyses of postulated multiple failure events, the two terms essentially mean the same thing .The challenge for Kozloduy NPP is to meet Bulgarian legislation and to show that all IAEA requirements have been taken into account in the safety assessment. Analyses of DECs are important part of the current safety assessment and they are using in Kozloduy NPP.

References

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