Analyses of DEC Events in the Czech Republic and their Implementation into SAR

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1. Introduction

Nuclear Energy in the Czech Republic

- Two operating nuclear power plants covered by the Convention on Nuclear Safety
  - NPP Dukovany with 4 x VVER-440/213 (current power 4x 510 MW_\text{e})
  - NPP Temelin with 2 x VVER-1000/320 (current power 2x1055 MW_\text{e})
- Both NPPs are operated by single utility - the joint stock company ČEZ
- Building of new nuclear unit is under consideration. It would be in compliance with government Energy Policy, but final decision is due to prices on EU energy market etc. not yet taken
- Consistent implementation of DEC (BDBA) assessment of existing Czech NPP’s started in 2009 as a consequence of PSR20 of Dukovany NPP

Virtual tours to Czech NPP’s:

http://virtualniprohlidky.cez.cz/cez-temelin-aj/
http://virtualniprohlidky.cez.cz/cez-dukovany-aj/
1. Introduction (cont’d)

- The concept of “design extension condition” (DEC) is and isn’t new. But for sure it is still under development and needs to be discussed and harmonized.

- The concept originated in 70-ies when the ATWS and later SBO were firstly analyzed.

- Unfortunately these beyond DBC events were assessed (or ignored) in each country in little bit different way. The harmonization has started only in last years.

- Besides the safety assessment, the concept of DEC has number of other aspects:
  - Changes and enhancement of DiD,
  - Safety analyses of DEC and relevant methodology,
  - NPP design modifications, structuring of safety system and other mitigation measures,
  - Effects on EOP,
  - Considerable differences in countries approach to DEC – need for harmonization.
2. Evolution of DEC concept

- The term “design extension condition” (DEC) was firstly formally introduced in the European Utility Requirements (EUR) in 1994 to define some selected sequences due to multiple failures with the intent to improve the safety of the plant extending the DB. The DEC are in EUR divided to “complex sequences” and “severe accidents”.

- In 2008 WENRA published document “Reactor Safety Reference Levels” and used the term “design extension”.


- The 2014 update of WENRA Reference Levels and 2016 Revision-1 of IAEA SSR-2/1 added clear differentiation between DEC-A (without core melt) and DEC-B (with core melt), respectively.
3. Methodology basis for DEC-A analyses

Major international documents dealing with DEC concept and analysis:

- WENRA, Reactor Safety Reference Levels for Existing Reactors, 2014 (the first version published in 2008)
- IAEA, Safety of NPPs: Design, Specific Safety Requirements, SSR-2/1, Revision 1, 2016 (the previous version containing already DEC published in 2012)
- IAEA, General Safety Requirements GSR Part 4, Revision 1, 2016
- IAEA-TECDOC-1791, Considerations for the application of the IAEA Safety Requirements on Design, 2016
Methodology basis for DBA and BDBA (DEC-A) analyses in the Czech Republic:

- SUJB “Regulation No. 1.95 on Requirements on Nuclear Facilities to Ensure Nuclear Safety, Radiation Protection and Emergency Preparedness”
- SUJB “Safety Guide BN-JB-1.7 Selection and Evaluation of Design and Beyond Design Events and Risks for NPP”, 2010
  
  Note: both documents to be revised in 2017-2018 due to new Atomic Law
- Krhounkova, Kral, Macek: Proposal of Methodology Procedure of Performing BDBA Analyses of NPP Dukovany, Revision 1, 2013

Approach to analyses:

- Selection of DEC-A (BDBA) events to be analyzed based on requirements of BN-JB-1.7 plus supplements according to PSA
- In selection based on PSA, transfer from “frequency of occurrence of initiating event” to “frequency of occurrence of scenarios”
- Realistic computer codes, models and analysis assumptions
- Acceptance criteria same as for DBA (with exceptions like higher system pressure AC etc.)
3. Methodology basis for DEC-A analyses (cont’d)

Overall approach and situation in safety assessment of DEC

- Introduction of DEC concept into area of safety assessment field in the Czech Republic has different impacts in different subareas like probabilistic analysis, deterministic analyses of DBA and BDBA (DEC-A), and deterministic analyses of severe accidents.
- Whereas the probabilistic and severe accident analyses were not too much affected by implementation of DEC concept (as the relevant sequences had been analysed before), the deterministic analyses of BDBA (DEC-A) experienced new strong impulse and requirements. In fact the conceptual and terminological changes in DBA-DEC area are still under evolution.

Computer codes selection and validation

- Analyses of DEC-A events for the Czech NPP’s Dukovany and Temelin have been done with help of RELAP5 computer code.
- In UJV Rez the RELAP5 has been validated against experimental data from more than 20 tests carried out at various integral and separate test facilities.
- Approximately half of these tests were events of DEC-A type.
- Also computer codes to be used for safety analyses in the Czech Republic must be reviewed and licensed according to regulatory body (SUJB) directive VDS-030.
4. Selection of DEC-A events for deterministic safety analyses

SUJB directive BN-JB-1.7 requires besides the standard set of ATWS analyses the following DEC-A (BDBA) events to be analysed:

- Total long-term loss of inner and outer AC power sources;
- Total long-term loss of feed water („feed-and-bleed„, procedure);
- LOCA combined with the loss of ECCS;
- Uncontrolled reactor level drop or loss of circulation in regime with open reactor or during refuelling;
- Total loss of the component cooling water system;
- Loss of residual heat removal system;
- Loss of cooling of spent fuel pool;
- Loss of ultimate heat sink (from secondary circuit);
- Uncontrolled boron dilution;
- Multiple steam generator tube rupture;
- Steam generator tube ruptures induced by main steam line break (MSLB);
- Loss of required safety systems in the long term after a design basis accident.
4. Selection of DEC-A events for deterministic safety analyses (cont’d)

Types of DEC-A events:

- **Initiating events more severe than DBA or not covered by DBA**
  (e.g. rupture of SG primary collector, loss of residual heat removal system etc.)

- **Combination of DBA events**
  (e.g. MSLB + rupture of SG tubes)

- **DBA initiating event + failure of safety systems above SFC**
  (e.g. SBLOCA with failure of all HPIS trains)

- **DBA initiating event + human error**
  (e.g. PRZ SV stuck open combined by operator closure in later phase with full and cold RCS)
5. Analysis of SBLOCA without PRPS in VVER-1000

Example of DEC-A analysis for VVER-1000:

- Analysis of small break loss of coolant accident (SBLOCA) with break D50 mm in cold leg and without Primary Reactor Protection System (PRPS) which lead among other to failure of start of emergency core cooling systems (ECCS)

- Reactor is scrammed by DPS

- Operator manual start of high pressure safety injection (HPSI) at 30 min

- Calculation performed with RELAP5 computer code and detailed input model of VVER-1000
Nodalization of VVER-1000 for RELAP5:

Input model statistics:
- 1800 control volumes
- 2400 hydraulic junctions
- 1600 heat structures with 8700 mesh points
- 2680 control variables
- 1110 trips
5. Analysis of SBLOCA without PRPS in VVER-1000 (cont’d)

Primary and secondary pressure
5. Analysis of SBLOCA without PRPS in VVER-1000 (cont’d)

Break outflow and total ECCS injection

Operator start of 1 HPSI
5. Analysis of SBLOCA without PRPS in VVER-1000 (cont’d)

Mixture and collapsed level in reactor
5. Analysis of SBLOCA without PRPS in VVER-1000 (cont’d)

**Reactor core temperatures**
Concluding remarks to the analysis SBLOCA without PRPS:

- Operator manual start of HPSI (based on EOP: E-0, E-1, FR-C) proved to be effective action and led to fast restoration of core cooling.
- Number of other variant of SBLOCA and LBLOCA with PRPS failure was analysed.
6. Implementation of DEC analyses results into Safety Analysis Report (SAR)

The whole set of prescribed DEC-A analyses was already performed both for Dukovany NPP (VVER-440) and for Temelin NPP (VVER-1000). From 15 to 20 DEC-A analyses for each plant.

As for the documentation of DEC-A analyses in Safety Analysis Report, the temporary solution was the creation of a new SAR subchapter 15.9.1 which contains basic results of all DEC-A (BDBA) analyses required by BN-JB-1.7.

Beside that the ATWS analyses are documented in subchapter 15.8 of the SAR as usually.

The future foreseen solution is introduction of new SAR charter 19, that would contain both DEC-A (BDBA without core melt) and DEC-B (severe accident) analyses presented in systematic and integrated way. Then the Chapter 15 will contain only analyses of events ranging from normal operation (NO) to design basis accident (DBA).
The object of the work partly presented here is the implementation of design extension conditions (DEC) concept to safety assessment of Czech nuclear power plants Dukovany (VVER-440) and Temelin (VVER-1000).

The core of the paper and presentation is focused on the deterministic safety analyses of the design extension conditions without core melt (DEC-A).

All major steps and tasks connected with the deterministic safety analysis of DEC-A events – methodology basis, selection of events to be analyzed, computer tools used and their validation, overview of safety analyses performed, example of results, and incorporation of analyses results into modified format of Safety Analysis Report (SAR) – have been briefly described.

It should be also mentioned, that the safety assessment of DEC-A is important not only as a proof of extended plant safety, but also as prevention of event development to severe accident with core melt (DEC-B).