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P16. PSA Usage for Development and Improvement of Emergency Operating Procedures

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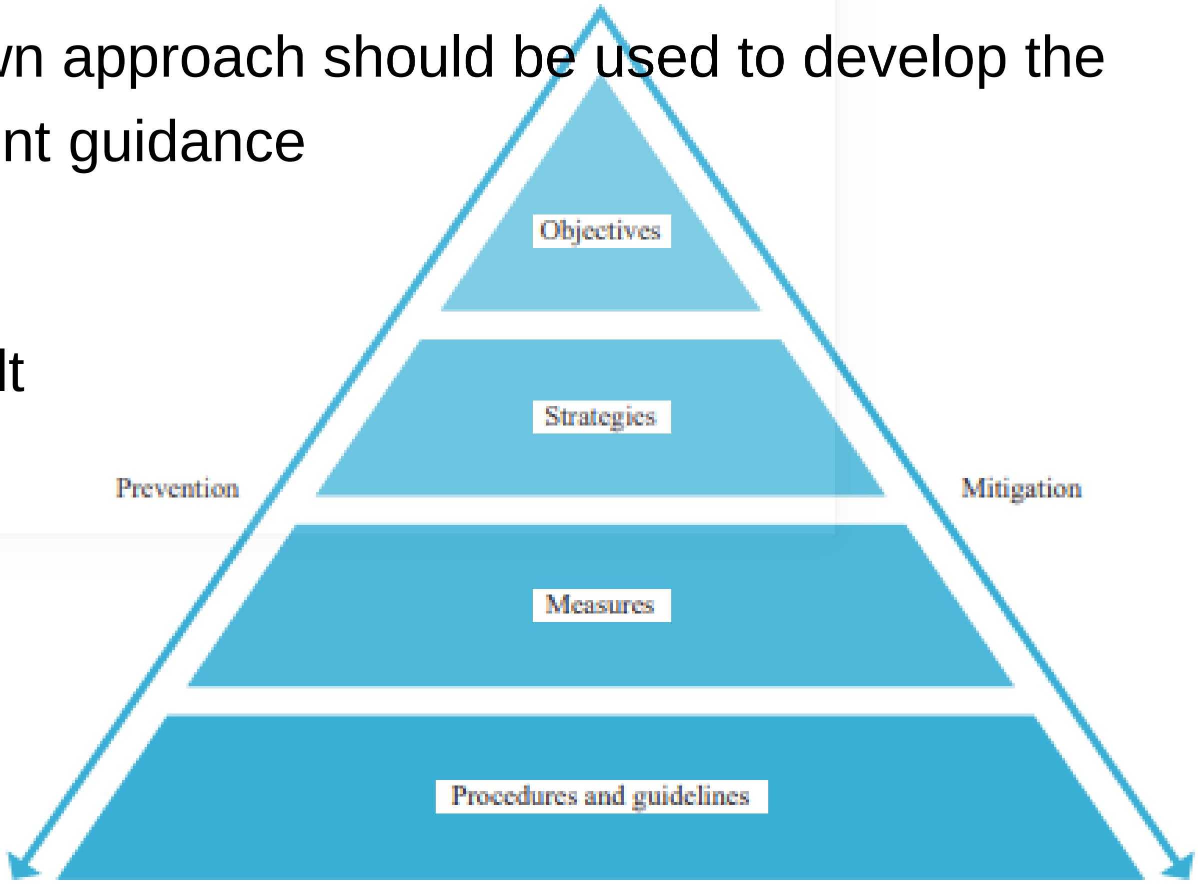
Outline

- Concept of Accident management programme (EOP&SAMG)
- Emergency Operating Procedures
- Use of PSA for EOPs
- Use of PSA for SAMGs
- Quality of PSA for applications
- Summary

Concept of AMP

- Accident management programme (AMP) should be developed for all plants, irrespective of the total CDF(or FDF) and LERF/LRF calculated for the plant.
- A structured top-down approach should be used to develop the accident management guidance
- Should begin with the objectives and strategies, and result in procedures and guidelines, and should cover both the **preventive** and the **mitigatory** domains.



Objectives

- Objectives of accident management are defined as follows:
  - Preventing significant core/fuel damage;
  - Terminating the progress of core/fuel damage once it has started;
  - Maintaining the integrity of the containment as long as possible;
  - Minimizing releases of radioactive material;
  - Achieving a long term stable state.

Strategies

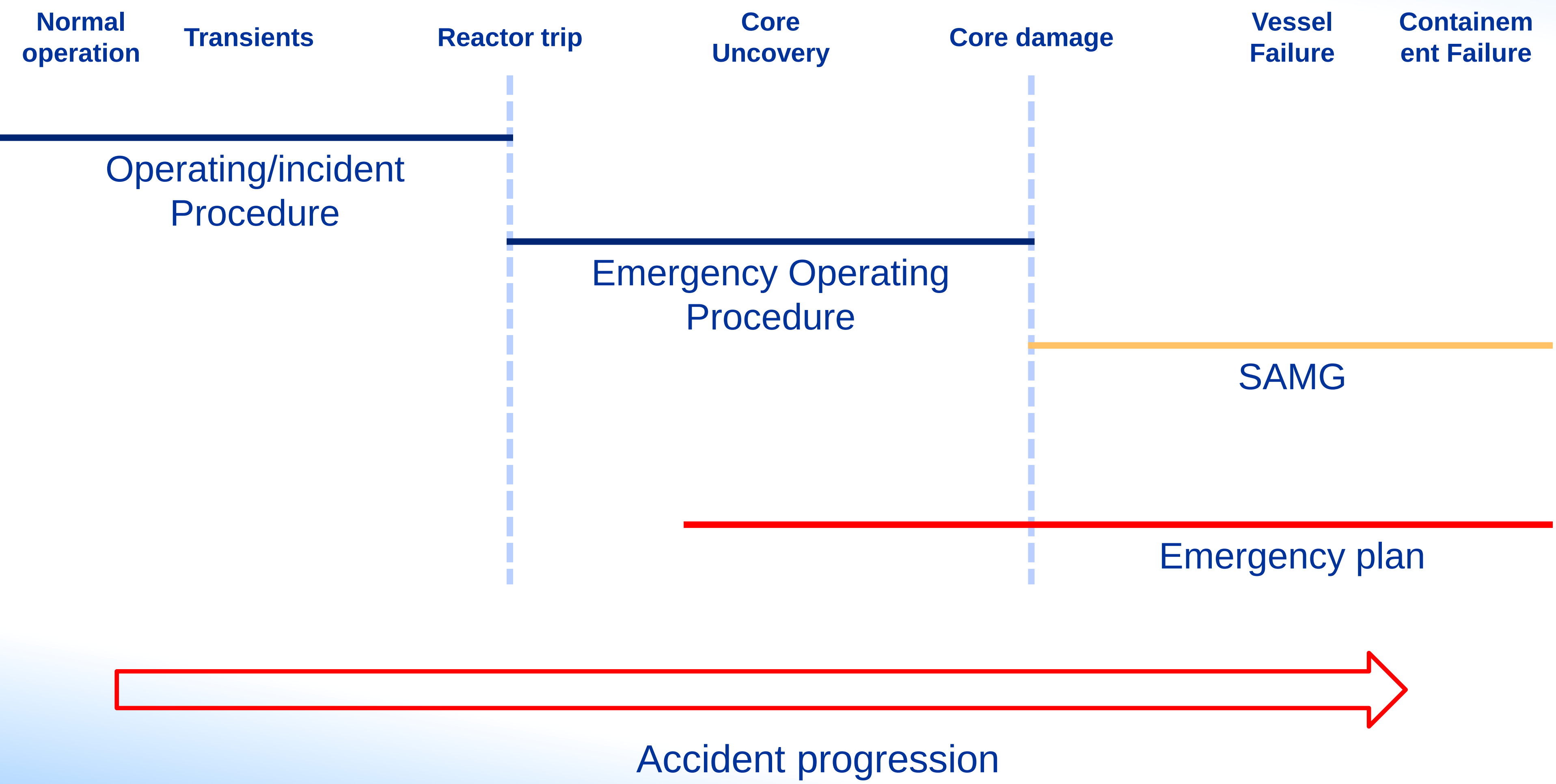
To achieve these objectives, the strategies should be developed

- For each individual challenge or plant vulnerability, in both the preventive and mitigatory domains

- **Preventive domain:** to preserve safety functions that are important to prevent CD maintaining core subcriticality, core cooling, primary inventory and containment integrity. *Example: ‘feed and bleed’.*

- **Mitigatory domain:** strategies should be developed to enable:
  - Terminating the progress of core damage once it has started;
  - Maintaining the integrity of the containment as long as possible;
  - Minimizing releases of radioactive material;
  - Achieving a long term stable state. *Example: depressurizing the reactor circuit to prevent high pressure reactor vessel failure*

Strategies

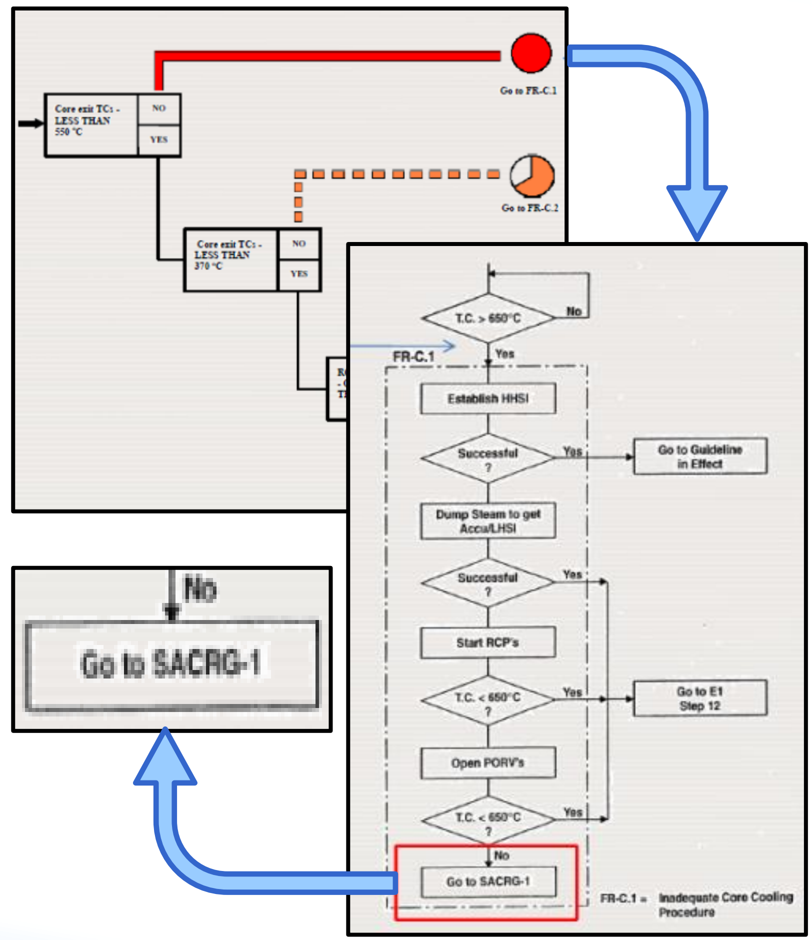

Normal operation
Transients
Reactor trip
Core Uncovery
Core damage
Vessel Failure
Containem ent Failure
Operating/incident Procedure
Emergency Operating Procedure
SAMG
Emergency plan
Accident progression

Procedures & guidance

- Procedures and guidelines, should be developed for the personnel responsible for executing the measures for AM

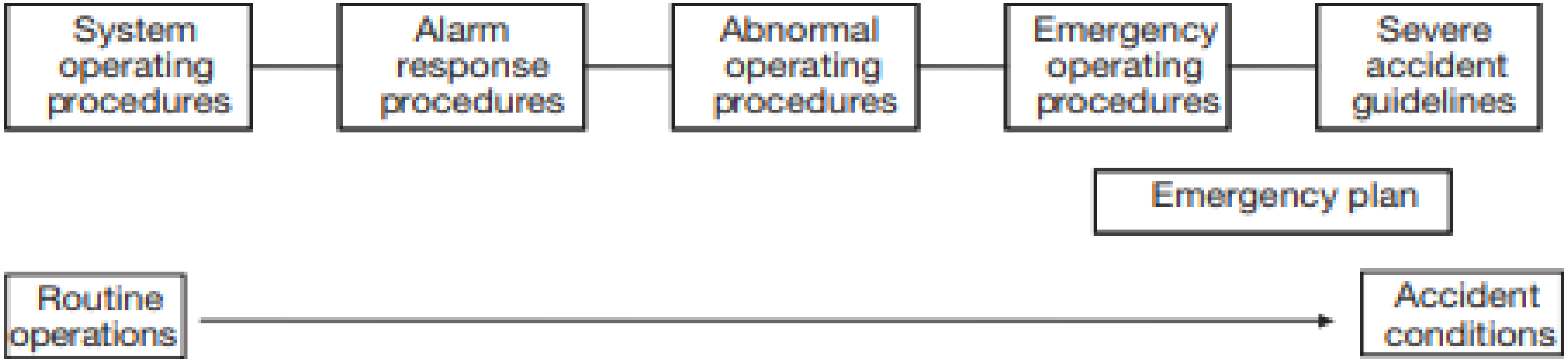
- **Preventive domain:** descriptive steps, usually called EOP, and is prescriptive in nature, are generally limited to actions taken before core damage occurs.

- **Mitigatory domain:** uncertainties may exist both in the plant status and in the outcome of actions → should not be prescriptive in nature, propose a range of possible mitigatory actions, usually termed SAMG.



Emergency Operating Procedures

- EOPs are providing procedural guidance for operators to deal with accident conditions up to the point of core damage.
- EOPs generally provide actions for a wide spectrum of operating conditions, ranging from abnormal operation up to accidents exceeding the design basis of the NPP.
- The EOPs represent one particular set of procedures in the entire spectrum of plant operating procedures.



Emergency Operating Procedures

- Depending on the scope, the set of EOPs should cover the following:
  a) Postulated DBAs;
  b) Abnormal situations with the potential of leading to accidents;
  c) Some BDBAs (combination of accidents, time evolving accidents, operator errors, etc.)
  d) Situations that cannot be clearly diagnosed;
  e) Challenges to a safety function ensuring overall safety of the plant, etc.;
  f) Multiple simultaneous failures;
  g) Continuous diagnosis;
  h) Shutdown accidents (if not already covered by DBAs).

Emergency Operating Procedures

Different sources of information can be used for definition and justification of the scope of the EOP. Examples of sources typically available at each nuclear power plant are:

- Safety analysis report
- Regulatory body requirements
- Operating experience
- Probabilistic Safety Analysis

Use of PSA for EOPs

- In general, deciding on the EOP’s scope is deterministic in nature and remains too arbitrary. A method of avoiding this is the application of probabilistic techniques.
- Probabilistic techniques can be applied in the determination of the EOP’s scope.
- When the decision on the scope of EOPs is made (based on plant specific probabilistic reasoning), it should be made on the cut-off probability for events to be covered only in the EOP package. Typically, the acceptable cut-off frequency is 10^{-6}–10^{-8} per reactor-year (SRS No. 48). The final choice of the cut-off probability should be negotiated with the regulatory body.

Use of PSA for EOPs

Step 1: Define Scope of the EOP

Step 2: Identification of the scenarios

Step 3: Grouping of the scenarios

Step 4: Analysis of the bounding scenario

Step 5: V&V + feedback

Defining the safety functions which failure (with or without additional failure of equipment) can lead to CD.

- For each safety function comprehensive set of scenarios should be identified.
- determination of critical technological parameters in terms of considered safety function
- grouping of scenarios based on critical technological parameters

Use of PSA for EOPs

- Step 1: Define Scope of the EOP
- **Step 2: Identification of the scenarios**
- Step 3: Grouping of the scenarios
- Step 4: Analysis of the bounding scenario
- Step 5: V&V + feedback

To determine comprehensive set of accident scenarios that occur with violation of safety function under consideration, the PSA model is applied.

The completeness of the list of initiating events considered in the PSA and the systematic analysis of accident sequences make it possible to substantiate the completeness of the list of considered accident scenarios.

Usually the selection of accident scenarios is carried out using event trees (ET)

Use of PSA for EOPs

- Step 1: Define Scope of the EOP
- Step 2: Identification of the scenarios
- **Step 3: Grouping of the scenarios**
- Step 4: Analysis of the bounding scenario
- Step 5: V&V + feedback

To perform grouping of the identified scenarios critical technological parameters and conditions in terms of function under consideration. E.g. depending from considered function this parameters can vary. Examples of parameters and conditions:

- type of initiating event
- reactor power
- number of operational SGs
- operability of the MCP
- Ect.

Based on the above parameters, grouping of selected scenarios is performed. Based on the grouping, the representative accident scenarios are identified for further analysis.

Use of PSA for EOPs

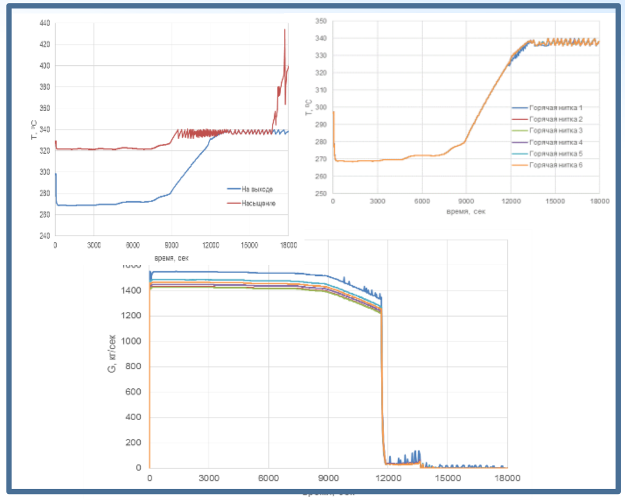
Step 1: Define Scope of the EOP

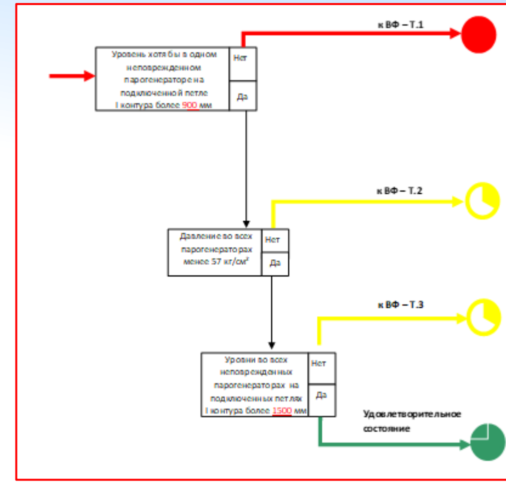
Step 2: Identification of the scenarios

Step 3: Grouping of the scenarios

Step 4: Analysis of the bounding scenario

Step 5: V&V + feedback





The key elements of the EOP packages are (Westinghouse owners group):

- Immediate actions and diagnostics procedures;
- Event related symptom based optimal recovery guidelines (ORGs);
- CSF restoration guidelines (scenario independent);
- CSF status trees.

Use of PSA for EOPs

Step 1: Define Scope of the EOP

Step 2: Identification of the scenarios

Step 3: Grouping of the scenarios

Step 4: Analysis of the bounding scenario

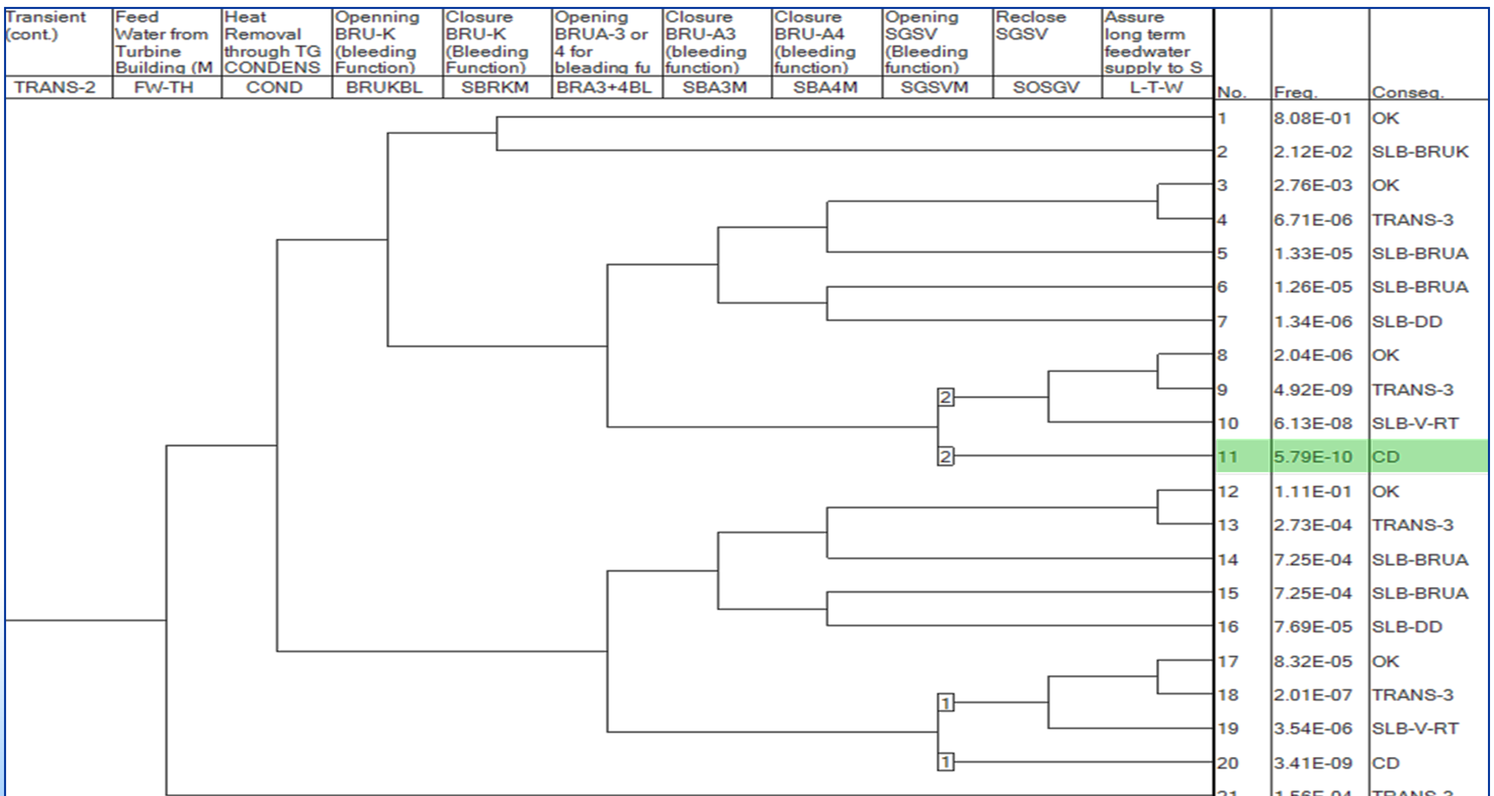
Step 5: V&V + feedback

- Once the procedures have been developed, they should be verified and validated (see §3.99–3.103 of NS-G-2.15)
- Analysis should be performed to investigate the:
  - the effectiveness of the EOPs
  - **the associated reduction of risks at the plant**
- Feedback based on the analysis results

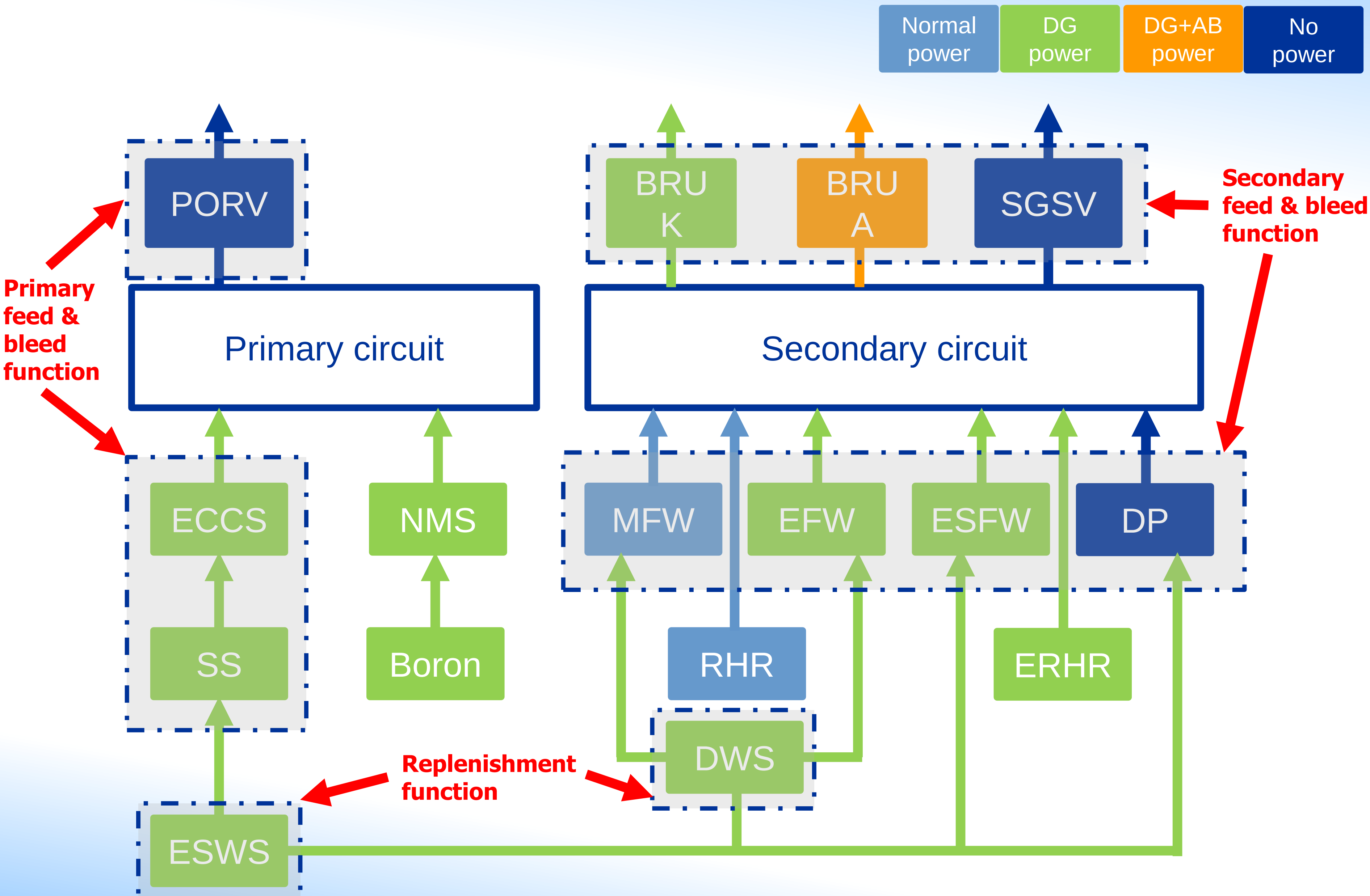
Use of PSA for EOPs

Example: loss of heat sink

- Possible accidents progressions are reflected in event trees
- Accident progressions connected with loss of heat sink have been selected from PSA model event trees



Use of PSA for EOPs



Use of PSA for EOPs

- As a result of IE analysis:
  - 118 initiating events were considered
  - 71 initiating events were selected
  - 36 groups of initiating events
- 109 scenarios have been selected from PSA in regard to loss of heat sink
- Preliminary look through the scenarios allowed to break them into following groups
  - IE + Failure of secondary relief valves (BRUK, BRUA and SG SV)
  - IE + Failure of TG stop valves + Failure of SG SV
  - IE + Failure of FW from TH + Failure of FW from BU + Failure of PFB
  - IE + Failure to replenish water in TH+ Failure of FW from BU + Failure of PFB
  - etc.
- Selected scenarios have different boundary conditions:
  - 1 out of 6 SG is unavailable
  - Vacuum is lost in condensers (BRUK is unavailable)
  - etc.

Use of PSA for EOPs

- EOPs should be symptom based or state based;
- EOPs should be consistent with the design basis of the plant. EOPs may impact the final safety analysis report (FSAR), limits and conditions/ technical specifications and other safety documents, since the scope of EOPs extends from expected plant transients to BDBAs;
- EOPs should cope with all possible accident situations and provide guidance for a wide variety of equipment failures and operator errors.

Emergency Operating Procedures

- EOPs improvements will be necessary throughout their NPP lifetimes.
- Implementation of EOP maintenance programme by NPP is a good practice. This should be done in a systematic way so that they are always as current, efficient and effective as possible. For that reason following can be used:
  - results from PSA studies,
  - feedback from simulator training,
  - internal operational experience,
  - plant design modifications,
  - additional TH analysis,
  - regulatory requirements.

Additionally, feedback may be obtained from other plants through review of generic operating experience and through owner's groups.

Use of PSA for SAMGs

- The PSA should be used as a basis for the evaluation of the measures in place and the actions that can be carried out to mitigate the effects of a severe accident after core damage has occurred.

- The aim of mitigatory measures and actions should be to arrest the progression of the severe accident or mitigate its consequences
  - e.g. by preventing the accident from leading to failure of the RPV
  - e.g. by controlling the transport and release of radioactive material with the aim of minimizing off-site consequences.

Use of PSA for SAMGs

- The results of the PSA should be used to determine the effectiveness of the measures that are described in the SAMGs

- The phenomena that occur during severe accident are often interrelated, one measure might make another phenomenon more likely.
  - Depressurization of the primary circuit may prevent high pressure melt ejection but might increase the probability of an in-vessel steam explosion
  - Containment sprays may provide a means of removing heat and radioactive material from the containment atmosphere but might increase the flammability of the containment atmosphere by condensing steam.

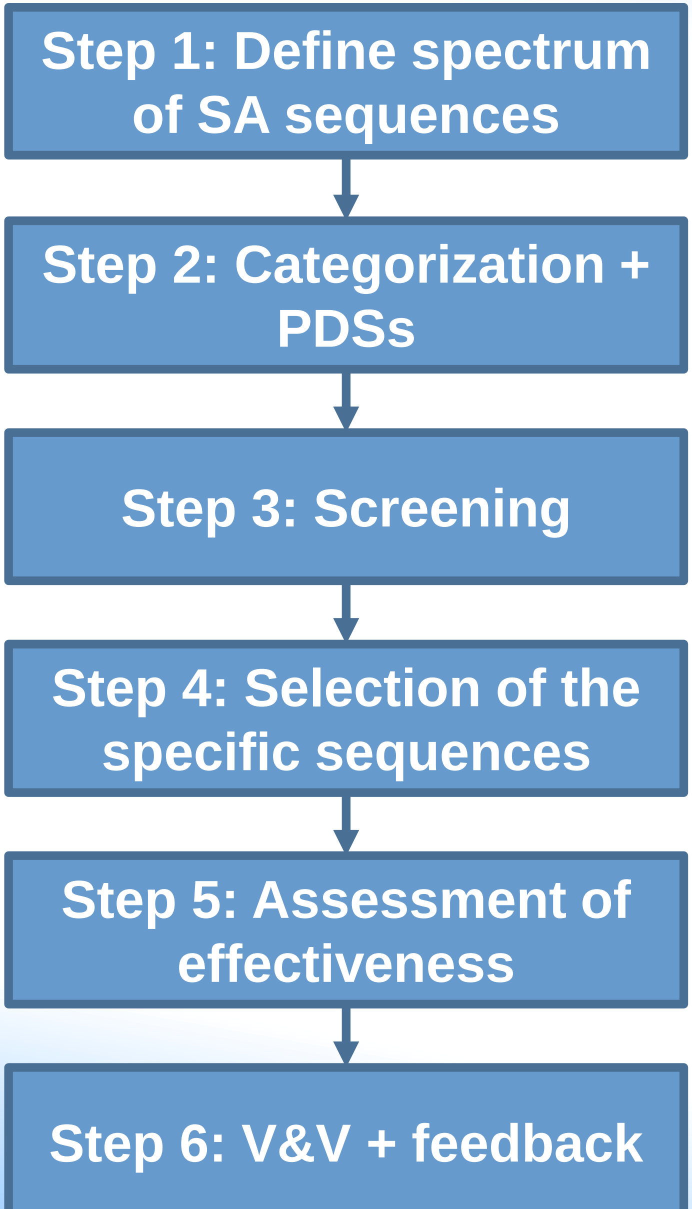
Use of PSA for SAMGs

- These interdependencies should be reflected in Level 2 PSA and should be taken into account in the development of the SAMGs

- In addition, severe accident conditions that result from operator errors prior to core damage should be considered in developing strategies for SAM (both from either operator errors of omission or errors of commission)

- Updates of the Level 2 PSA and updates of the SAMGs should be performed in an iterative manner

Use of PSA for SAMGs



Supporting analysis

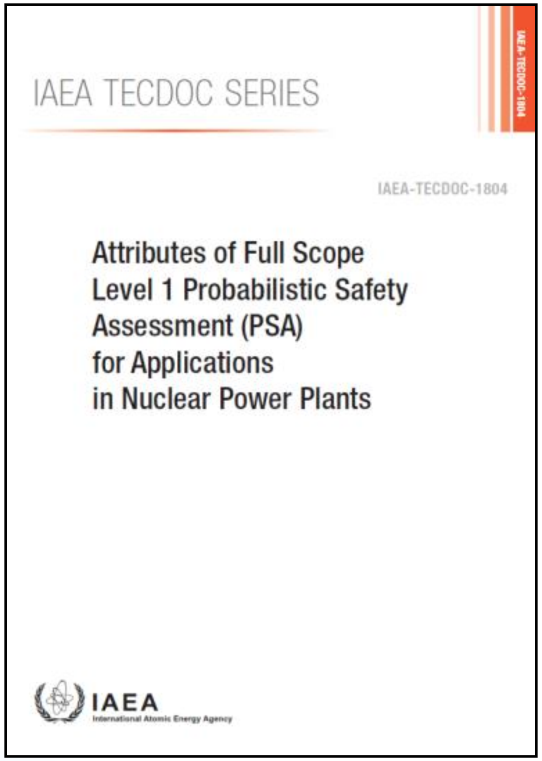
Analysis of a potential severe accident sequence typically has one of the following objectives:

- (1) formulation of the technical basis for development of strategies, procedures or guidance;
- (2) demonstration of the acceptability of design solutions to support the selected strategies, procedures and guidelines in accordance with the established criteria
- (3) determination of the reference source terms for emergency plans.

Quality of PSA for applications

Quality of PSA for applications

- The appropriate quality of Level 1 and Level 2 PSA models is an absolute for PSA applications (including use of PSA for AMP development)
- The TECDOC-1804 replaces the TECDOC-1511 issued in 2006
- Provides attributes for achieving the technical quality of PSA
- Support various PSA applications including “Development and improvement of the emergency operating procedures” and “Support for NPP accident management”



Quality of Level 1 PSA: Attributes

Mapping the special attributes of PSA elements to PSA applications (those attributes should be assured before using the PSA model for particular application)

PSA Application Group/ PSA Application	PSA Elements								
	IE	AS	SC	SY	HR	DA	DF	MQ	Other
3.1.3 Risk informed support for plant ageing management programme	IE-H02-S1	-	-	**SY-B19-S1** **SY-B22-S1**	-	**DA-E01-S1**	DF-F01-S1 DF-G01-S1	-	-
3.1.4 Risk informed on-line maintenance	-	-	-	-	-	-	-	MQ-A01-S1 MQ-C02-S1	-
3.1.5 Plant outage management	-	-	SC-A03-S1	-	HR-G02-S1 HR-G04-S1 HR-K02-S1 HR-K05-S1	-	-	-	OS-A03-S1 OS-C01-S2
3.2 Accident mitigation and emergency planning									
3.2.1 Development and improvement of the emergency operating procedures	-	**AS-B03-S1** **AS-C03-S1** **AS-C04-S1** **AS-C16-S1** **AS-C05-S1** **AS-C06-S1** **AS-C08-S1**	-	-	**HR-G02-S1** **HR-G04-S1**	-	DF-F01-S1 DF-G01-S1	-	-
3.2.2 Support for NPP accident management (severe accident prevention, severe accident mitigation)	IE-B01-S1	-	-	-	**HR-G02-S1**	DA-D06-S1	DF-F01-S1 DF-G01-S1	-	OS-A01-S1 HE-D04-S1
3.2.3 Support for NPP emergency planning	IE-B01-S1	AS-C05-S1	-	-	-	-	-	-	-

Quality of Level 1 PSA: Attributes

Attributes for "Development and improvement of the emergency operating procedures"

3.2.1 Development and improvement of the emergency operating procedures	-	**AS-B03-S1** **AS-C03-S1** **AS-C04-S1** **AS-C16-S1** **AS-C05-S1** **AS-C06-S1** **AS-C08-S1**	-	-	**HR-G02-S1** **HR-G04-S1**	-	DF-F01-S1 DF-G01-S1	-	-

AS-B03-S1	*Justification for the achievement of the non-success end state conditions is performed with the use of 'best estimate' models and parameters of the applicable justification tools.*	*RATIONALE: Use of conservative parameters for justification of non-success end states may lead to excessively conservative consideration of certain ASs, bias the results and insights and make certain applications non-credible.*

AS-C03-S1	*Plant specific realistic thermal hydraulic analyses are used to determine the accident progression for ASs.*	*RATIONALE: Use of thermal hydraulic analysis from similar units may produce results, which do not account for specific plant features influencing accident progression for specific sequences. The ASs constructed without taking into account plant specific features may not be appropriate for some PSA applications.*

AS-C16-S1	*Realistic plant specific analyses are made for specific ASs in order to verify whether the conditions for operator actions and operation of the specific equipment are achieved.*	*RATIONALE: Use of conservative assumptions instead of realistic analysis may bias the benefits of many applications aimed at improving/checking the influence of specific plant changes (e.g. hardware or procedures).*

HR-G04-S1	*The time line is based on plant specific thermal hydraulic analyses and/or simulator exercises.*

Quality of Level 1 PSA: Attributes

Attributes for "Support for NPP accident management (SA prevention and mitigation)"

3.2.2 Support for NPP accident management (severe accident prevention, severe accident mitigation)	IE-B01-S1	-	-	-	**<u>HR-G02-S1</u>**	DA-D06-S1	DF-F01-S1 DF-G01-S1	-	OS-A01-S1 HE-D04-S1

IE-B01-S1	*Events with frequency below the truncation value are revisited in the screening process and retained in the list of IEs to identify a wider range of possible hazards.*	*EXAMPLE: Changes in plant test and maintenance practice may impact the frequencies of these IEs. Exclusion of IEs of this type may mask their potential importance for certain applications.*

HR-G02-S1	*The method used to assess HEPs is capable of evaluating the impact of procedure changes.*	*RATIONALE: Evaluation of the impact of procedural changes is essential for applications aimed to optimize EOPs and AMPs.*

HE-D04-S1	*A list of equipment for each fire compartment is established including equipment required for each POS and/or cables whose fire induced failure, including spurious operation that may affect containment (confinement) function, such as containment isolation or cooling.*	*COMMENT: This attribute applies to additional containment functions that are beyond those that are required to prevent core/fuel damage.*

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Thank you!