Impact of Epistemic Uncertainties on the Probabilistic Assessment of the EOP ‘Secondary Side Bleed and Feed’

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Overview

- **Relevant tasks and relations of the ‘Secondary Side Bleed and Feed’ (SSBF) procedure.**
- **Motivation for a probabilistic dynamics analysis of the SSBF-procedure.**
- **Reasons of performing an extension of the analysis.**
- **Discussion of results**
- **Conclusions**

‘Secondary Side Bleed and Feed’-Procedure /1/

- The ’SSBF’ is employed in German PWR to restore the feed-water supply of the steam generators (SG).

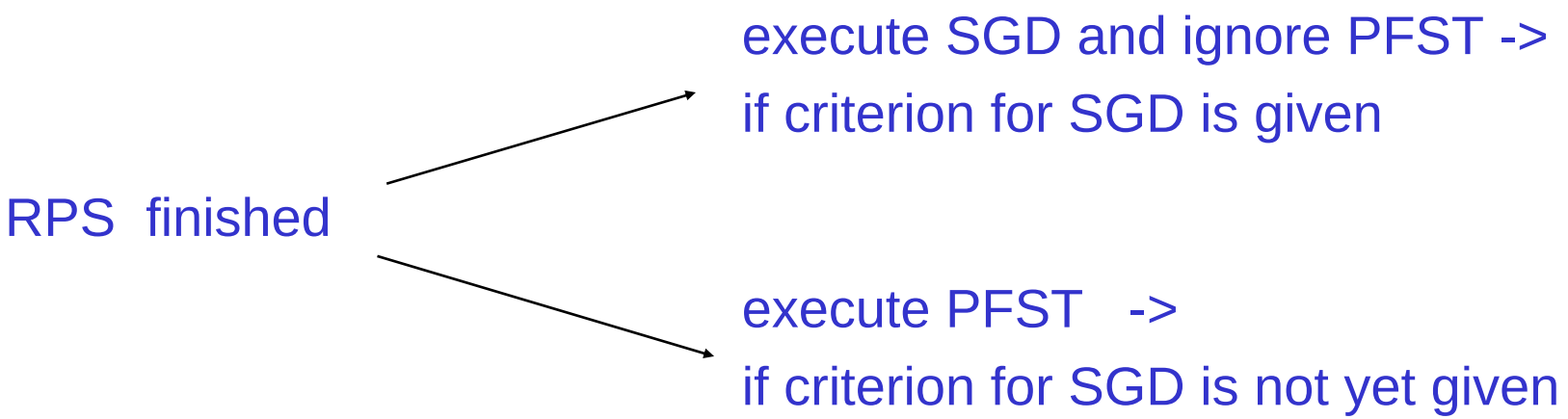
- One essential task is the pressurization of the feed-water storage tank (PFST) in order to use its water inventory for steam generator injection.

- The successful execution might cause a time delay of the critical situation which requires primary side depressurization.

- According to the EOP instructions, PFST can be performed only,
  - if the simulation of the reactor protection system (RPS) has been accomplished and
  - the criterion for the steam generator depressurization (SGD) is not yet given by corresponding system and process conditions.

‘Secondary Side Bleed and Feed’-Procedure /2/

- The criterion to execute SGD is given, if either
  - Coolant inlet temperature of primary system > 310°C or
  - Pressurizer water level > 9.5 m or
  - Pressurizer relief valve has been activated several times.
- The timing when the criterion for SGD is given is important because



Intention and features of the analysis /1/

- We have to deal with time-dependent interactions between the system- and process dynamics, human behavior and stochastic influences.
- For that reason a probabilistic dynamics analysis was applied to the ‘SSBF’ procedure, where the MCDET-method was combined with MELCOR.
- Human actions of ’SSBF’ were modeled within the ‘Crew-Module’.
- The combination of MCDET, the ‘Crew Module’ and a deterministic dynamics code (MELCOR) allows to model interactions between
  - the process of human actions,
  - the system- and process dynamics and
  - stochastic influences

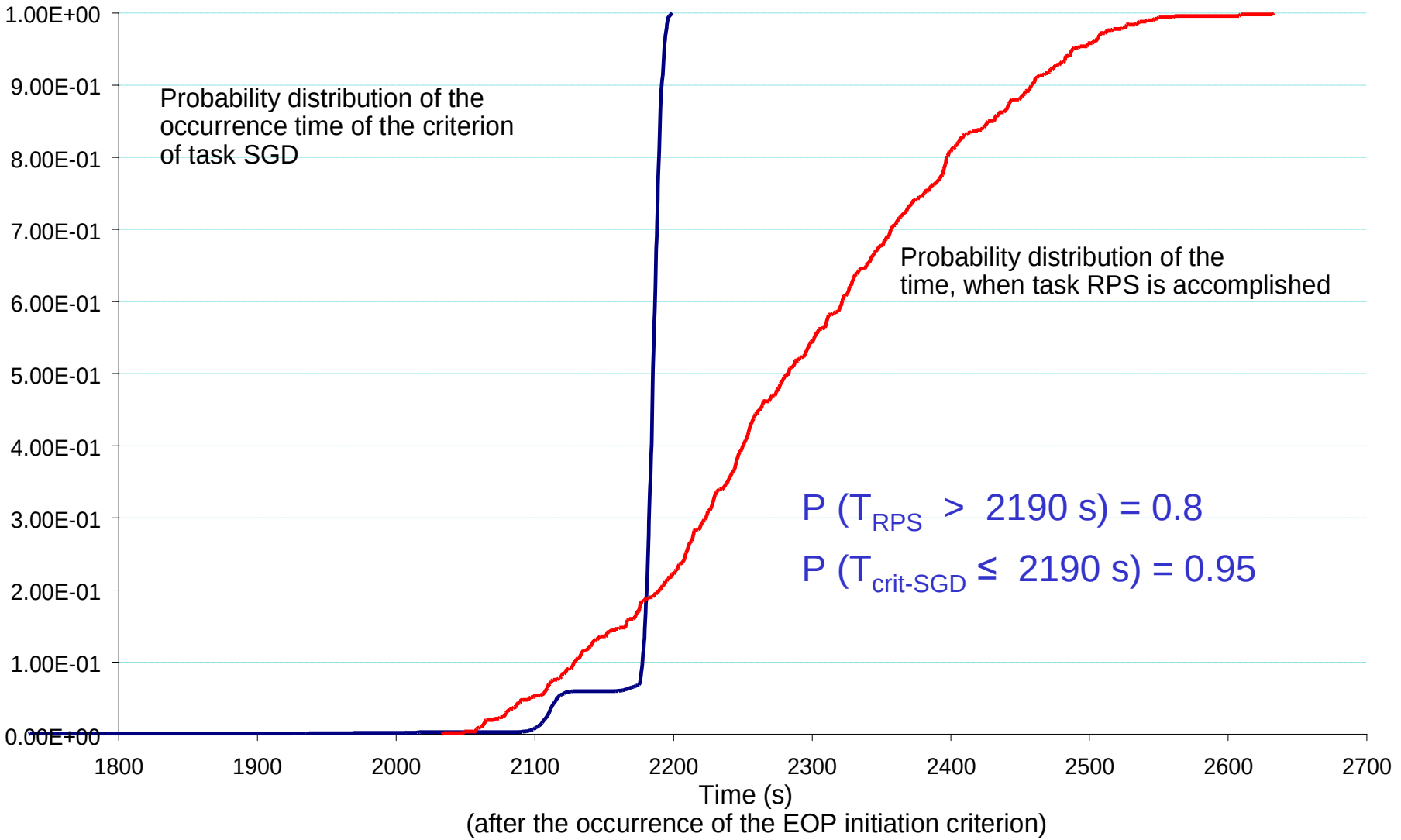
  in an integral way along the time axis.

Intention and features of the analysis /2/

Assumptions of the analysis

- No failures of technical components.
- Only stochastic (aleatory) and no epistemic uncertainties were taken into account:
  - execution times of human actions and
  - failure behavior of human actions.
- According to the EOP instructions ‘SSBF’ is initiated after the loss of feed-water
  - if the water level of all 4 SG < 4m.

Result of the analysis /1/



Result of the analysis /2/

Implication :

- Task PFST cannot be performed with a relatively high probability because
  - after accomplishing RPS (requirement for task PFST), the criterion for SGD is already given with a high probability and
  - the crew is forced to start SGD and must ignore task PFST.
- Neither technical failures nor human errors leading to the omission of task PFST are accountable for this situation.
- The only reasons are time effects resulting from the interaction between system and process dynamics, operator performance and stochastic influences regarding human activities.

Extended analysis /1/

- As a consequence of ignoring PFST with a high probability,
  - the failure probability of SSBF increases and
  - might affect the frequency of a core damage state.

- Deficiency of the analysis: No epistemic uncertainties have been taken into account.

- Model predictions of deterministic codes might be largely uncertain due lack of knowledge.

- A more comprehensive uncertainty analysis was performed considering both epistemic and aleatory uncertainties.

Extended analysis /2/

- The thermal-hydraulics code ATHLET was applied instead of MELCOR, because
  - the influence of the tasks of SSBF to the reactor plant behavior could be modeled in a more detailed way.
- Epistemic Uncertainties considered in the extended analysis refer to
  - input parameter of the ATHLET-code,
  - HEP (information of epistemic uncertainties given in ASEP).
- Regarding the input of ATHLET, 46 epistemic uncertainties were specified:
  - Heat loss (reactor coolant system, SG), [W/(m²K)] : U (1;7)
  - Correction factor for decay heat: U(0.9 ; 1.1)
  - Alternative sub-models for single phase forced convection on vapor: Discrete (50%-Dittus-Boelter , 50%-McEligott)

  etc.

Results of the extended analysis /1/

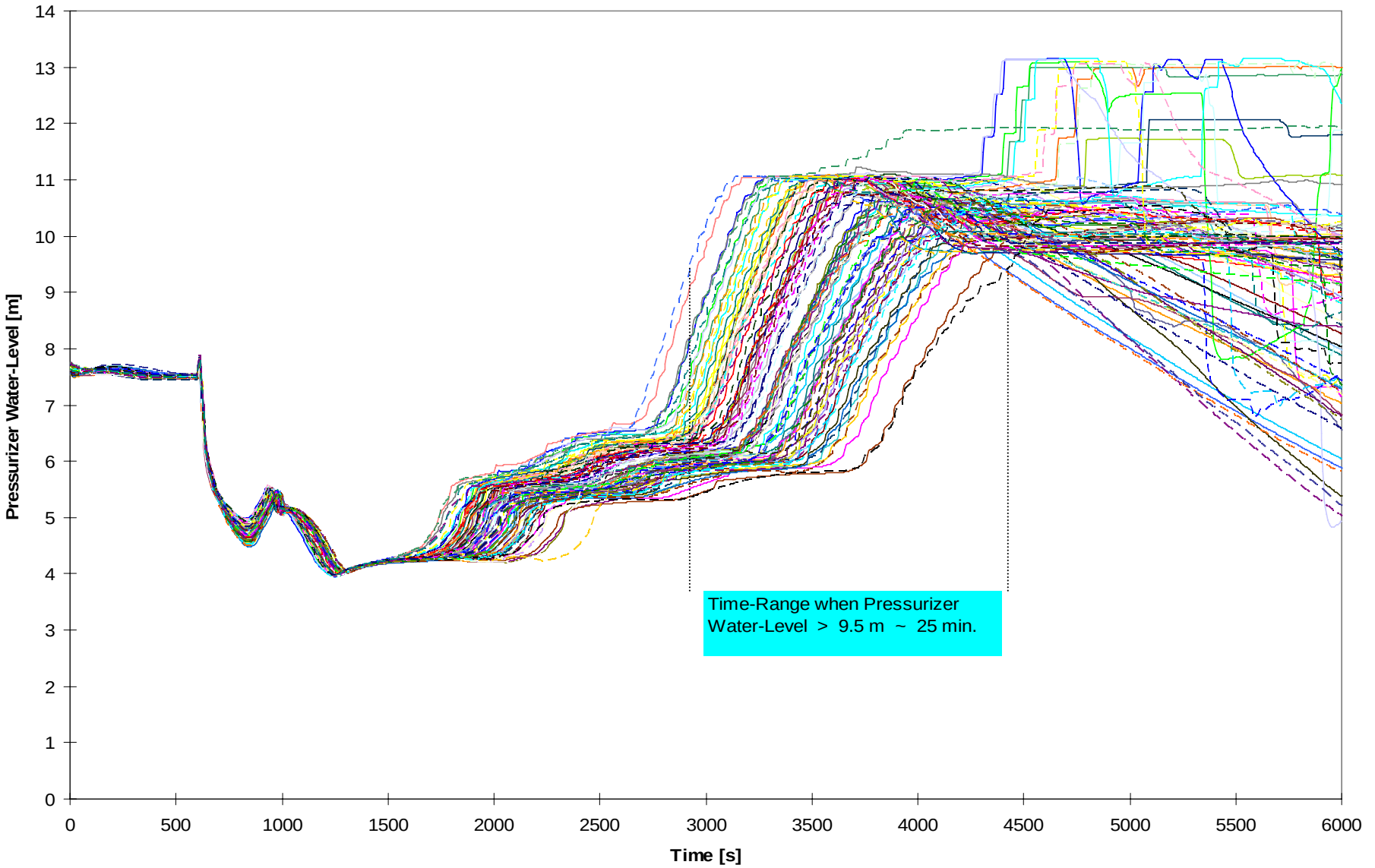
- 100 ATHLET-calculations were performed on the basis of a sample of the specified uncertain quantities.

- They provide a sample of model predictions reflecting the uncertainty of output quantities due to the common influence of epistemic and aleatory uncertainties.

- One criterion for SGD is: Pressurizer water-level > 9.5 m.

- The uncertainties specified in the ATHLET-code have a considerable influence on the
  - evolution of the pressurizer water-level and
  - time when the pressurizer water–level > 9.5 m.

Results of the extended analysis /2/



Results of the extended analysis /3/

- The extended analysis confirms that PFST cannot be performed with a relatively high probability
  - due to time effects resulting from interactions between human performance and system- and process dynamics.

Task PFST cannot be performed

	aleatory	aleatory and epistemic
Mean probability:	0.81	0.69
95%-Conf.-Interval:	(0.77 , 0.85)	(0.59 , 0.78)

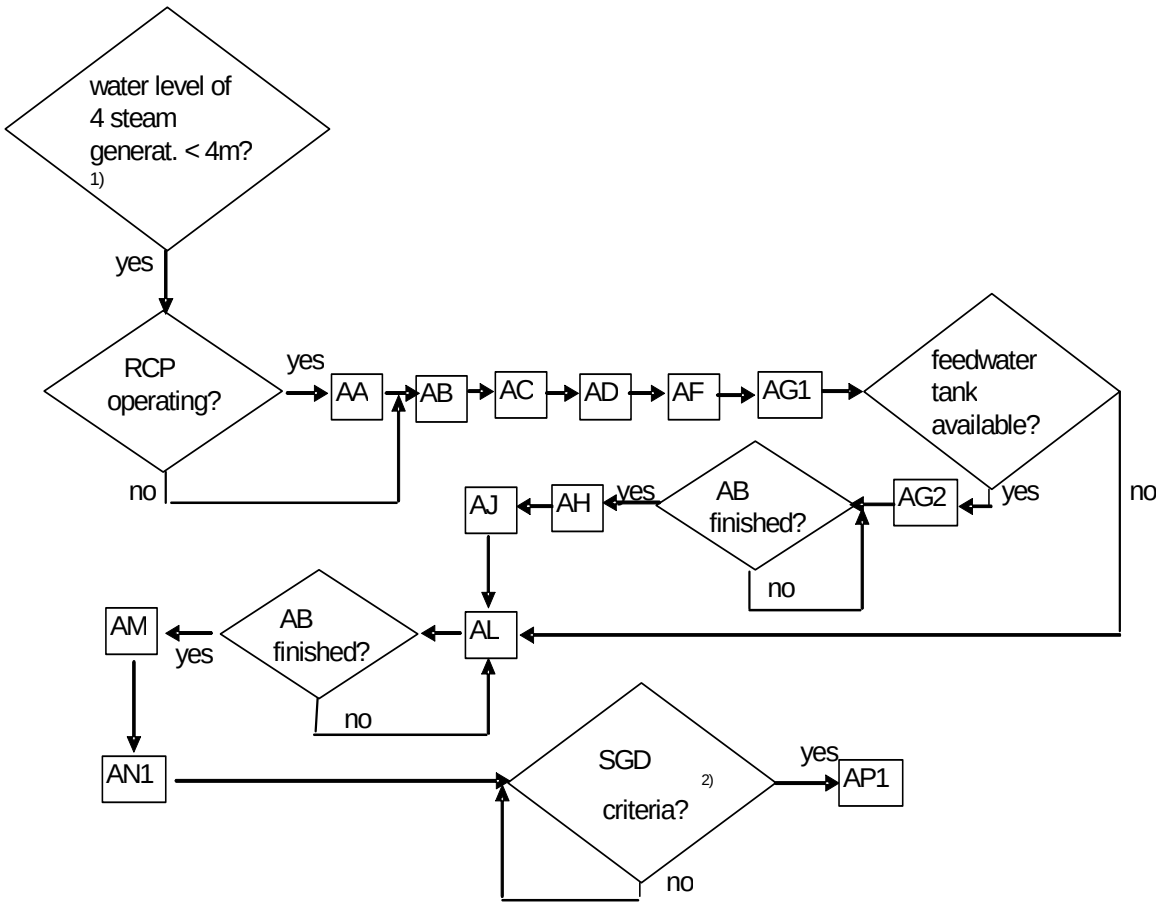
1. Conclusion

- EOP’s generally are developed deterministically.
- The complex interactions between human performance, system and process dynamics and the influence of stochastic events cannot all be anticipated.
- A validation of EOP’s should be performed probabilistically using advanced methods of probabilistic dynamics.

2. Conclusion

- Information from model results of deterministic codes are indispensable for a PSA.
- Epistemic uncertainties of input parameter of deterministic codes may have a significant influence on
  - the predictions of computer code applications and
  - the results of a PSA.
- Epistemic uncertainties of deterministic codes applied in a PSA should be taken into account.

‘Secondary Side Bleed and Feed’-Procedure /1/



EOP tasks:

AA: Switch off of the reactor coolant pumps (RCP).
AB: Simulation of the reactor protection system (takes place in the emergency feedwater building outside the control room).
AC: Installation of the mobile pump (in the emergency feedwater building).
AD: Inspection of the availability of the feedwater tank (in the engine house).
AF: Permanent monitoring of the system and process state.
AG1: Closing of the warm-up valves of the feedwater pumps to keep pressure in the feedwater pipe.
AG2: Isolation of the feedwater tank.
AH: Pressurization of the feedwater tank.
AJ: Locking of the auxiliary steam stop valves to keep pressure in the feedwater tank.
AL: Opening of valves to make available water content of the feedwater pipe after secondary side depressurization.
AM: Placing the emergency feedwater lines into operation.
AN1: Start of the mobile pump.
AP1: Opening of the main steam relief control valves for SGD.

1) Process criterion for EOP initiation
2) Condition for the steam generator depressurization is fulfilled, if one of the following criteria occurs:
- pressurizer relief valve opens several times, or
- pressurizer water level > 9.5 m, or
- coolant temperature in the primary system > 310°C.