PSA data base, comparison of the German and French approach

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Abstract: The results of probabilistic safety assessments (PSA) of nuclear power plants strongly depend on the reliability data used. This report describes coarsely the general process to generate reliability data for components and resumes the differences between the German and French approaches. As has been shown in former studies which compared international PSA data, PSA data are closely related to the model definitions of the PSA. Therefore single PSA data cannot be compared directly without regard e.g. to the corresponding fault trees. These findings are confirmed by this study. The comparison of German and French methods shows a lot of differences concerning various details of the data generation process. Some differences between single reliability data should be eliminated when taking into account the complete fault tree analysis. But there are some other differences which have a direct impact on the obtained results of a PSA. In view of the all differences between both approaches concerning the definition of data and the data collection process, it is not possible to compare directly German and French PSA data. However, the database differences give no indication on the influence on the PSA results. Therefore, it is a need to perform a common IPSN/GRS assessment on how the different databases impact the PSA results.

1. INTRODUCTION

The results of probabilistic safety assessments (PSA) of nuclear power plants strongly depend on the input data used. Therefore, the generation of reliability data plays an important role. This report describes coarsely the general process to generate reliability data for components and resumes the differences between the German and French approaches.

Regarded are the reliability data for independent failures of components, for common cause failures and the frequencies of initiating events. Outside of the scope of this report are the reliability data for pipes and human actions.

This report should be considered as a basis for further discussion about the comparability of German and French methods to generate reliability data.

Chapter 2 describes the general data generation process common to both approaches. In chapter 3 the differences between the German and the French approaches are pointed out. In chapter 4 some conclusions are drawn.

2. REQUIREMENTS FOR THE RELIABILITY DATA GENERATION PROCESS

In order to achieve realistic results of probabilistic safety assessments, the input data used have to be as realistic as possible. It is generally accepted, that the most realistic approach consists in evaluating the operation experience of nuclear power plants and to extrapolate this past experience to the future.

The reliability data discussed in this report are:

- reliability data for components (independent failures)

- common cause failures
- frequencies of initiating events.

In the following paragraphs, the main steps of this data generation process are summarised. A more detailed presentation of the German and French methods is given in [ref].

2.1 Reliability Data for Components

Reliability data for components are generated either for specific plants or for series of identical plants depending on the structure of the park of plants and on statistical needs. The generation of reliability data for a PSA can be structured in three tasks:

- Selection of the components, which are considered to be a homogeneous population of components with the same reliability characteristic
- Selection of the failure events depending on the required failure mode
- Calculation of reliability data from the selected failure events and related operation data.

2.1.1 Selection of Populations of Components

PSA fault tree analysis defines the components for which reliability data are needed. This includes a clear definition of the component boundaries. The selection of a population of components serves to put together those components for which common reliability data are generated. The selection is depending on the technical and operational comparability of the components and on the time period under observation. In general, a population is formed so that a sufficient statistical basis exists to generate representative reliability data.

2.1.2 Selection of Failure Events

The fundamental information to evaluate failure events comes from plant reports like maintenance or test reports. Large database systems are used in Germany and in France either to store the reports themselves and adding detailed coded information and assessment to allow for selection of relevant events or to store pre-selected potentially relevant events and adding less coded information.

Engineering judgement always plays an important role in assessing events. The assessment of each selected event is always discussed between plant operator and analyst.

2.1.3 Mathematical Evaluation

Failure rates and failure probabilities are always needed as input data for fault tree analysis. Depending on fault tree models and data definition, repair times and rates of unavailability can also be separate input data. Depending on the homogeneity of the selected populations of components Bayesian or frequentistic approaches are used to calculate the needed data.

The operation data needed for these calculations contain the operation times and cycles of the considered components. Depending on the regarded demand, different time intervals or numbers of demands are taken into account, such as calendar time (observation period), operation time of the generator, time during which circuit is filled with medium or hold under pressure, time of plant connection of electrical equipment, operation time of the component (e.g. pumps, fans, emergency diesel generators) or number of cycles (demands of the component).

2.2 Common Cause Failures

The fault tree analysis identifies groups of identical or nearly identical components which in most cases are redundant components performing the same functions in different trains of a system. For these components probabilities or rates of common cause failures (CCF) for different combinations of failures are needed.

Due to the low number of observed CCF events, reliability data for CCF generally are generic data. Even for these generic data, the populations for the evaluation of CCF data in many cases are broader, and thus less homogeneous, than the populations of components for the generation of independent data. Primary basis for these generic data is the entire national operation experience. If necessary, this information is supplemented by international experience.

Once the populations are defined and the therein observed CCF events are assessed, the quantification of the needed CCF reliability data is done by using a suitable model.

2.3 Frequency of Initiating Events

Fault tree analysis starts with defining a set of initiating events. Depending on the definition of the initiating events, failure events from operation experience are counted to determine the frequencies of occurrence of the corresponding initiating events or to determine the reliability of the corresponding safety functions. For rare initiators, generic data or estimated theoretical values are used.

3. DIFFERENCES BETWEEN GERMAN AND FRENCH APPROACH

In tables 1 to 3 steps of the data evaluation process where differences exist between the German and the French approach are listed. For each step the differing features are mentioned.

Table 1: Component reliability data

Step of data evaluation process	German approach	French approach
•Scope of data	Plant specific reliability data combined with prior information from other comparable German plants	Reliability data for standardised series of plants
•Operating profiles	No profiles elaborated, but regarding of plant state at event assessment	Elaboration of a generic reference profile for each series of plants, indicating the medium duration per standard state.
•Unavailability data	Generally not collected, except some special components	Collected
•Population of components	Both approaches use the same principles for forming populations, like technical and operational comparability of the components and sufficient statistical basis, but for some types of components different classifications are chosen. E.g. for motor operated valves the following classification is used :	
	- Globe valves - Gate valves - Butterfly valves For these sub-types of valves there can be a further subdivision of populations per system or per other technological features.	- Borated water valves - Condensed water valves - Intermediate cooling water valves - Primary coolant valves - Steam valves
•Component boundaries	Both approaches have well defined boundaries, but some definitions differ, e.g.	
- motor operated valves	control unit and electrical connection included	control unit and electrical connection not included
- pumps	drive, control unit and electrical connection included	drive, control unit and electrical connection not included
- emergency diesel generators	circuit breaker included	circuit breaker not included Remark : For the data analysis in the frame of the reliability based on the optimisation of maintenance, the component boundaries equal the ones used in German PSA.
•Operating conditions	For some components, the operating conditions in German and French plants are different. This may lead to different stresses to the components and thus to different failure rates. One example are the emergency feedwater pumps which are purely stand-by pumps for incident situations in the newer German PWR whereas they are also used as operational start-up and shut-down pumps in French PWR.	

•Failure events : source of information evaluated by PSA experts	Maintenance reports of plant	National database of anomalies. Each plant reports to this database using an EdF-guideline defining reporting criteria. This procedure is initiated by the plant pre-selection which could be completed by the maintenance report.
•Codification of events	Expanded codification in view of different PSA-applications including - affected part of component - failure mode and - assessment of criticality of failure based on engineering judgement Common decision of plant operator and analyst about codification	PSA aspects have been taken into account at the creation of the national database. This database contains a general codification to allow pre-selection of events, but no additional PSA-specific codes which would allow an automatic evaluation of the database.
•Selection of failure events	Computerised evaluation of completely coded events for each population of components and for each failure mode requested by PSA fault tree	Computerised request to select the event in national database Set up of failure criteria for each population of components Individual analysis of criticality of failures by EdF and verified by IPSN
•Event boundaries	Failures due to human errors taken into account for failure rates if these failures lead to maintenance reports or if they were detected during a test. Failures which were detected in shutdown state of the plant can be taken into account if there is an indication that there would have been a failure if the component had been demanded after the last successful test in power state	Failures where the direct cause is a human error are not taken into account for failure rates but are modelled separately. Failures which were detected during preventive maintenance in shutdown state of the plant are not systematic considered.
•Observation period	Generally large (e.g. 10 years)	Recent period (e.g. 3 to 5 years)
•Mathematical evaluation	Bayesian approach combining plant specific data with prior distributions of data from other German plants	Frequentistic approach

•Determination of probabilities of failures per demand	Calculation of a distribution of a failure rate by a Bayesian approach with the parameters « number of observed failures » and « accumulated observation time of the components in the population ». Multiplication of half of test interval with failure rate.	Division of « number of observed failures » by « accumulated number of demands of the components in the population ».
•Repair times	In general not determined. Recently, for single components, failure rates split up in rates for component parts and associating individual repair times to each component part	Determined. Used for some components to split up the failure rate in rates for failures with long and short repair times, e.g. emergency diesel generators.
•Uncertainties	Determination results implicitly from Bayesian approach	Determined by «chi-square» law

Table 2: Common Cause Failures

•Scope of evaluated operation experience	Nearly all common cause data are based on operation experience	The majority of common cause data are based on operation experience, some are based on engineering judgement e.g. emergency diesel generators
•Exhaustivity in regard of potential common cause failures	Reporting criteria demand explicitly reporting of events with indication of a systematic failure	No explicit criteria demanding to report systematic or common cause failures : potential common cause failures with one failed component and additional indications on comparable components may not be identified in national database because observations during maintenance are not reported as long as the availability of the component is not in doubt.

•Populations of component groups	There are some types of components where the German approach is more detailed and some types of components where the French approach is more detailed. Examples are :	
	- motor operated gate valves - motor operated globe valves - motor operated butterfly valves	- motor operated valves
	- measured value transducers for flow rate - measured value transducers for level - measured value transducers for pressure	- measured value transducers
	- circulating pumps	- emergency feed water pumps - other circulating pumps
•Type of applied model	Generation of common cause failure data without referring to independent reliability data results in absolute CCF data	Generation of common cause failure data relatively to independent reliability data results in relative CCF factors
•Uncertainties	Determination results implicitly from Bayesian approach	Uncertainties on CCF are related to independent reliability data and not to CCF factors

Table 3: Initiating Events (including leakages)

•Source of information	Plant specific for initiators with frequencies of about 0.1 per year Experience of similar plants for initiators with frequencies of about 0.01 to 0.001 per year	Experience of all French plants for initiators having occurred at least once in French plants Experience of PWR plants world-wide for initiators having never occurred in French plants but occurred elsewhere
•Degree of detail	Initiating events grouped to about 30 initiators including internal and external events	Initiating events grouped to about 70 initiators. Internal and external events not regarded in PSA. Initiator « fire » examined at the moment
•Example for different modelling	Loss of suction for essential service water pumps taken into account in common cause failure data for essential service water pumps	Loss of suction for essential service water pumps taken into account in frequency of initiating event « loss of essential service water ».

4. CONCLUSION

As has been shown in former studies which compared international PSA data, PSA data are closely related to the model definitions of the PSA. Therefore single PSA data cannot be compared directly without regard e.g. to the corresponding fault trees. These findings are confirmed by this study.

The comparison of German and French methods in Chapter 3 of this report shows a lot of differences concerning various details of the data generation process. Some important examples are :

- the different component boundaries for numerous important components, like emergency diesel generators, pumps and motor operated valves,
- the separate modelling of failures, which are directly due to human errors, in French PSA, whereas such events are taken into account for the component reliability data in German PSA,
- the different grouping of initiating events, which influences the assignment of observed failures either to the reliability data for components or to the frequencies of initiators.

These three differences between the single reliability data should be eliminated when taking into account the complete fault tree analysis. But there are some other differences which have a direct impact on the obtained results of a PSA.

One difference in the component failure event analysis process seems to be the non systematic consideration of failures detected during preventive maintenance in shutdown state of a plant in France. In Germany a case by case decision is made whether a finding during preventive maintenance in shutdown state of a plant is considered as failure or not.

Besides, there is one remarkable difference in the mathematical evaluation of reliability data for independent failures. In the German « failure rate approach » the unavailability of a component due to a failure on demand is calculated by the number of observed failures on demand, the accumulated observation time and the test interval (half of the test interval). The French failure rate per demand is calculated by the number of observed failures on demand and the number of demands. This methodological difference leads to different reliability data even if the same raw data are used (larger values of nearly a factor 2 with the French model).

The cause of this difference are the different model assumptions about the kind of mechanisms leading to failures of components : based on German operation experience the German model assumes that failures depend on the stand by time of a component and not on the number of demands of a component. The French model more cautiously assumes that the occurrence of failures depends on the demand of the component. This would correspond to the German model if the full test interval would be taken for the calculation of the German data for failures on demand.

An advantage of the French approach is the standardisation of equipment. This leads to a broad database which results in a reduction of the statistical uncertainty compared to the German situation. Further, the larger operation experience of the standardised French plants allows sometimes to model more precisely and thus reducing conservatism.

The most important of the above described differences of German and French PSA data are summarised in table 4.

In view of the totality of differences between both approaches concerning the definition of data and the data collection process, it is not possible to compare directly German and French PSA data. However, the database differences give no indications on the influence on the PSA results. This can only be analysed by evaluating the whole process to generate PSA results beginning with the collection of information about operation experience in the plants up to the analysis of whole fault trees. Therefore, it is a need to perform a common IPSN/GRS assessment on how the different databases effect the PSA results.

Reference

A. Kreuser, PSA Data Base Approaches in Germany and France, Report IPSN/GRS N° 77, 24.09.1999

Table 4: Most important differences of German and French PSA data

Step of data evaluation process	German approach	French approach
•Component boundaries, e.g. - pumps - motor operated valves - emergency diesel generators	drive, control unit and electrical connection included control unit and electrical connection included circuit breaker included	drive, control unit and electrical connection not included control unit and electrical connection not included circuit breaker not included Remark : For the data analysis in the frame of the reliability based optimisation of maintenance the component boundaries equal the ones used in German PSA
•Failure events : source of information evaluated by PSA experts	Maintenance reports of plant – therefore the exhaustivity of data is under the control of the PSA expert	National database of anomalies. Each plant reports to this database using an EdF-guideline defining reporting criteria. This procedure is initiated by a plant preselection which could be completed by the maintenance report
•Event boundaries	Failures due to human errors taken into account for failure rates if these failures lead to maintenance reports or if they were detected during a test. Failures detected in shutdown state of the plant can be taken into account if there is an indication that there would have been a failure if the component had been demanded after the last successful test in power state.	Failures where the direct cause is a human error are not taken into account for failure rates but are modelled separately. Failures which were detected during preventive maintenance in shutdown state of the plant generally are not systematic considered.
•Determination of probabilities of failures per demand	Calculation of a distribution of a failure rate by a Bayesian approach with the parameters « number of observed failures » and « accumulated observation time of the components in the population ». Multiplication of half of test interval with failure rate	Division of « number of observed failures » by « accumulated number of demands of the components in the population ». This leads to larger values of nearly a factor 2 with the French model even if the same raw data are used
•Differences in modelling failures as Common Cause failures or as initiating events, e.g.	Loss of suction for essential service water pumps taken into account in common cause failure data for essential service water pumps	Loss of suction for essential service water pumps taken into account in frequency of initiating event « loss of essential service water »