

A PROPOSAL FOR AN APPROACH TO SYSTEMATIC PRECURSOR EVALUATION

G. Skoff¹, G. Breiling¹ and H.P. Berg²

¹ABB Reaktor GmbH, Department of Engineering Service, Mannheim, Germany

²Bundesamt für Strahlenschutz, Department of Nuclear Safety, Salzgitter, Germany

ABSTRACT

The current international state of the approach to a systematic precursor evaluation is described. The systematic study and evaluation of "Precursors to potentially significant accident sequences" can provide an important supplement to PSA-work both on a qualitative and quantitative basis. Precursor analysis utilizes some of the PSA-methods but uses only data from operational experience to quantify the models. A concept for the systematic evaluation of precursors to severe core accidents in German nuclear power plants is outlined, taking into account international experience. It provides a tool for analyzing actual events in plants with respect to their significance of causing severe core damage and of identifying possible weak spots.

1 INTRODUCTION

The term "Precursors" describes special events in nuclear power plants that can lead to severe accidents with core damage if certain additional failures occur in safety systems on demand to mitigate such transient or accident events. Precursors can be:

- System/component failures that lead directly to initiating events such as small LOCAs, loss of offsite power etc.,
- equipment unavailabilities (system failures) in safety systems necessary to handle the consequences of possible initiators
- or a combination of both.

The systematic study of precursors provides a tool for identifying weak spots in plants and indicates ways for possible improvements. Precursor analysis is based on an evaluation of the special event reports which have to be filed with the licensing authorities. These reports are analyzed with respect to their significance of potentially causing severe core damage. The analysis of precursors can thus provide a qualitative and quantitative backup of living PSAs on the basis of actual plant experience and operating data.

The leading effort in this field has been done in the USA, where detailed analyses have been started in 1979 and have been performed on a yearly basis since 1984. Some work has been done

in Germany, covering the period 1975 to 1983. In Sweden extensive data bases for trend analyses on Swedish plants have been established by the Swedish Nuclear Power Inspectorate, but a detailed precursor evaluation is currently not done.

2 INTERNATIONAL DEVELOPMENT

2.1 US-Precursor-Program

The so-called Accident Sequence Precursor Program (ASP) was initiated in 1979 at the Oak Ridge National Laboratory at the request of the US Nuclear Regulatory Commission (NRC). The Risk Assessment Review Group concluded that potentially significant accident sequences and actual precursors should be subjected to the same kind of analysis that was performed in the "WASH-1400", the US Reactor Safety Study [1]. The US-program is based on the analysis and evaluation of the so-called Licensee Event Reports (LERs), which have to be submitted to the NRC by the US-utilities in case of special events. The first comprehensive report was published in 1982 and includes the detailed analysis of all LERs that occurred during the period 1969 - 1979 [2]. Starting in 1984, yearly reports were published that describe the precursors of the corresponding calendar year. The initial method was subsequently modified to some extent as the methods were further developed and refined [2, 3]. One of the refinements was the definition of a number of plant classes which provided a better plant-specific resolution. The analytical methods used are compatible to those used in standard PSA-work. The ASP program uses a set of standard event trees for every PWR/BWR plant class. Most events are mapped onto 3 standard event diagrams called "Nonspecific Reactor Trip" (TRANS), "Loss of Offsite Power" (LOOP), "Small Break Loss of Coolant Accident" (LOCA).

The initial set of about 3000 - 4000 LERs per year are screened in a 2-step process according to a set of well-defined selection criteria and yield a set of 30 to 40 precursors/yr for all US-plants. The choice of the selection criteria used has a substantial impact on the results as other investigations [4] have demonstrated. Initiating event frequencies and system unavailabilities are determined from operating data that are averages over many plants and many calendar years. The latter data are derived mainly from failure rates discovered during regular system/component testing giving relatively good statistics but poor plant-specific resolution.

The ASP-study uses the concept of "conditional probability of severe core damage" as a measure for quantifying the significance of each precursor, i.e. the relative distance to a severe core accident. It is the sum of the conditional core damage probabilities for the different branch sequences for the particular precursor. The sum of these probabilities for all precursors yield an industry-wide global value for the expected frequency of severe core damage [2]. Simple fault tree overhead structures in which train unavailabilities form the basic events are applied for the quantification of the event diagrams. This allows the modelling of common cause influences in the unavailability data for mitigating systems. The influence of human errors is

included by applying a global set of so-called recovery factors which account for the chance of recovery under the given conditions.

The precursors are ranked according to their relative order of importance and attention can be focussed to the most significant events at power plants, i.e. the ones that would most likely have led to core damage in case of additional unavailabilities. Certain generic weaknesses in systems/plant-design or operation can thus be uncovered. Many changes (such as the use of bleed and feed operation) have already been made as a result of these new insights.

2.2 German Precursor Study

The precursor work in Germany to date is limited to the "Deutsche Precursor Studie" [5], performed in 1988 by the Gesellschaft für Reaktorsicherheit (GRS). Contrary to the US approach, which concentrates on industry-wide global evaluations, this study was specifically limited to the plants Biblis A and B and covers a total of 16 reactor years up to 1983. Because of this choice, many data from the Deutsche Risikostudie A [6] could be used and the methods (fault trees) and the results could be compared. Because of the relatively limited data base many initiators as well as component or system unavailabilities have not been observed at all during that span of time. The data base was supplied by the German Event Reports which are comparable to the US-LERs. Events were generally selected as precursors if they satisfied one of the following general criteria:

- All initiating events which actually caused an intervention of safety systems,
- all events in which system unavailabilities occurred or could have occurred in combination with an actual or postulated initiator.

The model used for quantifying the events was based on the method described in [6], i.e. the event diagrams fault trees and to some extent the unavailability data were taken from this reference. 64 events were classified as precursors and an estimate was made for the global expected frequency of severe core damage.

The distribution of the main initiators differs somewhere from the ASP-results for the same period, as shown in table 1. Whereas the ASP-analysis shows a strong predominance of loss of off-site power (LOOP) events in the earlier period and of transients (incl. LOFW) in later years, the GRS-study [5] found that loss of main feedwater (LOFW) was the most frequent event.

Table 1: Distribution of various initiating events

Initiator	fraction (%)		
	German Study [6]	ASP (69-81)	ASP (84-90)
Loss of Main Feedwater	46	17	1
Loss of Main Heat Sink	19	no data	no data
Loss of Offsite Power	10	50	20
LOCA (small leak)	25	19	3
Main Steamline Break	-	8	3
Transients (incl. LOFW)	-	no data	69

3 PROPOSAL FOR A SYSTEMATIC EVALUATION OF PRECURSORS IN GERMAN NPP'S

A systematic and periodical evaluation of precursors in German nuclear power plants would have to include all German PWR and BWR plants and should be performed on a regular basis with continuous updating. Under the sponsorship of the Bundesamt für Strahlenschutz in Salzgitter, ABB Reaktor has investigated a concept for a methodical approach to the selection, evaluation, quantification and statistical assessment of precursors in Germany, including a proposal for possible periodical reports to be updated on a regular basis.

The data base for the evaluation would be supplied by the German Event Reports which are submitted to the Licensing Authorities at the rate of about 400 per year. The selection process would proceed in 3 stages: First the non-relevant events are eliminated, then in a second stage the events of lower significance are sorted out, and in the last step the significant events (precursors) are selected. The criteria chosen for this selection process are a combination of most of the US-criteria (ASP and INPO) and the criteria used by the GRS. Once set, these criteria should not be changed significantly in order to assure comparability of later and earlier data. Additional information such as the so-called "Weiterleitungsnachrichtenungen" would complement the basis input data.

Plants with similar systems-responses should be combined into plant classes, thereby improving the statistics without too much loss in plant-specific information. The ASP-method of using only 3 standard event diagrams for every plant class should not be adapted because of its lack of resolution. Instead, the already existing diagrams for living PSAs could be utilized and every major initiating event should be assigned its own event tree. Full use can thus be made of plant-specific PSA material as it becomes available. Another characteristic of the approach would be the widest possible use of computer support and a high degree of standardization and structuring. The suggested method would, therefore, use several data bases that contain the relevant data at each stage in the evaluation and would be updated periodically.

The method of analysis would employ standard PSA-techniques for quantifying the event diagrams. Unavailability data are derived from event statistics (train unavailabilities) using simple fault tree (FT) overhead structures. The conditional core damage probabilities for the different sequences of each precursor as well as for the precursors themselves are calculated. Fig. 1 shows a typical event tree and demonstrates the method for the 4 basic types of precursor:

- Actual initiators without mitigating-system-unavailabilities.
- Actual initiators with mitigating-system-unavailabilities.
- Single or multiple system-unavailabilities with postulated initiators.
- "Almost-initiators" with or without unavailabilities. This category has been added in addition to the standard options. A typical example for this type of event would be the Biblis incident in Dec. 1987 (an "Interfacing Systems LOCA"-precursor).

All important results of the final precursor evaluation of the particular period would be compiled in a summary table to be included in the main part of the periodical report. Trends and tendencies over several years are best presented graphically. Examples are shown in Figs. 2 to 4. The data for these figures were taken from the ASP-reports because of the statistical significance and public availability.

4 CONCLUSION

Systematic precursor analysis is an important supplement for PSAs, because it can provide a qualitative and quantitative support and verification, if sufficient emphasis is placed on the use of plant or plant class specific data. It can furthermore be a suitable method for identifying weak spots and problem areas in plant and systems design, in the operating practice and in the training of operators and maintenance crews. The results of such an analysis of actual operating data can thus provide the utilities with a tool for indicating ways of improving the reliability and upgrading the safety of their plants. The quantitative results can be used for example as a reliable measure for setting back-fitting priorities.

5. REFERENCES

- [1] U.S. Nuclear Regulatory Commission. October 1975. Reactor Safety Study - An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants. WASH 1400 (NUREG 75 014)
- [2] Minarick, J.W., Kukielka, C.A. June 1982. Precursors to Potential Severe Core Damage Accidents: 1969 - 1979 A Status Report. Oak Ridge Nat., NUREG/CR-2497
- [3] Oak Ridge National Laboratory. 1987 - 1991. Precursors to Potential Severe Core Damage Accidents: 1983 - 1990 A Status Report. NUREG/CR-4674, Vols. 3 - 14
- [4] INPO. 1982. Review of NRC Report: Precursors to Potential Severe Core Damage Accidents: 1969 - 1979. INPO 82-025
- [5] Gesellschaft für Reaktorsicherheit. 1988. Deutsche Precursor-Studie. BMU-1988-187 bzw. GRS-A-1370
- [6] Gesellschaft für Reaktorsicherheit. 1979. Deutsche Risiko-studie Kernkraftwerke, Phase A. Verlag TÜV-Rheinland

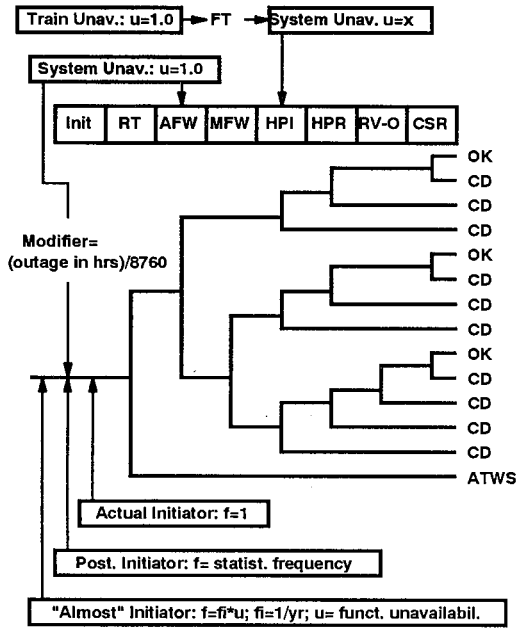


Fig. 1 Quantification of Precursors

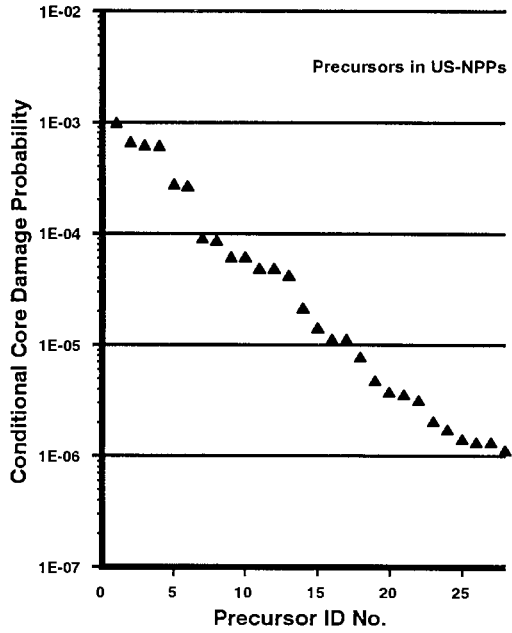


Fig. 2 Distribution of Core Damage Probability

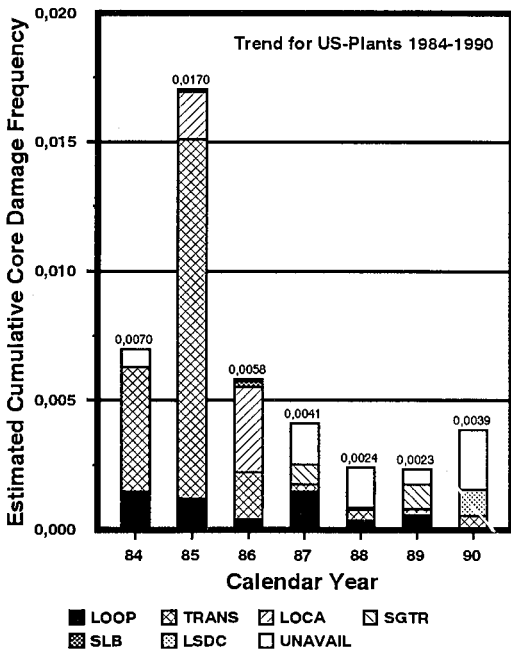


Fig. 3 Estimated Cumulative Core Damage Frequency

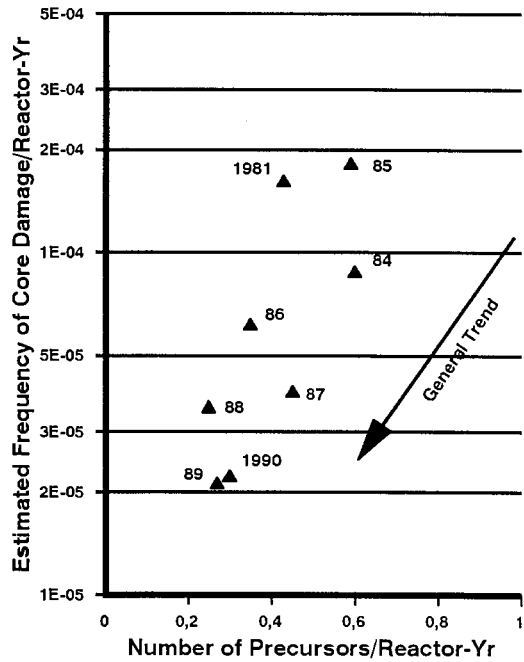


Fig. 4 Estimated Frequency of Core Damage versus Number of Precursors