ATWS Events

Statement by the Commission on Reactor Safety
May 3rd, 2001

1 Request for Discussion

In 1998 the Commission on Reactor Safety (RSK) discussed the safety-related aspects of high burn-up strategies and the use of MOX fuel elements and concluded this discussion in its 320th meeting on 16th September 1998 with a statement. In this statement the RSK achieved the following result with regard to plant behaviour in case of ATWS:

> "Since there is a functional interrelation between design parameters of the reactor core and the burn-up to be achieved, the burn-up cycle time has to be organised such that in connection with the boric acid and gadolinium concentration the moderator-temperature coefficient and the void coefficient in case of ATWS lead to temperature and pressure transients in the primary coolant system which do not exceed the maximum pressure level according to the ASME-code, level C, in full-load and part-load operation. The RSK requests to investigate if, to create safety reserves, a sufficiently negative moderator-temperature coefficient and void coefficient can be achieved by optimising burn-up cycle times and gadolinium concentration, so that no credit has to be taken from an early shutdown of the reactor coolant pumps."

The RSK-Committee on Plant and System Engineering has taken over the task to clarify this fact in its discussion programme.

2 Facts

In the RSK Guideline for Pressurised Water Reactors (3rd edition of 14th October 1981) the following has been stated in chapter 20 regarding the failing of the scram system at operational transients:

> "To reduce the remaining risk in case of a failure of the scram system at operational transients the RSK considers the following investigations or the fulfilling of the mentioned conditions necessary:
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> (1) The course of operational transients has to be investigated assuming a complete failure of the scram system. In detail it has to be shown that at the following operational transients the conditions mentioned under (2) and (3) are met, even in case of failure of the scram system:

1. Failure of main heat sink, e. g. due to loss of condenser vacuum or closing of the main steam slide, with existing auxiliary supply.
2. Failure of main heat sink with failure of auxiliary supply.
3. Maximum increase of steam extraction, e. g. due to opening of the turbine bypass system or the main steam safety valves.
4. Complete failure of main feedwater supply.
5. Maximum reduction of coolant throughput.
6. Maximum reactivity insertion due to withdrawal of control elements or control element groups, assuming full load and hot stand-by operational states.
7. Pressure relief due to unintentional opening of a relief valve.
8. Maximum reduction of coolant inlet temperature caused by a failure in an active component of the feedwater system.

When analysing these events a normal operational state can be assumed basically. The changes of operational parameters and system states possibly caused by control processes have to be taken into account in the analysis, however. With the exception of the systems assumed to have failed, it can be assumed that all other systems are operable as long as their operability is not reduced due to the consequences of the event. I. e. the simultaneous occurrence of a single failure cannot be supposed, neither is a simultaneous repair postulated.

(2) Permissible tensions according to ASME Code Section III, Division 1, NB-3224 Level C Service Limits must bot be exceeded in case of these incidents in the pressure boundary.

(3) The boric acid injection system (operational system permissible) and the heat removal systems must be designed such that their operability is guaranteed under these incident conditions and/or following these incidents and that the reactor can be shut down."

3 Discussion

In its second meeting on 16th December 1999 the RSK-Committee on Plant and System Engineering was informed by GRS about the fundamental procedure regarding the establishing of proof for ATWS events.

In connection with this GRS stated that in some plants credit was taken from the early shut-down of the reactor coolant pumps to limit the increase of reactor pressure. The wording of the RSK guideline admits this procedure.

GRS set out that because of a different core design there were reactor plants with steep and flat courses of curve of reactivity in dependency of the moderator density ("moderator density function"). In plants with steep curve the power raise can be limited sufficiently by the reactivity feedback of the moderator density, in order to not exceed the permissible pressure. In plants with flat course shut-down of the reactor coolant pumps is required additionally.

GRS classified the plants in three groups with regard to the measures to control ATWS cases:

- The 1300-MW plants of Biblis A and B, Unterweser, Grafenrheinfeld and Grohnde have an active shut-down of the reactor coolant pumps of reactor emergency shutdown control signal(ATWS signal). This was retrofitted at Biblis A and B in 1989.
- The convoy plants have an ATWS signal which is used for the excitation of the additional boric acid injection system but not for shutting down the pumps. Irrespective of this the reactor coolant pumps are shut down by the operational pump protection *(betrieblicher Pumpenschutz)* (triggered off by sealing protection *(Dichtungsschutz)* at Brokdorf at 17.1 MPa; at Emsland, Isar-2 and Neckarwestheim-2 at 18 MPa).
- The plants of Obrigheim, Stade and Neckarwestheim-1 have safety valves with a large blowdown capacity. Shut-down of the reactor coolant pumps is thus not required.

The plants with flat moderator density function include the plants of Biblis A and B, Unterweser, Grafenrheinfeld, Grohnde and Brokdorf, the plants with steep moderator density function include the plants of Emsland, Isar-2, Neckarwestheim-2 and Philippsburg-2.

At its fifth meeting on 21st September 2000 the RSK-Committee on Plant and System Engineering continued its discussion by examining the question if the core design at the plants requiring shut-down of the reactor coolant pumps can be modified on the medium term such that the control of an incident can be guaranteed also without shutting down the pumps. Those operators who supported the viewpoint that ATWS events as special, very rare events had to be classified as safety level 4a were heard on the subject. Corresponding to the RSK Guideline for Pressurised Water Reactors it would therefore be permissible to consider all systems available and to assume no single failure and no repair.

With the help of the design-determining event “failure of main feedwater supply with simultaneously postulated mechanical sticking of all control rods” the operators represented the calculation results in case of ATWS.

Furthermore the operators explained that proof would be established for the safety-related permissibility for follower cores for each reactor core, since the characteristics of the reactor core change from core cycle to core cycle. Proof is either established by explicit calculation of e. g. power density and the possibility of shutting down for each core or by proof with the help of core parameters covering all probable performance parameters. With regard to the reactivity influence of the moderator density the fuel-temperature coefficient, the spectral coefficient of the coolant and the void coefficient have to be examined. The strongest dependency on variations of core design (e. g. modification of the length of core cycle) shows the void coefficient (“void curve”).

The operators explained that in principle there were three possibilities to choose covering core parameters for the covering void curve (design void curve) to establish proof in case of ATWS:

- Selection of a borderline case which cannot be exceeded by follower cores for reasons of physics.

This method is applied at the plants Unterweser, Grafenrheinfeld and Brokdorf. Since an early shut-down of the reactor coolant pumps leads to increased void generation, it was possible to select a flat, extremely conservative “first core void curve”, at which the permissible pressure level is clearly fallen below.

- Selection of the parameter which in the incident assessment just reaches the permissible limit.

  A “void limit curve” was determined at the Philippsburg-2, Neckarwestheim-2 and Emsland plants without taking credit from the shutdown of the reactor coolant pumps, with which the permissible pressure was barely fallen below. This curve is steeper than the “first core void curve” because of the necessary stronger reactivity feedback.

- Selection of a parameter which covers the planned follower cores but does not reach any limit. In case the planning is modified new proof will have to be established, if required.

  This method was chosen for the remaining plants at which credit is taken as well from the shut-down of the reactor coolant pumps and different void design curves were used for the establishing of proof in case of ATWS.

The reactor coolant pumps are shut down at the beginning of the transient (exceeding of the pressure level at the pump protection or reactor emergency shutdown control signal).

Under the conditions that

- The plants are generally operated in an annual cycle at maximum and
- All fuel elements have an enrichment of 4% for refuelling – with the exception of Biblis – and show correspondingly high burnup,

even the steepest design curve (Philippsburg-2, Neckarwestheim-2, Emsland) covers the void curves of cycles that are normally carried out today according to the statements of the operators, so that actually an ATWS event would not result in an exceeding of the permissible pressure, even without the reactor coolant pumps being shut down.

Additionally, the operators expressed their expectations that by reducing conservativities in the establishing of proof, proof of incident control could be established also without shutting down the reactor coolant pumps, e. g. by using programs with a 3D core picture.

On the other hand they pointed out that shutting down the pumps lead to a considerably more favourable pressure in case of ATWS. Flexibility gained with this would be desirable for the transition to longer cycles that could be necessary from the operational point of view.

4 Safety Assessment

In its assessment regarding the treating of ATWS cases the RSK took

- The RSK Guideline for Pressurised Water Reactors (3rd edition of 14th October 1981, chapter 20),
- The Safety Criteria for Nuclear Power Plants (Announcement of the Federal Minister of the Interior of 21st October 1977, section 3, criterion 3.2), and
- The practice in France and in the USA investigated by GRS

as a basis. The RSK Guideline for Pressurised Water Reactors and the Safety Criteria for Nuclear Power Plants do not include explicit statements on taking credit from shutting down the reactor coolant pumps in the establishing of proof with regard to ATWS. In the opinion of the RSK the procedure of not taking credit from shutting down the reactor coolant pumps in the establishing of proof with regard to ATWS is state-of-the-art of science and technology. This corresponds to the practice in France and the USA.

In its discussion the RSK stated that using the shutting down of the reactor coolant pumps to prove pressure limitation in case of ATWS does formally not contradict the RSK Guideline.

Shutting down the reactor coolant pumps in case of ATWS is a safety measure that results in an effective limitation of an increase in pressure and, thus, reduces the occurring loads of the components in the primary coolant circuit. It should therefore be kept as additional operational measure.

Independent of this the RSK supports the opinion that incident control must be guaranteed in future in the short-term range by an inherent safe core behaviour in connection with the automatic opening of the safety valves without taking credit from measures actively steered for, such as shutting down the reactor coolant pumps.

Documents Used for Discussion

[1] Untersuchungen zu ATWS-Ereignissen
RSK-Information AST2/5
22.11.1999
(Investigations on ATWS Events. RSK information RSK-Committee on Plant and System Engineering*(AST) 2*/5, 22.11.1999)

[2] Beschreibung der Behandlung von ATWS-Ereignissen in deutschen DWR-Anlagen und Einzeluntersuchungen zum Ereignisablauf
S. Langenbuch, G. Höppner, W. Horche
Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) mbH, Garching, 25.06.1999
(Description of the Treatment of ATWS Events in German Pressurised Water Reactor Plants and Single Investigations on the Course of Events.

S. Langenbuch, G. Höppner, W. Horche, Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) mbH, Garching, 25.06.1999)

[3] Untersuchungen zu ATWS in deutschen DWR-Anlagen
G. Höppner, H. Hörtner, W. Horche, S. Langenbuch
Bericht zur 2. Sitzung des RSK-Ausschusses ANLAGEN- UND SYSTEMTECHNIK am 16. Dezember 1999
GRS, Folienkopien
(Investigations on ATWS in German Pressurised Water Reactor Plants. G. Höppner, H. Hörtner, W. Horche, S. Langenbuch. Report on the 2nd meeting of the RSK-Committee on Plant and System Engineering on 16th December 1999. GRS, copies of foils)

[4] AST-Information AST5/3.1 vom 05.09.2000
(RSK-Committee on Plant and System Engineering information AST5/3.1 of 05.09.2000)

[5] PreussenElektra Kernkraft
ATWS-Ereignisse NTT-Dr. So/Len 14.09.2000, Folienkopien
(PreussenElektra Nuclear Power. ATWS Events NTT – Dr. So/Len 14.09.2000, copies of foils)

[6] ATWS-Fall: Ausfall Hauptspeisewasserversorgung
Kopien von Folien der GRS zum Vortrag in der 5. Sitzung AST am 21.09.2000
(ATWS Case: Failure of Main Feedwater Supply. Copies of foils by GRS of the lecture in the 5th meeting RSK-Committee on Plant and System Engineering on 21.09.2000)