Realistic Design Principles of Nuclear Power Plants against Earthquakes in the FRG — Present Stage of Discussion of the New Concept for a KTA-Safety-Standard Concerning Earthquake Design

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Abstract

A new concept for the seismic design of npp was drafted in germany. This new concept is thought to be a substitute of the existing safety standard KTA 2201.1 "Basic principles of the design of npp against seismic events" (issued 6/75).

The aim of this presentation is to give a survey of the present stage of the relevant discussions within the regulatory committees.

1. Introduction

During the 7th SMiRT-Conference in Chicago 1983 it was reported by M. Hintergräber and R. Wittmann (Session K 14/3 "Changes of the Basic Principles for the Seismic Design of Nuclear Power Plants - A Realistic Approach) that a new concept for the seismic design of NPP was drafted in Germany. This new concept is thought to be a substitute for the existing safety standard KTA 2201.1 "Basic principles of the design of NPP against seismic events" (issued 6/75). It was furthermore reported that this concept was under discussion within the relevant regulatory committees in the FRG. Because of the fact that this new concept, drafted by a group of experts existing of seismologists, mechanical and structural engineers, differs in some essential items from the actual design concept a lot of detailled information had to be provided to answer fundamental questions, e.g. the question whether the new concept were satisfactory under safety aspects. Therefore the important modifications of the design principles of NPP against earthquakes in the FRG were discussed in detail especially in respect to there influence on nuclear safety.

2. A Proposal for New Design Principles against Earthquake

Already in the late seventies it was recognized by some experts that a discrepancy between the analytical and real behaviour of structural and mechanical equipment of NPP exists. German seismologist which were involved in the task to conceive or derive the seismic design input data were for instance, of the opinion that this was also due to the fact that seismic loadings, derived from US-, especially west-coast datas (e.g. USNRC-Reg.-Guide 1.60-spectra) were too conservative for the seismicity within the FRG. Other experts in the field of structural and mechanical engineering were of the opinion that this discrepancy were also the result of the practiced double-earthquake-design. That means the design against both the "Operating Basis Earthquake" (OBE) and the "Safe Shutdown Earthquake" (SSE).

Therefore it was the aim of the new draft of KTA 2201.1 to master these findings by means of the following modifications:

(1) The definition of and the analysis for the Operating Basis Earthquake shall be deleted.

(2) The "Safe Shutdown Earthquake" shall be the only earthquake to ensure the safety related functions of npp-components and buildings. It can be defined in a probabilistic manner with a recurrence period of about 10.000 years.

(3) A probabilistic map of earthquake zones in the FRG, which identifies site-specific intensities with a recurrence period of about 10.000 years shall be defined. On the basis of this map it would then be possible to identify regional site specific SSE-intensities. An example for such a map can be seen from figure 1; it was prepared by Dr. Rosenhauer (INTERATOM) and Prof. Ahorner (Universität Köln).

(4) Seismic engineering data shall be defined site specific, taking into account the characteristics (e.g. magnitudes, source-distances) of the site-specific earthquakes, representative for the SSE.

(5) If there is a lack of information about site-specific geological and seismological terms typical german standard-freefield-response-spectra shall be used. Proposals for such soil-independent spectra were made by Prof. König (TH-Darmstadt).

(6) For sites with SSE-intensities I $\leq$ 6 (MSK) there shall be no necessity of defining seismic engineering data; the seismic safety of structures and components shall be ensured only by structural provisions.

(7) An additional smaller earthquake shall be specified for the combination of earthquake and earthquake-independent plant-internal fires and external floods. This additional earthquake shall only be taken into account for the design of fire- and flooding-prevention measurements. It shall be specified as a small event which can reasonably be expected during

life-time of the plant, e.g. with a recurrence period of about 100-200 years.

(8) Based on the site specific design of safety relevant equipment a socalled "Earthquake Inspection-Level" shall be defined by the applicant as a ratio of the maximum acceleration of the SSE. It shall be defined on such a level so that no relevant deformations of the safety relevant equipment will be caused. If the inspection-level is defined as not exceeding 50 % of the amplitudes of the SSE, the deformations can be considered as not being relevant.

3. Discussion of the Modifications

(1) Deleting of the OBE

It should be noted, that the basic requirement for the OBE-definition differs fundamentally between Germany and e.g. the US.
Whereas according US-practice the OBE can be chosen on a probabilistic basis so that the relation OBE/SSE could be in the order of 1/4 to 1/3, in Germany the purely deterministic procedure led to relations of 1/2 or 2/3. Therefore the design impact of the OBE for German plants is unrealistically high.
Reffering to the justification for the previous double earthquake design (OBE and SSE) it must be pointed out that this design is based on two independent analysis using different input but identical physical-mechanical limit-states. By means of this procedure it is obvious that no additional plant safety can be reached; this would only be possible if the design requirements for the SSE were recognized as too low and shall be corrected indirectly by means of an additional design against the OBE. Since the SSE design requirements are conservative enough, the OBE-analysis can be neglected. A former argument for an OBE-design was the idea that the OBE is so frequent that the influence of fatigue must be considered. Meanwhile the discussion within the german regulatory committee, responsible for the earthquake design of mechanical and electrical equipment of npp let to the finding that there is no significant increase in fatigue caused by earthquakes.

Therefore there is no physical reason for a double earthquake design that means the OBE can be deleated.

(2) Probabilistic Definition of the SSE

A subsequent conducted examination of the probability of exceedence of the previous load assumptions for SSE for german nuclear power plant sites demonstrates a large variety of individual probabilities. Values for the probability of exceedence for the specific SSE-site-intensity from 10^{-4}/a up to 10^{-8}/a were calculated. Therefore it is obvious that a given probability of exceedence as an orientation-value would ensure a comparable and well balanced earthquake design. In cases, where the seismic design input data were based on an unbalanced low probability of exceedence (e.g. 10^{-8}) unecessary

stiff constructions had to be realized. A result which is especially for pipings very questonable with respect to operational condition.
Based on the practiced design requirements for the SSE a probability of exceedence for the SSE intensity of less than 10^{-4} is proposed. By this a probability of structural failure can be assumed as less than 10^{-6}. This design value of 10^{-4} is in accordance with the international practice.

An example for the possible decrease in site-intensities due to a probabilistic estimation can be seen in figure 2.

(4) Possibility of Defining Site Specific Seismic Engineering Data

The actual practice in the FRG of defining seismic design input data on the basis of the US-NRC-Reg. Guide 1.60 standard response spectra has led to unrealistic high seismic input data. This finding is based on the fact that in the FRG the earthquake magnitudes are obvious smaller (M_L = 6,5) and the relevant source distances are shorter (5-20 km) than the magnitudes and distances of those earthquakes which formed the basis for the USNRC-Reg. guide spectra.

(5) German Standard-Free-Field Response Spectra

Based on the discussions within the german regulatory committee, responsible for the basic principles of earthquake design, a group of german experts, under the leadership of Prof. König (TH Darmstadt) evaluated 1200 european earthquake time histories, for each of them the magnitude, source-distance, intensity and subsurface-conditions were known. They were classified in to 3 groups of intensities (I_{MSK} = 6-7/7-8/8-9) and into 3 groups of subsurface-conditions (rock, medium, alluvium).

As a result of this evaluation free field response spectra, were obtained.

From the 1200 given time histories 100 matches the foregiven site criterias. Compared with the data base for the US-Standard spectra this number should be enough. But it should not withhold that some experts are of a different opinion

(6) No Definition of Seismic Engineering Parameters for Sites with Intensities I ≤ 6 (MSK)

The intensity I = 6 is defined as that intensity where no relevant damage on buildings were recognized. Therefore its obvious that there is no necessity for performing dynamic analysis; earthquake resistance can be ensured only by means of constructional measurements.

(7) Definition of a Smaller Earthquake for the Combination with Plant-Internal Fires and External Floods

Due to specifications in the safety standards for the protection of npp against floods and fires it is necessary to make some additional requirements for such an earthquake.

According to a probabilistic safety concept this earthquake has to be more frequent than the SSE. Therefore a probability of exceedance of about 10^{-2}/a to 5 . 10^{-3}/a is proposed. A design against such an earthquake shall only be realized for those parts of equipment and structures which are necessary to mitigate the consequences of plant internal fires and external flooding in a safety relevant sense and which are not designed against the SSE.

Regarding the german seismicity it can be stated that a "10^{-2}/a - 5.10^{-3}/a-earthquake" is correlated with a maximum intensity I = 6 (MSK). In the light of the international experience about the behaviour of equipment under strong earthquakes (see also the presentation of P.I. Yanev, EQE during 7th SMiRT, session K13) and the understanding that there is no necessity for an analysis for buildings, objected to earthquakes with intensities less than I = 6 (MSK) it is conceivable that the resistance of the above mentioned installations for the fire- and flooding.safety can be demonstrated only by means of constructive measurements.

(8) Definition of an "Earthquake-Inspection-Level"

The safety aspects for the earthquake-design of npp-equipment and -structures are met by the design against the Safe-Shutdown-Earthquake. In respect to the formal question, whether the plant can be operated furthermore after a real earthquake there is a necessity to define an "earthquake-inspection-level" in order not to impair the plant availability unnecessary.

In the light of the typical design of npp-equipment in the FRG it was demonstrated, that such an "inspection-level" can be defined as 0,5 times the maximum acceleration of site SSE. If an earthquake with higher acceleration-values occures the plant must be shutdown and inspected on the basis of the actual registrated earthquake data.

3. Conclusions

The proposed "Earthquake-Design-Principles" which are thought to be the basis for the modification of the actual KTA-safety standard will ensure a well-balanced seismic design concept with positive safety related design aspects, e.g. more flexible pipings and avoid unnecessary hardware-measurement.

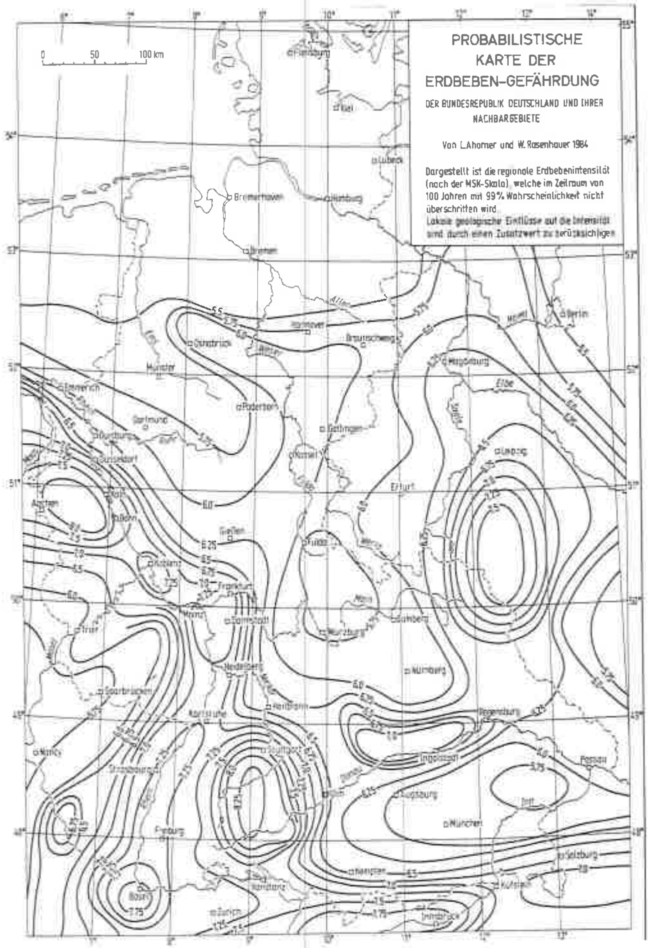

Fig. 1: probab. map of earthquake zones in FRG

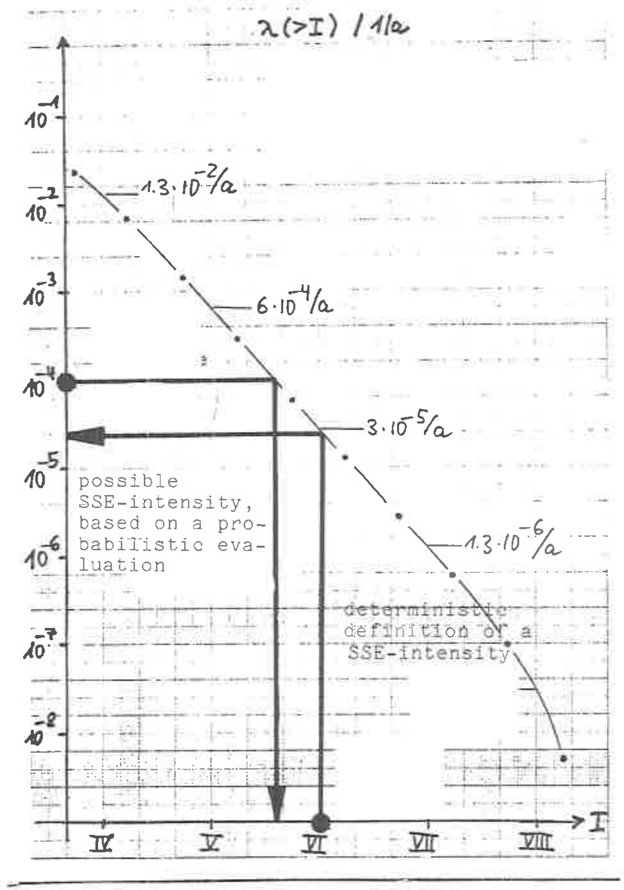

Fig. 2: example for a decrease in site-intensities due to probabilistic estimation