PROTECTION OF NUCLEAR INSTALLATIONS IN THE CZECH REPUBLIC AGAINST EARTHQUAKES

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SUMMARY

The protection of nuclear installations against earthquakes is based on the knowledge of real seismic hazard and on the use of preventive means that mitigate the earthquake impact when a strong earthquake comes into existence.

INTRODUCTION

The seismic risk protection strategy of nuclear installations belonging to the critical facilities [22] is based on the knowledge of real seismic hazard, on the choice of reliable design and on the use of preventive means (technological and organisational) that mitigate the earthquake impact when a strong earthquake comes into existence. To be able to reduce a seismic risk we call for: the determination of real seismic hazard; the use of aseismic design of constructions and equipment (components and systems) taking into account a quantitative prediction of the inelastic dynamic response of structures to extreme loads caused by earthquakes (this is important from the economical and safety viewpoints); the satisfaction of demands of legal rules in force; the use of technical means that can mitigate earthquake effects; the set of organisational measures (including the staff training) for the case when strong earthquake (equal or greater than design one) will come into existence.

LEGAL RULES IN FORCE

To guarantee the nuclear installation protection against earthquakes the legal rules [1 - 5] in force are used, i.e. Civil Construction Act, Atomic Act, special Regulations and Technical Standard. These regulations are in keeping with the current used international rules and the IAEA recommendations [6,7] and with the EU demands [23].

DATA SETS USED

The seismic database contains the earthquake catalogues (macroseismic and instrumental) for Central Europe and for its individual parts, atlas of isoseismal maps of earthquakes macroseismically felt on the territory of Central Europe, maps of maximum observed intensities, investigation of individual earthquakes or earthquake sequences (e.g. swarms), description and characteristics of seismic regime of Central Europe and individual focal zones being found there and analysis of seismotectonic connections.

The geological database contains the geological maps, hydrogeological, tectonic maps, maps of vertical crustal movements, gravimetrical, geomagnetic and geothermal maps for Central Europe and for individual regions in different scales, tables and analysis.

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To obtain realistic seismic hazard assessment the following issues were determined for Central Europe: Chronological model of neotectonic movements for the last 40 Ma [9], Neotectonic regional units and their present movements [9], The scenario of earthquake occurrence [8,10], Specification of seismogenic movements [9,20].

SEISMIC HAZARD DETERMINATION

For the seismic hazard determination we use the methodology specified in the IAEA safety guide [6] and accepted in the EU countries [23]. Seismic, geological and tectonical histories of Central Europe and its parts were evaluated by several independent methods. Revealed basic trends are generally coincident, only in evaluation of some partial events some differences from time to time occur.

A seismic hazard of any site depends on: a model of earthquake occurrence used; input data that calibrate the model used as: the boundaries of focal regions or the boundaries of seismoactive parts of faults (i.e. fault parts that can produce an earthquake); the values of maximum earthquakes that can be generated.

The assumptions and demands for the seismic hazard determination are given in the papers [11,18]. The assumptions are: an earthquake may origin at any place of a focal zone or a seismoactive part of a fault; an attenuation in the direction „focal zone - given locality“ is the least favourable (from the safety reasons) of all empirical relations known; a M max value must be determined by the following way: in a focal zone as a magnitude equal to the magnitude of maximum observed earthquakes in the history plus 0.5 - 1o MSK-64, as a result of expert assessment of symptoms of fault ability to generate earthquakes.

FUNDAMENTAL SITE AND DESIGN SEISMIC DATA

Taking into account the results of seismotectonic and statistical studies for the NPP sites the safe shutdown earthquake (SSE = MVZ, that corresponds to SL-2 according to the IAEA recommendation [6]), the design basis earthquake (DBE = PZ, that corresponds to SL-1 according to the IAEA recommendation [6]), the hazard curves for different return periods, the ground motion parameters of the site (site accelerograms or site specific spectral shape scaling to the ground motion level) are established for localities under account. If accelerograms are calculated from the response spectra the maximum probable estimation of duration of maximum phase of acceleration for real site is considered. The design response spectra, the zero period peak ground acceleration, the accelerograms and the duration of the maximum phase of acceleration are given to the nuclear installation designers and operators.

Taking into account the models of constructions of individual plant buildings of the category I of seismic resistance (the finite element method is used), the site dependent ground accelerograms and the site dependent design ground response spectra the set of floor design response spectra for individual constructions and floors are calculated considering the site specific soil conditions. The floor response spectra are generated by help of ground accelerograms and of the individual buildings models for several places on the floor and the results are obtained by the technique „median plus σ (standard deviation)“. The combination of seismic stresses with other stresses resulted from dead load, live load, thermal load, pressure load, etc. in the total stress determination is considered for generation of floor response spectra for design and qualification of mechanical and electrical equipment and piping systems [17,19].

For the important equipment that are ranked in the category I of seismic resistance, the bounding spectra are determined taking into account the corresponding floor accelerograms, floor response spectra, floor model and the load combinations corresponding to the normal operating conditions [13] using the expert system [14].

On the basis of real data we determine: SAFE SHUTDOWN EARTHQUAKE (SSE), DESIGN basis Earthquake (DBE), Control Earthquake (cz), ground motion accelerogram, duration of maximum phase of acceleration, floor accelerogram, ground response spectrum, floor response spectrum.

The used determination of the site accelerograms, the site response spectra, the duration of maximum phase of acceleration in the given site and the used evaluation of influence of local soil conditions on seismic waves are in the agreement with the IAEA recommendations [6,7]. Because the response spectra predicted from the ground acceleration time histories, the amplitudes and the amplification effects vary over the period range and are strongly influenced by the subsoil, the magnitude of earthquake and the distance of a building to the source rupture, their determination is very careful; they are determined in agreement with the IAEA materials [6,7,12,15].

SEISMIC TERMS OF REFERENCES

Seismic terms of references for the nuclear installation design depend on site seismic parameters and on a nuclear installation model and type [11,17,19]. They are created by the following data: safe shutdown earthquake; design basis earthquake; control earthquake; set of ground motion accelerograms; set of floor accelerograms; duration of maximum phase of accelerogram; ground response spectrum; floor response spectrum; bounding spectra for important equipment; number of earthquakes to be accounted for in the design; ranking the nuclear installation constructions; systems and components into seismic categories.

The structures, systems and components shall be designed to withstand 1 Safe shutdown earthquake and a specified number of design earthquakes. Buildings are not designed for fatigue due to design earthquakes. This effect is important for mechanical components at high temperature, and also for sliding devices which are not self-centring, or for viscous dampers, for which cycling may cause considerable temperature increase of the inner fluid [23]; the minimum number of design earthquakes is five for components remaining in the nuclear plant during the entire life.

The seismic categories[17,18] are defined in agreement with the IAEA guide [7] .

PROTECTION AGAINST EARTHQUAKES

The nuclear installation seismic resistance is defined as the ability of the nuclear power plant's civil structures, systems and components to maintain their functionality, mechanical rigidity and hermetic sealing, or only to prevent their being disturbed as a result of seismic interactions. Seismic interactions denote events occurring in the course of an earthquake and similar phenomena that may cause damage to systems, structures, technical systems or individual components as the result of a mechanical interaction with civil structures, system or components in their vicinity [17,19].

The evaluation of the seismic resistance of civil structures, systems and components of the nuclear installation facilities of the category I of seismic resistance must be carried out by calculations and tests, the details are in report [17]. The sloshing effects and the loss of liquid are carefully follower and if necessary the prevention measures are performed.

In conjunction with the impact of a seismic alarm on the functionality of the regulating devices of the reactor, it must be demonstrated by calculations or by experiment that the duration of their emergency outage from the full level of operational functioning, with the electromagnets switched off, even in the case of MVZ will be within allowable limits given by the manufacturer, i.e., less than 4 seconds [17].

In conjunction with the installation of viscous pipe dampers on the primary circuit, condenser circuit and other piping systems, the requirements of the respective technical conditions stipulated for their delivery must be met, including the requirement for an attestation of these dampers for use at a nuclear power plant.

To proof the resistance against earthquakes only verified, generally accessible and reliable methods, models, codes and standards are acceptable [3].

THe nuclear installation protection against earthquakes is provided by: the aseismic design of civil structures, systems and components that belong to the category i of seismic resistance; the selection of systems and components that belong to the category i of seismic resistance; the use of different types of supports, dampers, anchoring, etc. According to [23] there are used seismic isolation systems using elastometer bearings (low damping natural and synthetic rubber bearings, high damping rubber bearings, lead plug bearings, multistage rubber bearings), seismic isolation systems formed by other types of springs, seismic isolation systems based on friction (friction pendulum system, polytetrafluorinethylene elastometric bearing resilient – friction base isolation, edf system, combined sliding disc bearing and helical steel spring isolation systém, friction – controlable sliding bearings), russian pneumocord system and seismic isolation system consisting of elastometric bearings coupled with separate energy dissipation devices [2,3,7,15,16].

ASEISMIC DESIGN

The objective of the aseismic design is to make the contribution of earthquake - induced accidents to the total plant risk negligible with respect to the total risk.

Facilities that are important for nuclear safety must be designed in such a way that in the case of natural events that may realistically be expected to occur (earthquakes, hurricanes, flooding, etc.) or events caused by human activity outside of the nuclear energy facility (aeroplane crashes, explosion in the nuclear power plant's vicinity, etc.) it should be possible: to safety shutdown the reactor and maintain it in a sub-critical condition; to remove the residual output of the reactor for a sufficiently extensive period of time; to maintain any radioactive leakage under the limiting values stipulated for the given locality of the nuclear energy facility [3,15] in agreement with the IAEA recommendations [6,7,16].

SEISMOMETRIC INSTRUMENTATION

If an earthquake occurs the level of which is equal or greater than design earthquake, the plant shall be shutdown. Two different intervention approaches are usually adopted. The first foresees that the operator shall actuate the shutdown on the basis of information immediately available in the control room. The second foresees that an automatic shutdown of the plant shall be carried out by the seismic safety system. The first philosophy is based on the conviction that seismic design is reliable enough to guarantee plant safety and that even in the case of component failure due to the safe shutdown earthquake, the plant will be shutdown by normal safety systems. In any case, the operator has time enough to decide whether or not the plant should be shutdown. The second philosophy has the advantage of a more rapid achievement of plant safe conditions, without requiring the direct intervention of the operator.

The plant shall be also equipped with an adequate seismic monitoring system (SMS). This system shall provide sufficiently reliable information to the operator in the case of a large earthquake, with regard to both its level and the structure response. It shall provide an alarm if the threshold level for shutdown is likely to be exceeded. The additional instrumentation is adopted to measure and record the vibrator response of representative structures and components (including reactor building foundations). The data collected by the SMS, i.e. time - history, response spectrum, peak acceleration are also useful to verify hypotheses used in the seismic design.

The seismometric instrumentation (SMS) is designed in conformity with the IAEA requirements [7, 17, 19]. It is considered acceptable if control earthquake (KZ) = design earthquake (PZ) for the nuclear power plant [17, 19].

INSPECTIONS AND WALKDOWNS

Systematic investigation of NPP resistivity to earthquakes is provided by regular inspections of the State Office for Nuclear Safety [2] and by professional walkdowns either after stronger earthquakes (greater or equal to design basis earthquake) or after important inspector's findings (e.g. effects caused by ageing) [18].

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