European protection principles against external hazards by means of Emergency Power Supply and Control Safety System Building in Nuclear Power Plants

Dipl.-Ing. Anna Gallinat
Max Aicher Engineering GmbH, Teisenbergstraße 7; 83395 Freilassing, Germany
a.gallinat@max-aicher.de

1. **Introduction**

The predominant means of supplying onsite emergency (standby) electrical power for nuclear power plants is the use of emergency diesel generators. One of the most important nuclear power plant safety requirements is a redundant and independent power system. This requires such a design of emergency power systems that failure of one will not adversely impact the other. External hazards of natural origin or linked to human activity could potentially affect plant safety. The general objective of the design provisions is to ensure that the safety functions of the systems and components required to return the plant to a safe shutdown state and to prevent and limit radioactive release are not adversely affected.

2. General principles to be considered by design

As external hazards are site dependent, Technical Guidelines specify that "it is not necessary to take all of the hazards in a standardized design; such external hazards as external flooding, drought, ice formation and toxic, corrosive or combustible gases may be dealt with only for a specific plant, on a plant specific basis". The external hazards, and the associated design measures, shall be defined either at the generic design stage or are site specific including the following hazards:

- earthquakes
- airplane crash
- external explosion
- lightning and electromagnetic disturbances
- groundwater
- Extreme meteorological conditions (temperatures, wind, rain, etc.)
- external flooding
- site proximity hazards

Other external hazards, which are specific to the chosen site, are to be considered on a case by case basis.

3. General principles for the protection against external hazards

In accordance with the Technical Guidelines [2], external hazards are taken into consideration at the design stage consistently with internal events or hazards. The basic design principle is to protect against external hazards in accordance with the Technical Guidelines using a "load case" procedure.

This procedure consisders the impact of a hazard on the normal and accidental operating conditions of the plant avoiding it to enhance the impact of other hazards:

- the objective of the design provisions against external hazards is to ensure that the safety functions performed by the safety classified structures, systems and components remains active
- design provisions are defined to limit the consequential failures of structures, systems and components which could be source of internal events or internal hazards.

For each external hazard, the safety requirements and the design basis define the loads which shall be considered and the structures, systems and components which shall resist the hazard. The structures, systems and components are designed to withstand both the different load cases associated with the hazard and appropriate combinations with other load cases:

- Hazards such as earthquakes for which all items of equipment that are safety classified, as a consequence of their safety or containment function, are protected (with the possible exception of equipment whose failure would not jeopardize compliance with the radiological release criteria).
- Hazards such as aircraft crash, which have localized effects and for which protection may be achieved by geographical separation of the required systems or components. In this instance, the partial protection is justified on a probabilistic basis and/or by analysis of the consequences of the failure of the unprotected equipment.

4. Consideration of combined events

4.1 Combination of physical phenomena inherent in the hazard

The external hazards, associated with meteorological or climate conditions, intrinsically involve a combination of several phenomena. This is the case for natural external flooding (except dam break). For example a major flood (Design Basis Flood or DBF) is for the biggest part the result of an extended period of heavy rainfall. This event cannot be dissociated from an increased level in the ground water or from the arrival of a significant amount of water on the base mat. These hazards cannot be considered in isolation of each other.

4.2 Combinations of the considered hazard with potentially dependent internal or external events or hazards

This scenario refers to the potential for an external hazard to result in either a consequential internal hazard or a consequential internal event.

4.3 Combinations of the hazard and independent internal or external initial conditions

When there is no dependency or direct link, the analysis of an external hazard may require consideration of independent physical parameters associated with other external hazards. As a general rule, combined events are considered when there is a dependency which cannot be excluded by a design measure. Additional combined events may also be introduced when there may only be a potential dependency.

5. Safety function of the Emergency Power Supply Building

Emergency Power Supply and Control Safety Buildings contains the diesel generator, the switchgear, the storage tank, the pumps, batteries and smaller associated assemblies.

The main task of the building with its equipment is

- to provide power supply in case of Loss of Offsite Power (LOOP) and an accident occur
- to supply power continuously to the equipment needed to maintain the plant in a safe condition
- allocation of electrical engineering equipment of the safety control systems.

6. Safety Requirements and Design

6.1 Protection against earthquakes

Structures, materials and systems shall be designed so to ensure their functionality, their integrity or remain at least stable under the conditions caused by the seismic movements. Seismic events shall be considered in the design of the plant. In addition relevant meteorological parameters are included in the seismic design of the civil structures and materials:

- Wind: the combination of stresses resulting from the design ground spectrum and the stresses resulting from wind (Design Basis Earthquake + 0.2 maximum wind) is taken into account for designing the cladding and chimneys
- Snow: the combination of stresses resulting from the design ground spectrum and the stresses resulting from snow (Design Basis Earthquake + 0.2 maximum snow) are taken into account in the design of buildings
- External temperatures (within the limits of the high and low design values)
- The level of the water table

6.2 Protection against Aircraft crash

Aircraft crash has been identified as a potential external hazard resulting from human activity, which shall be taken into consideration in the design of nuclear power stations. Following an aircraft crash, the objective is to ensure that the safety functions for the systems and equipment needed to limit the radiological consequences are not unacceptably affected by the initiating event or by any consequential hazards such as fire, explosions, missile impact, steam release etc. All structures, systems and components needed to achieve the safety objectives shall be protected. Identification of these structures and items of equipment is based on the applicable regulations, supplemented by additional deterministic requirements. The initial approach for protection against an aircraft crash is deterministic and is based on specific scenarios applied to different groups of aircraft. Protection against aircraft impact is achieved by the design of the safety classified buildings or by physical separation of redundant systems.

6.3 Protection against the hazards associated with the industrial environment – external explosion

Industrial installations and transport routes which may pose a hazard to the plant are identified for in site specific studies. The hazards to be considered are:

- Explosion: compression wave, ground movements, missiles, etc.
- Off-site Fire: thermal radiation, smoke.
- Movement of toxic, corrosive or radioactive gases.

The design cases to be used are defined with regard to external explosions. Design of nuclear power plants shall take into consideration, actually as a standard load over time, a triangular shaped pressure wave with a vertical leading edge and a maximum over-pressure of 100 mbar and duration of 300 ms. This means that, given the possible reflections on the walls and roofs of the buildings, the load over time on the building walls will consist of a maximum pressure wave of 200 mbar on the flat walls. Additionally the design loading cases are comparable to that presented in IAEA standard NS-G-1.5 [10] which is a triangular shaped pressure wave with a vertical leading edge and a maximum over-pressure of 100 mbar and a duration of 200 ms, based on United States Army Technical Manual TM 5-1300) [9]. A case-by-case analysis shall be performed for drift of gas clouds (toxic, corrosive or radioactive) and, where necessary, design measures shall be adopted for protection against this hazard (by design of suitable closed circuit ventilation systems or filtration).

Plant design in relation to the external explosion hazard uses a loading case which is referred to as an explosion Compression Wave.

6.4 Protection against external flooding

The requirements related to the protection against external flooding are to:

- Keep the buildings housing safety classified equipment dry, by setting the platforms at a level at least equal to the Maximum Design Flood Level.
- Prevent as far as possible any water present on the platforms from flowing into these buildings.

The area around the site will be evaluated to determine the potential for flooding due to the following hazards:

- Exceptional Coastal Flooding: this accounts for a combination of high tide and events like storm surge, barometric effects
- Tsunami: this high-amplitude wave is created following a landslide or an undersea earthquake and is considered to be covered by the Exceptional Coastal Flooding.
- Exceptional Estuary Flooding: it accounts for a combination of high tide, river flood, events like storm surge, barometric effect, upstream dam rupture or failure.
- High Waves: this hazard includes all the surface waves.
- Break of Systems or Equipment: this hazard is characterized by the amount of water released by the break taking into account the specific flow rate of the opening and the event, until isolation of the flow (manually, automatically, etc.).
- Heavy Rainfall: this hazard is characterized by the maximum average intensity parameter. This intensity corresponds to the maximum amount of water that falls during a relatively short period. It characterizes the violence of the initial phase of a storm.
- Long Heavy Rainfall: this hazard is characterized in the same way, but using daily maximum average intensities.
- Rise in Groundwater: this hazard is characterized by the evaluation of the water table level and the speed of change

Additional combinations have been identified and are to be considered in the safety analysis. The selected combinations are such that their frequency is of the same order of magnitude as the Exceptional Coastal Flooding. These various combinations are first defined for the hazards which have a certain level of dependency:

- Exceptional Coastal Flooding combined with a hundred-year High Waves.
- Exceptional Estuary Flooding combined with a hundred-year High Waves,
- A hundred-year Coastal flooding combined with a hundred-year Long Heavy Rainfall,
- Exceptional Coastal Flooding combined with a ten-year Long Heavy Rainfall of 24 hours (as part of defense in depth),
- Exceptional Flooding, Coastal or Estuary, combined with Swell,
- External flooding combined with a Loss Of Off-site Power (for certain sites LOOP of 1 day to 3 days, according to sites)

6.5 Protection against extreme climatic conditions

The objectives for protecting against extreme climatic conditions are to prevent or reduce any resulting adverse effects and to limit possible radioactive releases. All of the civil engineering structures are designed in accordance with the appropriate "Snow and Wind" design codes [7, 8]. Extreme Cold is considered to be a natural external hazard. Extreme Cold occurs when the temperatures fall below the temperature used for the design.

The loss of off-site power supplies is more likely to occur during a period of cold where the grid is subject to greater loads. It is therefore necessary to ensure that the reactor can be shut down and maintained in a safe shutdown condition following loss of grid. The equipment, which is required in periods of Extreme Cold in other operating conditions, shall be available after the LOOP. The postulated loss of off-site power in Extreme Cold conditions is assumed to be due to loss of grid and not an on-site equipment failure.

6.6 Protection against high ambient temperatures

Two temperatures for the air shall be considered:

- a maximum daily average ($T_{\text{daily air max}}$)
- an instantaneous maximum ($T_{\text{prompt air max}}$)

Unless mentioned specifically, all of the standard structures and equipment are designed using the temperatures defined above. The site specific temperatures are taken into consideration when designing the site specific structures and equipment. The buildings are designed in accordance with the relevant Eurocodes [6]. The adaptability of the design of the installation to accommodate future climatic changes does not require a specific study for snow. Considering predicted climatic changes, cold weather conditions, including snow, are expected to be less severe in the future. Unless specifically stated, the civil engineering structures and the ventilation and air conditioning systems are designed to accommodate the high ambient temperatures.

6.7 Protection against extreme wind

In accordance with i. 8.9 of RB-022-01 (Recommendations for Estimating the Characteristics of Tornado for Nuclear Energy Utilization Facilities) [11], the design shall take into account the effect of bodies driven by a tornado, starting from intensity class 3.

The considered range of such bodies includes:

- a motor car with a weight of 1800 kg;
- a 200-mm armor-piercing shell with a weight of 125 kg;
- a solid steel sphere with a diameter of 2.5 cm.

The impact velocity is taken to be equal to 35% of the maximum horizontal velocity of tornado wall rotation motion (item 8.9 RB-022-01) - Recommendations on the assessment of tornado characteristics for the objects using nuclear energy. Moscow, 2001): $V = 0.35 \times V_{tor} = 0.35 \times 85.0 \approx 30.0$ m/s. The body motion direction at the moment it collides with the structure is taken to be the most unfavorable, i.e., orthogonal with respect to the structure's outer surface. Safety factor for loads from tornado - $\gamma f = 1.0$. Regarding systems of ventilation all air intakes of the ventilation safety systems and important for safety are equipped with the unified protective systems which start to close at wind speed more than 49 km/s, thus systems of ventilation do not carry out their functions. However it does not influence nuclear safety (the cooling systems of the internal containment, external containment, the cooling systems of the process safety systems, conditioning systems of UCR and SCR are independent from external air).

REFERENCES

[1] KTA 2201.3 Design of Nuclear Power Plants against Seismic Events Part 3: Design of Structural Components

[2] Technical guidelines for the design and construction of the next generation of nuclear power plants with pressurized water reactors (French nuclear safety)

[3] European Utility Requirements for LWR Nuclear Power, Volume 2 Generic Nuclear

[4] Regulatory Guide 1.76, U.S. Nuclear Regulatory Commission, Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants

[5] DIN EN 1998-1 Eurocode EC8: Design provisions for earthquake resistance of structures

[6] DIN EN 1992-2 Eurocode EC2: Design of concrete structures

[7] Eurocode 1: Actions on structures – Part 1-3: General actions – Snow loads

[8] Eurocode 1: Actions on structures – Part 1-4: General actions – Wind actions.

[9] United States Army Technical Manual TM 5-1300 "The design of structures to resist explosions".

[10] Standard NS-G-1.5 (External Events Excluding Earthquakes in the Design of Nuclear Power Plants). IAEA. 2003.

[11] Safety guide RB-022-01 Recommendations for estimating the characteristics of a tornado for nuclear energy utilization facilities – GAN, Russia