

Hazards and hazard combinations relevant for the safety of nuclear power plants

Kurt Decker (1), Hans Brinkman (2), and Emmanuel Raimond (3)

(1) University Vienna, Department of Geological Sciences, Austria (kurt.decker@univie.ac.at), (2) Nuclear Research and Consultancy Group (NRG), The Netherlands, (3) Institut de Radioprotection et de Sûreté Nucléaire (IRSN), France

The potential of the contemporaneous impact of different, yet causally related, hazardous events and event cascades on nuclear power plants is a major contributor to the overall risk of nuclear installations. In the aftermath of the Fukushima accident, which was caused by a combination of severe ground shaking by an earthquake, an earthquake-triggered tsunami and the disruption of the plants from the electrical grid by a seismically induced landslide, hazard combinations and hazard cascades moved into the focus of nuclear safety research. We therefore developed an exhaustive list of external hazards and hazard combinations which pose potential threats to nuclear installations in the framework of the European project ASAMPSA_E (Advanced Safety Assessment: Extended PSA). The project gathers 31 partners from Europe, North America and Japan. The list comprises of exhaustive lists of natural hazards, external man-made hazards, and a cross-correlation matrix of these hazards.

The hazard list is regarded comprehensive by including all types of hazards that were previously cited in documents by IAEA, the Western European Nuclear Regulators Association (WENRA), and others. 73 natural hazards and 24 man-made external hazards are included. Natural hazards are grouped into seismotectonic hazards, flooding and hydrological hazards, extreme values of meteorological phenomena, rare meteorological phenomena, biological hazards / infestation, geological hazards, and forest fire / wild fire. The list of external man-made hazards includes industry accidents, military accidents, transportation accidents, pipeline accidents and other man-made external events.

The large number of different hazards results in the extremely large number of 5.151 theoretically possible hazard combinations (not considering hazard cascades). In principle all of these combinations are possible to occur by random coincidence except for 82 hazard combinations that – depending on the time scale – are mutually exclusive (e.g., extremely high air temperature and surface ice).

Our dataset further provides information on hazard combinations which are more likely to occur than just by random coincidence. 577 correlations between individual hazards are identified by expert opinion and shown in a cross-correlation chart. Combinations discriminate between: (1) causally connected hazards (cause-effect relation) where one hazard (e.g., coastal erosion) may be caused by another hazard (e.g., storm surge); or where one hazard (e.g., high wind) is a prerequisite for a correlated hazard (e.g., storm surge). The identified causal links are not commutative. (2) Associated hazards (“contemporary” events) which are probable to occur at the same time due to a common root cause (e.g., a cold front of a meteorological low pressure area which leads to a drop of air pressure, high wind, thunderstorm, lightning, heavy rain and hail). The root cause may not necessarily be regarded as a hazard by itself.

The hazard list and the hazard correlation chart may serve as a starting point for the hazard analysis process for nuclear installations in Level 1 PSA as outlined by IAEA (2010), the definition of design basis for nuclear reactors, and the assessment of design extension conditions as required by WENRA-RHWG (2014). It may further be helpful for the identification of hazard combinations and hazard cascades which threaten other critical infrastructure.

References:

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