Extreme weather and nuclear power plants (EXWE)

Introduction
Estimates of probabilities of hazards related to external events are needed for overall safety management of nuclear power plants (NPPs). Extreme weather and sea level events affect the design principles of NPPs and may pose external threats to the plants.

The safety assessments of the NPPs require estimates on the probabilities of such extremely rare events that they have not occurred during the past 100 years. Therefore, observation-based frequencies for the extreme events have to be complemented with other methods.

Extreme convective weather (ECW) in summer
In the warm season, ECW is characterized by thunderstorms producing heavy rain, large hail, intensive lightning, strong wind gusts (downbursts) and tornadoes. Historical time series of ECW events show cross correlations between summertime:
1) thunderstorm days, lightning and heavy rainfall,
2) heavy rainfall and tornadoes and
3) large hail and tornadoes.

Large hail
Atmospheric conditions favouring significant hail (diameter of 5 cm or larger) can be clustered into four distinct synoptic classes, two of which resemble the patterns observed in tornado situations in Finland.

Dispersion modelling
Dispersion in the air of pollutants emitted from a coastline source is complicated by differences in atmospheric structures above land and sea.

Extensive space weather
Although no serious effects have occurred in Finland, large geomagnetically induced currents (GIC) must be taken into account when installing new transformers or power lines affecting the operation of NPPs. In high-voltage power grids, GIC can cause transformer failures, malfunctions of protection relays, and blackouts (Québec 1989, Malmi 2003).

Strong winds
Impacts of storms will alter due to decrease in soil frost and increase in forest growth, urbanization and dependence on electricity.

Sea-effect snowfall
Sea-effect snowfall is formed when cold air flows over a warm ice-free water surface. Water area acts as a source of heat and moisture. This generates shallow convection that induces small and intensive convective precipitation which can drift to the coast as snowbands.

Severe freezing rain
After calibrations against weather station observations in Europe, a method for estimating the occurrence of freezing rain in grid-based atmospheric datasets was used together with reanalysis data and output from regional climate models. Freezing rain probabilities are projected to increase in northern and decrease in southern Europe.

Sea level rise
Scenarios for the global mean sea level rise during this century range from 20 to 200 cm. On the Finnish coast, this is partially compensated by the local postglacial land uplift. The largest uncertainty in the sea level scenarios is still the response of the Antarctic ice sheets to a warming climate.

Extreme sea level and waves
The height to which the continuous water mass rises in a flood event in the future is a combination of:
1) The extent of short-term sea level; storm surge.
2) Scenarios for the mean sea level.
3) Local wind-generated wave heights, depending on the shape of the shoreline, seabed topography, and archipelago shielding the coastline.

Combining these yields more accurate probability estimates for the flooding risks than the sea level based estimates alone.

Sea level oscillations
Rapid sea level oscillations of up to 1 m (in only ~15 min) have been observed on the Finnish coast.

• The summer events are likely meteotsunamis caused by air pressure disturbances, such as thunderstorms, moving over the sea.
• The winter events are small storm surges related to cold fronts propagating over the sea, with storm winds.

More research is still needed to better assess the occurrence frequencies of these events.

References

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