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Space Weather Impact on the European Interconnected Power Transmission System at High Latitudes

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High voltage power transmission grids can suffer outages or blackouts during geomagnetic storms (GMS). More specifically, GMS can inject geomagnetically induced currents (GICs) into the power network. Transformers were identified as the most vulnerable components of the power networks: GICs cause transformers to work in saturation regions generating voltage instabilities and eventually driving the system to collapse.

Since GMS are expected to cause more pronounced disturbances at high latitudes, we addressed the effects of extreme GMS on the Scandinavian 400 kV interconnected power transmission grid, including Finland, Sweden and Norway. By applying extreme 100-year-benchmark scenarios, we analyzed potential space-weather triggered voltage instabilities in the power grid considering mono-phase transformers, which are known to be more vulnerable to GIC injection, and three-phase transformers, which are more resistant. We assumed that every node of the grid included either transformers of the mono-phase type, or three-phase transformers.Our simulations indicate that the three-phase configuration of the network is significantly more robust than the mono-phase one.

Our study indicates that for a system with only three-phase transformers the likelihood of grid collapse is very low, and collapse only occurs for the worst-case scenario with extremely high geoelectric field intensities. In such a case, the increase in reactive power demand caused by transformer saturation is too high for the system to continue to provide power. Our results indicate that lines that experience higher reactive power losses during normal operation are more likely to increase losses during a GMS event. According to our study, the portion of the Scandinavian interconnected power transmission grid most vulnerable to extreme space weather is the part where the highest reactive losses in transmission lines and in voltage magnitudes are observed. This corresponds to the southern parts of Sweden and Norway.

In the near future, this study will be extended to assess the risk of extreme space weather for larger portions of the EU power grid.