

Topological Insights into the Resilience of European High-Voltage Grids: A Cross-Country Comparison

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The reliability of electric supply relies on the seamless operation of high-voltage (HV) grids, spanning both transmission and sub-transmission levels. While these grids may seem uniform, their structural diversity significantly impacts system vulnerability. In this work, we present harmonized topological models of HV grids from 15 European countries, integrating all elements above 110 kV. Our analysis reveals a common pattern: node degree distributions follow an exponential decay, though the decay parameter varies notably across countries. A detailed evaluation of network resilience through node and edge removals shows that the decay parameter separates more resilient grids from those prone to large-scale failures. Furthermore, we demonstrate that including sub-transmission elements and redundant edges in the models significantly alters this boundary. This study offers the first quantitative cross-country comparison of 15 European high-voltage grids, linking topological features with vulnerability and underscoring the importance of multi-metric assessments for understanding grid resilience.