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Risk Of Blackouts And Social Vulnerability In The Italian Power Transmission System

Andrej Stankovski, Katherine Emma Lonergan, Blazhe Gjorgiev, Giovanni Sansavini

[a]*Reliability and Risk Engineering Laboratory, Institute of Energy and Process Engineering, Department of Mechanical and Process Engineering, ETH Zurich, Zurich, Switzerland*

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Electricity is essential for human well-being, though access to reliable power supply varies considerably across the globe. Although no electricity system is immune to blackout events, recent studies have shown that vulnerable communities are more exposed to their adverse effects than their less vulnerable peers, even within wealthy nations. An investigation shows that indigenous communities in Australia (Longden et al., 2022) are far more likely to experience outages, especially with rising ambient temperatures. Similar studies in the USA (Dugan et al., 2023; Ganz et al., 2023) show that vulnerable communities take longer to be reconnected to the grid following significant weather events. Despite this ample research, comparable studies are lacking for the European context. Moreover, the relationship between transmission system performance and regional vulnerabilities has not yet been explored.

To address these research gaps, we assess the relationship between social vulnerability and power blackouts in the Italian electric power transmission system. For this purpose, we analyze 14'577 blackout events published by the Italian transmission system operator TERNA (TERNA, 2022) and compile them in a European blackouts database (Stankovski et al., 2023). Each event in the database contains the following information:

- general information (date, time, affected region);
- type of the event (single, cascade, potential cascade) and number of failures;
- demand not served (in MW);
- main cause (weather-related, human error, third party, grid instability, random failure, causes);
- affected assets (line, transformer, substation components, etc.) and asset ownership;
- duration of the event (in hours);
- grid (demand, generation, etc.) and weather conditions (temperature, wind speed, etc.).

We proxy social vulnerability at a sub-national level (NUTS2) with literature-established socioeconomic indicators (Mitsova et al., 2018; Dugan et al., 2023), including age, health, wealth, and human development index (HDI). The data is sourced from Eurostat (Eurostat, 2024) and the Italian Statistical Institute (Istat, 2024). We derive preliminary results for eight Italian regions following TERNA's nomenclature to facilitate matching between blackout events and host communities. However, future work will present results on a more spatially disaggregated basis.

Our preliminary findings substantiate a relationship between social vulnerability and electricity blackout frequency, demand not served (DNS) [MW], and performance loss in the region [MWh]. Figure 1 shows the relationship between three blackout indicators and the regions' average human development index (HDI), all showing a negative correlation between electricity system performance and HDI. We selected these indicators to represent both the frequency and severity of the blackout events. In practice, these results indicate that wealthier regions in the north experience up to 2.5 times fewer failures per capita and up to 3 times lower DNS per capita than poorer regions in the south.

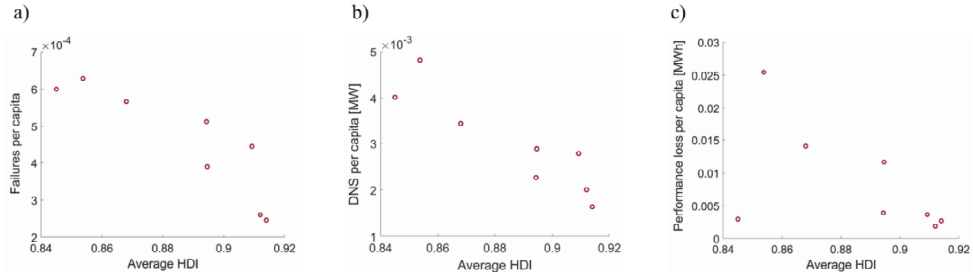

Fig. 1. Correlation between the human development index of a region and event severity indicators (a) failures per capita; (b) demand not served (DNS) in MW; (c) performance loss per capita in MWh.

We find that asset ownership moderates the strength of the correlation between social vulnerability and transmission system performance. Namely, electricity system performance is more consistent when systems are owned and operated by the national transmission system operator as opposed to third-party companies, such as distribution companies, utilities, power plants, and large industrial consumers. Unified practices and centralized funding may help explain why the national transmission system operator is more consistent than the third-party companies; procedural and training deficiencies and insufficient disposable resources may also contribute to this performance gap.

Our findings establish a relationship between transmission system performance and social vulnerability in a European context, confirming that the performance-vulnerability link is a global phenomenon. Identifying the leading causes of this relationship is imperative for identifying system vulnerabilities and ensuring energy equity. In our future work, we will address these issues and expand the analysis on a component level.

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