Reliability in multi-regional power systems – Capacity adequacy and the role of interconnectors

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Executive summary

Due to its high economic value, reliability of supply has always been a major concern in electricity systems. However, new challenges are currently arising due to the large-scale deployment of renewable energies to avoid greenhouse gas emissions and combat climate change. The reason lies in the variable nature of many renewable energy resources, such as wind and solar, and the possible risk of recurring unavailability during times of stress. In order to foster reliability of supply in power systems, interconnections with neighboring regions have proven an effective means. Yet, cooperative action is required to reach envisaged reliability levels at lower costs compared to an isolated approach.

From a political perspective, however, reliability of supply is often considered an issue of national interest. As a consequence, assessments and measures to ensure reliability often have a narrow spatial scope, e.g., bounded by national borders. This inevitably results in market distortions and economic inefficiencies. At the same time, it so far lacks stringent approaches to investigate reliability in multi-regional power systems with capacity-constrained interconnectors to ensure security of supply in highly meshed and interdependent electricity systems.

In this paper, we therefore investigate cross-regional effects and the role of interconnectors for reliability assessments. Based upon probabilistic reliability metrics, we develop an optimization model to determine the efficient amount and location of firm generation capacity to achieve reliability targets in multi-regional electricity systems. A particular focus lies on the representation and contribution of transmission capacities as well as variable renewable resources.

Calibrating our model with a comprehensive dataset for Europe, we find that there are substantial benefits from regional cooperation. The amount of firm generation capacity to meet a perfectly reliable system could be reduced by 36.2 GW (i.e., 6.4 %) compared to an isolated regional approach, which translates to savings of 14.5 bn Euro. Individual countries could reduce their amounts by up to 31.8 %.

In this cooperative solution, several interconnectors contribute substantially - in both directions. Especially valuable are the interconnectors from/to Great Britain, Italy, and Romania, as well as the interconnector between France and Spain, with capacity values close to 200%. Capacity expansions at those borders would therefore help to further reduce the need for firm generation capacity. Despite its fluctuations, wind power in European countries would in the cooperative solution be able to contribute with 3.8 - 29.5 % of its nominal capacity to the reduction of necessary

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firm generation capacity, compared to a capacity value of 3.2 - 25.5 % when considering reliability in isolated countries.

As an additional insight, we find that the amount and distribution of reliable capacity as well as the contribution of individual technologies is also heavily affected by specific reliability target. Policymakers and system engineers should therefore choose target values with care to avoid inefficiencies from excessively high (or low) capacity levels.

Overall, our analysis provides evidence that a consistent analysis of multi-regional systems with restricted interconnector capacities is crucial for reliability mechanisms. In practice, our approach could thus be used for the improved design of capacity mechanisms by providing an approach to consider interdependencies with physically connected neighbors. Moreover, the large differences between the first-best and isolated results provide strong arguments to achieve reliability targets efficiently in a cooperative manner, e.g., by means of joint capacity mechanisms.

Keywords Reliability of supply, Capacity adequacy, Multi-regional power system, Interconnector, Variable renewable energy

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