Interdependence in Security of Supply in Electricity

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Overview

Security of Supply in electricity has become a major concern over the last decade in most countries. Whereas in other energy areas, such as oil, the various crises have highlighted the danger of shortages (Pascual and Elkind, 2010), security of supply has only recently been considered a central issue in the electricity sector (e.g. Cepeda and Finon, 2011). Investments in renewables, decisions to retire nuclear generation in many countries, aging thermal generation, limited investments in infrastructure and increased awareness of environmental issues have placed security of supply into the centre of attention of regulators and policy makers. Time lags in the electricity sector are long by any standard, whether for building new capacity or for improving the infrastructure. Consequently, it is important to be proactive rather than reactive, waiting problems to surface (e.g., a shortage of capacity) and being forced to take undesirable and costly emergency measures (e.g., capacity choices that will later be regretted) at the expense of a coherent long-term strategy Several aspects have been studied in isolation:: adequacy of peak-load capacity, dependency on fuel imports, grid capacity (Albert et al., 2004), etc. At a more global level, several studies have aimed to develop a single measure to summarize the state of the system; examples include Vivoda (2010) and Sovacool et al. (20011).

EURELECTRIC defines security of electricity supply as "*the ability of the electrical power system to provide electricity to end-users with a specified level of continuity and quality in a sustainable manner, relating to the existing standards and contractual agreements at the points of delivery*" (Eurelectric, 2004, p. 8). Building on this view, Larsen et al. (2015) developed a comprehensive framework to assess security of supply. They suggest that security of supply should be evaluated based on a set of dimensions, each of which affects the future supply. They argue that the evolution of these dimensions should be assessed over time and that t no single indicator can characterise the level of security of supply in an electricity system. The eleven dimensions selected for this monitoring are *generation adequacy* (meeting demand in the short and medium term); *Resilience* (meeting demand under changing circumstances); *Reliability* (uninterrupted supply); *Social and cultural factors* (societal influence on the system's development); *Regulatory efficiency* (having the right regulation); *Sustainability* (including both the environmental and economic dimensions); (*Condition of the grid)* ; *Geopolitics* (e.g., fuels such as oil and gas); *Demand management* (flexibility as well as efficiency); (*Supply flexibility)* (e.g., generation and smart grids) and *Terrorism* (disruption of installation). They also propose metrics to track the evolution of these different dimensions.

Larsen et al. (2015) consider these eleven dimensions in isolation. The next step is to acknowledge their interdependency: actions to improve one aspect of the system could have undesirable consequences for other parts of the system. Incorporating these interdependencies enables us to get one step closer to determining the true level of security of supply in an electricity system.

Methods

We evaluate the interdependence of the factors based on a literature review, combined with cross impact analysis. Furthermore, we develop a visual representation of the framework using different types of diagrams.

Results

The analysis shows that the suggested framework is a useful tool for creating awareness of the evolution of security of supply over time. The visualization makes it easy to communicate the changes and draw attention to the areas that are most likely to cause disruption in the delivery of electricity. Mapping the situation of consecutive years in a single spider diagram provides insight into the speed at which the different factors evolve, thus visualising the consequence of lags in the electricity system.

We find that many of the dimensions we selected exhibit a significant degree of interdependence, and we identify the presence of feedback between these dimensions. For instance, consider regulatory efficiency, technology and sustainability: regulatory efficiency affects technology choice; this impacts the environmental sustainability of the system, which will influence regulation (e.g., subsidies for renewables), thus closing the loop.

We establish the underlying structure of the interdependencies between the variables and map it in a causal loop diagram. This helps to create an understanding of what the consequences of an intervention in the system might be, in particular the unanticipated consequences due to the interdependencies in the electricity system. Understanding these interdependencies will help regulators and policy makers avoid costly mistakes when deciding where and how to intervene.

Conclusions

This paper is based on a broad framework which identifies the interaction between eleven dimensions that are critical for security of supply. The interdependencies between these dimensions make the electricity system particularly hard to manage. It is therefore of crucial importance that, when making decisions that affect the electrical system, policy makers and regulators not only understand how to assess these different dimensions in isolation, but also how they interact. Spider diagrams can help visualize and understand the changes in the different dimensions as they take place over time; causal loop diagrams are useful to identify the most appropriate interventions, while drawing attention to their potential side-effects. This leads to a better monitoring of security of supply, enabling decision makes to take preventive action before the electricity system reaches a critical stage.

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