FORMULATING A FRAMEWORK FOR ASSESSING THE SECURITY OF SUPPLY IN ELECTRICITY MARKETS

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Overview

Energy security became a national policy issue following events such as the oil crisis in the 70s. Previous work mainly analyses energy security as the challenge of ensuring the combustible supply (Jansen and Seebregts 2010). However, energy security goes well beyond securing fuel supply; its definition involves multiple dimensions, which have different specificities depending on the region, timeframe or energy source. Several authors, e.g. Vivoda (2010) and Sovacool et al. (2011), assess those multiple dimensions by calculating an aggregated index. However, attempting to summarise these by a single number gives a very myopic view of the system state.

Although the electricity sector is considered in these evaluations, there is no work focusing specifically on the security of supply (SoS) in electricity markets. These markets have particular characteristics: non-storability of electricity requiring real-time balance of demand and supply, long construction delays of generation and transmission infrastructure, low demand elasticity, rigidity of the transport infrastructure and the regional nature of markets (Arango 2007). Thus, studies on SoS for the other energy sectors cannot be applied directly to electricity markets.

SoS in the electricity sector has become a more central issue for all the actors in the industry. Over the past 20 years the effort in this sector has been on designing deregulated markets, while providing the right incentives and controls for these markets (Newbery 2001). Consequently, today many countries have competitive markets, and regional markets are gaining more importance following an increase in cross border trade.

The particularities of electricity systems, the changes in the market structure, the pressure caused by environmentally driven policies together with technological innovations over the last thirty years, have also led to a notable change in the technologies used for electricity generation. There has been a significant shift towards gas fired turbines as the main technology for newly installed conventional generation capacity (Newbery, 2001). Likewise, renewables have reached a significant share of production in the last decade. To further complicate the situation, the decision of several countries to phase out nuclear power generation, which often accounts for a non-trivial fraction of their generation, will affect their future capacity adequacy. In addition, in many countries the grid (network) is more fragile than anticipated, as illustrated by the large blackouts in 2003 in Europe and the USA (Andersson et al. 2005).

To increase the complexity further, many of these factors are increasingly interdependent. To achieve an understanding of SoS, it is of paramount importance to understand these links and their consequences across the whole electricity sector, since an action might improve one aspect but have a negative effect on another.

In this paper we develop a framework aimed primarily at assisting regulators and policymakers in evaluating the current SoS of their electricity sector. We differ from other work in the area in that, firstly, we consider only the electricity sector and not the energy sector as a whole. Secondly, we aim at developing a set of measures that can be used to access the current state of the SoS, using a multi-dimensional view; we do not try to aggregate these measures into one single indicator. Thirdly, we aim at developing a framework that will allow the decision makers to follow the development over time, allowing them to get a better view of the changes that take place in the different dimensions of SoS, as opposed to making cross-country comparisons.

Methods

Conceptualization of a framework starting from an extensive literature review and Cross impact analysis to analyse the relationship among variables.

Results

Based on an extensive review of the literature, we identify eleven variables for assessing the SoS in electricity markets.

- Availability: Capability of the country to meet demand in the short and middle term with its own means (capacity and resources). The de-rated margin is commonly used to measure the capacity adequacy. However, results for systems with a large share of intermittent renewable energies (solar and wind) and/or hydropower could be misleading. Other alternatives such as the tightest hourly de-rated margin or the aggregate availability of energy in a year, should also be analysed.
- Resilience: Capability of the system to meet demand in the short term under changing supply availability. This is linked to the dependency on imports as well as the diversification of generation technologies.
- Reliability: Capability of the system to provide an uninterrupted supply. Unlike capacity adequacy, this variable is in itself a measure of risks to SoS, and provides information on how large an outage might be.

There are two well established measures to express the risks to SoS associated with the generation mix and demand levels: Loss of Load Expectation (LOLE) and Expected Energy Unserved (EEU).

- Social cultural factors: Refers to the extent to which electricity projects can be affected by people's opposition, including the NIMBY factor.
- Regulation efficiency: Measures how regulation helps ensuring the electricity supply, in particular with respect to sending the right signals to investors (without intervening into the market), to internalising the costs (and risks) in the tariffs, and to controlling the market concentration.
- Sustainability: Includes not only environmental sustainability, but also economic and technical viability: generating should be profitable and tariffs should be affordable.
- Infrastructure: Refers to grid performance and its adequacy, as well as the difficulty of balancing the grid given the system particularities. Useful indicators of performance and potential problems include congestion, degree of decentralisation, grid efficiency, age of the grid and geographical distribution of demand/supply nodes.
- Geopolitics: Refers to the extent to which relying on other countries to meet domestic electricity demand might affect the SoS. Participating in international markets, whether for electricity trade or fuel supply, carries risks if these markets are vulnerable to changes in regulatory regimes, external shocks, among others. A metric could be the degree of supplier diversification.
- Demand: There are two aspects to be considered: demand flexibility and efficiency. The former depends on the demand management, which is expected to gain importance with new technologies such as smart grids. Both are encouraged by government policies. Demand response and the electricity intensity (GDP/electricity consumption) give some insights about this matter.
- Technology: Given the expected increasing penetration of intermittent renewable energies, electricity systems should deal with less predictable production. Sudden imbalances could result from the inherent variability of these sources as well as from inaccurate forecasts. Measures should focus on the supply flexibility and the availability of back up supply.
- Terrorism: Physical security risks, such as sabotage, faced by high voltage transmission systems, as overhead transmission lines are vulnerable to possible attacks.

Conclusions

Electricity markets are facing significant transformations that threaten the SoS. Given their specificity, assessing this threat with analyses formulated for other energy sources is not appropriate. We develop a framework focused on the electricity sector at the regional level, accounting for the interconnections with neighbouring regions or countries. As the suggested variables show, the framework is comprehensive to ensure that the central elements that determine the SoS are taken into account, while being sufficiently flexible to be adaptable to the characteristics of an individual region. We acknowledge that it might be difficult to develop a framework useful for the comparison of different regions. For these reasons, we focus on a framework aimed at providing insight in the SoS of one region to the regulator, planning authorities and government, among others.

This framework is designed for two uses: first, to provide a snapshot of the situation to understand current weaknesses and determine what actions are required; second, to capture the evolution over time in order to identify progress and discover new problem areas, thus providing an indicator of the effectiveness of current actions and of the need to adapt.

One of the main challenges of this framework will be the calculation of certain metrics: data might be unavailable or inexistent (e.g. spatial data of demand and supply nodes) or measurements might be non-reliable (e.g. socio-cultural factors). The implementability of such a framework will thus depend on the collaboration among all parties involved.

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