The Systemic Value of Wind Generation in Brazil

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Overview

The penetration of variable renewable energy (VREs) in power systems results in integration and adequacy costs. The common notion that a particular source becomes competitive when its levelized cost of electricity (LCOE) becomes lower than the average price of electricity or the average tariff of a given region (grid parity) neglects the presence of integration costs (IC) in the present and its evolution in the future. As noted by Hirth et al. (2016), all sources are subject to IC, so that their marginal value depends on their degree of penetration and the characteristics of the system to which they are introduced. That is, the relationship between cost and price does not determine an absolute competitiveness (per se) of the source, but rather a relative one – for a given price, in a specific power system, a given amount of energy from a source proves to be competitive. Thus, ICs determine the systemic value of the sources, while the adequacy costs delimit the evolution of dynamic ICs.

The literature of IC usually refers to cost additive components, but in practice, these may be negative, reflecting systemic benefits of source introduction in a given system (LAMONT, 2008; SCHMALENSEE, 2016). In addition, the traditional approach of IC faces challenges related to the definition, decomposition and calculation of costs, since (i) there is no consensus or guarantee that the list of usual components is exhaustive; (ii) there is no clarity about the dynamic interaction with the systems, with respect to the direction and dimension of costs; and (iii) there is no clear methodology to compute the components and their interrelationships (MILLIGAN et al., 2011).

In order to allow comparisons between different sources, an alternative system (without the source) common to all analyzes should be used, establishing a comparative benchmark. Another sensitive aspect refers to the time horizon under consideration, since often the usual analyzes disregard that the transformation of the systems can reduce ICs over time, restricting them only to short-term effects. In this sense, the traditional IC analyzes do not contribute adequately to the comparative analysis of sources (HIRTH et al., 2015).

The top-down approach proposed by Ueckerdt et al. (2013) and Hirth et al. (2015), in contrast to the traditional bottom-up additive approach, has the advantage of defining marginal costs of integration, rather than average costs. This insight leads to the merging of the two parallel literatures (value of technologies and integration costs) in a single framework, decomposing systemic costs and benefits.

As ICs jointly affect the value of technologies and their total costs, the proposed approach establishes a dual definition from these two different perspectives. Under the "cost perspective", traditional LCOEs are increased by marginal integration costs, resulting in systemic levelized costs (SLCOE). From the "value perspective", the ICs derive from the marginal economic value of the technology to the system, reflecting on welfare variation due to the additional increase in source generation. In perfect and complete markets, the marginal value of the source is expressed by its market value, that is, by the average price weighted by the generation profile of the source - expressing time, location, and avalilability uncertainty. On the other hand, the average price of electricity represents, theoretically, the market value of a hypothetical technology with a generation that is perfectly correlated to the load, constituting a comparative benchmark. Thus, under the "value perspective", marginal integration costs for a given source penetration are defined as the difference between the average electricity price and the source-weighted average electricity price accordingly its generation profile.

From the “value perspective”, IC can be inferred by the premium or discount that the market value of the sources – used as a proxy for its marginal value – obtains on the average elecricity price. The ratio between the source-weighted average electricity price and the load-weighted average electricity price is denominated in the literature as value factor, which allows to infer the dimension of IC incurred in practice by the penetration of the sources in the systems. The premium or discount under the average price is determined by the degree of source penetration (market share) and is conditioned by the characteristics of the systems. Faced with the disadvantage of calculating ICs from a cost perspective, its inference from the value perspective has the advantages of (i) not requiring explicit cost decomposition; (ii) does not imply additivity of the components; (iii) allow the analysis of the time evolution of both past and projected costs; and (iv) allow the comparison between different systems, since the ratio expressed by the value factor is dimensionless, translating into a relative price.

In order to maximize synergies among energy sources, the power dispatch in Brazil is performed centrally by the Brazilian Power System Operator (ONS). From the use of optimization models, ONS attempts to minimize the total cost of supply by deciding whether to use reservoir water now or to store it for the future. The solution for this intertemporal problem results in determination of the week-ahead operation marginal costs (OMC), for each four subsystems and daily level of load (light, medium and heavy). The OMC ultimately expresses the opportunity cost of water retained in the water reservoirs, that is, the shadow price of electricity in Brazil. For commercial purposes, the CMO is limited by minimum and maximum values, determining the settlement price of differences (PLD), used to settle short-term differences between previously contracted and effectively realized flows. Since April 2018, the ONS has preliminarily published the hourly OMC to turn the operation schedule on an hourly basis by 2020.

Brazil has set a Benefit-Cost Index (BCI) to compare the different sources in centralized power expansion auctions. The BCI compares the technologies that compete for availability contracts, ranking them in terms of expected benefit-cost. The BCI considers the generating alternatives from the point of view of buyer pool formed by distribution companies, valued for a 5-year future operation. The calculation is made from two thousand series of simulated hydrological scenarios, for each subsystem, which result in two thousand monthly equiprobable values for the future OMC. The ICB contains a cost component that captures the systemic benefit of the source. The CEC component (short-term expected economic costs) calculates the expected energy contribution of the source, in relation to its physical guarantee (expected annual average energy contribution, ie. the expected value of its firm energy), assessed by the PLD, for each of the two thousand monthly scenarios.

The main objective of the article is to discuss the costs of integrating wind in the Brazilian power system, from the systemic value perspective, investigating the value factor observed for wind power and its evolution over time and comparing with the projected benefit in power auctions.

Methods

The value factor can be calculated based on observed prices (static ICs) or based on projected prices (dynamic ICs). In addition, the calculation can be made from observable market prices or shadow prices calculated by system optimization (OMC). For Brazil, one can consider the OMC projected or observed, weekly by load level or preliminarily by hour, or even the respective PLD (OMC limited by a price cap). The wind generation can be considered in aggregated or individualized form per wind farm by weekly load level or by hourly basis.

Results

The analysis of value factor for wind generation in Brazil, calculated through different observed or projected parameters (PLD, weekly CMO, hourly CMO) can subsidize several analyzes such as (i) comparison with other systems and different markets; (ii) evolution of ICs in face of greater penetration of wind and Brazilian system transformation; (iii) impact of the price cap level (PLD) on the OMC; (iv) preliminary impact of the introduction of hourly OMC in the Brazilian system, and (iv) comparison of implicitly projected ICs in the ICB at the auctions and ICs explicitly observed in the optimized system operation.

Conclusions

The installed capacity of wind already exceeds 13 GW of the Brazilian power matrix (8% in 2018), mainly in the northeast, reaching more than 70% of the daily load of the region and 15% of the national system. The value factor analysis of wind generation in Brazil may (i) reinforce the notion of the systemic benefit of wind geeration in the Brazilian system; (ii) better dimension the wind systemic benefit; (iii) point to non-evident or unaccounted ICs, mainly related to capacity location; (iii) to contrast the systemic value estimated by the value factor with the systemic value implicitly considered in the ICB in power auctions; and (iv) to suggest that the current electricity pricing mechanism in Brazil does not translate the systemic value of sources in the power system under transformation, point out the need for pricing electricity adequately, with sufficient spatial and temporal granularity to remunerate new services, especially related to flexibility provision.

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