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Analysis of the imbalance price scheme in the Spanish electricity market: A wind power test case

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HIGHLIGHTS

- We propose a new imbalance price scheme to foster the power deviations reduction.
- We run a test case to assess the effectiveness of the new IP scheme.
- We include policy recommendations for the regulation of power systems.
- Real data analysis and realistic results are included.

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ABSTRACT

This work investigates the interaction between wind power and electricity markets. The paper is focused on balancing markets pricing policies. The proposal of a new imbalance price scheme is included and conveniently evaluated. This proposed scheme tries to minimise the use of ancillary services to compensate for deviations in searching for a more efficient market design. The effectiveness of imbalance prices as market signals is also examined, and policy recommendations regarding imbalance services are discussed. Two test cases are included that analyse the participation of a wind power producer in the Spanish electricity market using a stochastic optimisation strategy. For this purpose, the uncertainty of the variables is considered, i.e., wind power production and prediction, intraday and imbalance prices. Test cases were run with real data for 10 months, and realistic results are presented along with a hypothetical test case. The regulation of the imbalance prices may not be adequate for the Spanish electricity market because an error drop is not sufficiently encouraged. Therefore, we suggest the application of a new imbalance price scheme, which includes an additional constraint. The conclusions of this paper can be assumed to be general policy recommendations.

1. Introduction

Because electricity markets liberalisation, intermittent energies should participate in such a scheme. This interaction is two-fold; on one hand, renewable energy sources for electricity (RES-E) assume risks that originate from market participation, and consequently, RES-E should pay the costs of the deviations produced in the power system. On the other hand, regulations should enhance RES-E participation, as they possess positive environmental externalities.

Regarding the first issue, in the Spanish electricity market case, wind power producers participate in a similar manner as conventional plants, except that they receive a feed-in tariff to compensate for market risks. For this, the producers should forecast their expected production to bid it to the market during the settlement period. Generally, their production is estimated using short-term wind power production tools, which usually provide the forecasted power level and the associated uncertainty. The accuracy of these tools has been widely studied in the literature, including in studies reported by González et al. (2004), Martí et al. (2006), and Pinson et al. (2009a). Today, great development in this field provides us with very precise predictions. However, the deviations between forecasted and committed power produce imbalances, which should be paid by the wind power producers, as suggested by Bathurst et al. (2002), Fabbri et al. (2005), and Holttinen (2005). Therefore, some scientific works have focused on considering the uncertainty of the prediction to reduce the imbalance costs. Given that an estimation of the uncertainty should be provided, several approaches to determine this uncertainty can be considered, including those described by Monteiro et al. (2009), Morales et al. (2010), Nielsen et al. (2006), and Pinson et al. (2009a,b). Once the uncertainty has been estimated, several techniques can be used to reduce the effects of deviations from initial schedules. Optimisation strategies can be widely employed to reduce

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economic losses and, consequently, improve the revenues. Accordingly, these strategies are based on updating the bid made to the daily market in the intraday market, when predictions with shorter horizons are available; the accuracy of the predictions thus rises. These methods can be found in studies reported by Angarita-Márquez et al. (2007), Bourry and Kariniotakis (2009), Fabbri et al. (2005), Holttinen (2005), Usaola and Angarita (2007), and Usaola and Moreno (2009).

However, market participation risks do not only rely on power deviations, as electricity market prices are highly variable and difficult to forecast. Therefore, an estimation of these prices is a relevant problem. Due to the unavoidable difference between the produced and committed power, the imbalance costs borne by wind power producers are especially important, and the imbalance prices should thus be considered. While most studies are not based on actual balancing energy prices and only consider estimations (Angarita-Márquez et al., 2007; Fabbri et al., 2005; Holttinen, 2005; Matevosyan and Soder, 2006), realistic assumptions can be found in certain studies, such as Bueno et al. (2010) and Moreno et al. (2012).

In addition to the optimisation strategy, risk management restriction can be considered in an effort to reduce the hazard of having extremely high imbalance losses or to reduce the deviations produced in the power system. These methods consider the variability of imbalance prices and/or production and address them to reduce the risk of incurring excessive costs. These methods can be found in previous studies reported by Botterud et al. (2010), Bourry et al. (2008), Dent et al. (2011), Dicorato et al. (2009), and Moreno et al. (2012).

In the literature, some works analyse the market design. Most researchers focus on support schemes, such as Hiroux and Saguan (2010), Klessmann et al. (2008), and Rivier-Abbad (2010), but the studies also include other integration issues, including technical and economic issues. Other articles analyse the design and structure of the balancing prices scheme, such as those reported by Barth et al. (2008), Vandezande et al. (2010), and Weber (2009). Thus, in these works, a trade-off between the effect of market signals on the behaviour of wind generators and efficient support schemes is suggested, and some policy recommendations are included. Although these works analyse the present regulation, none of them are based on particular test cases.

This paper addresses the interaction between the electricity market and wind energy. An optimal participation of wind power producers in adjustment markets, which is focused on reducing imbalances, is investigated. The optimisation process is stochastic and considers the uncertainty of both market and production variables, i.e., short-term wind power prediction, intraday prices and imbalance prices. This study is conducted in a realistic manner, as actual market prices and wind power productions are employed to assess the results. Moreover, data for one year were collected; therefore, a thorough analysis was performed. These test cases were run, and their results are conveniently discussed and related to a regulation analysis. Furthermore, policy recommendations that are applicable to the imbalance price scheme are suggested and tested.

Below, the main contributions of this work are explained. First, the inclusion of a risk management analyses entails deviation reductions. This test is performed using real data; thus, realistic scenarios are considered. The analysis performed is exhaustive, as a large quantity of data is considered through a stochastic optimisation that addresses the uncertainties associated with the variables. Second, diverse test cases are used to analyse the effectiveness of Imbalance Prices (IPs) as market signals. For this, the imbalance pricing and the diverse power producers' behaviours under the present regulations are analysed to develop a new cost-reflective imbalance price scheme, which is also proposed and tested. Finally, policy recommendations are designed to prevent an overuse of balancing services.

In this test case, the production and forecasts of a wind farm of 20-MW rated power is employed along with the historical data of market prices, that is, daily, intraday and imbalance prices. The optimisation strategy was programmed in Matlab and, because of its simplicity, can be easily integrated in a real-time routine.

The aim of this work is two-fold; on one hand, it assesses the sensitivity of producers to market signals. On the other hand, the efficiency of the imbalance prices scheme is evaluated. Given the assumption that the regulation of imbalance market prices should foster the reduction of power system balancing costs and, thus, promote the diminution of unexpected deviations, a new imbalance price scheme is proposed.

The paper begins with a description of the Spanish electricity market structure, which includes daily, intraday and imbalance markets. Later, a short introduction to wind power participation in electricity markets is provided. This section includes a discussion on short-term wind power forecast and the prediction and modelling of market prices in the intraday market and balancing services. Next, the formulation of the optimisation strategy for bidding in intraday markets is discussed. Then, an analysis of the current imbalance prices scheme is performed, and a new proposal is included. Finally, the participation of a windfarm in the Spanish electricity market is simulated over nearly a year under diverse assumptions. First, results following an optimal strategy are presented with the present imbalance price scheme, and the proposed imbalance price scheme is then tested for diverse risk attitudes. The results are compared with reference cases based on point predictions. Section 7 summarises the conclusions of this study.

2. Spanish electricity market

The electricity market is composed of a set of sub-markets in which generators participate to sell their hourly power production. Generally, producers participate in the daily market (DM). Afterwards, they may update their productions in the adjustment or intraday markets (IMs). Finally, the transmission system operator (TSO) addresses real-time deviations through ancillary services and, if necessary, draws on the imbalance management process. These market processes are explained in the following sections.

2.1. Daily market

In the DM, bids must be made between 14 and 38 h before the operation settlement period (OSP). In the Spanish case, the gate closure time is 10 a.m. This market possesses the largest liquidity, as most energy is negotiated on it.

2.2. Intraday markets

These markets may be continuous or composed of several sessions, as in the Spanish case, where 6 intraday market sessions are held. The Spanish IM sessions occur 4–7 h before the OSP.

Table 1
Spanish intraday markets structure.

Session number	1	2	3	4	5	6
Session Opening	16:00	21:00	01:00	04:00	08:00	12:00
Session Closing	17:45	21:45	01:45	04:45	08:45	12:45
Schedule horizon (h)	28	24	20	17	13	9
Hourly periods	21–24	1–24	5–24	8–24	12–24	16–24