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# The impact of European balancing rules on wind power economics and on short-term bidding strategies

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## HIGHLIGHTS

- European countries apply different imbalance pricing rules.
- The allocation of balance responsibility to wind power varies between the countries.
- A stochastic optimization model is used to compare the effect of balancing rules.
- Balancing rules have an important impact on wind generators bidding strategies.
- Balancing rules have also an effect on the system imbalances.

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## ABSTRACT

Wind power represents a significant percentage of the European generation mix and this will increase to fulfill the renewable energy targets. Different balancing rules are applied to wind power among the countries; for instance, to what extent wind power producers (WPPs) are responsible for the energy imbalances and how those imbalances are penalized. This paper discusses those different rules and evaluates their effects on WPP bidding strategies. To do so, a quantitative analysis is presented for an offshore wind farm, considering the differences in the balancing rules and prices of Belgium, Denmark, Germany and the Netherlands. The quantitative approach consists of a stochastic optimization model that maximizes the profits of a WPP by trading in different markets (day-ahead and intraday) and computes the final energy delivered. The model considers uncertainties of most important parameters such as wind energy forecasts and prices at different time frames. The results show that the imbalance pricing design and the allocation of balance responsibility significantly affect WPP' revenues. Additionally, WPPs deviate differently from the expected energy depending on the balancing rules, which can impact the system. Furthermore, these balancing rules should be considered with other market regulations, such as the design of support schemes.



## 1. Introduction

Wind power has specific rules with respect to other generation units. First, it usually receives support schemes in order to make it competitive at the current price levels. Second, wind power may also be subject to specific balancing rules, for instance, to what extent it is responsible for the energy committed in the different energy markets, put forward by the limited capability to forecast its energy. Additionally, market designs were usually created for conventional generation units. For example, the day-ahead (DA) market is usually liquid; and the market clearing takes place the day before delivery, in order to program the dispatch of conventional generation units. However, at DA gate-closure, there is still a lot of uncertainty for wind power due to meteorological data that affect its predictability. On the other hand, intraday (ID) markets, which have gate closure times closer to real time, are less liquid (Weber, 2010).

Electricity markets have the characteristic that supply and demand should constantly match. Market parties, such as Wind Power Producers (WPPs), are incentivized to participate actively in the balancing arrangements, by sending accurate schedules to the Transmission System Operator (TSO) and by participating in the provision of balancing services. These balancing arrangements can be divided into three main pillars (van der Veen and Hakvoort, 2009): balance responsibility, balancing service provision and imbalance settlement.

The balance responsibility defines the obligation for market participants (generators, consumers and traders) to send schedules

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**Nomenclature**

*Indexes*

| | |
|---|---|
| h | hour under consideration |
| $\omega$ | scenario |
| $N_t$ | total number of hours |
| $N_\omega$ | total number of scenarios |

*Parameters*

| | |
|---|---|
| $\lambda^{da}_{h\omega}$, $\lambda^{i}_{h\omega}$ | day-ahead and intraday prices, respectively |
| $\lambda^{+}_{h\omega}$, $\lambda^{-}_{h\omega}$ | imbalance price for positive and negative deviations, respectively |
| $p^{max}$ | maximum power that can be sold in the market (wind farm installed capacity). |

*Variables*

| | |
|---|---|
| $p^{da}_{h\omega}$, $p^{i}_{h\omega}$ | power sold in the day-ahead and intraday market, respectively |
| $\Delta^{+}_{h\omega}$, $\Delta^{-}_{h\omega}$ | positive and negative deviations, respectively |
| $\Delta_{h\omega}$ | net sum of imbalances |
| $\Delta^{+}_{1h\omega}$, $\Delta^{-}_{1h\omega}$ | positive and negative imbalances (respectively) higher than 30% of the nominated power (belgium) |
| $p^{s}_{h\omega}$ | sum of the power bid in the day-ahead and intraday markets |
| $p_{h\omega}$ | power delivered |
| $\alpha_{h\omega}$, $\beta_{h\omega}$ | binary variables active when positive and negative imbalances are higher than 30%, respectively (Belgium) |
| $\gamma_{h\omega}$ | binary variable active in case of positive imbalances |
| $X_{h\omega}$, $Y_{h\omega}$ | continuous variables necessary for the model linearization |

(for both consumption and production) to the TSO and the financial responsibility for the deviation from those schedules. The market participants, in this sense, are called Balance Responsible Parties (BRPs). However, the limited predictability of meteorological factors has significant implications for wind production forecasts and the ability to submit accurate schedules. Therefore, in some countries there are exceptions to these obligations.

The balancing service provision defines how different balancing services (i.e. ancillary services for frequency control) are bought, and how the producers are remunerated. The TSOs usually buy the balancing services in the balancing markets (which have capacity and energy components). The parties providing these services are called Balance Service Providers (BSPs). WPPs in some countries cannot participate directly in the balancing market, such as in the Netherlands or Belgium. However, passive participation in the provision of balancing services is possible by changing the energy generated in real time and react to real time information. This passive balancing is possible in a system with single imbalance pricing mechanism (Grande et al., 2008). In Denmark, wind power can participate directly in the balancing market (Sorknæs et al., 2013). Chaves-Avila and Hakvoort (2013) provide further discussion on the procurement designs of balancing services in Europe and on the possibilities for wind power to provide these services.

The third pillar of balancing arrangements deals with how the energy imbalances and the imbalance (IM) prices are determined, and thereby how the balancing costs are allocated to BRPs. BRPs are incentivized to send accurate schedules, because they pay the IM prices for imbalances (however, under certain imbalance pricing rules and price levels, BRPs might be incentivized to deviate from their schedules).

Balancing rules can affect other market regulations. For example, the European Commission (2013) has pointed out that the costs of market integration, such as balancing costs, need to be considered to compute the support schemes interactions with the electricity markets. Therefore, the economic impact of balancing costs needs to be considered for the well-designed support schemes.

The objectives of this paper are: first, to describe the impact of different balancing designs on the allocation of balance responsibility to wind power and the design of the imbalance pricing. Second, to explore the advantages and disadvantages of those designs related to incentives for market parties and efficient inclusion of wind power in the electricity system. Third, to develop a methodology that provides a quantitative assessment of different balancing designs and the economic implications for WPPs. Fourth, to apply the proposed methodology considering market data from different European countries (Belgium, Denmark, Germany and the Netherlands). These countries have been chosen because they apply different balancing rules to wind power. In addition, a significant increase of wind power is expected in these countries in the coming years and decades (in which offshore wind will have a large share). Finally, from the quantitative analysis and based on the literature review, we derive some policy recommendations related to the design of the balancing arrangements in relation to wind power.

This paper continues as follows: Section 2 describes the regulatory context for the allocation of balance responsibility and the imbalance pricing design in Belgium, Denmark, Germany and the Netherlands. Section 3 describes the methodology used and the data for the quantitative evaluation of the different balancing rules. Section 4 presents the model results. Finally, Section 5 provides the main conclusions and gives some policy recommendations.

## 2. Regulatory context

This section describes the last changes on the balancing rules applied in the four analyzed countries with respect to the allocation of balance responsibility to wind power and the imbalance pricing designs. Both regulations have been significantly modified during the last years in these countries, which reflects the importance of balancing rules for policy makers.

### 2.1. Balance responsibility

Among the European countries, there is no a uniform way to allocate balance responsibility to WPPs. Some countries give full responsibility to WPPs, as any other market party (i.e., the Netherlands, Sweden, and U.K.).