INTEGRATION OF WIND POWER IN THE ELECTRICITY MARKET: IMPACT OF THE RES-E SUPPORT MECHANISM

Lina RUIZ
Grenoble Electrical Engineering Laboratory (G2ELab) – France
Lina-Maria.Ruiz@g2elab.grenoble-inp.fr

ABSTRACT
Additional operating costs taken place due to the variability of wind power in comparison with conventional means of power generation. Forecast and market design play an important role when integrating wind power because they determine additional reserve capacity and any other imbalances. The objective of the work presented in this paper is to analyse the management of wind power variability in the operation of the balancing market.

INTRODUCTION
Energy independence, security of supply and the emission of greenhouse gases are the key factors in the development of renewable energy sources (RES-E). European Directive 2001/77/EC encourages the development of RES-E in Europe by imposing quantitative targets to be achieved in the power generation from renewable sources. Wind power is already the most advanced technology among the various energy resources, but in terms of installation capacity further development is still to be achieved in most of the European countries. The development of wind power raises two significant issues: wind projects are still not cost competitive compared to conventional power production and wind is intermittent. The first problem is being overcome by the support mechanism set up to stimulate the construction of wind parks. The second problem, however, is yet to be solved and requires extra efforts from system operators to ensure the balance and continuity of the service and the reliability of the system. These efforts will involve additional reserve capacities and immediate response, which will result in extra technical costs.

In this paper, we examine how support mechanisms can help improve efficiency in the management of wind intermittency in the balancing market. This is all the more important since the contribution of intermittent energy sources (wind first and then PV) is expected to increase if renewable energy is to play a significant role in the coming years.

Section 1 provides a description of how the support mechanisms operate in three European countries. Section 2 analyses the problem of wind intermittency in the balancing market management. Finally, in section 3, we compare the ways in which countries deal with wind intermittency in the balancing market.
**Premium Tariff: example of Spain**

The Premium tariff system applied in Spain is a variation of the guaranteed price mechanism whereby producers of electricity from renewable sources sell the electricity they generate on the wholesale market and receive an additional fixed bonus for their environmental contribution. The idea behind this mechanism is to gradually integrate renewable energy generators into the electricity market.

In the case of guaranteed feed-in tariffs producers are paid a fixed amount that is not linked to market price changes. With the premium mechanism the revenue of the producers is variable because it depends partly on the price of electricity on the market. It is the sum of the market price of electricity and the premium that represents a bonus for the green character of renewable electricity.

Because of variations of the spot market price, the revenue of the renewable producers is subject to important risks. In order to limit these variations, the Spanish government has introduced a cap and floor system that links the evolution of the premium to the spot market price and establishes minimum / maximum revenues for the periods of extreme prices.

**Renewables Obligation (RO): example of the United Kingdom**

Under a scheme of green certificates, the public authorities set quantitative objectives of renewable electricity production (quotas or RO) for electricity suppliers. These quotas are determined in accordance with energy policy goals. Thus in England, the initial goal under the Renewable Obligation was set at 3% in 2003, increased to 10.4 % for 2010 and 15% for 2015.

Renewable electricity producers receive green certificates for the electricity they generate according to a predetermined equivalence (e.g. 1 MWh = one certificate). These certificates can be sold along with the actual electricity produced (long term contracts) or on a special market independently from transactions on the electricity market. The ROC market fulfills the needs of producers who do not meet their renewable energy generation obligations. By purchasing green certificates to make up their assigned quota, they avoid paying penalties determined in relation to the shortfall.

Suppliers can meet renewable obligations by purchasing ROCs (Renewable Obligation Certificates) or by purchasing renewable electricity directly from renewable producers. They can also meet their obligation by paying the “buy-out” price (45€/MWh in 2002) for each MWh they fall short of their target.

As a consequence, the income of wind energy producers in the English RO system is determined by the price of electricity on the market, the income from sales of ROCs, the green premium (from the redistribution of funds obtained from “buy out” payments) and the Levy Exemption Certificate in cases where the consumer is eligible.[2]

In conclusion, the revenue of renewable energy producers obtained through the various mechanisms is linked to many factors, including a principal remuneration, which is a regulated fixed-price or the market price, premiums or bonuses and penalties. This complementary income is intended to act as an incentive to producers: to improve technology, to make investments less risky, to boost the development of RES-E and increase renewable energy integration in the electricity market. The table below summarises the sources of income of wind energy producers according to the tariff in place for each of RES-E mechanism.

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>Constituent of remuneration of wind producer</th>
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<tbody>
<tr>
<td>TGC</td>
<td>Price spot + Market Price(TGC) - Penalty + Incentive(Ancillary serv)</td>
</tr>
<tr>
<td>Premium Tariff</td>
<td>Price spot + Premium(TAE) - Penalty + Incentive(Ancillary serv.)</td>
</tr>
<tr>
<td>Feed-in tariff</td>
<td>Feed-in tariff - Penalty + Incentive + complement (Ancillary serv.)</td>
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Table 1. Components of remuneration of wind generators

**INTEGRATION OF WIND POWER IN THE ELECTRICITY MARKET**

**Wind power is intermittent**

The incentive mechanisms described above have to differing degrees proved their effectiveness in stimulating the development of renewable energy and wind power in particular. The contribution of wind power to the electricity mix has increased considerably, so that today the effects of its intermittency must be tackled. These effects differ according to the degree of variability and the time frame considered. In the short term, the main problems are frequency and voltage, which place constraints on the stability and reliability of the network. In the long –term, the problem of variability concerns the effect it will have on the capacities available to cover peak demand. [3] [4]

Consequently, the technical costs of integrating intermittent resources (wind power, PV) in power systems relate to two different issues the risk of non- availability in peak power load periods and the need for additional reserves to safeguard instantaneous balance between supply and demand [5] i.e. operating costs of power stations that provide reserve capacity.

Intermittency only causes real problems when penetration rates are above 10 or 20%. In fact, for penetration rates below 5%, imbalances are managed like fluctuations in demand by the transmission system operator. For penetration rates between 5 and 10%, additional costs are...
limited [5]. For penetration rates between 10 and 20%, a secondary reserve capacity representing 10% of intermittent capacity is sufficient for managing intermittency [6]. In the case of higher penetration levels, additional costs mean that, depending on the method of payment for imbalances, it is in the interests of wind power producers to diversify their sources both in terms of energy (hydraulic to compensate for intermittency) or strategy (several producers grouping together within a virtual power station to smooth their generation levels and reduce intermittency.

In the longer term, if no changes are made within the electricity system (expansion and reinforcement of national and interconnected grids, investment in primary and secondary reserves, improvement in storage techniques) wind power intermittency could have a more lasting impact on the system reliability.

Technical costs and the balancing market in the management of intermittency

Several studies show that an increase in the proportion of wind energy in a system results in significant technical costs. Depending on the penetration level of wind production, these costs are between 0 and 3€/MWh [7].

The Green-Net study [3] examines the results of several studies carried out in various countries in which the costs of short-term balancing are extremely different and are or are not allocated to wind producers. One can draw a first conclusion already: the extent of balancing requirements and thus their cost depends on the attribution of responsibilities when imbalances occur.

Even though the Transmission System Operator (TSO) is responsible for ensuring balancing mechanisms, penalties could be imposed in order to encourage wind farms operators to optimize their forecasts and minimize balancing markets needs. Thus, it is necessary to identify the responsibility of each actor in the case of imbalances. In certain situations, a new entity called the responsible balancing party settles imbalances for conventional and renewable energy producers and ensures a balance between energy fed into the system and energy used.

Balancing responsibilities in Germany

Balancing mechanisms (Regelleistung) in Germany are directly sourced by TSOs in a tendering procedure. This procedure concerns primary and secondary reserves and minute reserves. The balancing system is based on distributed responsibility for adjustment and takes care of parties responsible for balance (RBP). Imbalances are established 15 min before the moment of delivery and the prices of positive or negative adjustment are symmetrical: an exchange with a surplus of production receives the same amount that a RBP must pay because of its deficit. However, in balancing systems for wind producers in FIT systems (as in Germany where the costs of balancing are highest: 7€/MWh), the TSO is also responsible for managing wind production intermittency via the Balancing Group (BG) by smoothing the production profile. First, the TSO calculates the difference between the day-ahead wind production forecast and spot market requirements. It is then possible to settle the error for each hour in the intraday market or to determine needs and to activate reserves. These costs are ultimately included in the network’s “grid tariffs”.

Balancing responsibilities in Spain

In Spain, with the FIT option, imbalances are handled in much the same way as in Germany. On the other hand, with the premium option, the wind producer sells the electricity on the electricity market like any other producer. Consequently, the producer is responsible for managing its forecasts and the costs of any imbalances resulting from inaccurate forecasts. Errors in forecasting are penalized if there is a difference of ±5% depending on conditions in the market.

The problems of uncertainty in the prediction of Spanish wind production are overcome by incorporating various wind farms with the same production offer in the market (concept of virtual power station). Because of its intermittency, wind production must be taken into account in managing the balance between offers and bids. The creation of a control centre for renewable energies by the TSO has enabled the Spanish electricity authority to solve the problem of intermittency of wind capacities and also to increase these capacities.

Balancing responsibilities in the UK

In the balancing system of the UK, each supplier is encouraged to balance his position and a system-wide aggregation occurs separately, in the balancing market. A side effect of this is that suppliers tend to maintain their own spinning reserves, which is less efficient than if the system operator performs this function. The wind producer is affected by any imbalance caused in the system through a two-price system: 1) The producer will pay for any shortfall in the contracted generation at, the “System -Buy -Price” and 2) it will receive payment for the excess production at, the “System Sell Price” [2]. Simply speaking it has to pay a high price for missing kWh and it is badly paid for excess production.”.

Whether or not wind generators incur the full penalty depends on the nature of their contracts with suppliers. It is generally felt that large-scale aggregation by wind generators might be a solution to the problem however there are significant penalties that would be incurred.

IMPACT OF RES-E SUPPORT MECHANISM

At today’s wind penetration level, the costs of intermittency
are not a barrier to integrating wind power, but taking into consideration the objectives in Spain, i.e. 29.4% of renewable energies penetration into the grid and 20% in Germany and UK for 2020, these costs become an obstacle for the integration. This hindrance is due to the fact that most of this share will come from wind power. The strategies for handling intermittency in power grids are a key factor in guaranteeing supply and reliability of the system.

The energy cost allocation is done by two methods. In the first one, the costs are managed and supported by the system operator which affect the network’s operators. In the second one, the costs are managed by the system’s operator who then transfers it to the balance accountant. In this case the operator manages the adjustments but invoices the balance accountant for the interminnences.

In Germany, wind generators benefit from dispatch priority and do not have responsibilities for imbalances caused to the system. They do not have to pay balancing penalties that would decrease their revenue when forecast production is not achieved. This situation stimulates installation of new wind capacity, though on the other hand producers are not encouraged to improve forecasting accuracy.

In contrast, generators in the RO system in the UK or the premium system in Spain are responsible for inaccurate forecasts and risk paying balancing penalties. These penalties reduce their income but may encourage them to improve forecasts, which would facilitate the integration of wind power in the electricity system.

FIT systems limit the risks for wind power generators and are therefore more conducive to new capacity investment. On the other hand, it is the system operator that incurs additional costs because it is obliged to manage any imbalances. Wind power producers do not receive any economic signals that might encourage them to reduce imbalances.

In contrast, mechanisms such as tradable quotas that oblige producers to assume all or part of the costs of imbalances are an incentive to these producers to improve their forecasts (weather forecast models) or to reduce imbalances (mutualisation, virtual power stations). But such mechanisms have not yet proved to be as effective as FITs in stimulating the installation of new generating capacity.

Premium systems could perhaps be a solution that combines the good points of these two systems. They have the advantages of the FIT mechanism but by imposing penalties for imbalances they encourage producers to give greater priority to this essential issue and facilitate the development of electricity system configurations in which wind power will play a greater role.

**CONCLUSION**

Climate and energy independence policies promoted in the European Directives have led to the integration of a growing proportion of renewable energy sources, and particularly intermittent sources, into electrical power systems. Intermittent production results in additional costs related to the management of reserves and imbalances. Additional balancing costs are particularly substantial in certain European countries and will continue to increase as more and more intermittent power sources are integrated into the system.

The question that arises is whether renewable energy support policies can have a positive impact on management of imbalances. Certain mechanisms (premiums in Spain for example) which oblige producers to pay the additional costs seem to act as incentives to reduce imbalances.

Whether through improved forecasting, mutualisation, or other methods (storage), it is important that producers of electricity from intermittent sources tackle this problem. They must therefore receive appropriate price signals so as to ultimately enable massive integration of renewable energy into electricity systems.

**REFERENCES**


