WILMAR - Wind Power Integration in Liberalised Electricity Markets
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WP9 RECOMMENDATIONS

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Summary: During the work in the WILMAR project recommendations have been identified on how the electricity markets should be organised to enable a cost-effective integration of wind power in large liberalised electricity systems. The main recommendations concern reducing imbalances caused by wind power by bidding closer to delivery hour and aggregating wind power production as well as changing rules for imbalance settlement to make the imbalance charges better reflect the system imbalance costs actually incurred. Also recommendations on improving the use of transmission capacity, making sure that enough regulating power is bid in the markets and enhancing flexible demand and storage participation in markets are suggested.

1. Introduction: System integration of wind power

Work Package 9 of the EU project WILMAR (http://www.wilmar.risoe.dk/) is dedicated to the identification and formulation of recommendations from the project.

The starting point is the technical system operation and how wind power will affect this. The power system and the electricity markets should be designed for various power generation units, including wind power. Ideally, the payments for wind power in the markets should reflect any technical costs but not penalise the variable production beyond its contribution to increases in the system costs. It is important here to note that system costs do not only origin from wind power. Also other sources, such as large thermal power plants, have system costs since they need reserves for outages and transmission lines. In the ideal system all sources pay their share of the system costs.

In most markets there is a day-ahead spot market, an intra-day market or hour-ahead market and a real time or regulation power market. We may say that the spot market provides the energy price. The intra-day market price and the real time price reflect the system's capability to balance generation and load. It should be observed that in many real time markets the imbalance price charged from market participants includes a penalty. This penalty is a financial incentive to carefully execute appropriate load and generation forecasts to balance schedules. Also system operators need to cover the expenses of balance settlement procedure. This means that one can not always draw conclusions concerning penalty costs, since they do not always reflect true system costs.

Wind power will replace other production forms and this will lead to reduction of CO_2 emissions and reduction of operating costs of thermal power plants (avoided costs). Wind power forecast errors will result in intra-day re-scheduling and increased use of regulation capacity. For higher penetration levels of wind power, increase is foreseen in the transmission between regions/countries and the amount of regulation capacity allocated and used. The extra costs due to this will depend on how much flexibility there is in the power system, including transmission capability to neighbouring systems, to absorb the variability of wind power. Integration of wind power means that the special characteristics of wind power production are taken into account in power system operation. This means that the scheduling of other power plants takes into account the wind power that will be fed in the system, with its uncertainty. The imbalance treatment and transmission allocation should be done in a way that will enable wind power to act in the markets without penalising the variable production more than its share of actual costs incurred for the system.

2. Integration measures

As the share of wind power production in given electricity system increases, more and more flexibility will be required to absorb the fluctuations in the wind power production. This can be done by dispatchable production units and consumption, or by increasing transmission or energy storages in the system. Integration measures encompass:

- Increased transmission and larger control areas.
- Introduction of more flexible production units with high part load efficiencies and low minimum production levels e.g. hydropower plants.

- Flexible loads e.g. cooling or heating buildings. Some types of loads can provide frequency activated reserves, other types can provide minute reserves or make price flexible bids on the day-ahead markets on the power pools.
- Relieving the bound between heat and power production in combined heat and power (CHP) plants by the introduction of heat storages, heat pumps or electrical heat boilers.
- Electricity storages e.g. pumped hydro or compressed air storage (CAES).

Market operation will lead to use of flexibility of other production forms, like CHP, through lower prices when large share of consumption is produced by wind power and other production needs to be reduced. The bidding rules on the power pools are important for market driven introduction of more flexibility in the power system. For example, integration measures that work by shifting load or production between hours cannot be submitted in a general way on the Elspot market of Nord Pool today. A cooling building can reduce consumption in some hours but then need to increase consumption in the following hours to restore temperature levels. Such a consumer should be able to submit a bid offering to consume a given amount of consumption within a given time period, where the consumption is flexible in that it can be situated in the hours with the lowest power prices within the time period while respecting a maximum hourly consumption level.

Electricity used for heating in electric boilers and large heat pumps should be taxed in a way that reflects the environmental benefits in replacing fossil fuel based heat production with electrical heating in situations with surplus electricity. The tax levels on electrical heating in some countries today is hindering the use of a potential integration measure, used in situations with large wind power production during low load.

The development and introduction of cost effective, low loss electricity storage would be beneficial for the power system. The electricity storage could provide back-up production capacity in low wind/high load periods and absorb power in high wind/low load periods, and could provide flexibility to the power system as a whole.

Wilmar model results have shown that increased interconnection allows increasing the share of wind power in the power system. For cost allocation, deep grid connection charges where wind power producer pays also grid reinforcement costs are in principle better in providing locational signals on where wind power should be installed. However, grid reinforcements deep behind the point of connection have multiple benefits in cases where the new lines are used by others as well. Consequently the costs of such grid extensions cannot be attributed solely to one source. A location-dependent component of grid connection charges should therefore be applied with care and should not be fixed once for ever, but revised regularly according to a transparent mechanism.

Recommendations:

- Network reinforcements and building of new transmission capacity in areas with excellent wind conditions would be necessary solutions in order to get wind power to the market. Increased transmission capacity also helps overall functioning of electricity markets and increases the possibility to use cost efficient balancing resources. See also sections 3 and 4.
- Bidding rules on the power pools should be developed to fit in integration measures that work by shifting load or production between hours. See also section 4.

- Taxation levels on electricity used for heat production in electric boilers and large heat pumps should make electrical heating a competitive option in situations with surplus electricity i.e. low power prices.
- New investment in production forms with flexibility should be encouraged in the power system.
- Supporting research and development of large-scale electricity storage.

3. Use of transmission capacity

Liberalisation of electricity markets have led to increased use of transmission capacity as a result of increased demand for power exchange between countries and regions. Large scale wind power production will further increase the demand for transmission capacity. One reason for this is that good wind resources are located far from the main load centres in many cases. Transmission capacity is also needed to handle the natural variations in wind power generation and to accommodate the need for reserves and necessary balancing power. Larger geographical spreading of wind power will result in considerable smoothing effects: less variable, more predictable production with fewer situations with near zero or peak production.

A main challenge in transmission operation, in addition to the requirement for new transmission lines, is to ensure that the existing transmission capacity is used to full extent. The operating limits on transmission capacity are determined by the system operators (TSOs) based on operating security standards. The security standards applied by most TSOs are based on the deterministic N-1 criterion,. The N-1 criterion has generally resulted in acceptable security levels, but in the simplest form does not ensure maximal use of transmission capacity. In particular this may be the case with large scale wind power integration. For determination of transmission capacity for the hourly (Elspot) market, wind power and other important operating conditions are not known in detail 48 hours before delivery. The uncertainty may result in conservative limits. In order to increase utilisation of the available transmission capacity, the transfer limits should be determined more often with the most recent updates on wind power forecasts. With increasing amounts of wind power and short term variations it is important to look for also alternative security criteria with a probabilistic approach.

Recommendations:

- Increase efforts to develop TSO control centre tools to determine operating transmission limits in the day-ahead market and for on-line use. These tools should include wind power forecasts and be combined with real time information and system monitoring. This would increase the operational (market) limits closer to real security limits when facing larger amounts of wind power.
- Develop methods and applications for both planning and operation of transmission capacity that are based on probabilistic security criteria as alternatives to the deterministic N-1 criterion.
- Continue to develop and implement system protection schemes in conjunction with wind farms to enable increased transmission limits and improved security of operation.

4. Demand for and provision of regulating power

Demand for regulating power will increase as the forecast errors of wind power production start affecting the system net imbalances. The forecast error of wind power production is considerable when forecasting day ahead, and with hour-to-hour precision. For wind power, as is the case for loads, there is significant benefit in combining individual units from larger areas instead of forecasting for single wind farms. For wind power there is also significant benefit when forecasting to shorter time horizons, for example couple of hours ahead compared to day ahead.

Reducing the demand for regulating power caused by wind power can be achieved by reducing forecast horizon. This means allowing bidding as close to delivery hour as possible, i.e. changing the day-ahead markets in place at Nord Pool and EEX to hour-ahead markets. An example of this is the Betta market introduced in UK. A more continuous market operation can bring about more cost for especially smaller actors, and some thermal capacity can have difficulties in operating for shorter time scales than the start-up times. An alternative to changing the bidding horizon of the day-ahead markets can be to introduce an intra-day market being cleared close to the actual delivery hour giving the wind power producers a chance of retrading the wind power production as more accurate wind power forecasts arrive. An example of such a market is the Elbas market on Nord Pool.

Extension of the interconnected area is an important way of reducing the demand of regulating power, both for the overall system and for wind power. Whenever there is no capacity problems between TSO areas, schedules on the interconnections should be flexible. If all quality parameters are perfect the TSOs should not always automatically regulate inside their areas due to high or low area control error. This error should instead be traded off by the TSOs involved. This rule is introduced within Nordel but not in most other European markets.

When introducing large amounts of wind power to the market, it is also important to make the provision of regulating power as efficient as possible. It is important to ensure that all power producers make their regulation capabilities available for the intra-day and regulating power markets. Even base load plants such as nuclear power plants could technically reduce their power production level some, providing significant regulating capacity during critical hours. Also flexible loads and storage could provide balancing.

Recommendations:

- Allow bidding as close to delivery hour as possible, or ensure a well functioning intra-day market being cleared close to the actual delivery. This gives wind power producers a chance of trading their production with more accurate forecasts reducing imbalances.
- Ensure that all power producers make their regulation capabilities available for the intra-day and regulating power markets.
- Continue to develop market based solutions that enable demand (flexible loads) to participate in the balancing market.

5. Rules for imbalance settlement

Imbalance settlement rules are crucial for the introduction of wind power in the markets. The system costs for imbalances are the regulation reserves used during the operating hour. This is according to the system net imbalance. System operators have to treat all the sources of system imbalance with equal principles and have to also recover the incurred balancing cost by those who have caused the imbalance. For the individual producers and consumers, most of their imbalances will be cancelled out by each other. This is the benefit of operating a large interconnected power system. However, when charging for imbalances, often all the individual imbalances will be penalised. When wind power is charged for the balancing costs it imposes on the system, a basic requirement must be that the costs in the balancing mechanism reflect the real costs, not penalties.

An example of existing imbalance settlement rules that gives wind power producers easier access to markets is the Norwegian case using one-price model. There system operator calculates the price of balancing energy based on the cost of needed regulation in power system during operating hour in question. Power producers receive this balancing energy price for any quantity they supply in excess of the schedule and have to pay this balancing energy price for any missing quantity compared to the schedule. During the hours when their imbalance has been to the same direction as system imbalance, they end up paying more like in two-price model. However, when wind power imbalances are to the opposite direction than the system net imbalance, they receive extra money compared to the spot price. In the one-price model the payments by wind power also reflect the increase in the actual costs of the system caused by wind power. When wind penetration increases wind power is causing more of the imbalances. Hence the correlation between system imbalance and wind power imbalance will raise and the effective balancing cost paid by the wind power producer will also increase. Drawback with one-price model is that income from balance energy does not guarantee recovering cost incurred by regulation and balance settlement process. System operator could introduce additional fees for market players, for example by adding a fixed fee to the balancing energy. Another example is California, where imbalance for wind power is calculated from a longer time horizon (month instead of hour). This is efficient only when the wind power penetration is small so as not to affect the total system imbalance significantly.

Recommendations:

- Ensure that the imbalance settlement rules for producers and consumers lead to imbalance costs being equal to realised system regulation costs, such that wind power producers are not penalised more than the actual costs incurred by the wind power prediction errors.
- Applying a one-price model based on actual real-time balancing costs would give producers benefit for the hours when their imbalance has decreased the system net imbalance and this benefit would counterbalance the penalising charges for the hours when their imbalance has been partly causing the imbalance cost for the system.
- If a two-price model is used, it should be ensured that the imbalance costs paid correspond to the actual expenses of the TSO incurred on the regulating power market. Only a part of each individual imbalance should be charged so that the total corresponds to the net imbalance that has occurred. Also wind power production should be aggregated to reduce the overall forecast error/imbalance. Wind power pools or large distributed wind power together with larger portfolios with loads and other production forms would reduce imbalance costs for an individual producer.