Wind Power Requires Flexible Market and Subsidy Design

By Orvika Rosnes*

Wind power – the preferred renewable energy source in many countries – may be challenging to accommodate in existing power systems due to its unique characteristics. How easy it is to integrate wind power in an efficient way depends on the flexibility of the rest of the power system. Technology mix and size of the power system, the possibility for trade and flexibility of demand play a role in flexibility. However, market design and regulation can contribute substantially to increase the flexibility of a given power system by conveying correct price signals. Moreover, subsidy schemes to wind power are important for flexibility.

Wind power represents a variable – or intermittent – energy source: it is only possible to produce wind power when the wind is blowing. Thus, the available wind power production in a given hour may vary substantially during the day and is often significantly lower than the nominal installed capacity. The variation in wind power production must be immediately accommodated by other producers in order to maintain the system balance.

Conventional coal-fired and natural gas-fired thermal power plants are relatively inflexible in the short term due to the costs related to starting the plant. In the presence of start-up costs, production does not necessarily occur according to merit order. Instead, a thermal power plant will occasionally produce, even when the electricity price falls below the operational marginal cost, in order to avoid a shutdown; similarly, it might choose not to start production, even when the price exceeds the operational marginal cost (Rosnes, 2008).

Due to low marginal production costs and the possibility to adjust production easily and without cost within the limits of the available wind, one would expect wind power to be produced up to those limits at all times. However, from the system point of view, it would sometimes be cheaper to keep a thermal power plant running in order to avoid the shutdown and reduce wind power production instead.

Market Design Should Enhance Flexibility

Therefore, market design should promote efficient dispatch by incorporating the shadow price of a start-up in the market price. This can be done through negative power price. As the thermal power producers would be willing to carry a short-term loss in order to avoid shutdown (that implies a start-up later), negative price signals the shadow price of a start-up to other producers.

A wind power producer has no reason to carry on producing with negative prices. Wind power producers are perfectly flexible within the limits of the available capacity: they can stop and start costlessly when the price exceeds marginal cost.

Negative prices have been introduced at several European power pools: European Energy Exchange (EEX) introduced negative prices in September 2008 and the Nordic power pool, Nord Pool, in October 2009 (at day-ahead market).

Wind power has priority of dispatch, i.e., assured access to the grid (EC, 2001). This means that whenever wind power is available, it must be accommodated by the grid companies; wind power production can be curtailed only if it endangers the system security. Originally, this rule was meant to promote development of renewables by providing security to investors. However, this also means that the dispatch is not necessarily optimal: when wind power production is high compared to demand, thermal power plants must be turned off, implying a start-up later. An efficient dispatch would often imply that wind power production is reduced instead. This typically happens during low demand periods (nights and week-ends), but not necessarily. As more wind power capacity is developed, situations when wind power can meet a large share of demand alone become more frequent.

Subsidies Should not Blur Market Signals

Wind power, as many other renewable energy sources, is not profitable without subsidies. There are a variety of subsidies used to support wind power: feed-in tariffs (either as a guaranteed price or a guaranteed mark-up on market price), tradable green certificates, investment subsidies. It is somewhat paradoxical that production subsidies have been the most common support mechanism to wind power, even though it is the high investment costs that prevent expansion of renewable capacity.

Even though the principal goal of the support is to promote investments, the subsidy schemes also influence the short-term production decisions once the investment is carried out: the wind power producer may often produce in order to

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collect the subsidy, even if the market price is below the producer's marginal costs.

Rosnes (2007) studies the short-term effects of different subsidies to wind power and quantifies the costs of integrating wind power in Denmark. Given its predominantly fossil-fuelled capacity, but with an ambitious goal of boosting wind power to meet 50% of electricity demand by 2025, Denmark provides a highly relevant case for the analysis of the role of flexibility. Rosnes (2007) uses a short-term model, with hourly time steps and one week as time horizon.[1]

The results of the numerical model indicate that total production costs are higher with feed-in tariffs than with investment subsidies. With inelastic demand, wind power replaces thermal production. In the sample week, thermal production is reduced 9% with fixed feed-in tariff, compared to optimal dispatch. However, this reduction does not imply lower costs, on the contrary: thermal production costs (fuel costs and CO_2 costs) are 12% higher. In other words, the same total production level is achieved with considerably higher costs. The reason for that is that wind power produces at the maximum available level (to collect the fixed feed-in tariff) and does not take into account market prices or the impact on other producers. When demand is low, the thermal power plants are forced to stop in order to maintain balance in the market.

Figures 1 and 2 show thermal and wind power production with different subsidies to wind power throughout the sample week. With investment subsidy (that does not influence the short-term production decision), wind power producers take into account the shadow prices of the start-ups in thermal power plants, signalled through the market prices. When wind power is optimally scheduled (from the system point of view), it is sometimes profitable to reduce wind power production in order to avoid the shutdown of a thermal unit. When the production subsidy is designed as a mark-up on market price, the market signals are distorted, but still visible.

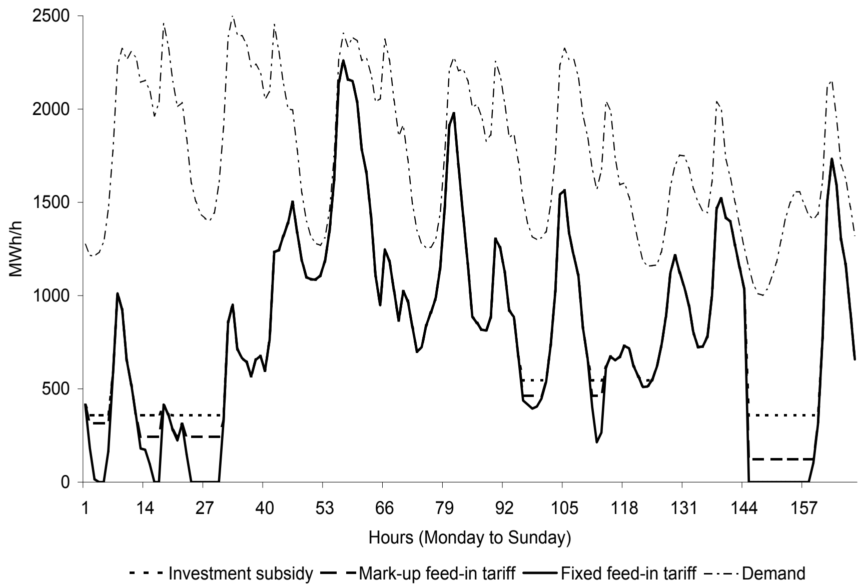

Figure 1. Thermal power production with different subsidies to wind power throughout the sample week

Sensitivity analyses confirm the effects found in the base case, but the effects depend on the wind power capacity. Typically, the additional costs increase with increasing wind power capacity. Clearly, it is easier to accommodate wind power when wind power capacity is small relative to demand. As long as wind power can be accommodated without starting and stopping thermal power plants, only adjusting the production level, the additional costs are relatively low. The model results indicate that the incentives to adjust wind power even slightly would pay off: a small reduction in wind power often saves considerable costs.

It is also worth noting that increasing wind power capacity does not translate into an equal increase in wind power availability. Since the market must be in balance at all times, wind power production must be reduced if it exceeds demand and all thermal plants are already turned off. As wind power capacity increases, situations where wind power production exceeds demand become increasingly frequent. Thus, some of the capacity increase is 'in vain'. Therefore, an increase in wind power capacity by one kWh does not replace one kWh of thermal power – the increase in 'useful' wind power capacity is lower than the nominal increase. In the modelled week, doubling of wind power capacity increases maximum available wind power production by only 50%, compared to the base case.

Price Signals are Important for Investments in Renewables and Grid

Wind power is envisaged to be an important source of renewable energy in many countries (COM, 2011). Large-scale development of wind power requires additional investments in network. The wind parks are often situated in uninhabited areas and new transmission lines must be built in order to get power to the demand centres. This additional investment cost must be borne by consumers.

If market prices are based on the principle of nodal pricing, they convey signals of the profitability of investments in different locations. Hence, market prices are important not only for short-term production decisions, but also long-term investment decisions. Regulation and grid tariffs may complement these price signals. Even though wind resources must be utilized where they are, not all of them will be developed. Which ones will be developed and in which order is important for efficiency.

It may well be that the wind power investment would be more profitable if the wind parks were more sparsely located; then less transmission investments were necessary. It may also be that the investment in transmission is profitable ex post (once the wind park is built); however, the transmission investment would have been unnecessary (or another line would have been more profitable) if the wind park was located somewhere else.

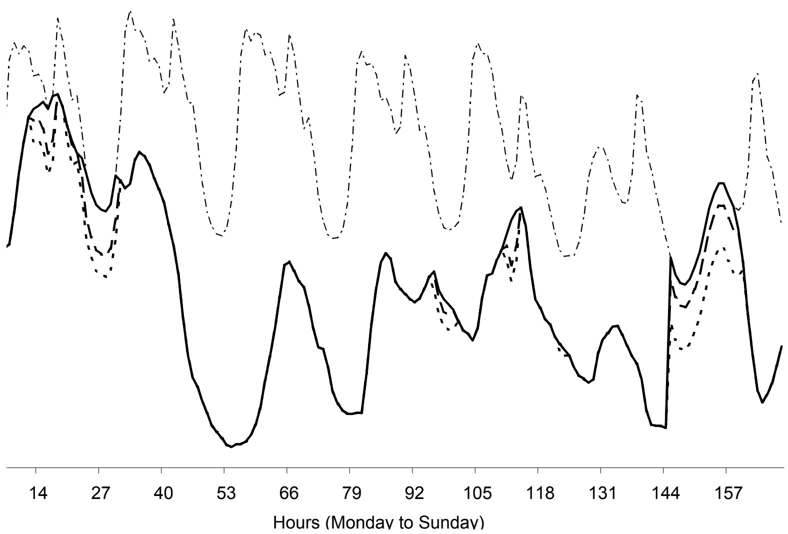

Figure 2. Wind power production with different subsidies throughout the sample week

Concluding Remarks

Flexibility of the power market is important for how costly it is to accommodate wind power in an existing power system. While technology mix is largely given, market rules and subsidy design play an important role for flexibility of the power market. An ill-designed subsidy scheme for wind power (i.e., one that conceals market signals and reduces the responsiveness to market prices), combined with an inflexible system, may amplify the adverse effects of wind power and contribute to excessive cost of emission reductions.

Nonetheless, if wind power or other intermittent power source is the preferred technology in the inflexible system, it is important to promote flexibility. Flexibility can be achieved by technical measures or economic incentives. Measures to increase flexibility may involve increasing the demand response (either technically, by investing in two-way-communication, or economically, by exposing consumers to actual market prices) or on the supply side (investing in more flexible plants or increasing trade possibilities with other regions). A larger system would increase flexibility per se, because it is easier to adjust production in active power plants without shutting down plants in a larger system. Further, trade with a more flexible system that can easily adjust the production level (like hydropower) is even more beneficial. In the longer term, electric vehicles could play an important role as storage capacity. However, these measures to increase flexibility require further investments that add to costs, in addition to the subsidies to wind power.

A market design that conveys correct price signals and an economically sound subsidy design that does not distort the production decision of wind power and promotes flexibility in wind power production may be the cheapest way of integrating wind power.

Footnote

[1] Hence, it differs from and complements the traditional economic models of power markets where time horizon is considerably longer (typically one year with only a few seasons and load periods).

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