CAPACITY CREDITS FOR WIND ENERGY IN DEREGULATED UTILITIES ELECTRICITY MARKETS – LIMITATIONS AND EXTENSIONS

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ABSTRACT: The assessment of capacity credits for wind energy and the value interpretation is reviewed critically. It is shown that the electricity market values the contribution to system reliability with market prices in a more precise way. This requires that markets for ancillary services exist and are based on price spike incentives given by the regulator. Price signals sent out by markets to investors and customers enable the electricity system to adjust more effectively to the challenge of high wind power penetration in the near future. Additional incentives can be provided within certificate support schemes that supports both customers' desire for green energy as well as the correlation of electricity demand and supply.
Keywords: Capacity Credits - 1; Reliability - 2; Ancillary Services - 3

1 INTRODUCTION

Studies of wind energy capacity credits have been carried out since the late 1970s. In the light of deregulated electricity markets both their interpretation and possible new applications need to be examined.

In the following chapter, the traditional concept of determination and interpretation of capacity credit is reviewed and criticised briefly. Chapter three introduces the market view with special attention to ways of dealing with reliability issues in deregulated markets which are of special importance for wind energy. In the final chapter, some ideas for a market design are presented that might foster the adaptation of the electricity supply system to integrate more sustainable energy sources such as wind energy.

2 THE TRADITIONAL CONCEPT OF CAPACITY CREDIT

2.1 Calculation of capacity credits

The value of wind energy has traditionally been assessed by a comparison of wind power output characteristics to those of conventional power plants [1-3]. This reflects the cost-based planning paradigm of the regulated electricity market.

The standard of measure of the comparison is the availability of both plant types. Forced outage rates of conventional plants and wind availability captured by the probability distributions of wind speed are aggregated to a cumulative availability function using reliability models. An acceptable loss of load probability determines the maximum load. On this basis capacity credit is calculated as an "equivalent capacity" of wind generators to conventional generators with respect to reliability.

As available wind energy varies over time, capacity credit changes as well. Therefore the capacity credit in time of peak demand is generally used for further interpretation Consequently, a high correlation between wind energy production and electricity demand would result in a high capacity credit assigned to wind generators.

2.2 Interpretation

Capacity credits are generally interpreted in two ways. Firstly, from a planning perspective, capacity credit should indicate the replaceable conventional capacity in order to set targets for energy policy. Secondly, capacity credit is interpreted as a component of the economic value of wind energy: The capacity credit is multiplied with the capacity cost of avoided or replaced conventional generators (assuming that replacement or extension is necessary). The other component is the cost of fuel from generating units on the margin displaced by wind energy [1-2]. The value of reduced emissions is an additional component but external costs or benefits will not be considered in this paper.

2.3 Limitations

As mentioned before, the actual determination of capacity credit depends on the parameters of power plants of a given supply area and the demand characteristics. In deregulated markets, it becomes more and more difficult to justify the assumption of a closed supply area. Long term forward contracts, futures contracts with physical delivery as well as day-ahead trade on a power lead to a frequent change of generation capacity which had to be used for reliability calculations and the determination of the time of peak load or minimum surplus capacity. What is more, load management programs with interruptible loads which are likely to be applied more widely can also shift the time of system peak load. On top of these ambiguities, the stochastic characteristic of wind energy availability makes it even more difficult to determine the peak load time.

Further limitations of the capacity credit concept refer to the value interpretation. The approach to compare different types of generators with respect to one feature (availability) and draw conclusions from this comparison to all other features (e.g. value) is not feasible. As with any value, value of generation capacity is now determined by the market forces supply and demand but not by (avoided) cost. In liberalised markets, electricity is traded but not capacity (the reserve market can be an exception – see chapter 3.2). From an economic point of view, capacity represents only an option to produce energy at the price of the variable cost. The value of the option depends on the price development of the "underlying" good, which is a certain electricity product traded at power exchanges. Consequently, value interpretations of capacity credits have to make assumptions about system expansion or generator replacement to justify the choice of the reference technology. The choice of plant technology depends on many factors such as individual expectations of the development of market prices of electricity and fuel, which, in turn, depend on technology development, im- and export transmission capacity, market power, financial economic and environmental legislation and so forth. It becomes obvious, that any judgement of the value of wind energy on this basis is very fragile.

The second component of the value interpretation, the avoided variable (fuel) cost, can also be challenged by market considerations. The price on the electricity market is determined by the marginal cost of the last dispatched unit which is different from the avoided cost of a replaced or additional generator. The price changes hourly with demand fluctuations and bids of generators. If a generator is physically replaced by a certain amount of wind generators, the impact on the merit order in the spot market has to be examined as described below.

Furthermore, wind generators can not sell ancillary services such as AGC, spinning reserve or installed reserve. Participation in these markets might increase generator profitability by 10 to 50 % [4].

3 MARKET PERSPECTIVE

3.1 Principles

As mentioned before, in deregulated electricity markets, market prices for energy determine the value of capacity. The dispatch of the available capacity follows contracts made in competitive spot and forward markets. Although it is expected that only 20 % of energy traded in the market will be traded at Power Exchanges (PX), the liquidity and transparency of these marketplaces lead to prices which can be used as reference prices for the whole market.

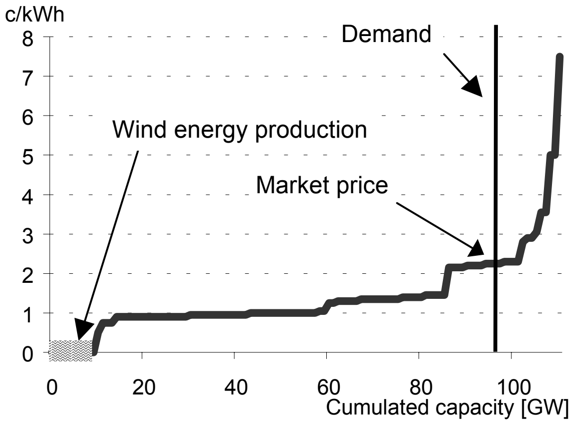

Figure 1: Determination of the market price of wind energy

Figure 1 shows the fixing of the market price for wind energy in the market where all generators bid their marginal cost and an assumed price inelastic total demand curve. Prices are fixed for every single hour of the day ahead and follow the demand and supply situation. Wind energy bids are integrated in the market according to the wind forecast. Since wind energy has a variable cost of zero, it is always “in the market” and receives the respective market price. Thus, a high correlation of wind energy production and demand results in high peak prices paid to wind generators. Here it becomes obvious again that prices are below variable cost of all displaced conventional generators since the marginal cost of the last dispatched generator determines the spot-market price.

3.2 System reliability

Reliability issues are crucial when it comes to integration of wind energy. Therefore, this section discusses how reliability is ensured in deregulated markets.

Even if capacity investment, dispatch and pricing are determined by market forces, system reliability can not be provided without regulation. Since every participant is affected by a system blackout caused by unexpected mismatches between supply and demand, system reliability can be considered to be a public good to be provided by an Independent System Operator (ISO). The cost for reliability (supply of reserves) has to be carried by all market participants. In economic theory, the marginal benefit of increased reliability has to be made equal to the incremental cost of supplying reserve [5]. In practice marginal benefit can not easily be determined and is surely varying among market participants. Therefore, a reliability standard is defined and incentives to keep excess capacity to provide installed and operating reserves at this defined level have to be given by the ISO. The concrete regulatory regime is mostly specified on national or state level and varies widely so only basic principles can be presented here.

An ISO can ensure that market forces lead to the optimal reserve level in basically two different ways [6]. The first, and more common way is to define a capacity requirement, share it among participants, and penalise whoever falls short of that requirement. The second way is to make the ISO to pay a lot more for energy if remaining capacity falls below a certain level and thus causing a price spike. Both systems ensure that excess capacity is not rewarded when it is worthless (which means that it is abundant in times of total excess capacity), but investments are encouraged when they are necessary for system reliability: At the “correct” level of total installed capacity, peaking units on the margin of the merit order will be able to recover their fixed costs from the incentives given by the ISO either directly through peak prices or through a capacity price that will establish on a market of reserve capacity close to the penalty value.

For wind generators, the peak price solution is more attractive since they can make use of price peaks but would have to give up revenue from electricity sales to offer a share of the capacity (e.g. the capacity credit) in the reserves market.

3.3 Ancillary services and wind power prediction

No generally accepted definition of Ancillary Services (AS) exists but most of the reserve requirement discussed above is treated within this framework. The total reserve requirement, arranged in the order of response time includes primary reserve (Automatic Generation Control - AGC) and operating reserves (spinning and supplemental). Some ISOs also count the energy imbalance service (traded one or two hours ahead of delivery) as ancillary service. Markets for these services do exist or are about to be established. The general market design options discussed before can be applied to draw a more precise picture of the marketplace and the impact for wind energy (aspects of voltage control and power quality will be omitted though).

A recently conducted study [7] for the case of Germany showed, that wind power plants have no significant impact on the demand for AGC. When it comes to operating reserves the situation changes: Wind power plants require operating reserve and in case of Germany plants that provide additional secondary reserve needs to be added if wind power penetration was very high.

The need for supplemental and balancing service depends mainly on the accuracy of prediction and is therefore extremely relevant for wind power. Therefore demand forecasting errors and the imperfect day-ahead prediction of wind energy output influence prices on markets for balance energy and ancillary services where wind generators would have to participate. On the balance energy market, prices can be higher or lower than spot-market prices depending on the direction of the deviation from predicted amount. If wind predictions were too pessimistic and produced electricity was abundant, prices on the balance market are lower than spot market prices which results in a loss of revenue. If predictions were too optimistic and wind energy falls short of sold capacity, energy has to be purchased from the balance market at any price to meet the contract obligations which means a loss as well. Consequently, the market gives incentives for further development and application of wind forecasting systems.

Load following is also sometimes counted as ancillary service. It is defined as the use of generation equipment to track expected changes in loads within a time range of several minutes up to an hour. Load following is ensured by keeping flexible generation equipment online. It is clear that wind generators would have to purchase this service to reflect their load ramp rates [8-9]. This would encourage widespread wind development leading to declining ramp rates.

In the AGC market capacity charges need to be used since the supplied energy is hardly measurable. In all other markets the price spike system can be applied: Energy sold in the spinning reserve or balancing market is sold for market prices. Only if capacity in the respective market becomes scarce, regulator must intervene and rise prices to give an incentive that more capacity in the specific reserve market segment is made available. This can for instance simply be done by turning a shut down gas turbine into the spinning mode which means that capacity is transferred from the balance to the spinning reserve market.

3.4 Interpretation

In the electricity market where wind energy will be traded in the near future, the value of capacity credit is "assigned" by the market by valuing the contribution to system reliability with market prices: The regulatory regime should be designed in a way that price peaks give incentives for investments. This principle applies not only to the day-ahead energy market but also to ancillary services markets where reserves have to be provided with the appropriate reaction time. A high penetration of wind power in the electricity system will lead to price peaks on energy and ancillary services markets. They, in turn, provide incentives for the use of interruptible loads and will also increase the profitability of different electricity storage systems which make use of price differences. Hence, market forces lead to an adaptation of the system, which is frequently demanded by integrated system studies [10].

Intelligent networks with interconnected decentralised systems that provide the different services will be established and be able run automatically to allow the use of a greater variety of supply and demand options such as electric vehicles and flexible combined heat and power systems [10-11].

3.5 Practical application of market prices

The fact that in most cases wind generators are not able to be competitive in the marketplace and therefore different support schemes are applied has blocked the view on the market value of wind energy in the past.

In countries where Renewable Energy Feed In Tariffs (REFIT) are applied (e.g. Spain, Germany or, until 1999 Denmark) but markets are deregulated, utilities or Transport System Operators (TSO) would have to calculate shadow prices for wind energy. In certificate systems market prices for wind energy will be established as a part of the support scheme [13]. A valuation of wind capacity in an electricity market by spot market prices is already in practice in Scandinavia where both PXs exist for a long time and wind penetration is high. In these countries, both day-ahead and balance market are used to trade wind energy [14]. Both in Germany and in Scandinavia operating reserve requirements do not exceed existing capacity at least for the next five years and operating reserve markets do not exist, but price signals should be given to adjust the generation system in the long term [7, 12]

4 A VISIONARY PERSPECTIVE: WIND POWER AND THE GREEN MARKET

Besides certificate support schemes for wind energy which are likely to be established more commonly in the near future, "green electricity" is defined and sold to customers who have a willingness to pay an extra contribution to foster the adaptation of the electricity system towards the use of more sustainable sources. In this framework, any additional demand for certificates caused by "green customers" provides extra income for renewable energy generators.

4.1 Reintroducing the capacity credit

A further modification of the certificate support scheme can be introduced to cope with the articulated desire of certain "green" customers for real time supply with renewable energy sources. Real time supply is one of many criteria which some labels for green electricity apply.

In this scenario, different capacity credits of generators in certain climatic zones (e.g. offshore, coast, inland) can be calculated an used as a tool to ensure the correlation of demand and peak production: In this case the certificates are valued with the capacity credit.

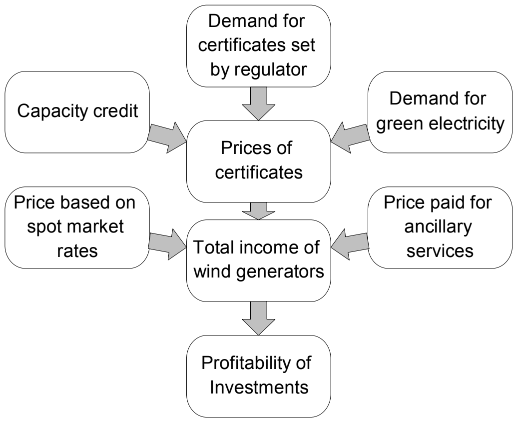

Figure 2: Elements of income of wind generators in a modified certificate support scheme

As Figure 2 shows, the total income of wind generators would consist of three basic elements: The spot-market price, the cost of ancillary services and the income from selling the certificates. The certificate price, in turn, is also set by a market. Firstly the regulator demands a certain quantity according to the political goal of wind energy expansion. Secondly, green customers purchase an extra amount. And finally the capacity credit component ensures, that wind generation plants with an output matching the load profile can issue more certificates. The consequences of this pricing scheme are additional incentives to adjust renewable electricity production to the load curve of demand and vice versa.

5 SUMMARY AND CONCLUSION

When politicians set high targets for the expansion of renewable energies and especially wind energy, aspects of technical integration and market design become more important. The just recently deregulated marketplace for energy values wind energy according to the rules of supply and demand. Thus, value interpretations of capacity credit and avoided fuel cost are not valid any longer.

Although in most markets reserve capacity in its various needed forms is available and able to cope with high wind power penetration, market mechanisms have to ensure that reserve allocation (including ancillary services) as well as demand management and investment in storage is encouraged efficiently. The price spike system for reserve markets was reviewed briefly and is appropriate to send the right price signals to market participants.

To accelerate the system adaptation, additional incentives can be given by green customers and regulators.

NOTE

This paper represents a summary of first results of a research project that examines the impact of certain market designs for electricity from renewable sources on day-ahead and ancillary market prices [15]. Questions and comments are very welcome.

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