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The looming impact of higher shares of renewables on electricity market prices

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Abstract

In several European countries with Germany leading a remarkable increase in capacities and corresponding electricity generation from wind and photovoltaic power plants took place in recent years. The core objective of this paper is to investigate the possible effects of such a further uptake of renewables on the European electricity markets. The major effects of these developments on the electricity markets will be: (i) a much higher price volatility from hour-to-hour and day-to-day; (ii) increasing relevance of intra-day markets; (iii) higher costs and prices for fossil capacities (due to higher shares of investment depreciation costs); (iv) increasing relevance of storages and "smart" grids, (vi) higher market shares for balancing markets; (vii) continuously increasing complexity of managing supply, storages and demand over time.

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1. Introduction

The current energy supply is mainly relying on fossil fuels. Alternative energy carriers (AEC) – based on renewables, CO_2 -poor or CO_2 -free sources of energy - are of central importance for the transition towards a sustainable energy system and economy. One of the major reasons for a forced introduction of AEC is that they are expected to reduce GHG emissions significantly.

For a long time generating electricity from renewable energy sources (RES) has been considered as environmentally benign technologies with a huge potential yet very high costs for electricity generation ([1], [2], [3]). In recent years due to comprehensive support programmes in several countries and a significant drop in system costs – e.g of PV systems—with Germany leading – a remarkable increase in capacities and corresponding electricity generation from "new" RES took place, see Fig. 7. These increase in RES capacities had in recent years since 2009 on some days significant impacts on the spot market prices at the German electricity exchange EEX, see Fig. 9.



Figure 1. Development of "New RES-E capacities" in Europe in recent years

In the next years in Europe at least a continuous further growth of PV capacities can be expected. In Germany only it is expected that total installed PV capacity will increase from about 20 GW (installed by the end of 2011) to at least 50 GW by 2020. This is half of total fossil and nuclear capacity in Germany in 2011.

Recently, these increasing shares of RES-E – especially wind and PV – have especially in Germany and the affiliated part of the European electricity market led to several calls for new political interferences. Among these the most important are: (i) Calls for the implementation of capacity markets to ensure supply security; (ii) unjustified high subsidies which squeeze these RES-E capacities in the system without any market incentives; (iii) they further lead to high cost burdens for electricity customers (households but also industry); (iv) calls for new market structures because due to the high share of RES-E which are not subject to market

conditions but to government interventions, e.g. due to FIT; (v) High expected additional costs for grid extension and storages which are necessary to compensate for the higher volatility of the RES-E due to their higher shares. These will even further increase the burden for customers.

The core objective of this paper is to investigate the possible effects of such a further uptake of RES-E on the prices in European electricity markets. Because Western Europe is currently already influenced by this effect we explain the likely consequences for the example of the EUR-4 electricity market (Austria, Germany, France, Switzerland).

Three major effects of how larger shares of volatile renewables impact electricity market prices are examined:

(i) the direct impact of renewables at specific times of the year when renewables shift the supply curve of conventional electricity virtually out of the market leading to temporarily very low market prices close to Zero; (ii) the indirect impact of volatile renewables on the costs at which fossil mainly natural gas capacities are offered; (iii) change of spreads between high and low price levels.

2. The changes after the liberalization of the electricity markets

In former regulated electricity markets prices came about by setting a tariff which was calculated by dividing the total costs of a utility by the total amount of electricity sold (with some differences between different groups of customers). The major change that took place after the liberalization of the electricity markets especially in Europe was that prices now were expected to reflect the marginal costs of electricity generation, see e.g. Haas [14]. Figure 2 depicts the basic opportunities: If excess capacities exist, prices will reflect short-term marginal costs (STMC,) if no excess capacities exist but if a market with perfect foresight exists prices will reflect long-term marginal costs (LTMC). And if short-term shortages in capacities are looming prices will be set strategically¹.

¹ Strategic prices might also occur due to market power. However, this issue is not a focus of this paper



Figure 2. Basic possibilities for the price formation in liberalized electricity market

The price developments in different European electricity sub-markets from 2000-2011 is shown in Fig. 3. We can see a high volatility and considerable differences between different sub-markets. How does this price pattern come about?



Figure 3. Price developments in different European electricity markets 2000-2012

Figure 4 shows a typical merit order supply curve for a specific point-of-time with conventional capacities (incl. large hydro).



Figure 4. Typical short-term merit order supply curve for a specific point-of-time with conventional capacities (incl. large run-of-river hydro)

Figure 5 shows how prices come about in markets with conventional capacities (incl. large hydro): intersection of supply curve with demand gives electricity price at the short term system marginal costs The change in this pattern due to considering wind in addition is described in Fig. 6.



Figure 5. How prices come about in markets with conventional capacities (incl. large hydro): intersection of supply and demand gives electricity price at the short term system marginal costs



Figure 6. Merit order supply curve with additional wind capacities (incl. large hydro) at off-peak time

3. The direct impact of PV on the electricity market price

That RES have an impact on electricity prices (or in former regulated markets at least at the conceived marginal costs of electricity generation) is already known since volatile hydro power was used for electricity generation. Later in the time of starting wind booms (about 2007 to 2009, in Denmark already earlier) there was experience with temporarily high wind in the systems and sometimes even negative prices (see also [18], [19]). However, these effects due to wind happened mostly at off-peak times (at some times also due to wrong or careless wind forecasts).

What makes PV now specifically different? Figure 7 depicts an example from Germany for the impact of PV capacities on the price developments in the German electricity market on 22nd October 2011. As Fig. 7 depicts on sunny days PV- electricity generation follows the daily load profile and on these days it substitutes virtually completely the former production of hydro storages. In addition it changes the increase of prices at noon to a decrease. We can see that around noon – when prices historically were typically high –prices dropped.

Figure 8 shows the merit order supply curve with additional wind and PV capacities (incl. large hydro) at on-peak time of a nice summer day with short term marginal costs for conventional capacities.



Figure 7. Example for the impact of PV capacities on the price developments in the German electricity market on 22nd October 2011



Figure 8. Merit order supply curve with and without additional PV capacities at on-peak time of a bright summer day with short term marginal costs for conventional capacities

4. Effect of temporarily higher shares of renewables on the pricing of fossil capacities

In a market with larger shares of RES the role of gas capacities will change see e.g. Auer ([6], Pantos [10], Hasoni/Hosseini [11], Carraretto [16]). Aside from the above described direct effect volatile renewables also have an indirect impact on prices in spot markets for electricity. Volatile renewables will influence the costs at which fossil – especially natural gas – capacities are offered. In Fig. 5 the supply curve is still based on the short-term marginal costs of conventional capacities only. Usually for natural gas this corresponds to about 6000 full-load

hours per year. Yet, for every plant fixed costs have to be recovered in addition to the variable costs, Fig. 9. This Figure depicts the total and variable (short term) electricity generation costs of a new combined-cycled gas turbine (CCGT) depending on yearly full-load hours. As can be seen the share of fix costs is considerably higher when fullload hours are low (e.g. 1000 h/yr)2 than when full-load hours are high (e.g. 6000 h/yr).

In the past different types of fossil plants over a year – even over a day – made it possible to recover fixed costs when more expensive plants set the price. In the market that prevailed in recent years frequently old depreciated coal power plants with low efficiency and low remaining fixed costs determined the STMC. There was more room for covering the fixed costs of new CCGT than in a future system where this might not apply. Moreover, as Fig. 9 shows at 6000 hours/year operation time the fixed costs to be recovered are rather low compared to the variable costs.

This pattern is likely to change, because in markets with large shares of volatile renewables mainly highly flexible CCGT plants will survive, see e.g. Auer [6] or Carraretto [16]. But what will happen, if the full-load hours per year drop to 1000-2000 hours/year? Of course, in this case other pricing strategies (or the implementation of capacity markets) becomes relevant. Pricing with long term marginal costs (incl. the capacity costs) or even short-term strategic costs will become much more important than today. How this aspect will impact market structures and whether there is a need for changing market structures will be discussed in section 6.



Figure 9. Total and variable (short term) electricity generation costs of a CCGT depending on yearly fulload hours

How these new pricing strategies might affect the future pricing of fossil (or biomass) power plants is shown in Fig. 10. This Figure depicts the merit order supply curve and high and low demand curve at times with low volatile renewables' availability. Three examples for supply

² Of course, these fullload hours will also vary year-by-year. They will be lower a year with higher hydro power than on average and vice versa.

curves are included in this Figure: merit order supply curves for STMC vs LTMC of CCGT plants and a supply curve for strategic bidding (vertical line).



Figure 10. Merit order supply curve with additional wind capacities at off-peak time with total costs or strategic bidding for conventional capacities

5. Changes in price spreads

Of further relevance in this context is how price structures will change, mainly what will be the future "spread". In recent years the "price spread" – the difference between the off-peak and the on-peak price for electricity – has decreased. Of core interest is how these price spreads will change in the future when larger amounts of PV and wind electricity enter the market. The consequence for electricity prices in a dynamic picture is shown in Fig. 11. It depicts exemplary the development of renewables from wind, PV and run-of-river hydro plants over a week in summer on an hourly base (based on synthetic data over an average year in Germany) in comparison to demand and resulting electricity market prices with total costs charged for conventional capacities. One can see that in this example tremendous volatilities in electricity prices – black solid line – ranging from zero to 14 cents/kWh are expected within very short-term time intervals. Of course, in practice the prices will not be Zero (but rather low) and not meet the exact LTMC but will rather be set strategically. Note, that the number 14 cents/kWh results from Fig. 9 with fullload hours of about 1000 h/yr.

If larger shares of renewables will temporarily be fed into the grid the price spread will increase. The reason is that at some times the prices will be close to Zero and at other time – when renewables are scarce – prices will be much higher due to strategic pricing of fossile capacities. These two effects on prices are depicted in Fig. 10 (solid black line). But as already mentioned, in future high prices will not necessarily appear at peak-demand times but at times with low renewables availability. The low price level will be associated with high renewables production. Among other effects this will also change the handling of hydro storages. These



will in future not work mainly in the night-to-day-shift rhythm but in the context of availability or scarcity of renewables.

Figure 11. Development of volatile renewables from wind, PV and run-of-river hydro plants over a week in summer on an hourly base in comparison to demand and resulting electricity market prices with total costs charged for conventional capacities

The following remark is also important. For the price effect it does not make a difference whether PV electricity is fed into the grid or directly used by the customer. As the total demand profile over a day will not change (except some possible minor shifts due to individual customer behaviour) the price effects described in Fig. 11 will be in principle the same.

6. Future challenges

The above described developments and effects lead to further reflections and requests that may accompany the further uptake of PV. The most important are (see also Auer (6), Nielsen et al (8), Pantos (9), Wen (11), Lund (12), Lund (13)):

1. <u>From a rigid one-way supply system to a "breathing" system:</u>

The major change must be a paradigm change in our understanding of the whole electricity system – from generation over "smart" grids to electricity-based services finally provided. This major change in thinking is to switch from a unflexible rigid static one-way system to an overall "breathing" system, which allows bi-directional flows, technical flexibility in the system, incl. DSM, load management from utilities and storages which also contribute to "breathing".

2. Are there needs for capacity markets?

The discussion of the economics of remaining fossile power plants – see Fig. 7 and Fig. 8 – leads to the question whether there is a need for so-called electricity markets. The major argument of the apologets of this idea is that only if a fixed "stand-by fee" is paid for these

mainly fossil plants, operators/owners of these plants will be retained from closing down these plants.

However, in practice it is only necessary to get rid of one simplified and anachronistic argument of the initial theoretical requests of liberalised markets: That prices must equal short-term marginal costs.

3. <u>New market structures:</u>

With respect to time-dependent market structures different new patterns will emerge. Regarding the role of Hedging and future contracts an argument raised recently is that in markets with high shares of RES no hedging is possible and future markets will break down. We think that actually the opposite will be true: With hedging and tradable long-term contracts these instruments will take over to a large extent the role of capacity markets. E.g long-term contracts (LTC) traded years ahead on an annual basis will serve to reserve (and ensure) LT capacity. The closer the delivery date comes the more fine-tuned will b the capacity reservation due to purchasing LTC. E.g. if good hydro power conditions are observed less capacity will be hedged than vice versa.

On the other hand there is a growing relevance of short-term markets like intraday- and secondary energy markets. In this context it is likely from our perspective that also "longer" term markets for secondary energy will emerge.

7. Conclusions

The major effects of these developments on the electricity markets will be: (i) a much higher price volatility from hour-to-hour and day-to-day; (ii) increasing relevance of intra-day markets; (iii) higher costs and prices for fossil capacities (due to higher shares of investment depreciation costs); (iv) increasing relevance of storages and "smart" grids, (v) higher incentives for PV owners in households for own use of electricity; (vi) balancing markets will gain higher market shares, which will be filled in by hydro and gas; (vii) finally the complexity of managing supply, storages and demand will increase continuously over time. (viii) Regarding the final electricity price for customers the share of costs for auxiliary services will increase remarkably compared to the pure energy production costs.

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