HOW PHOTOVOLTAICS WILL CHANGE ELECTRICITY MARKETS WORLD-WIDE FUNDAMENTALLY

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Overview

For a long time Photovoltaic (PV) systems have been seen as a mature and environmentally benign technology with a huge potential for electricity generation yet very high costs. In recent years due to the drop of costs of PV systems in several countries – with Germany leading – a remarkable increase in capacities took place. Already, the impact of large amounts of PV generation is being felt on the spot market prices at the German electricity exchange, EEX, as shown in Figure 1.

Germany plays a significant role in this context due to the large size of its economy and the political decision to phase out its nuclear fleet by 2022, mostly to be replaced by renewable generation. The impact of the German "Energiewende" or turnaround, plus similar developments in other EU countries is likely to fundamentally change the electricity supply system in Europe.

The growth of renewables, especially PVs, is expected to become even more pronounced in the next years up to 2020. In Germany alone, total installed PV capacity is projected to increase from about 20 GW installed by the end of 2011 to at least 50 GW by 2020. This is roughly half of total fossil and nuclear capacity in Germany in 2011. Moreover, grid-parity and even Bill-parity (incl. feed-in of excess electricity) is looming in Europe and other countries (see Fig.2 for Germany, small systems).

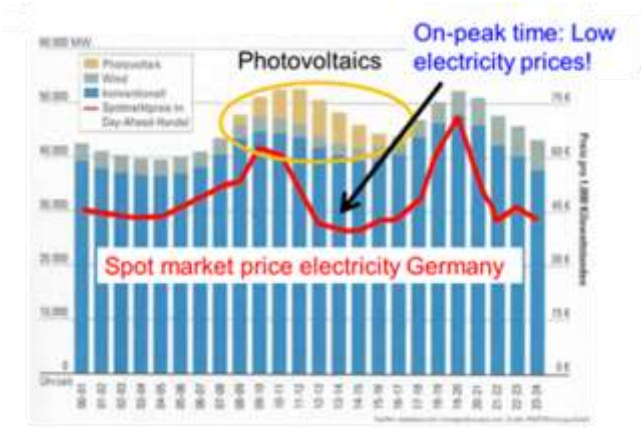

Fig. 1. Example for the impact of PV capacities on the daily price development in the German electricity market

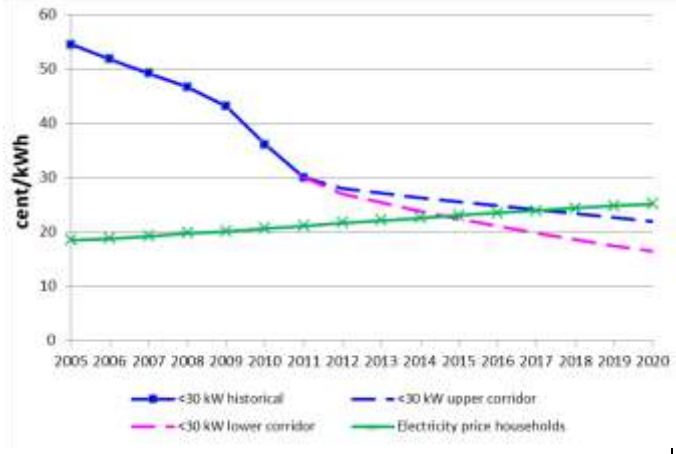

Fig. 2. Looming Grid-Parity and Bill-Parity in Germany

The core objective of this paper is to investigate the possible effects of a further uptake of PV on the prices in an electricity market. Because Western Europe is currently already influenced by this effect we explain the likely consequences for the example of thismarket[1]. We analyse two major effects: (i) the direct impact of PV at specific times of the year when PV shifts the supply curve of conventional electricity virtually out of the marketleading to temporarily very low market prices close to Zero; (ii) the indirect impact of PV (and wind) on the costs at which fossil and natural gas capacities are offered;

Methods

The method of approach applied in this work is based on a fundamental approach where the intersection of supply and demand at every point-of-time gives the corresponding market price. Specific emphasis is put on the difference between short-term and long-term marginal costs.

Results

The major results of our analysis are:

With respect to the development of the price spreads in electricity due to larger amounts of PV generation the consequence for electricity prices is shown in Fig. 4 where a hypothetical scenario with high levels of generation from wind and Ü V over a week in summer are depicted using synthetic hourly data for an average year in Germany. The graph shows significant volatilities in electricity market prices with total costs charged for conventional capacities – black solid line – ranging from zero to 14

[1] Despite this analysis is conducted for a European sub-market the perceptions and conclusions of this analysis can be used in many countries world-wide.

cents/kWhwithin very short-term time intervals. In practice, of course, the prices may not go to zero but would be rather low.

A more important development may be that future high prices will not necessarily appear at peak-demand times but at times of low renewables availability. This will also change the operation of pumped hydro facilities and lead to new investment in energy storage technologies to take advantage of significant price differentials. Over time, the familiar patterns of the night-to-day-shift of generation will change in response to the unpredictable and variable rhythm of renewable generation. The most likely consequence of increased price volatility will be to make storage and flexible peaking units much more valuable than they currently are.

Aside from the above-described effects, intermittent renewables will also influence the costs at which fossil generation – especially natural gas – are offered. The left hand-side part of the illustration in Fig. 3shows the short-term marginal costs of conventional generation, which may correspond to some 6,000 full-load hours per year. The revenues derived from these hours must cover both the fixed and variable costs, as illustrated in Fig.3. The graph schematically shows the total and variable (short term) electricity generation costs of a new combined-cycled gas turbine (CCGT) based on its annual full-load generation hours. As can be seen, the share of fixed costs is considerably higher when the plant operates at full load for a minimal number of hours, say, 1,000 h/yr[2] as opposed to a high number of hours, say 6,000 h/yr.

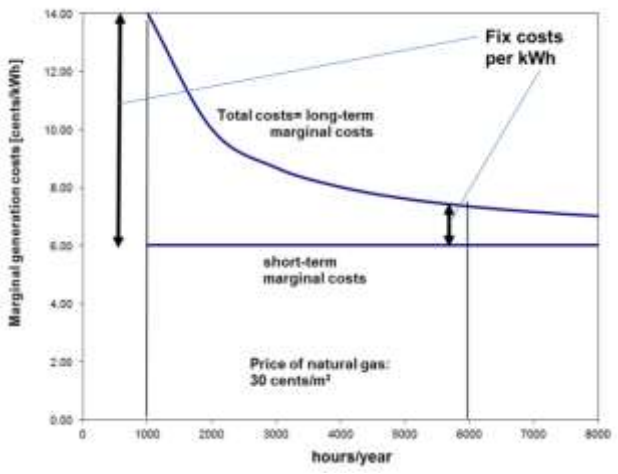

Fig. 3. Short term (variable) and long term (total) marginal costs of electricity generation in a CCGT plant depending on yearly full-load hours

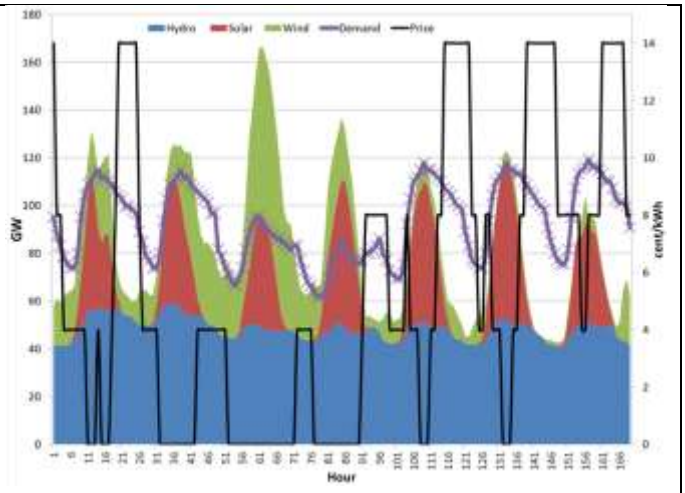

Fig. 4. Development of intermittent renewables from wind, PV and run-of-river hydro plants by hour over a summer week in comparison to demand and electricity market prices resulting from total costs charged for conventional capacities

Conclusions

The major conclusion of this chapter is that the electricity market and the electricity supply system of the future will look quite different than today while many of the fundamentals will remain. By and large, most of the effects of renewables are already known, what is new is that the variability of their generation will further increase if much higher quantities of wind and PV are fed into the grid, as appear to be the case for the EU.

The effects of these developments on the prices in electricity markets will be:

- Much more price volatility from hour-to-hour and day-to-day;
- Increasing relevance of intra-day markets;
- Higher prices for fossil capacities and storage technologies for balancing the intermittent renewable generation; and
- Growth of balancing markets and intensified competition at the level of decentralized balancing organizations.
- 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) reduced load factors of thermal power plants increasing their LCOE, being detrimental to high investment cost conventional technologies like coal and nuclear; (iv) higher costs and prices for fossil capacities (due to higher shares of investment depreciation costs if no capacity markets are implemented); (v) increasing relevance and complexity of balancing supply, storages, "smart" grids and demand response; (vi) higher incentives for PV owners in households for own use of electricity; (vii) balancing markets will gain higher market shares, which will be filled in by hydro and gas; (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.

References

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[2]Of course, full-load hours vary year-by-year depending on demand, hydro power and other factors.