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The looming revolution: How photovoltaics will change electricity markets in Europe fundamentally

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ABSTRACT

The increase in PV (photovoltaic) capacities in Germany had since 2011 on some days already significant impacts on spot market prices at the German electricity exchange. The core objective of this paper is to investigate the possible effects of a further uptake of PV on the prices in electricity markets. We analyze 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 market, leading to temporarily very low market prices close to Zero; (ii) the indirect impact of PV (and wind) on the costs at which fossil capacities are offered at times when renewable energy sources are scarce. 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) higher prices for electricity from fossil capacities and storage technologies for balancing the intermittent renewable generation; and (iii) growth of balancing markets and intensified competition at the level of decentralized balancing organizations.

1. Introduction

For a long time PV (photovoltaic) systems have been seen as a mature and environmentally benign technology with a huge potential [1] for electricity generation yet at very high costs [2–6]. In recent years a remarkable increase in capacities took place in various countries, yet among all countries with significant PV installations Germany showed the most continuous evolution. The major reason was the drop of costs of PV systems with Germany leading, see Fig. 1. By the end of 2012 Germany exceeded the 30 GW threshold, Fig. 1, and also in the next years at least a continuous further growth of PV capacities in Germany is expected. The minimum up to 2020 from a set of different scenarios (Quaschnig, [7]) is 50 GW. This is about half of total fossil and nuclear capacity in Germany in 2011. Moreover, the looming grid-parity – costs of PV lower than the household electricity price – will further emphasize this trend because PV will become economically more attractive.

The core objective of this paper is to investigate the possible effects of such a further uptake of PV on the prices in an electricity market. Because Germany is currently already influenced by this effect we explain the likely consequences for the example of this market.[1] We analyze 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 market leading 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 at times when RES (renewable energy sources) are scarce.

2. How prices in electricity markets come about

To investigate how PV will influence the prices in electricity markets it is first important to explain the current market structure and the market rules. Most important is to understand how prices in European electricity markets currently come about. The price formation is currently mainly based on a fundamental approach where the intersection of a merit order supply curve and demand at every point-of-time gives the corresponding market price.

Such a typical merit order supply curve for a specific point-of-time with conventional capacities is depicted in Fig. 2. This typical historical pattern of electricity generation in the Western European electricity market consisted since decades of conventional fossil, nuclear and large hydro capacities. As shown in Fig. 3, the intersection of the supply curve with demand determines the market clearing price at the short-term marginal costs of the system.

This fundamental approach of price formation has led to quite different price developments in different European electricity submarkets from 2000 to 2012, see Fig. 4. In this period a high volatility and considerable differences of electricity spot market prices

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

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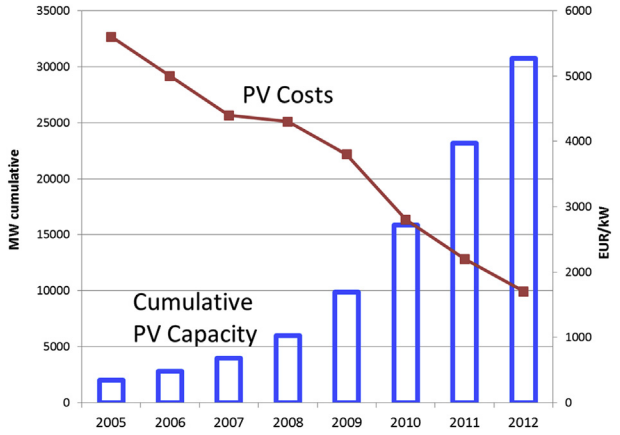

Fig. 1. Development of cumulated PV capacities and system prices in Germany in recent years. (Sources: [10–12], http://www.renewablesinternational.net/2012-record-year-for-pv-in-germany/150/510/60257/, Figures 2012 preliminary).

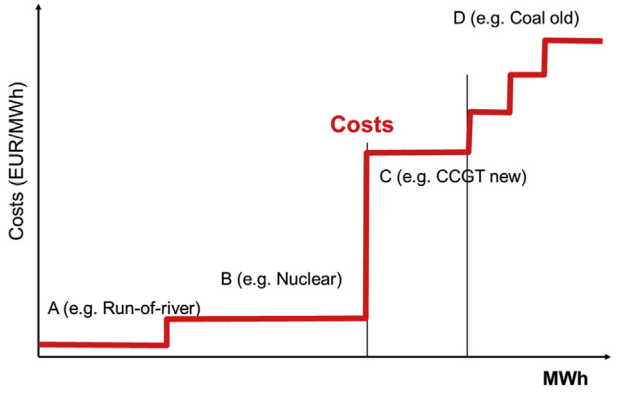

Fig. 2. Typical conventional merit order supply curve based on short-term marginal costs for a specific point-of-time with conventional capacities (incl. large run-of-river hydro). (Source: own illustration).

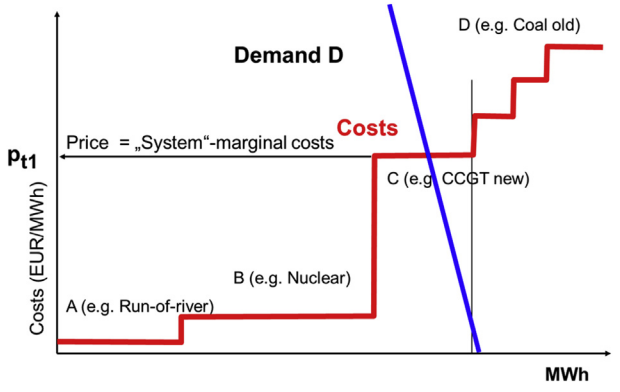

Fig. 3. How prices come about in markets with conventional capacities (incl. large hydro): intersection of supply curve with demand gives electricity price at the short term system marginal costs. (Source: own illustration).

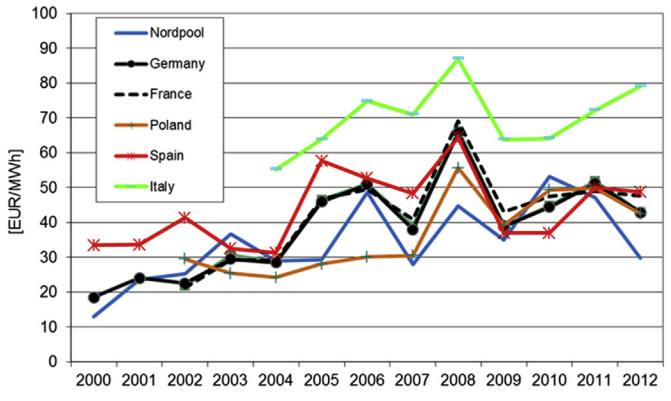

Fig. 4. Price developments in different European electricity markets 2000–2012. (Source: Homepages of different energy exchanges, Figures for 2012 preliminary).

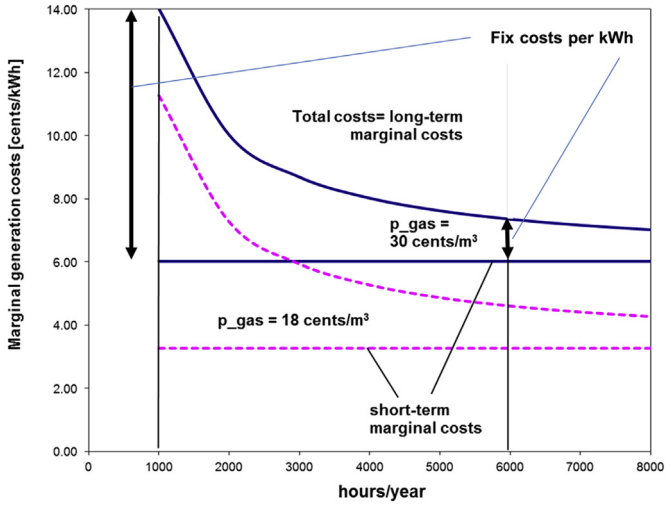

Fig. 5. Total and variable (short term) electricity generation costs of a CCGT depending on yearly full load hours. (Source: own illustration).

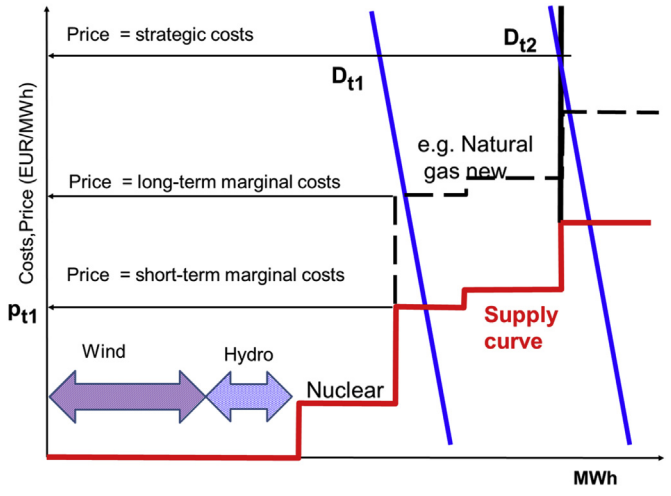

Fig. 6. Merit order supply curve with additional wind capacities (incl. run-of-river hydro) at off-peak time with total costs or strategic bidding for conventional capacities. (Source: own illustration).