Renewable Energy Price Indicator

Analysis of the Effect of Variable Renewable Energy Generation on Power Prices

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Introduction

In 2009 the EU adopted the renewable promotion directive, in which the commission agreed on a target of 20% renewables share in the whole EU energy mix, with 20% CO2 reduction and 20% increase in Energy efficiency. The deadline for these goals is set to the year 2020 compared to the levels in 1990 (1).

The EU set a suitable target for each member state considering its condition, but they let the local governments to choose their own pathways to get to their goals.

Then again the EU updated the targets to 27% share of renewable energy in total consumption and 40% cut in the GHG emissions by the year 2030 (2).

These actions aim to help the EU achieve secure and competitive energy systems and they are big steps in the way to full decarbonization.

Renewable energy resources (RES) in general are two categories:

- Dispatchable; where the power produced can be predicted controlled and utilized at the requested time such as biomass, concentrated solar with storage, geothermal power and hydro power plants)
- Non-Dispatchable; Where the energy generation is intermittent and tend to be variable according to the weather, those kinds of sources are called Variable Renewable Energy sources (VRE). The two main VRE sources are wind and solar energy as well as ocean and tidal power (3).

Wind and solar energy resources are intermittent, hard to control their output, and they are location dependent. These characters make their integration in the power grid a challenging task for the Transmission system operators (TSO's) (4).

This paper is going to assess the integration of VRE in the power systems of five selected EU member states, using market price indicator.

The selection of study group will be made according to their special power system characteristics, such as:

- VRE penetration in the energy mix.
- Percentage of solar to wind in the VRE portion.
- VRE ratio to the total installed capacity.
- VRE capacity compared to the peak load.

The paper will first describe briefly the background of the power markets and their structure, with an illustration of the reviewed literature on the effects of VRE on the power markets.

Then the method of analysis will be explained, results will be drawn and discussed.

Literature Review

Price reduction by the introduction of renewable energy in any system is widely argued to cause reduction in prices; because renewable power plants would bid their generated volumes in the power market at zero prices (zero marginal cost) (5).

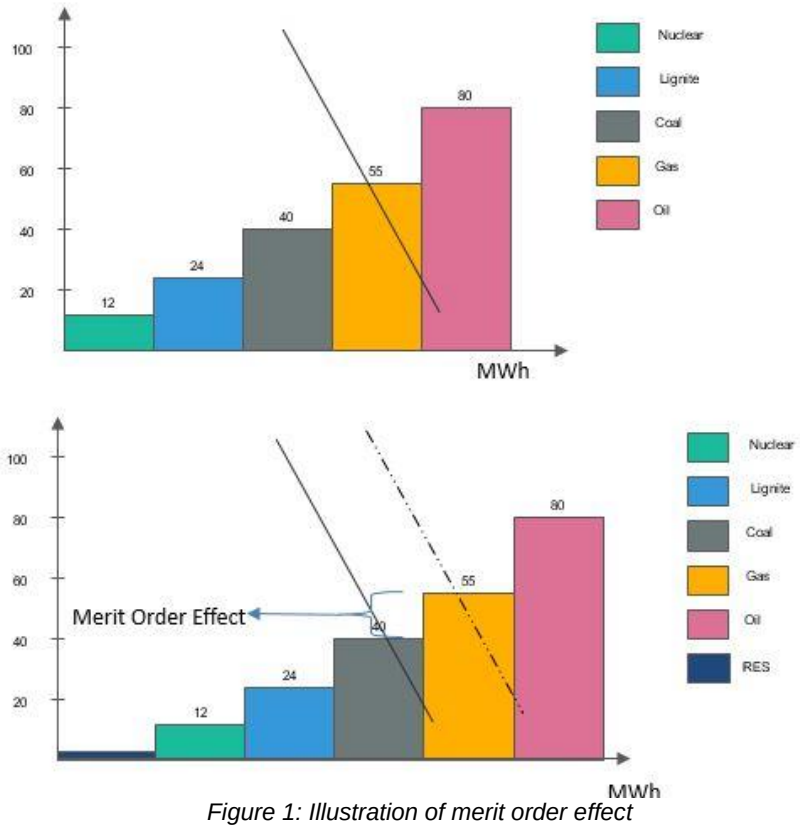

Figure 1: Illustration of merit order effect

The explanation of the immediate, yet temporary, low prices is explained by the merit order effect of the renewables as they appear first in the supply and demand figures which pushes higher prices power plants further right and then the intersection is at lower prices as illustrated by figure (1).

Power Markets

Power markets are the organizational side of the power system, were the trading of power and transactions of prices happens. The power market organizes and manages the connections between suppliers and customers, it ensure the transparency and efficiency of the bidding and bid awarding processes (6).

The power markets in Europe were subject to a wide liberalization process since the end of last century, a process of unbundling and enhancing transparency, thus a typical European power market will consist of:

- Bilateral electricity trading OTC (Over The counter)
- Day-Ahead power market (Spot Market)
- Intraday Market.
- Regulating power market (Balancing and ancillary service).

In the bilateral trading market, power volumes and prices are privately discussed and agreed upon between the two parties, however the other three power markets are publically disclosed bidding process and with complete transparency (7).

Spot market is where bidding is done for the fulfilment in the next day (next 24 hours), bidding goes for hour basis or block of hours. (8)

Intraday market is a supplement of the spot market where bidding happens and fulfilment is immediate, while the Balancing and ancillary service market is between the TSO (transmission system Operator) to ensure the security of supply at any moment, so TSO buys negative and positive reserves for in the process (9).

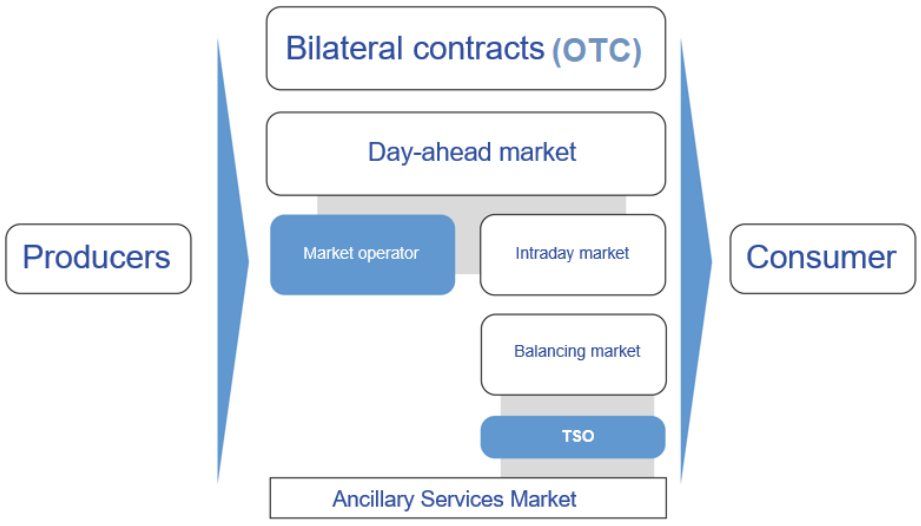

Figure 2: Power Market Structure

The main corner stone in any power market is the balance of supply and demand, electricity demand is expected to change at any point in time and it depends highly on users' behavior and the weather status (need for heating in winter and cooling in summer).

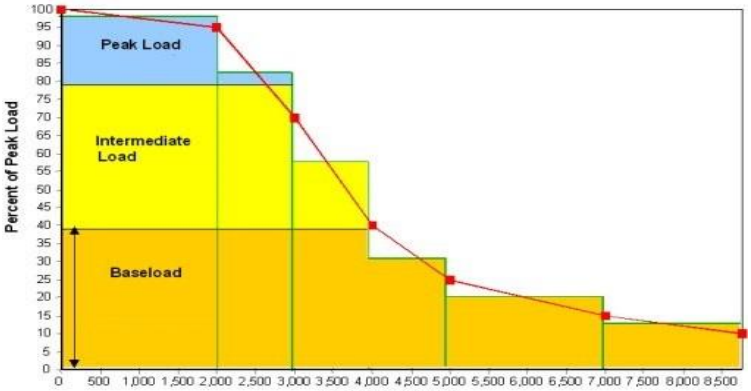

Figure 3: Demand duration curve (17)

Demand is usually described by Load Duration Curve which is an illustration of the number of hours in any year that the demand is at any particular level. It is constructed for any region by measuring load in hourly basis for the whole year.

From the figure (3) the system has three categories of load:

- Base Load: which exists most of the time.
- Peak load: this is when the load is on the high side and it typically exists at less than 20 % of the time.
- Intermediate load where the system is between the base and peak loads.

The load duration curve was mainly used to describe load behavior in the non-liberalized power markets, yet with the new market structure and the movement of liberalization, the price element is added to the load duration curve and power plants are stacked according to their marginal price starting with the lowest on the left side and going higher to the right (10).
There is a wide range of literature and research work that involves the investigation of the different effects of renewable energy technologies and adoption on the various components of the power systems.

The effect of variable renewables on the power market is an interesting and frequently visited research area.

In most of the literature reviewed the researchers tend to take the spot market price as the indicator for the electricity price, this is acceptable as in the EU usually the spot market account for the big portion of the electricity trading volumes. (11)

Although the public opinion often tend to believe that the introduction of renewables is increasing the power prices as a result of adding the economic burdens of the support schemes such as Feed in Tariff and Feed in Premium to the normal consumer's bill. Yet many studies and researchers came to a conclusion that the prices in the spot market price are either lowered or does not show much change with the introduction of renewables. (11)

For example in (Mulder & Scholtens 2013) study of the impact of renewable energy on electricity prices in Netherlands, in which they built a model based on historical data from 2006 to 2011, they found that the supply and demand intersection is hardly altered by the renewable energy generation.

They confirm that although the supply curve moved to the right yet this movement was too small to change the price significantly.

In addition to this they state that although the prices didn't change it can be reduced as the percentage of renewables in the energy mix increases further more. (12)

As well (Paraschiv, Erni, and Pietsch 2014) study which investigated The impact of renewable energies on EEX day-ahead electricity prices, showed that although the prices in the spot market incurred serious reduction yet the ordinary consumer wasn't affected by it as the added value of support schemes made up the gained gap.

Their paper investigated the instant variation that happen on the daily market prices (Spot Market Price) and the intraday market prices, to give detailed estimation on the variation that takes place in an hourly basis of intermittency.

They found that the sensitivity of power prices to fossil fuel prices decreased – especially gas – due to the introduction of renewable power plants which lead to shifting of the supply curve to the right. Yet the sensitivity to coal is still strong, this mean the support scheme for renewables resulted in replacing the low CO2 emission technologies first.

Although the normal consumers did not get any benefits from this change yet, the paper argues that intensive industrial consumers are the main winners here as they are exempted from the EEG[1] burden.

Another point is that the PV generation is important as it gets to its highest values at the peak load hours during the day, while wind generation is higher during night when the wind blows stronger. That also led to very low prices during the nights which sometimes reach negative values in the German spot market.

The paper suggest a cut in the Feed in tariff after the renewables reach a certain level to allow the normal consumers to benefit from the transition directly, the paper goes further to suggest a renewable energy policy that consider storage and distribution. To allow for the surplus of generation in the northern part to be equalized by the high demand in other parts of the country. (13)

Running alongside with more evidence is the study of (Clò, Cataldi & Zippoli 2014) where they examined the Italian power market for the effects of Solar and Wind power generation on the wholesale price.

Italian power system undergone one of the highest support schemes for renewables energy which just came at the same time of the economics recession there; so Italian power system had simultaneously large

[1] EEG (German: Erneuerbare-Energien-Gesetz) is The Renewable Energy Sources Act. It is a series of German laws that originally provided a feed-in tariff scheme to encourage the generation of renewable electricity.

expansion of renewable energy with a steep decrease in load. The paper goes on describing the situation and investigating the effect in the whole market price alongside the comparison between the profit gained from the renewables and the cost of the support scheme.

The papers finds strong evidence of alteration in the supply curve and thus the merit order effect of renewables. However further investigation shows that in contrary to the previously mentioned studies, this one claims that the effect on the price decreases with the increase in the renewable energy share. This is explained to be due to the difference in increment rate in savings and deployment cost, as the later increases much faster than the first.

Another very interesting finding is that the solar energy savings doesn't cover the cost of its support scheme, while wind energy easily overcome the cost and is an actual economics addition to the consumer's surplus. (14)

One unique study is the one accomplished by EWEA (The European Wind Energy Association) to estimate the merit order effect of wind energy in Europe. The study which is done by modeling approach to investigate the change in wholesale market price of electricity by the year 2020. The target is to investigate the pathway to reach the EU set target for 2020.

The model compares two different scenarios; one reference scenario of all the renewable resources levels are fixed at the level of 2008. And the wind scenario, that assumes Wind installed capacity to increase to 265 GW in the whole EU by the year 2020 compared to 65 GW at 2008 with fixing all other types of renewable energy including solar at their level in 2008.

The findings of the study shows lower prices for the wind scenario than the reference scenario. And the merit order effect is quantified to 10.8 €/MWh; this is explained by the difference in capacities and the difference in CO2 prices for the fossil fuels electricity generation that happens in the two scenarios (15).

Though there are many studies for the merit order effect on the spot market prices, using modeling and historic data analysis, yet there is scarcity in the studies considering the intraday market alteration due to renewables energy variable generation. This lack of interest can be explained by the traded power volumes difference; volume traded in the Spot market is larger than that traded in the intraday market. However the intraday market prices would be directly impacted by the errors in forecast which usually leads to high price spikes and also sometimes negative prices in the countries where the system allows the prices to go negative, or at least zero prices in other countries.

The third market which is directly affected by the errors in forecast and variation in renewable generation is the balancing energy market. This market is the first defense line for the TSO to mitigate the change in supply due to generation oscillation.

This paper is considering the spot market and the intraday market for five different countries in the EU. For these countries numbers are investigated in hourly basis for the two years of 2015 and 2016.

Methodology and data

The data about the installed capacity and actual generation is mainly taken from the EU Eurostat database[2] and also form the Entso-e transparency platform[3].

Other data about prices, and bidding procedures are taken form the respective countries TSO's, market operators, and regulatory authorities official websites.

Firstly all the installed capacity, load profile, and actual generation data from all the EU countries were analyzed and classified to select a reasonable sample of five countries, in order to give plausible results for the entire EU.

The following factors were took in mind to choose the sample countries:

- Current energy mix and percentage of VRE (wind and solar energy) in it.
- The development of wind installed capacity from 1990 – 2015.
- The development of solar installed capacity from 1990 – 2015.
- The percentage of VRE to the peak load registered in 2015
- The type of VRE resource in the mix; solar to wind percentage.
- Availability of data.

According to the data analyzed and also the availability of data the following countries were selected for the study:

- Germany; largest power system with the highest capacity of VRE.
- France; Nuclear dependent power system with relatively low penetration of VRE.
- Denmark; high penetration of wind with low solar.
- Portugal; unique power system with high hydro power and also high penetration of wind energy.
- Spain; relatively balanced penetration of solar and wind with significant share of solar thermal energy.

Secondly determination of critical hours, when the system flexibility is examined; critical hours are those hours of the year where:

[2] Eurostat is the statistical office of the European Union situated in Luxembourg. Its mission is to provide high quality statistics for Europe.

[3] ENTSO-E, the European Network of Transmission System Operators, represents 43 electricity transmission system operators (TSOs) from 36 countries across Europe

- Load is larger than forecasted with generation form the VRE (wind and Solar) is lower than expected (Top Hours) or,
- Load is lower than forecasted with the overwhelming generation from VRE (Bottom Hours).

In those critical hours the prices in the spot and intraday markets are expected be different than the normal averages.

- The forecasted and actual VRE generation were taken from ENTSO-E platform for all the five countries, along with the same data for load.
- All the data were normalized to hourly basis, because some countries TSOs provide data on half hourly or sometimes quarter hourly numbers.
- The difference between forecasted and Actual load and variable generation was taken and then the top 20 hours and bottom 20 hours were determined. Those critical hours are the numbers that actually analyzed as they show the extreme variation that happens in the system.
- The prices in those hours were taken from the respective Market and transmission operators' websites.

Results and Discussion

Results for the five countries showed wide spectrum of variation indicating the deference's in their power system characteristics starting from countries where the effect was clear, to other countries where the impact was minimal.

The German power system showed very high prices variation in the top and bottom hours, the results showed more effects in the intraday market, which is expected as it is the market that gets affected more by the deviation from the forecast.

The result showed higher vitality in 2015 compared to 206 in Germany, which can be an indication for more integration in the 2016 compared to 2015.

For France, the results shows lower variability in the spot and intraday market prices compared to Germany. Even though the prices are allowed to go negative in France yet no negative values were recorded in the two years of the study period. In general in France the difference between the spot market and intraday market is small which mainly reflect of the low penetration of VRE in the system.

In Denmark the average intraday and spot market prices are lower on average than the prices in the German and French markets, also a notice is that there is no recognized difference in the average prices between top critical and bottom critical hours. The results show more volatility in

the Spot market prices than the intraday market prices with several negative values in the Danish power system.

The difference between spot and intraday was small compared to what is noticed in the German power system, which indicates lower impact by VRE.

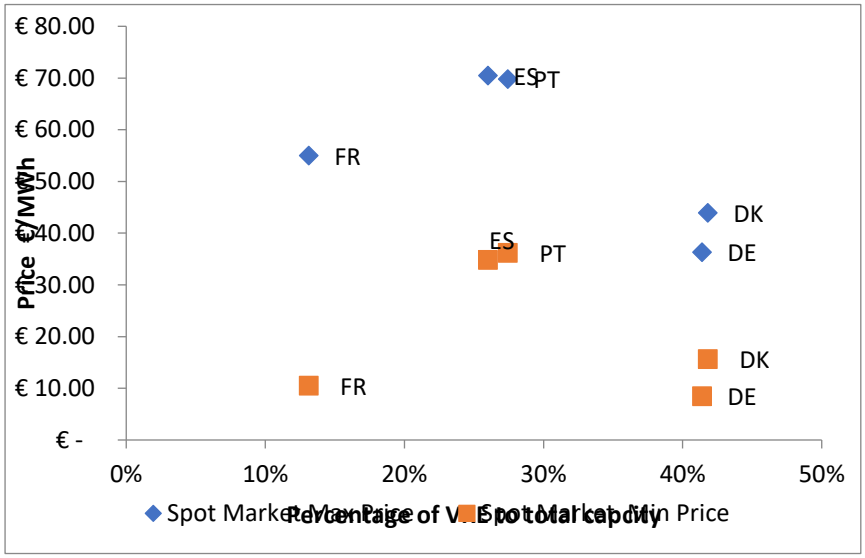

Figure 4: Spot Market Prices in the five countries

For Spain and Portugal the study procedure doesn't show much effect because the two systems has a very high interaction with diversity in generation types.

This diversity in generation makes each one of them a buffer of more flexibility to the other. The high hydro and wind capacity in the Portuguese side adds to the flexibility in the Spanish system where the solar and fossil fuels on the Spanish side are added flexibility and buffer for the Portuguese system. The critical hour's identification needs to be implemented again for the Iberian Peninsula as one system; that means finding points in time when the load and VRE generation in both countries hit peaks and bottoms.

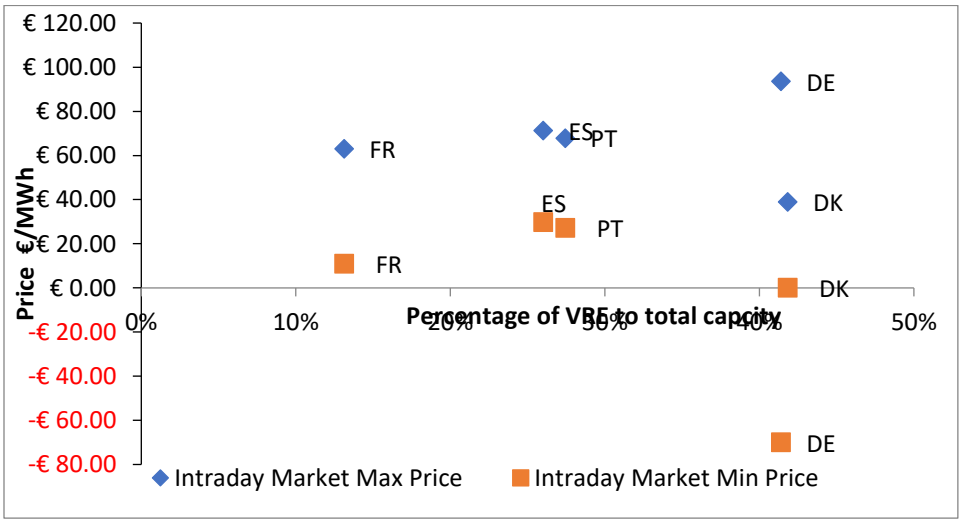

Figure 5: Intraday market prices in the five countries

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