Simulation of the Zero and Non-zero bids in the 2030 Day Ahead MIBEL Market

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Abstract Nowadays we live in a world that is rapidly heading towards a greener and more sustainable life. Actions have been taken by many countries to support decarbonization, improving efficiency and more use of renewable energy over fossil fuel. From its side the European commission established a very ambitious plan for the near and far future. Targets have been set for 2020 and been accomplished, yet more to be reached by 2030 and all the way to 2050. These targets are backed by national plans to be achieved by individual countries within the EU. In this paper Portugal and Spain's electricity market (MIBEL) is investigated to study the effect of the massive penetration of renewable energy on the future electricity market. Focusing on the supply curve, the main objective of this paper is to forecast the quantities of electricity bid in the 2030 day-ahead market to study the Iberian market's behaviour to the high renewable penetration, and its effect on the quantities that are bid at the day ahead market. The quantities are categorized into zero and non-zero price segments. As a final result of this study quantities bid by generation players were forecasted by an artificial neural network as a first step of predicting the supply curve. Results show that the quantities of electricity bid at zero price will increase significantly, which supports the speculation that renewable electricity will have a bigger share in the MIBEL energy mix by 2030.

1 Introduction

Modelling of electricity markets is an effective means of testing and evaluating the market design prior to its deployment, and therefore limiting problems before they occur. Also, it is an important tool as it can provide answers to a variety of concerns related to complex market scenarios and what if situations. Not only that, but it is very essential to have accurate forecasts since utility companies rely on these forecasts to operate. Moreover, long term planning of future investments or political initiatives and programs, like the European targets for implementing more renewable energy in the power system, all require reliable techniques and models to simulate the markets and forecast the electricity price to be able to take solid decisions and achieve the desired targets.

It can be fairly said that the majority of models and techniques for forecasting electricity price mainly focus on the price time series and neglect the root mechanism of determining the price, which is the supply and demand curves, which represent the quantities of electricity traded in an exchange. These two curves do not only contain all the information needed to determine the price but also additional information on other prices for other market volumes. Which is important when it comes to determining extreme price movements. Modelling and forecasting the electricity prices by using real auction data is considered to have lots of potential, yet not fully explored. In this section relevant studies will be reviewed discussing different forecasting approaches of future electricity markets, focusing on supply and demand curves approach to forecast the electricity prices and predict extreme price movements.

In [1] one of the first research that developed a model that uses real auction data of an electricity market along with an Ornstein-Uhlenbeck process to produce a model that can account for price spikes.

In [2] a promising study modelled the supply and demand curves to obtain the clearing price. In this study it was assumed that the demand curve followed a linear function, but the supply curve followed a non-linear function to build a price quantity model. Factors as gas prices, gas supply and temperatures were used to approximate the market curves.

A paper researched and developed a forecasting method to predict the bidding curve of generation players in the Iberian electricity market, MIBEL [3]. This forecasting model is constructed as a two-step artificial neural network (ANN) prediction model. The first step model works on the prediction of the amount of energy to be bid at zero price for a certain hour. The second step model involves the prediction of rest of the bidding curve. The accuracy of the trained ANN model is assessed by the determination coefficient R, Root Mean Squared Error (RMSE) and Mean Absolute Percentage Error (MAPE).

Study [4] proposes another approach for predicting the electricity price by forecasting supply and demand curves. This approach includes modelling and predicting of hourly supply and demand curves and the location of the intersection point to obtain the equilibrium volume and market price. This methodology is developed by using functional data analysis methods like parametric and non-parametric functional auto regressive models (FAR). This study is performed on the Italian electricity market (IPEX). In order to build the hourly demand and supply curves all individual bids and offers are considered for every auction. The model starts by accumulating raw bids and offers to obtain the empirical demand and supply curve which is then converted to smooth functions using a basis function.

In [5] a study conducted on the Italian electricity market presents a methodology to simulate the future electricity market by using hourly generation bids data sets. This method is capable of providing a deeper insight on the bidding behaviour of the generation participants, which gives an advantage over the historical time series forecasting of electricity price. Based on the future forecasted demand and supply the clearing price can be determined by the intersection of both curves.

Another study [6] researched the German and the Austrian day ahead electricity market, aimed to develop a model to forecast electricity prices by using the supply and demand curve approach instead of directly forecasting the electricity price time series. The model can be referred to as the X-model which combines the perceptions of market structure and econometric analysis. A stochastic model forecasts the bid volume of each price class. Finally, the supply and demand curves are calculated and by getting the intersection point the clearing price can be obtained.

This paper is organized as follows. Following this introduction, Section 2 briefly covers the design of the MIBEL electricity market and analyses the generation mix in Portugal and Spain. The suggested methodology is then discussed in Section 3. Section 4 covers the model validation process including the forecasting errors that were acquired. Last but not least, section 5 contains information on the dataset that was used to forecast for 2030 as well as the key outcomes. So far, the findings reveal a generally good performance, confirming the practicality of the proposed methodology.

2 Iberian Electricity market - MIBEL

In 1998 Portugal and Spain took the first step in building the Iberian electricity market which had the aim of integrating both countries electricity systems. The integrated market came to operation in 2007 bringing benefits not only to the consumers from both countries and allowing all participants to have a free access and equal rights [7] but also on the European scale, since it is a step towards building up the internal European electricity market.

The MIBEL market is operated by Operador del Mercado Ibérico (OMIE) [8], which is owned by the Spanish society OMEL and the Portuguese society OMIP, both owning equal shares. For each country there is a Transmission System Operator (TSO). In Portugal the TSO is Redes Energéticas Nacionais (REN) [9], and in Spain Red Eléctrica de España (REE) [10].

The electricity transport activities which are represented in transmission and distribution are based on the use of an existent network that allows the transportation of electricity from production facilities to the end user. These networks are characterized as natural monopolies. Regulations are subjected over the use of these networks allowing third parties to have access through payment of a regulated tariff. On the other hand, the electricity production (wholesale market) and the retail market are open to competition, which can be justified by the introduction of more efficient techniques to manage resources that are involved in these activities.

2.1 Day-Ahead Electricity Market

Since our case under study is focused on the day-ahead market (Spot market) and specifically the supply curve, the reader should have a better understanding of the day-ahead market in terms of its characteristics and working mechanism.

The spot market is by far the most important market in the MIBEL structure, since it is where most of the electricity is traded. Given its importance, this work will be focused only on the MIBEL spot market, and any reference made to a market feature will be regarding this specific market.

In the spot market electricity is generally traded in a daily auction for each hour of the following day. The closing hour of the spot market is 10:00 am on the day before the supply, and the clearing prices are announced at 11:00 am. The clearing price is the point where the supply curve meets the demand curve. These curves are composed of the supplier’s bids and the consumers offers. Each bid and offer include the quantity of electricity that a market agent is willing to sell or buy in [MWh], and the price in [€/MWh]. After all market agents submit their bids and offers, the supply bids are arranged in ascending order and demand offers are arranged in descending order. The two curves are then plotted against each other, and the intersection point is determined as seen in figure 1. This point is what so called clearing price or spot price. The corresponding quantity of electricity refers to the amount of electricity traded at a specific hour of the following day. It is important to note that all the suppliers that submit a bid at a price higher than the clearing price will not be able to participate, as well as all consumers that offer to buy electricity at a price lower that the clearing price will not be accepted in the market [7]. It is also important to note that if the quantity of the traded electricity exceeds the interconnection capacity between Portugal and Spain the market splits, and different prices of electricity take place in each country as a solution to this congestion.

As explained above, each market agent has to make a/an bid/offer to the market operator. These bids/offers can be simple or complex depending on their content. Simple bids/offers are those which express an amount of energy and an equivalent price. On the other hand, complex bids/offers are those which not only express an amount of energy and an equivalent price but also include complex conditions to be taken into consideration during the matching process and they are the one taken into consideration to calculate the electricity price [7].

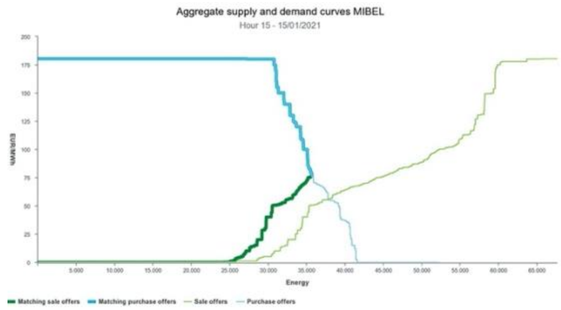

Figure 1 Supply and demand curves for hour 15 of day 15/01/202, [11]

2.2 Iberian generation portfolio

In this section the reader should gain more closure on the Iberian electricity mix in-terms of each country's national capabilities separately Starting with Portugal the total installed capacity till August 2021 is 21.2 GW with an increase of 0.8 GW from the previous year 2020.

In figure 3 bellow, a comparison between the annual production of electricity in Portugal between year 2019 and 2020. It can be seen that in 2020 the renewable production supplied 60% of the total national consumption, which is compared to a 51% in the previous year. It is also important to note that these percentages in 2020 are the highest ever recorded values for renewable sources annual generation in Portugal.

Figure 2 Portuguese energy generation structure comparison between 2019 and 2020 [12]

When it comes to Spain, the installed power capacity up till August 2021 is equivalent to 112.2 GW. Which is 6.6 GW higher than the previous year 2020. In the figure bellow another comparison between the annual production of electricity in Spain between year 2019 and 2020. It can be seen that in 2020 the renewable generation supplied 45.5% of the total national consumption, which is compared to a 38.9% from the previous year.

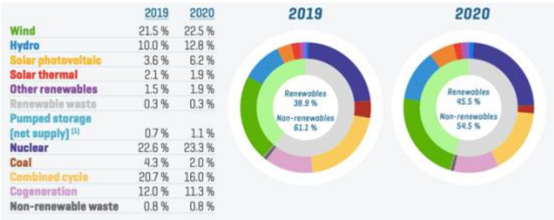

Figure 3 Spanish Energy Generation structure comparison between 2019 and 2020 [12]

3 Methodology

This section provides an overview over the methodology used in this research and guides the reader through the different phases to give a better understanding of the developed model.

As mentioned before in section 1, this paper focuses on the wholesale day-ahead MIBEL market. Real hourly market data coming from hundreds of generators has been collected and processed. This hourly data is then fed into an artificial neural network for the initial aim of creating a model that can predict the quantities of the electricity bid into the market, in other words the supply curve. These bids are categorized based on two price segments: zero and non-zero price. Therefore, the model's outputs are the total quantities of electricity bid at zero and non-zero price segments. Which is a first step towards the main goal of modelling the supply curve. The proposed methodology can be described by the following steps:

1. Data collection.
2. Data treatment and preparation.
3. Choosing the future scenario and projection to use.
4. Developing an Artificial neural network model (ANN).
5. Model validation and final results.

As it was mentioned before in section 2, the MIBEL market is operated by Portugal and Spain. Therefore, to evaluate and model the hourly supply curve of the day-ahead market it is mandatory to gather information with reference to both countries. Historical hourly bids and historical hourly electricity production per technology were collected from OMIE [8], which is the Spanish market operator. OMIE only provided two years and half of hourly data. From 2019 till June 2021. In this period over 900 files containing around 81,000,000 data samples are collected and processed.

It was also very important to have a description of the future energy mix and production distribution of the year under study. For this work only one projection is considered for the future scenario for 2030. The chosen projection is the governmental projection (RNC + PNIEC) proposed by Pereira [14]. The mentioned projection was selected due to the fact that it is the only ambitious projection where nuclear and coal generation totally phase out. Coal and nuclear power plants are planned to be decommissioned by 2030 and 2035 respectively. Moreover, data availability was a key point for the selection of this projection.

Table 1 represents the total annual electricity production in 2030 based on the (RNC + PNIEC) projection.

Table 1 Portugal and Spain Electricity Production in 2030 (RNC + PNIEC)

Technology	2030 Production [TWh]
Hydro	56.49
Wind	123.81
Solar (PV+CSP)	82.91
Nuclear	26.21
Natural Gas	25.14
Coal	0
Other renewables (Biomass)	13.29

For the proposed methodology a computational intelligence technique is chosen to develop the practical component of this paper. this technique is limited to an artificial neural network algorithm used to forecast the quantities of electricity bid at different price segments for the DAEM mainly, zero and non-zero price. The input variables to the model are represented in the table

Table 2 Model input variables

Model's Input variables
Wind hourly generation (MWh)
Solar hourly generation (MWh)
Hydro hourly generation (MWh)
Natural gas hourly generation (MWh)
Coal hourly generation (MWh)
Nuclear hourly generation (MWh)
Other renewables hourly generation (MWh)
Hour
Day
Month

The model's training dataset was composed of years 2019 and 2020. During the training phase it was made sure that the model doesn't have access to the validation data. This is a crucial step to obtain a good model validation.

4 Model validation

After the construction of the model's algorithm, setting all the hyperparameters and training the model, it is very important to evaluate its accuracy before using it to forecast. With the information gathered from OMIE regarding the hourly generation categorized by technology and using the hour, day, and month as inputs. It was possible to run the model and forecast the quantities for the first half of 2021 as it was the only data available at the time of the study. To perform the validation, process the idea is to have historical data for both the inputs, which are equivalent to the model predictors, and their corresponding outputs, as model targets. This enables us to compare the model with real data, thus, allowing to quantify the error. For this work, the validation process will be based on feeding the model with historical data of the previously explained inputs for year 2021 and comparing the output values of the hourly quantities of electricity bided in the day-ahead MIBEL market with the true historical values.

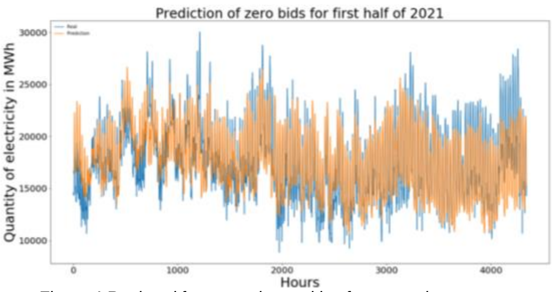

Figure 4 Real and forecasted quantities for zero price segment

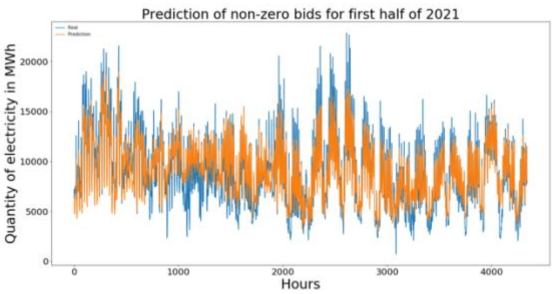

Figure 5 Real and forecasted quantities for non-zero price segment

As seen in figures 4 and 5, the model can clearly predict the main pattern of the forecasted quantities, yet it suffers some limitations when forecasting sharp peaks and dips. Such limitation can be justified by the ANN input variables. The fact that the model is provided only 10 variables mainly divided into hourly production of each technology and time, to fully describe the supplier's behaviour, made it hard for the model to detect such steep movements. An explanation of such limitation is that the model is forecasting quantities of electricity bided in the DAM for the two price segments. these quantities mainly depend on the production from each technology and the production also depend on weather conditions specially regarding renewable resources (represented by zero price segment), therefore a sudden change in weather conditions will eventually cause a change in the renewable production which will induce a change in the production of non-renewable resources to be able to supply the demand. A way of tackling this limitation would be by introducing hourly variables that represents weather conditions along with the proposed inputs, which can be very challenging and data availability is not guaranteed.

Following the prior visual study, a numerical evaluation is critical. Furthermore, it is also important to compare the models to similar studies as it provides an indication on how the model performs compared to similar models. In this section some forecasting key performance indicators (KPIs) are used to measure the model's accuracy (or error), utilizing the MAPE, MAE, RMSE and CV-RMSE indicators. Results can be found in table 3 bellow.

- **Mean Absolute Percentage Error (MAPE)**

$$MAPE = \frac{1}{n}\sum_{t=1}^{n}\left|\frac{A_t - F_t}{A_t}\right| * 100\%$$

  - n is the number of fitted points.
  - A_t is the actual value.
  - F_t is the forecast value.

- **Mean Absolute Error (MAE)**

$$MAE = \frac{1}{n}\sum_{t=1}^{n}|F_t - A_t|$$

- **Root Mean Squared Error (RMSE)**

$$RMSE = \sqrt{\frac{\sum_{t=1}^{n}(F_t - A_t)^2}{n}}$$

- **Coefficient of Variation of Root-Mean Squared Error - CV(RMSE)**

$$CV(RMSE) = \frac{1}{Y}\sqrt{\frac{\sum_{t=1}^{n}(F_t - A_t)^2}{n}}$$

  - Y is the mean value.

Table 3 KPIs of the developed model for the two price segments

Model	MAPE (%)	MAE (MWh)	RMSE (MWh)	CV-RMSE (%)
Zero price segment	8.7	1534.9	1950.3	11.1
Non-zero price segment	13.6	1148.8	1490.53	16.7

5 Results

Following creation, training, and validation, the model is ready to be utilized for predicting, with a high degree of confidence and reliability in the outcomes.

In order to forecast for 2030, the model inputs resembled in the hourly production of the mentioned year had to be developed. The production data presented in the chosen projection (RNC + PNIEC) for 2030's MIBEL energy mix is presented on an annual scale as seen in table 1, rather than on an hourly resolution. Therefore, it was necessary to convert these annual production values from a yearly basis to an hourly basis in order for the model to be able to forecast the quantities of electricity bid in the DAM for 2030. This was accomplished by collecting past patterns of such variables and duplicate them for 2030, assuming that the distribution of today's inputs which are the hourly generation per technology will be similar in 2030. This assumption is fairly correct, because the most significant change in the future will be in the total values of production, not in their distribution/pattern.

Looking at the simulated results in figure 6, it can be seen that the quantities of electricity bid at zero price will increase for year 2030 with a mean value of the distribution of 21463.86 MWh compared to a mean value of 15666.92 MWh for 2019. This observed increase was excepted and can be justified by the high increase in renewable production and the decrease in fossil fuel generation for 2030.

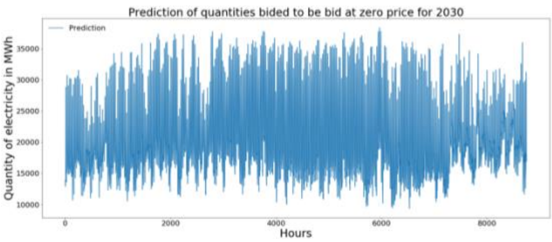

Figure 6 Forecasted hourly quantities bid at zero price for 2030, MIBEL

Looking at the simulated results in the figure 7, it can be observed that the quantities of electricity bid at non-zero price will not be affected much, only a slight increase from a mean value of 10606.17 MWh in 2019 to 10980.58 MWh for year 2030. This can cause some confusion as nuclear and natural gas power plants will decrease their production and coal will phase out, supposedly leading to less quantities bid at non-zero price. But This can be justified by the fact that hydro generation is set to increase by 2030, and hydro generators usually bid their quantities of electricity at a non-zero prices to maximize plant profitability and also for their pump and storage capabilities. Therefore, the quantiles bid at non-zero price will hold ground and will not be affected much by the planned change of the 2030 energy mix.

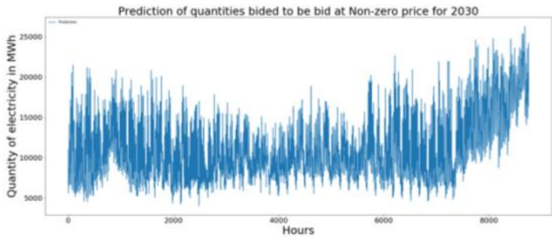

Figure 7 Forecasted hourly quantities bid at non-zero price for 2030, MIBEL

Form this section is possible to conclude that in 2030 an overall increase of quantities bid at zero price will occur. Such increase is caused by the enormous amount of renewable electricity generation, that increases from 39% in 2019 to 86% in 2030, specially from solar energy. On the other hand, the quantities bid at non-zero price will not be affected as explained in the section above

6 Conclusion

The main objective of this paper is to forecast the quantities of electricity bid in the 2030 day-ahead market, to study the Iberian market behaviour to the increasing renewable penetration, and its effect on the hourly quantities of electricity that are bid at the day ahead market. The quantities are based on two price segment, zero and non-zero prices. The zero price segment is the first part of the supply curve and usually expresses the quantity of renewable generation. The model that was used for the forecasting purpose is an artificial neural network model that is fed with input data like; hourly generation by technology, Month, day and hour, to forecast the hourly quantities of electricity for the mentioned price segments. This would be the first step towards forecasting the whole supply curve.

By the end of this dissertation, and after reviewing all of the developed work, it is necessary to highlight some of the most important findings and conclusions reached throughout the process.

First in order to have a model, data had to be collected. And since the MIBEL market is operated by Portugal and Spain. Therefore, it is mandatory to gather information with reference to both countries. Historical hourly bids and historical hourly electricity production per technology were collected from OMIE, which is the Spanish market operator. OMIE only provided two years and half of hourly data. From 2019 till June 2021 from which the model was fed.

For the model to be able to forecast for 2030, a future projection was selected for the year under study from which the model inputs for 2030 are developed. The chosen projection is the governmental projection (RNC + PNIEC). Being the only ambitious projection were where coal and nuclear generation totally phase out by 2030 and 2035 respectively.

After the model was trained, validation was performed to evaluate the model's accuracy. The idea behind validation is to have historical (real) data for both the inputs, which are equivalent to the model predictors, and their corresponding outputs, as model targets. This allows us to compare the model's outputs with real data and compute the error. The developed model is also evaluated by some error metrics to provide an overview of the models' capabilities to forecast, resulting in MAPE values of 8.7% and 13.6%, MAE values of 1534.9 and 1148.8 MWh, RMSE values of 1950.3 and 1490.53 MWh and finally CV-RMSE values of 11.6% and 16.7%. Respectively for zero and non-zero quantities.

According to the model findings, the expected increase in renewable penetration by 2030 tends to increase the quantities of electricity bid at zero price and hence lower the average hourly electricity market price as a result of shifting the supply curve against the demand, whereas an increase in fossil fuel-based production increases the quantities of electricity bid at non-zero price which also lead to increase the average hourly electricity market price. For year 2030 the increase of renewable generation is the main trend therefore, it is concluded that the quantities bid at zero price will significantly increase and this will cause spot prices to decrease at hours with high renewable generation.

Finally, it is clear that this study was created utilizing public data from the Iberian Electricity Market. However, the suggested approach may be carried out with different electricity markets if the variables of the prediction model are modified, and the weights of the associated ANN's are retrained.

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