ANALYSIS OF THE ECONOMIC IMPACT OF THE CHANGEOVER TO THE QUARTER-HOURLY ELECTRICITY MARKET ON THE COST OF EOLIC DEVIATIONS

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ABSTRACT:

The electricity sector, in global terms, has undergone significant and severe structural changes, with the aim of allowing free choice for energy consumers and achieving greater competition between markets. In this regard, quarter-hourly deviations are promoted by European regulations for the purpose of energy market management. The EU requires electricity suppliers to provide data on their energy production and consumption every 15 minutes. This requirement has been designed to promote transparency and competition in the energy market. Until now, Spain has used an hourly deviation settlement system, so the implementation of this new model will entail a complex and gradual change. In fact, the introduction of a quarter hourly market would enable consumers to access more frequent pricing information, which would help them make more informed decisions about their energy usage. This would also create opportunities for more sophisticated demand-side management strategies, such as real-time pricing and automated demand response.

Although the integration of the electrical sector is an important aspect of the EU's broader efforts to create a single energy market and reduce carbon emissions, there are still significant challenges to be overcome, such as the need to improve grid infrastructure, ensure the security of supply, and harmonize regulatory frameworks across member states.

The main objective of this article is to study the impact that the implementation of the new quarter-hourly model will have in a wind farm, given the intrinsic variability of this energy source and the current reliability of prediction systems. With continued advancements in technology and improved forecasting techniques that allow suppliers to adjust their operations in real-time based on changing conditions, it is likely that the uncertainty of unmanageable units will continue to decrease over time, making them an even more reliable and efficient source of clean energy in the future.

Keywords: Quarter-hourly model, imbalances, electricity market, wind energy, hourly deviation settlement system

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1. INTRODUCTION

Our society is conditioned by an extreme, continuous and permanent exposure to globalization, reaching an imperative need to achieve a cooperative and coherent development among the different countries. Its goal is to find a balance between national and global self-interest. This idea of international cooperation gave birth to the European Union (hereafter, EU) which, even today, continues to push its members towards the so-called European integration [1]. For that matter, the EU has been pursuing a policy of integrating the energy markets of its member states for several decades. This policy has significant implications for the electrical sector, as it involves the harmonization of regulatory frameworks, the creation of cross-border electricity infrastructure, and the promotion of competition and innovation. One of the main objectives of the EU's energy policy is to ensure security of supply by promoting diversification and reducing dependence on external sources of energy. This has led to the development of new interconnectors between member states, which allow for the transmission of electricity across national borders. These interconnectors have also helped to integrate renewable energy sources into the grid, by allowing surplus electricity from wind and solar farms in one country to be exported to another [2]-[3].

The electricity market in Spain is regulated by the Spanish government through the Ministry for Ecological Transition and Demographic Challenge, which sets prices for some components of the market and enforces rules to promote competition and fair play among market participants. It operates under the framework of the EU's electricity market regulations. In this regard, quarter-hourly deviations, also known as 15-minute time blocks, are promoted by European regulations for the purpose of energy market management. The EU requires electricity suppliers to provide data on their energy production and consumption every 15 minutes. This requirement has been designed to promote transparency and competition in the energy market. The use of quarter-hour deviations will allow for more accurate tracking of energy supply and demand, which in turn enables more efficient management of the energy grid [4]. This can help to reduce the risk of blackouts or other disruptions, while also promoting the use of renewable energy sources. Its aim is to favor exchanges within an intraday horizon in order to promote the exchange of energy in a simpler way by presenting the same entry schedules [5]-[8]. So far, Spain has been using an hourly deviation settlement system, so the implementation of this new deviation model will entail a complex and lengthy paradigm shift [9]-[16]. This change will have, as it is logical to think, its corresponding advantages as well as challenges. Although the real impact that this process of coupling adjustment services at international level may have been unknown, the aim of this dissertation is to reach a conclusion or, at least, a new approach to this new paradigm.

1.1 Previous contextualization

The electricity market in Spain operates on a competitive basis, with electricity prices determined by supply and demand. Electricity generators bid to sell their electricity into the market, and the cheapest offers are selected first. This process is called the "marginal cost pricing mechanism," which means that the price of electricity is set by the highest-priced generator needed to meet demand. The Spanish electricity market also includes a "pool" system, where electricity prices are determined through a daily auction process. An imbalance occurs when there is an unexpected difference between the supply of electricity and the demand for it. Then, the deviation settlement process is important for maintaining the reliability and stability of the electrical grid, as well as ensuring that market participants are properly compensated for the energy they produce or consume production deviations in the electricity market can also have far-reaching consequences, both for producers and consumers [17], as follows:

1. Production deviations can lead to fluctuations in the supply of electricity, which can cause price volatility in the market. If production is lower than expected, the price of electricity can increase due to increased demand and limited supply. Conversely, if production is higher than expected, the price of electricity can decrease due to excess supply.

2. Production deviations can also affect the stability of the electricity grid. If production is too low, there may not be enough electricity to meet demand, which can lead to brownouts or blackouts. On the other hand, if production is too high, it can overload the grid and cause equipment damage or even blackouts.

3. Production deviations can have financial implications for electricity producers. If a producer fails to meet its production targets, it may have to buy electricity from other producers at a higher price to fulfill its contractual obligations. Conversely, if a producer overproduces, it may have to sell electricity at a lower price than it would have otherwise received.

4. Production deviations can also have an environmental impact. If production is lower than expected, producers may have to rely more heavily on fossil fuels to make up the difference, which can increase greenhouse gas emissions. Conversely, if production is higher than expected, it may result in excess renewable energy production, which could be wasted if it cannot be stored or transmitted.

To date, there is no precedent about the study issue since, in Spain, the deviation settlement period has followed an hourly granularity. The European Commission Regulation 2017/2195 of November 23, 2017 [6]-[7], which established a Guideline on Electricity Balancing (hereinafter, EB Regulation) expresses that, no later than three years from the entry into force of said regulation, the 15-minute (quarter-hourly) deviation settlement period must be implemented throughout the Spanish region, in such a way that all market limits and time measures coincide with those of the deviation settlement period in question.

On January 15, 2020, Red Eléctrica de España (hereinafter, REE) initiated a public consultation as a previous step to start the transition to the new model of deviations. Finally, REE proposed a deadline of October 1, 2023 [10]-[12]. In addition, it proposed a detailed planning of how and when the implementation of the new electricity turnout model would take place.

Since last May 24, 2022, the system operator REE adapted its various system scheduling processes in such a way that since that date a quarter-hourly scheduling model, every 15 minutes (see Fig.1) was implemented in accordance with the European Balancing Regulation 2017/2195 published on November 23, 2017 [8]. This implies that the adjustment services of the peninsular system, as well as the allocation and settlement of deviations will be allocated in 15-minute periods.

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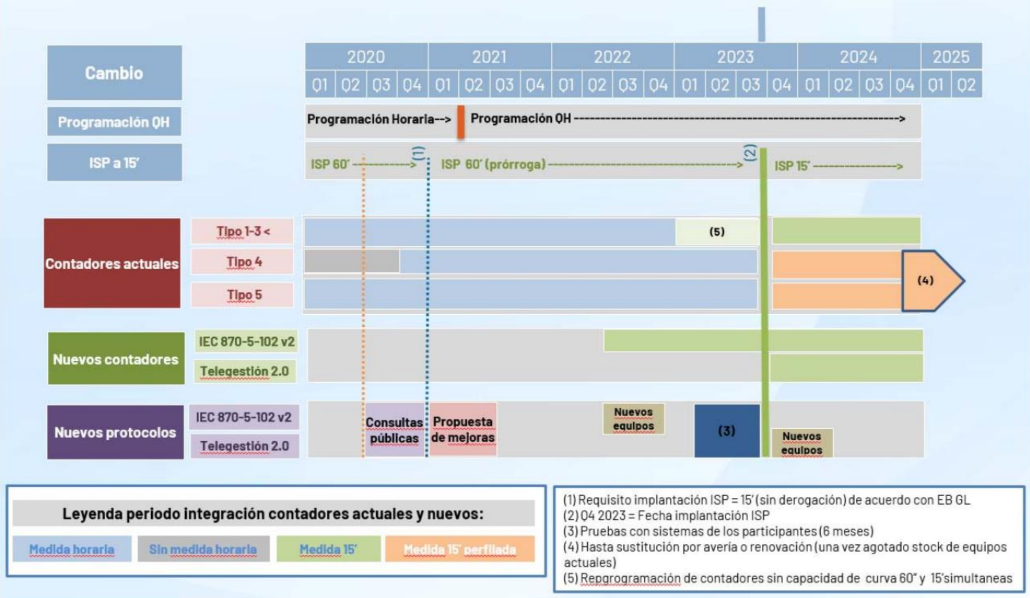

Fig. 1. Detailed plan and schedule. Source: [10]

*A quarter hourly market in the Spanish electricity market could be an effective way to improve the efficiency of the electricity system and provide more accurate price signals to consumers and producers. So far, the Spanish electricity market has operated on an hourly basis, with prices set for each hour of the day based on supply and demand conditions. However, this approach may not be optimal for managing the increasingly dynamic and variable nature of electricity supply and demand. A quarter hourly market would allow for more granular pricing and better alignment of supply and demand. Prices could be set every 15 minutes, reflecting changes in consumption patterns, weather conditions, and other factors that affect electricity demand and supply [17]. This would provide more accurate price signals to consumers, allowing them to make more informed decisions about their energy use and potentially reducing overall energy consumption. In addition, a quarter hourly market could benefit electricity producers by allowing them to better manage their generation assets. With more frequent price signals, producers could adjust their output levels in real-time to respond to changes in demand, maximizing their revenue and reducing the need for costly energy storage or backup generation. Nevertheless, implementing a quarter hourly market would require significant changes to the existing electricity market infrastructure, including new technologies and systems for monitoring and managing electricity supply and demand at a more granular level. It would also require coordination and cooperation among electricity market participants, including generators, grid operators, and energy retailers. Despite these challenges, a quarter hourly market could ultimately lead to a more efficient and sustainable electricity system in Spain, providing benefits to both consumers and producers, especially those using renewable energies, while reducing overall energy use and greenhouse gas emissions. However, i*n the electricity market, there is a need to have an internal network to promote the exchange of information between market participants.

2. - MATERIAL & METHODS

The purpose of this work is the study of t*he economic impact that the implementation of the new quarter-hourly model has in the methodology for the settlement of deviations. The data used correspond to a wind farm in Spain, whose measurements were provided by an external company to Comillas Pontifical University (which wants to remain anonymous). The wind power sector was chosen for this study given the variability of this electricity generation sector. Besides, the introduction of wind energy in the Spanish electricity market has had a major impact on deviations and bidding policy. This is because wind energy is a clean, renewable energy source that offers great environmental benefits while reducing the costs of electricity production. Wind power is a flexible form of electricity production, which means that it can easily adapt to fluctuations in demand. This helps to reduce diversions, as electricity generating companies can adjust their output to better meet demand. This means that the supply of electricity remains stable, reducing the risk of supply disruptions. In addition, wind power also helps to reduce the costs of electricity production by having a relatively low production cost. Wind energy has also had a significant impact on the bidding policy in the Spanish electricity market. This is because*

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wind producers provide a stable and predictable supply of electricity to the electricity market, which means that electricity prices are more stable and predictable. This also helps consumers to plan their energy expenses more accurately, as they know in advance how much electricity will cost at any given time. This also helps reduce investors' risk, as they have a better idea of future electricity prices.

What is more, it is intuitive to think that by working with data every 15 minutes instead of hourly, our predictive models will be better adjusted to reality. However, the impact of this change is not yet truly known and, therefore, by means of the work that supports this article we aspired to obtain a first approximation to this novel subject, as well as its corresponding conclusions.

When constructing bids for non-manageable units, the key consideration is the variability of the energy output. For example, wind power is an intermittent source of energy that can be affected by weather conditions and other factors. This means that the amount of energy that can be generated by these sources at any given time is uncertain. To construct a bid for a non-manageable unit, market participants typically use probabilistic forecasting models that take into account historical data on energy production and weather patterns. These models can help to estimate the expected output of the energy source over a given time period, such as an hour or a day. Based on this estimate, market participants can then submit a bid for the non-manageable unit that reflects the expected energy output and the prevailing market conditions. The bid will typically include the quantity of energy that can be supplied, the duration of the contract, and the price at which the energy will be sold. It is important to note that bids for non-manageable units may be subject to penalties or rewards based on the actual energy output compared to the forecasted output. This is known as the imbalance settlement process, and it is used to ensure that market participants are incentivized to accurately forecast their energy production and reduce imbalances in the system [18]-[21].

In the following, emphasis will be placed on the different stages that have just been carried out:

1. A process of data collection and measurements was started, which were vital for the realization of the work in question. The data provided consists of hourly and ten-minute measurements of the average wind speed, the generation of a wind farm at the foot of the turbine, the meter measurements (which take into account the internal losses of the wind farm) and finally the values expected in advance for the generation of the wind farm. All data belong to a time period equal to one year, although their measurement frequency differs depending on the data, e.g., the meter data can be either fifteen-minute or hourly measurements.
2. Once the data collection phase was completed, one of the most critical phases of the work began, since without this stage the subsequent ones would lack validity and/or value. Data cleaning and imputation. First of all, for data cleaning, it was observed that the files provided had irregularities. For example, those days sensitive to hourly changes had measurements outside the typical 24-hour range, so the extra data had to be cleaned. In addition, there were also some missing data initially, since technical failures are inevitable. In such situations, the data were inferred using various mathematical techniques such as interpolation [21]. The following is an extract of the code that imputes through interpolation those missing quarter-hour frequency data. The open-source code with Matlab required to replicate all analyses in this article is available in [22].

```
%% Obtaining the missing quarter-hour measurements through different
interpolation methods

vq_spline=interp1(x,v,xq,'spline');
vq_pchip=interp1(x,v,xq,'pchip');
vq_makima=interp1(x,v,xq,'makima');
vq_lin=interp1(x,v,xq,'linear');

datos_cuarto_horario_completo{1,1}=datos_cuarto_horario{1,1};
datos_cuarto_horario_completo{1,2}='Predicción spline';
datos_cuarto_horario_completo{1,3}='Predicción pchip';
datos_cuarto_horario_completo{1,4}='Predicción makima';
datos_cuarto_horario_completo{1,5}='Predicción lineal';

for i=2:(size(xq,1)+1)

        datos_cuarto_horario_completo{i,1}=xq(i-1,1);
        datos_cuarto_horario_completo{i,1}.Format='HH:mm--dd-MM-yyyy';
```


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```
        datos_cuarto_horario_completo{i,1}=cellstr(char(datos_cuarto_ho
        rario_completo{i,1}));
        datos_cuarto_horario_completo{i,2}=vq_spline(i-1,1);


        datos_cuarto_horario_completo{i,3}=vq_pchip(i-1,1);
        datos_cuarto_horario_completo{i,4}=vq_makima(i-1,1);
        datos_cuarto_horario_completo{i,5}=vq_lin(i-1,1);
end
```

Likewise, the code extract is shown, which imputes through interpolation those missing data of hourly frequency [23[:

```
%% Obtaining the missing hourly measurements through different interpolation methods

vq_spline=interp1(x,v,xq,'spline');
vq_pchip=interp1(x,v,xq,'pchip');
vq_makima=interp1(x,v,xq,'makima');
vq_lin=interp1(x,v,xq,'linear');

datos_horario_completo{1,1}=datos_horario{1,1};
datos_horario_completo{1,2}='Predicción spline';
datos_horario_completo{1,3}='Predicción pchip';
datos_horario_completo{1,4}='Predicción makima';
datos_horario_completo{1,5}='Predicción lineal';

for i=2:(size(xq,1)+1)

        datos_horario_completo{i,1}=xq(i-1,1);
        datos_horario_completo{i,1}.Format='HH:mm--dd-MM-yyyy';
        datos_horario_completo{i,1}=cellstr(char(datos_horario_completo
        {i,1}));
        datos_horario_completo{i,2}=vq_spline(i-1,1);
        datos_horario_completo{i,3}=vq_pchip(i-1,1);
        datos_horario_completo{i,4}=vq_makima(i-1,1);
        datos_horario_completo{i,5}=vq_lin(i-1,1);
end
```

3. In this phase, in order to be able to carry out a subsequent study of the data, it was decided to structure the data in such a way that they would follow two types of time frequencies, one hourly and the other quarter-hourly. The hourly frequency was the easiest to achieve since some of the data under study already initially followed hourly time series. Those data that did not were simply obtained by aggregation. For the quarter-hourly frequency, interpolation methods had to be used again, since the data had to be disaggregated to obtain the desired frequency. Finally, the desired data matrices were obtained (see Fig. 2 y Fig 3).

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Variables - forecast_hor

forecast_hor

8761x5 cell

	1	2	3	4	5
1	'date'	'Predicción spline'	'Predicción pchip'	'Predicción makima'	'Predicción lineal'
2	'00:00--01-01-2021'	12.6000	12.6000	12.6000	12.6000
3	'01:00--01-01-2021'	13.2000	13.2000	13.2000	13.2000
4	'02:00--01-01-2021'	14.9000	14.9000	14.9000	14.9000
5	'03:00--01-01-2021'	17.6000	17.6000	17.6000	17.6000
6	'04:00--01-01-2021'	22.1000	22.1000	22.1000	22.1000
7	'05:00--01-01-2021'	25.3000	25.3000	25.3000	25.3000
8	'06:00--01-01-2021'	25.4000	25.4000	25.4000	25.4000
9	'07:00--01-01-2021'	25.4000	25.4000	25.4000	25.4000
10	'08:00--01-01-2021'	25.5000	25.5000	25.5000	25.5000
11	'09:00--01-01-2021'	24.5000	24.5000	24.5000	24.5000
12	'10:00--01-01-2021'	21.5000	21.5000	21.5000	21.5000
13	'11:00--01-01-2021'	19.8000	19.8000	19.8000	19.8000
14	'12:00--01-01-2021'	20.5000	20.5000	20.5000	20.5000
15	'13:00--01-01-2021'	18.4000	18.4000	18.4000	18.4000
16	'14:00--01-01-2021'	14.1000	14.1000	14.1000	14.1000
17	'15:00--01-01-2021'	10	10	10	10
18	'16:00--01-01-2021'	6.7000	6.7000	6.7000	6.7000
19	'17:00--01-01-2021'	5.6000	5.6000	5.6000	5.6000
20	'18:00--01-01-2021'	7.7000	7.7000	7.7000	7.7000
21	'19:00--01-01-2021'	9.4000	9.4000	9.4000	9.4000
22	'20:00--01-01-2021'	7.6000	7.6000	7.6000	7.6000
23	'21:00--01-01-2021'	8.6000	8.6000	8.6000	8.6000
24	'22:00--01-01-2021'	10.3000	10.3000	10.3000	10.3000

Fig. 2. Hourly time vector obtained for the prediction of hourly generation in 2021 in kWh.

Variables - forecast_cuarthor

forecast_cuarthor

35041x5 cell

	1	2	3	4	5
1	'date'	'Predicción spline'	'Predicción pchip'	'Predicción makima'	'Predicción lineal'
2	'00:00--01-01-2021'	12.6000	12.6000	12.6000	12.6000
3	'00:15--01-01-2021'	12.6131	12.6592	12.6573	12.7500
4	'00:30--01-01-2021'	12.7239	12.7954	12.7933	12.9000
5	'00:45--01-01-2021'	12.9227	12.9839	12.9827	13.0500
6	'01:00--01-01-2021'	13.2000	13.2000	13.2000	13.2000
7	'01:15--01-01-2021'	13.5460	13.4926	13.4974	13.6250
8	'01:30--01-01-2021'	13.9511	13.9001	13.9121	14.0500
9	'01:45--01-01-2021'	14.4057	14.3826	14.3957	14.4750
10	'02:00--01-01-2021'	14.9000	14.9000	14.9000	14.9000
11	'02:15--01-01-2021'	15.4325	15.4571	15.4434	15.5750
12	'02:30--01-01-2021'	16.0341	16.0889	16.0755	16.2500
13	'02:45--01-01-2021'	16.7436	16.8013	16.7949	16.9250
14	'03:00--01-01-2021'	17.6000	17.6000	17.6000	17.6000
15	'03:15--01-01-2021'	18.6238	18.6024	18.6013	18.7250
16	'03:30--01-01-2021'	19.7624	19.8043	19.7977	19.8500
17	'03:45--01-01-2021'	20.9448	21.0291	21.0202	20.9750
18	'04:00--01-01-2021'	22.1000	22.1000	22.1000	22.1000
19	'04:15--01-01-2021'	23.1613	23.1169	23.1268	22.9000
20	'04:30--01-01-2021'	24.0789	24.1433	24.1526	23.7000
21	'04:45--01-01-2021'	24.8070	24.9481	24.9521	24.5000
22	'05:00--01-01-2021'	25.3000	25.3000	25.3000	25.3000
23	'05:15--01-01-2021'	25.5340	25.3429	25.3419	25.3250
24	'05:30--01-01-2021'	25.5721	25.3742	25.3731	25.3500

Fig. 3 Quarter-hour time vector obtained for the prediction of hourly generation in 2021 in kWh.

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4. The next stage consisted of a comparative analysis between both time frequencies (see calculation of deviations in a code extract from Matlab below [22]).

```
%% Calculation of total electrical deviation
% quarter-hour deviation

desvio_cuarthorario{1,1}=datos_cuarto_horario{1,1};
desvio_cuarthorario{1,2}='Desvío cuarto-horario';
sum_cuarthor=0;

        for i=2:size(datos_cuarto_horario,1)

             desvio_cuarthorario{i,1}=datos_cuarto_horario{i,1};
             desvio_cuarthorario{i,2}=4*datos_cuarto_horario{i,2}/1000-
             forecast_cuarthor{i,2};
             sum_cuarthor=sum_cuarthor+desvio_cuarthorario{i,2};

        end

%Desvío horario

desvio_horario{1,1}=datos_horario{1,1};
desvio_horario{1,2}='Desvío horario';
sum_hor=0;

        for i=2:size(datos_horario,1)

             desvio_horario{i,1}=datos_horario{i,1};
             desvio_horario{i,2}=datos_horario{i,2}/1000-
             forecast_hor{i,2};
             sum_hor=sum_hor+desvio_horario{i,2};

        end
```

5. Once the electrical deviations were calculated for both time frequencies, and after being represented graphically, the deviations for both frequencies were added in such a way that the total annual deviations were obtained. It was observed that the quarter-hourly frequency showed a deviation slightly higher than the deviation of the hourly frequency. After calculating the deviations and establishing the relevant differences between the frequencies according to the different mathematical interpolation methods, one of the final stages of this work could begin. The elaboration of the economic impact analysis by means of the calculation of the annual electrical deviations for both hourly and quarter-hourly frequencies.

3. - RESULTS

Having established the basis for the comparative analysis between both time frequencies, the following results were achieved using Matlab (see Fig. 4 and Fig. 5) :

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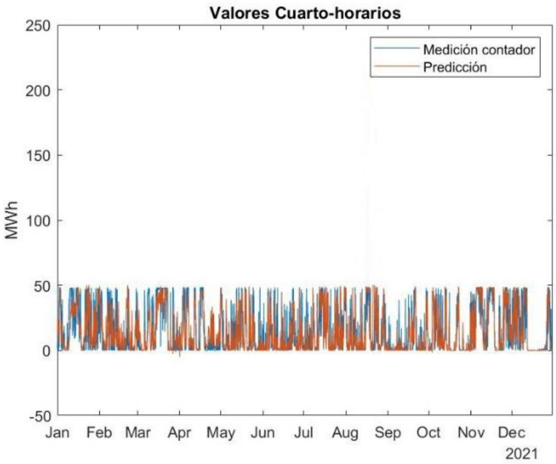

Fig. 4. Electrical deviations in the interval from 01-01-2021 to 31-12-2021 for a quarter-hourly measurement frequency.

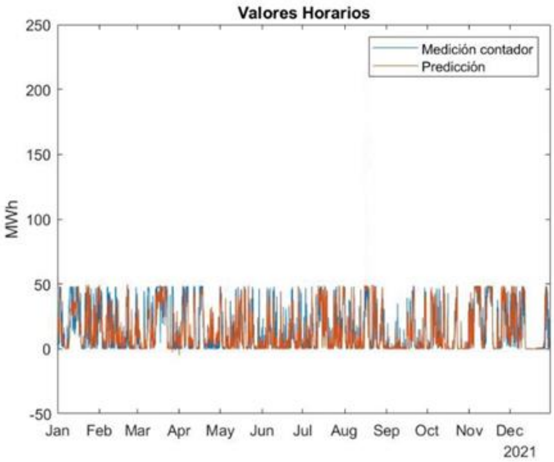

Fig. 5. Electrical deviations in the interval from 01-01-2021 to 31-12-2021 for an hourly measurement frequency.

In order to facilitate the comparison to the reader, the time scale was adjusted monthly and presented here just for the month of January (see Fig. 6 and Fig. 7). The rest of the graphs are showed in [22].

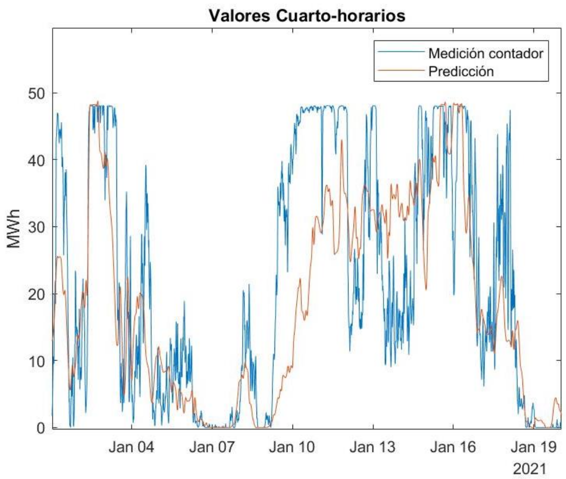

Fig. 6. Electrical deviations in the interval from 01-01-2021 to 20-01-2021 for quarter-hourly measurement frequency.

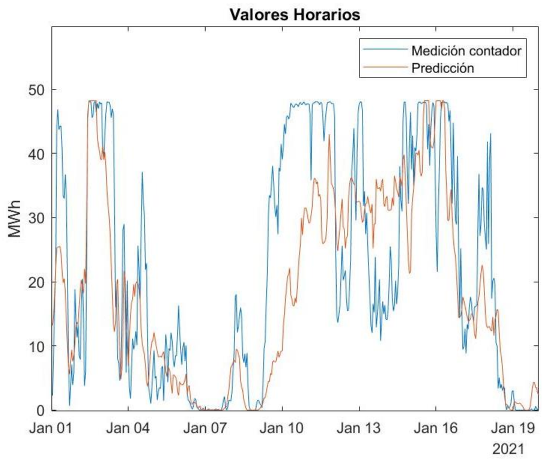

Fig. 7. Electrical deviations in the interval from 01-01-2021 to 20-01-2021 for one hourly measurement frequency.

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Since at first glance it is not possible to reach value conclusions by looking exclusively at the graphs, the deviations for both frequencies were added to obtain the total annual deviations. It was observed that the quarter-hourly frequency showed a slightly higher deviation than the deviation of the hourly frequency. This was attributed to the dispatch prediction itself, which is hourly and as it is logical to think it was better adjusted to the hourly generation, while the quarter-hourly prediction had been estimated from the hourly prediction values. This means that, as a consequence of the use of mathematical methods to obtain the quarter-hourly estimate, these methods conditioned the new values by means of a bias. After their corresponding execution in Matlab, the following results were obtained for the sum of the total quarter-hourly deviation and the sum of the hourly deviation: 2239.7 kWh and 553.44 kWh, respectively.

However, taking into account that both deviations are measured in kWh, since we would like to establish a fair and optimal comparison, we must take into consideration that the deviations of the quarter-hourly frequency, being measured by an hourly unit, must be adjusted by the quotient of K in order to be able to establish the comparison correctly. For this reason, in order to be able to establish a subsequent study of the total deviations, it must be taken into consideration that the deviations associated with the quarter-hourly frequency, when measured by means of an hourly unit, must be adjusted as the values actually obtained correspond to the average power correspond to the average power of deviation in the considered horizon. In this case, when the horizon is quarter-hourly, the period is 4 times smaller and, therefore is 4 times smaller and, therefore, the result must be divided by 4 according to equations (1) and (2):

$$\mathrm{Sum}_{\mathrm{hor}} = 553{,}4402\ kWh \tag{1}$$

$$\mathrm{Sum}_{\mathrm{cuarthor}} = \frac{2{,}2397*10^3}{4} = 559{,}925\ kWh \tag{2}$$

Finally, once the necessary conversion had been made to establish the comparison, the following results were obtained:

$$\mathrm{Sum}_{\mathrm{hor}} < \mathrm{Sum}_{\mathrm{cuarthor}}$$

It is coherent that the total annual addition of the quarter-hourly electric deviations, being higher than the hourly one, translates into a higher cost of associated deviations for a real wind farm. Economically speaking, this situation, given the new methodology for the settlement of deviations, it is of no interest. A possible solution as an alternative to the current situation would be achieved by making generation forecasts following a quarter-hourly frequency distribution directly. This would be done instead of obtaining them from hourly predictions, thus avoiding the inevitable addition of bias in the measurements estimated through the different mathematical methods already discussed.

4. - CONCLUSIONS

The main conclusions from this paper could be summarized as follows:

1. An active real-time market response has a direct impact on the structure of the electricity system. In this regard, in the electricity market, there is a need to have an internal network to promote the exchange of information between market participants, sharing of data on electricity production, consumption, and prices. The development of effective information networks and standards in the electricity market are critical for ensuring the reliability, competitiveness and efficiency of the power system. For example, real-time data on electricity demand and supply can help grid operators balance the system and avoid blackouts, while pricing information can enable consumers to make informed decisions about their energy usage and encourage the development of new and more efficient technologies. Regarding facilitating information exchanges in the electricity market, various standards and protocols have been developed, such as the Common Information Model (CIM) and the Open Automated Demand Response (OpenADR) standard, which are used globally. These standards help ensure interoperability between different systems and enable seamless data exchange between market participants. In addition to the CIM, Spain also has its own specific standards and protocols for the electricity industry, which are developed and maintained by various organizations, such as the Spanish Association for Standardization (for example, UNE-178501, which establishes the specifications for data exchange between distribution system operators and other market participants and the REE (for example, the Grid Code, which establishes the technical requirements for connecting to the grid and

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operating power plants and other facilities). Overall, the need for information exchanges in the electricity market will only continue to grow as the industry becomes more complex and interconnected.

2. Total quarter-hourly deviations tend to be higher than hourly deviations. By modeling an alternative scenario (quarter-hourly in this work), through mathematical methods and from a set of real data belonging to a wind farm, it has been observed that the quarter-hourly deviations tend to be higher. The increase in granularity of the deviations reduces the possibility of offsetting deviations in one the possibility of compensating for deviations in one direction with deviations in the other, and, therefore, it is to be expected that the quarter-hourly deviations would be greater than the hourly deviations. However, it is worth mentioning that this difference is not significantly high, being less than 10%. This implies that the consequences of the change to quarter-hourly adjustment periods will not cause serious economic damage to any company in the sector. And from the point of view of the company, this aspect is the most relevant. Consequently, wind farm forecasting data providers will need to refine their systems to be able to generate schedules with fifteen-minute rather than hourly granularity. Nevertheless, there may be concerns about the potential impact of a quarter-hourly market on energy suppliers, who may face greater volatility in their revenues due to more frequent price changes, especially those using renewable energies. To mitigate these risks, careful planning and stakeholder engagement would be necessary to ensure a smooth transition to a quarter-hourly market.

In conclusion, the introduction of a quarter-hourly market would enable consumers to access more frequent pricing information, which would help them make more informed decisions about their energy usage. This would also create opportunities for more sophisticated demand-side management strategies, such as real-time pricing and automated demand response. However, there are several challenges that would need to be addressed. For example, the infrastructure needed to support real-time pricing and demand response would need to be upgraded, and new regulations would need to be put in place to ensure fair and transparent pricing for all consumers. However, although the amount of electricity that eolic units generate can vary depending on the amount and strength of the wind, variations in air density and the physical characteristics of the wind turbine itself, other forms of renewable energy are becoming increasingly popular as a way to reduce our reliance on fossil fuels and combat climate change [24]-[25]. With continued advancements in technology and improved forecasting techniques that allow them to adjust their operations in real-time based on changing conditions, it is likely that the uncertainty of unmanageable units will continue to decrease over time, making them an even more reliable and efficient source of clean energy in the future.

In short, the impact of the wind power plant on deviations in the Spanish electricity market can be considerable. This is because wind power is one of the cheapest energy sources available, which means that it can help reduce electricity production costs and, therefore, electricity prices. In addition, increased wind power production helps to reduce the deviations between market prices and regulated prices. This is because, when more wind power is available, there is less need to purchase power at regulated prices, which helps reduce diversions. Reducing diversions helps stabilize electricity prices, which is beneficial to consumers. Finally, wind power helps reduce pollution as it does not produce any harmful emissions. This helps to improve air quality and people's health, which contributes to the reduction of deviations in the Spanish electricity market. However, modifications to the wind energy bidding policy in the Spanish electricity market should be carried out according to [26]:

1. Establishing a long-term wind energy bidding policy for a predictable price framework for wind energy producers. This would allow wind energy producers to more accurately plan their investments and energy production strategies.

2. Establishing incentives for wind energy production, such as subsidies, preferential loans and tax exemptions. This would help to increase wind energy production and improve the competitiveness of this energy source.

3. Establishing a market policy to ensure security of supply in wind energy production. This would help ensure that wind energy producers are able to deliver the energy needed by the market.

4. Establish an energy efficiency improvement policy to reduce energy consumption. This would help reduce wind energy production costs and allow producers to maximize their profits.

5. Establish a policy to improve grid connectivity to enable increased wind energy production. This would help improve the efficiency of wind energy production and increase the supply of wind energy to the market.

6. Establish a wind energy surplus management policy to ensure that surpluses are accumulated and used efficiently. This would allow wind energy producers to maximize their profits and reduce production costs.

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As for possible future lines of research, through the present paper, it is hoped that it will serve as a guide and/or precedent for those who in the future will try to explore and address similar issues.

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