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Analysis of the technical and operational availability of a wind farm in Uruguay

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***Abstract*—The massive use of energy from wind is a reality, each year there is a high growth in installed power and the number of wind farms worldwide. However, the investments to be made still remain high and in most countries the performance of the plant is directly related to the financial benefits. Therefore, evaluating the performance of each wind turbine as well as the wind farm is of paramount importance. Based on these factors, this article presents a study of the technical and operational availability of a wind farm located in Uruguay.**

***Index Terms*—Wind farms, technical availability, operational availability.**

I. Introduction

In Uruguay until approximately 2010 most of the electric energy came from hydroelectric dams, oil and imports from Argentina, which was a high cost for the country. Then began a rapid change in the energy matrix, with the implementation of non-traditional renewable sources such as wind, solar and biomass [1]. Wind energy in particular has had the greatest reach, reaching approximately 40% of the energy matrix, with a total of 49 wind farms throughout the country [2]. Currently, the production of wind energy represents a cost reduction compared to the previous energy matrix, in addition to the reduction of CO_2 emissions. According to the National Energy Balance [3], in 2019, 33.6% of electrical energy produced was of wind origin, 55.6% of hydraulic origin, 6% of biomass, 2.8% solar and only 2% of non-renewable origin.

Although wind energy represents a source with many benefits, it is necessary to take into account that there are some uncertainties regarding the production of wind farms, such as measurement uncertainties, uncertainties in long-term adjustment, uncertainties in the modelling of wind resources and uncertainties in the turbine power curve [4]. Moreover, wind generation requires large initial investments, where the profitability of these investments depends on the performance of the wind farms [5]. This profitability is measured according to the generation estimates, however, in many cases the generation is much lower than estimated.

Low productivity may be due to several factors, including machine malfunction, resource scarcity, improper disposal of wind turbines and problems in the management and operation of wind farms. This is addressed by [6] where he analyzes failure detection systems. To determine if a plant is producing what is expected, it is necessary to know the operating time of each machine, defined as availability, these aspects are analyzed by [7], where they determine the availability of a plant with one year of operation.

In addition to causing financial losses, low wind farm production can lead to problems in the operation and planning of the electricity system. Dispatch planning in Uruguay's electricity system is based on resource forecasting, which means that for a given wind speed the wind farm is expected to deliver a certain amount of power. The amount of energy to be delivered to the system is related to the energy guaranteed through contracts. If the plant is not producing as expected, that energy cannot be delivered to the system.

To minimize the negative effects of low productivity, careful maintenance planning is necessary, as well as knowledge of the possible factors that can affect the availability of the turbines. Taking into account this problem, this article aims to carry out a study of the technical and operational availability of a wind farm located in Uruguay. For the development of this study, data from the machine's SCADA system are analyzed.

II. ENERGY AVAILABILITY IN WIND FARMS

The availability can be temporary or energetic. Temporary availability considers the hours when the machine was in operation or stopped, while energy availability considers the production of the wind farm in terms of power [8].

This article will only consider the temporary availability that determines the percentage of the time that the wind turbine is able to generate energy. The calculation is crucial to determine the return on investment, since there are usually losses linked to the unavailability of the plant.

According to IEC 61400-26-1 there are two different concepts of availability:

- Operational or actual availability: Defined as the period of time in which the machine produces energy.
- Technical or contractual availability: Defined as the period of time in which the machine is operating according to the contract specifications.

In the contract for the installation of the plant, operational availability is not guaranteed, but technical availability is. It is possible to have a very high contractual availability but that does not mean that the real one is. According to the IEC 61400-26-1 standard, wind turbine events are classified into twelve categories, which determine whether the wind turbine is available or unavailable. The categories are described below.

Category 1: Total production, the machine is operating according to technical specifications without any restrictions.

Category 2: Partial performance, there are technical restrictions affecting generation.

Category 3: Technical standby, the machine is on but not generating because it is performing other tasks such as unwinding the cable, heating or cooling components.

Category 4: Environmental, the machine is operational but does not generate because it is in environmental conditions out of design, such as very high temperature, high wind speed, etc.

Category 5: Externally required stops, the machine is operational but a stop has been requested due to some external issue such as visits, demonstrations, inspections, bird protection, etc.

Category 6: Bad electrical conditions of the network, the conditions of the electrical network are out of the technical specifications, such as voltage, frequency, phase, etc.

Category 7: Scheduled maintenance, the machine is not operational, normally these maintenance hours are foreseen in the contract.

Category 8: Planned corrective action, this is corrective maintenance that is applied to the machine before a failure.

Category 9: Forced or emergency stop, the generation is immediately disabled due to failures, damages, alarms that compromise the machine, etc.

Category 10: Suspended, if there are maintenance activities and they must be suspended for safety reasons for the personnel, for example bad weather.

Category 11: Force majeure, extraordinary event, out of the ordinary.

Category 12: No communication with the park, communication problems with the wind turbines.

Table 1 shows the 12 categories, the categories to be considered in each analysis. The blue boxes represent the categories that count as availability, in yellow those of unavailability and in grey those that are not taken into account for the calculation.

TABLE I. TECHNICAL AND OPERATIONAL UNAVAILABILITY ACCORDING TO CATEGORIES

	Category 1	Category 2	Category 3	Category 4	Category 5	Category 6	Category 7	Category 8	Category 9	Category 10	Category 11	Category 12
O												
T												

Source: IEC 61400-26-1

III. METHODOLOGY

The availability analysis methodology used is in accordance with IEC 61400-26-1.

a) Data Acquisition

The technical and operational availability is determined by analyzing files from the SCADA system. These show the different alarms coming from each wind turbine, the date they occurred and their duration. In addition, data on energy production and wind speed is available, which is used to determine the category of each alarm. These files belong to a period of time between November 1, 2014 and February 9, 2015.

The set of data is based on the 10-minute period, which is measured every 1 second, according to the IEC 61400-12-1 standard.

b) Calculation of temporary availability

The methodology used is presented in Figure 1. Initially the wind speed and direction data, energy production and also the SCADA system data of the wind turbines are obtained. These data provide the duration and types of alarms on each machine.

In the second step the data are filtered and the records that are corrupted are stored as a NaN (Not a Number). Also, data whose power are lower than what should be measured for a determined speed were removed from the analysis. or that have power equal to zero or much lower than what should be measured for that speed, were removed from the analysis.

In the third step the data are classified in each category and the times when the wind turbine remains in each category are added together. From this, the technical and operational availabilities are calculated.

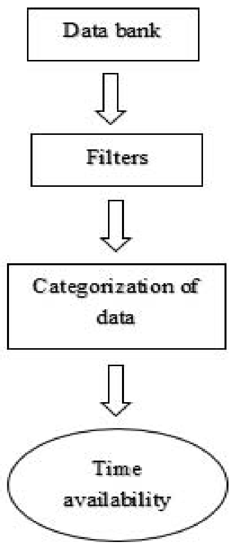

Fig. 1. Flowchart of the methodology used

After grouping the events of the wind turbines in their respective category, hours of availability, technical and operational unavailability of each machine must be counted (here the redaction is a few confuse). After counting the hours, the availability of the turbine is calculated by

$$\text{Availability} = 1 - \frac{\textit{Unavailable hours}}{\textit{Unavailable hours} + \textit{Available hours}} \qquad (1)$$

Finally, the Forced Equivalent Unavailability Rate (TEIF) is calculated, which is the percentage of time the plant cannot operate due to an emergency failure or interruption. This is calculated as following

$$TEIF = \frac{HDF + HEDF}{HS + HDF} \qquad (2)$$

Where:
HDF are the hours of forced stop
HEDF are the hours in which the machine operates with limited power.
HS are the hours of operation.

IV. Results and Discussion

The classified data are presented in Figure 2, showing the number of hours as a function of the number of wind turbines and the category where you can see the number of hours that each wind turbine is in the different categories.

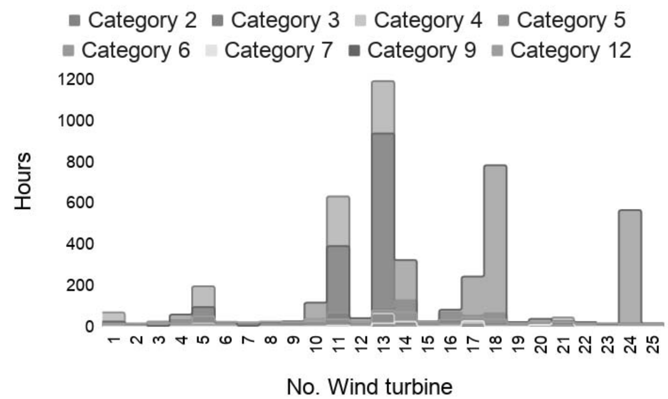

Fig 2. Hours according to category and number of wind turbines.

In Figure 2 it is possible to observe that some machines remain stopped mainly due to category 2, where the machine may be operating with reduced power caused by the effect of degradation, request or external restriction of the network operator. This category stands out mainly in turbines 5, 11 and 13. The second category that stands out is the 9. In this category the machine is stopped due to a failure that compromises the turbine operation. The most affected wind turbines are the 13, 18 and 24, totalizing 935, 780 and 563 hours without generation, respectively.

The results obtained from technical and operational availability are presented in Figure 3, where it can be seen that 72% of the turbines installed in the park have availability higher than 97%. For these turbines the difference between technical and operational availability does not exceed 1%.

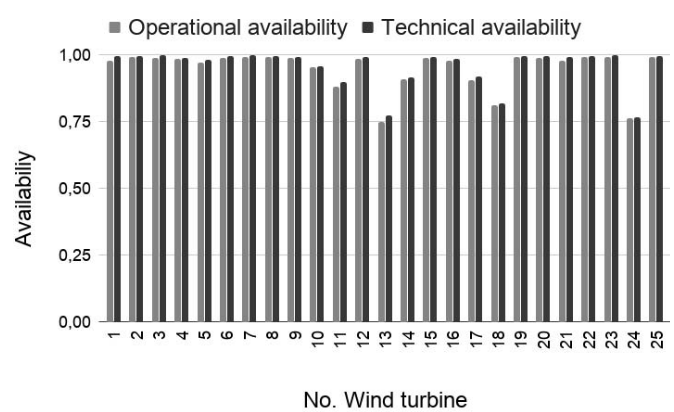

Fig 3. Technical availability and operation

Turbines 11, 13, 15, 18 and 24 have less than 90% availability, where 13, 18 and 24 remaining below 80%. For a more detailed analysis, in Figures 4 and 5 the monthly percentages for these turbines are shown.

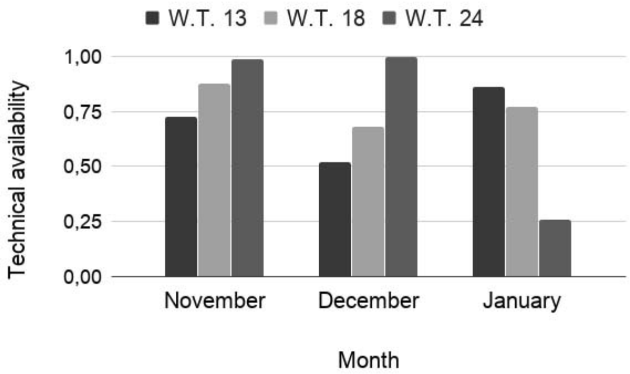

Fig. 4. Monthly technical availability

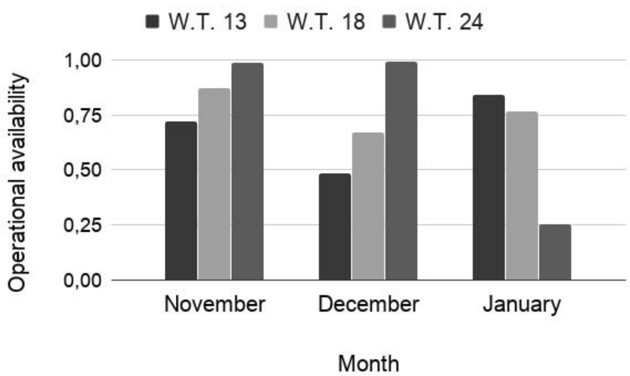

Fig. 5. Monthly operational availability

From the monthly analysis it is possible to conclude that turbines 13 and 18 have operating problems that are constant over the three months of analysis. The turbine 24, in November and December, expressed a technical availability equal to 99%, falling to 25% in January.

In December month the technical availability of turbine 13 was 52% while the operational availability was equal to 49%. This is due to that this turbine was subjected to many hours of partial operation.

The Forced Equivalent Unavailability Rate resulted in 0.124, meaning that 12.4% of the time the plant remains unavailable due to a forced shutdown condition.

V. CONCLUSIONS

The impact of availability can be very important in the management of a wind farm, and is also a key concept for generation contracts, considering that profits and penalties will be defined based on this term.

It is important to emphasize the need for inspections in the turbines that presented the lowest values of unavailability, with special focusing on the turbines that present problems throughout the analyzed period.

The results obtained showed that one of the wind turbines, specifically number 13, has a notoriously low availability in relation to the other ones.

For plant performance analysis, it is necessary to check whether or not the wind turbine is available for generation being necessary to assess whether the turbine is producing under normal conditions or similar to the theoretical power curve of the machine.

The analysis of causes leading to low availability in some turbines must be done carefully in order to correct possible failures that affect the generation in the plant. Therefore, the analysis realized along this work is important to define the cause of low productivity in the wind farm, enabling decision making for the actions that must be taken to correct this condition.

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