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MAINTENANCE OF WIND TURBINES – THE INFLUENCE OF THE TOWER BEHAVIOR ON THE SET UP CONDITION MONITORING SYSTEM

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Abstract. *The main goal of this work is to assess the effects of the tower vibrations on the response of the main components, mainly in the gearbox, generating false alarms in the CMS system. The gearbox is the most critical component in wind turbines since it is an expensive component and presents high failure rates causing long repair times. It should be noticed that normally the vibration data measurements are made on the top of the tower which is eighty meters high, this fact frequently contributes to false alarms occurrences in the conditioning monitoring system (CMS). These failures typically cause the entire replacement of the component which is extremely expensive. In order to quantify the influence of wind forces on the dynamic response of the tower, eight low frequency accelerometers were mounted, six inside the tower at three different levels and two inside the nacelle. The condition monitoring of the main components is based on the signals coming from vibration sensors installed on the main components (main bearing, gearbox and generator). Data is post-processed by using MATLAB software, in order to understand the influence of the tower response on the monitored signals on the nacelle components, thus allowing a better adjustment of the alarm levels.*

1 INTRODUCTION

The maintenance of wind turbines is characterized by the difficult accessibility, dependent on weather conditions forces, high spare part costs and availability of wind turbine components manufactures and operators.

Wind turbine technology has an unique technical identity, remarkable advances in the wind power design have been achieved due to modern technological progress. However, the industry still experiences premature turbine component failures [1]. The motivation for this research arises after some fall and early failure of wind turbine gearboxes thereof, resulting in substantial costs and lengthy stoppages of the wind turbines. The gearbox is the leading contributor to total turbine downtime and the element more expensive as a whole.

The goal of this study has the intention to show the importance of vibration analysis as a tool for improving the maintenance in wind turbines and planning the implementation of conditional preventive maintenance, reducing unexpected downtime and loss of production energy.

In order to understand the influence of the tower response in the early failure and in the monitored signals on the nacelle components, eight low frequency accelerometers were mounted, six inside the tower at three different levels and two inside the nacelle, the data was stored during 6 months studying possible resonances. This case study proves that a condition monitoring system generates an economic benefit compared to the currently applied maintenance strategy. However, the magnitude of this benefit strongly depends on the set-up of the alarm levels, conditioning the performance of the condition monitoring system (CMS).

1.1 Condition Monitoring System for Wind Turbines

In the wind turbine industry is debated if it’s necessary the implementation of the maintenance based in the condition, however, the time of performing a maintenance action is dependant on several uncertain factors, like, weather conditions, availability of some equipment, logistics, which causes long waiting times and possible consequential damage. The main contribution of the CMS is the early detection of the mechanism failure and move failure modes to lower failure repair classes which reduces the effect of failure [2].

The most important benefit of implementing a CMS lies in the ability to detect a potential failure before the actual functional failure happens, which reduces or completely prevents consequential damage and corrective maintenance actions. Preventing consequential damage ensures a cost reduction and a gain in availability of the equipment. Although preventing consequential damage is an important or maybe the most important gain when implementing a CMS [3].

A failure that is detected by the CMS before leading to a functional failure, creates the opportunity to keep the gearbox running while the lead time of the appropriate components is passing by. As a result, the stock level can be reduced without increasing the risk of running out of spare parts.

Most operators just collect data related to CMS and don’t correlate with the tower vibrations, as a result some operators lack a full understanding of their cms alarm levels.

2 CASE OF STUDY

2.1 Description of the experimental model

In this work a wind turbine Vestas – V80, with 2MW was studied, they are pitch regulated upwind turbines with active yaw and rotors with three blades. The rotor diameter of V80, is 80 m. The special opti-speed feature enables the rotor to operate at variable speed. The optitip, is the pitch angle of the blades they are constantly regulated to the optimal angle for current wind conditions. This optimizes power production and noise levels. The blades are made of fiberglass reinforced epoxy and carbon fiber. Each blade consists of two blade shells, bonded to a supporting spar. Special thread inserts connect the blades to the blade bearing. The blade bearing is a 4-point ball bearing, which is bolted to the rotor hub.

The main shaft transmits the power to the generator through the gearbox. The gearbox is a combined planetary and helical gearbox. From the gearbox, power is transmitted via a maintenance-free composite coupling to the generator. The generator is a special asynchronous 4-pole generator with wound rotor.

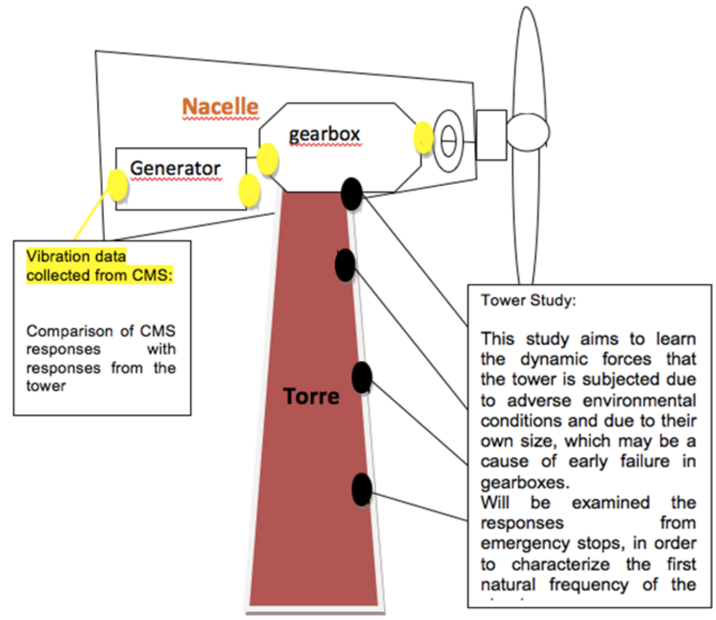
At high wind speeds, the opti-speed and the pitch regulation keep the power at nominal, regardless of the air temperature and density. At lower wind speeds, the system optimise the power output by selecting the optimal RPM and pitch angle. The wind turbine brakes by full feathering the blades. A parking brake is mounted on the gearbox high-speed shaft. The position of the blades is regulated by a hydraulic/mechanical pitch system enabling the blades to rotate 95°. This system also supplies the pressure for the disc brake system.

In the operational mode emergency stop the turbine brakes by full feathering the blades (aerodynamic brake), if it is the manual emergency stop they are activated by the aerodynamic brake and the hydraulic disc brake, which is mounted on the high speed shaft of the gearbox.

All functions of the wind turbine are monitored and controlled by SCADA.

The glass fibre reinforced nacelle cover protects all the components inside the nacelle against rain, snow, dust, sun, etc. A central opening provides access to the nacelle from the tower. An 800 kg service crane is located inside the nacelle, with the capacity to hoist main components of 7,500 kilograms. The tubular steel tower has a service lift inside.

2.2 Description of the work methods



Vibration data collected from CMS:

Comparison of CMS responses with responses from the tower

Tower Study:

This study aims to learn the dynamic forces that the tower is subjected due to adverse environmental conditions and due to their own size, which may be a cause of early failure in gearboxes.
Will be examined the responses from emergency stops, in order to characterize the first natural frequency of the

Figure 1 – Work scheme

2.3 Description of the physical model and sensors installation on the tower

In the experimental work it was selected the 3 directions x, y e z for the collections.

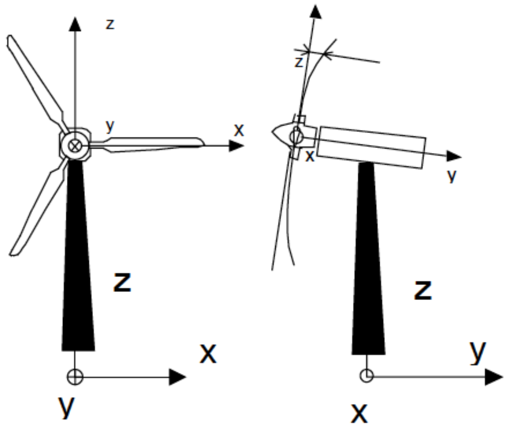


Figure 2 – Simplification of the model and directions of data collection

The steel wind tower has conical shape divided into three sections. The first has a height of 10.7 m, where two sensors are installed in the x and y directions (identified by x1 and y1), as can be observed in figure 3, the second also has a 33.7 m in x and y (identified by x2 and y2), note in figure 4, and a third at a height of 56.9 m, the three sensors in x, y and z (identified by x3, y3 and z3), see figure 5.

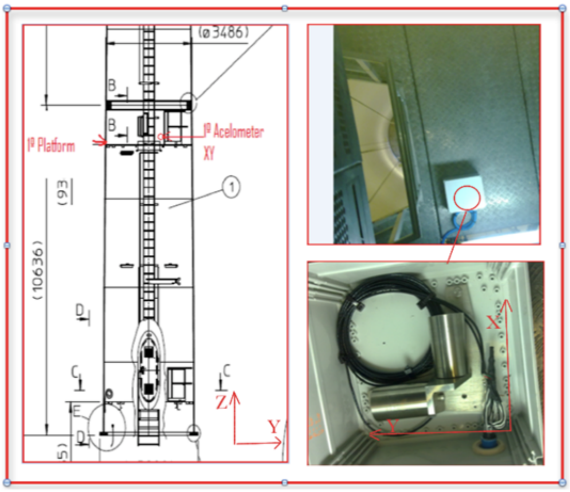


Figure 3 – Localization of sensors at platform1 – 10,6m

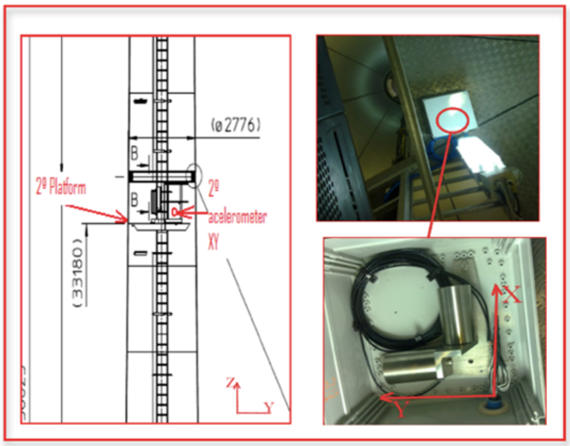


Figure 4 – Localization sensors at platform 2 – 33,18 m

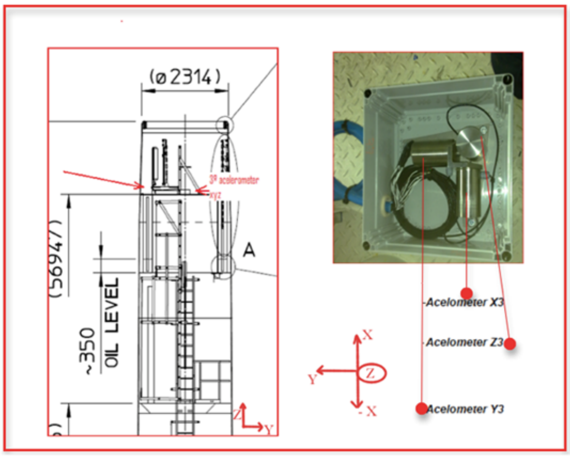


Figure 5 – Localization of sensors at platform 3 – 56,9m

3 RESULTS

3.1 Comparison of results of the CMS based in the Tower response

To be possible to compare vibrations in mechanical components (fig.6) and vibrations on the tower (fig. 7) it was necessary to find similar wind speeds at 8 m/s.

On figures 6 and 7 below we have observed that the frequencies of the mechanical components are transmitted to the structure (tower) and they show greater amplitude at the highest points of the tower.

Fig. 6 illustrates the spectrum of frequencies in acceleration and the peaks are at 24 Hz, that is the TMF tooth mesh frequency (1st stage), 28 Hz is the fundamental frequency and at 188 Hz is the TMF (2nd stage).

In the spectrum Fig.7 can be observed that various frequencies appear that cannot be related to the kinematical data. The frequency of 3.12 Hz presents a higher amplitude at X2, situated 33m high, followed by a 10 Hz with bigger expression at the point Y1 located at 10,7 m. Regarding the known frequencies, such as fundamental and meshing it is clear that presents at x3 twice the amplitude than X1.

At high frequencies is where the points X1, Y1 and X2, begin to distinguish themselves from points located at the top of the wind tower.

Frequencies 48, 72 and 96 Hz are harmonic with the frequency of engagement at the 1st stage, and all of them are felt with higher amplitude at the highest point of the tower (x3).

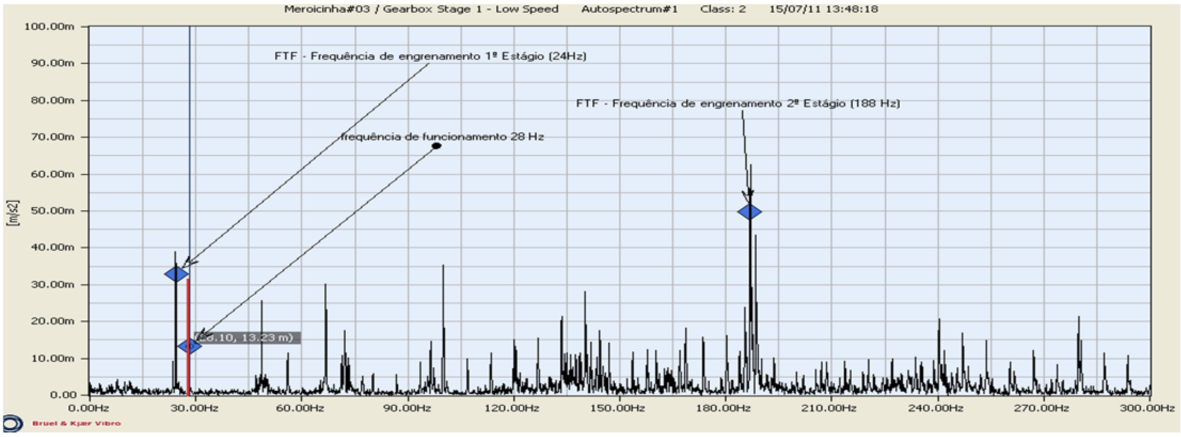


Figure 6 – Spectrum from CMS – Amplitude $F_{fundamental}$ e $TMF_{1^o\ e\ 2^o\ stages}$

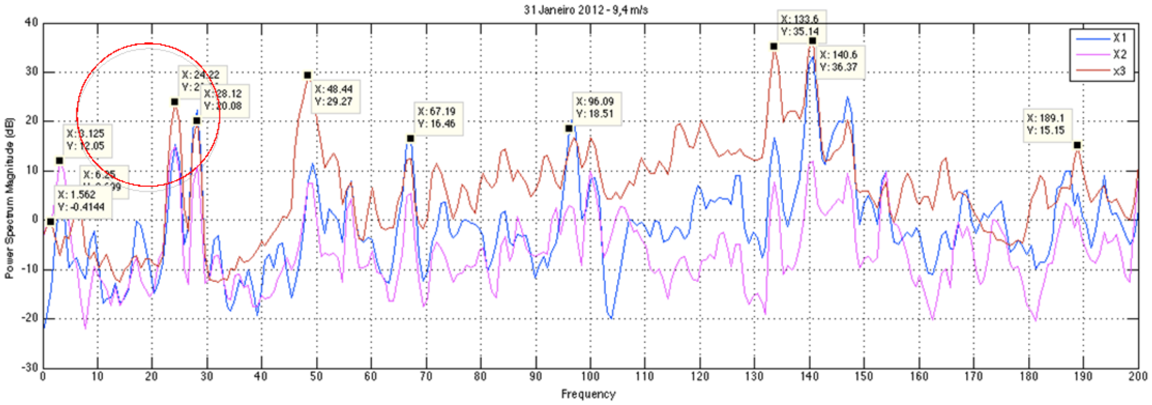


Figure 7 – Power density spectrum of sensors at 3 different levels – x1,x2 and x3

Through Fig. 8 it can be observed that for wind speeds equal to 6.5 m/s in the same sensor x3, but on different days, the response of the structure is different just by changing the wind direction.

It is found that the response of the tower at the point x2 does not suffer large changes due to wind direction changing. We can verify that the highest point of the tower (x3) suffers the major changes at low frequencies, which may contribute to the response variation in CMS.

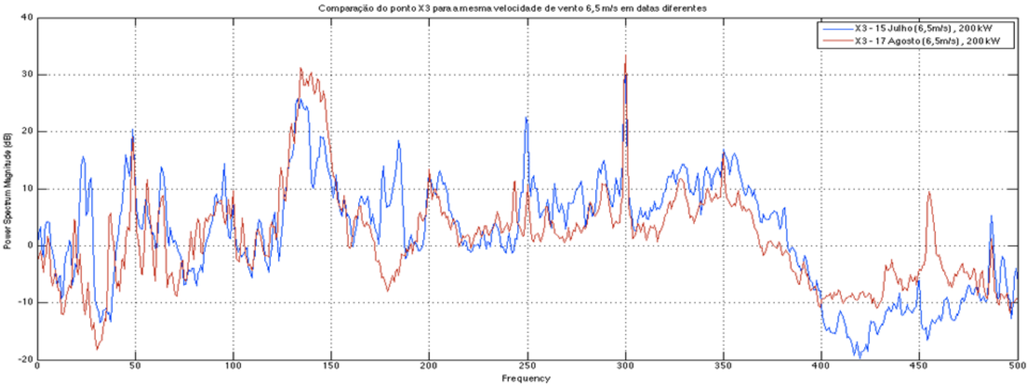
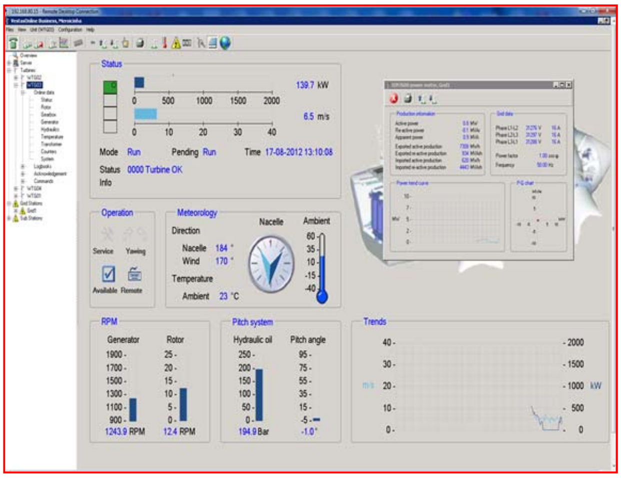


Figure 8 – Power density spectrum sensor x3 for different days but with wind speed equal

On 17 and 31 August 2012 we performed two safety stops in the turbine Nº 3 in Meroicinha park, in order to simulate the stops due to the action of winds exceeding 25 m/s and thus allowing the knowledge of the responses of the structure and identify natural frequencies.



139.7 kW

6.5 m/s

Mode Run

Pending Run

Time 17-08-2012 13:10:08

Status 0000 Turbine OK

Info

Nacelle 184 °

Wind 170 °

Temperature

Ambient 23 °C

1243.9 RPM

12.4 RPM

194.9 Bar

-1.0°

Figure 9 – Recording of test conditions during stop August 17

After these stops the data was treated in Matlab program, the Fourier transforms were made just in the marked red window corresponding to the 20s of total 81.92s where the wind turbine was maintained without producing.

In Figure 10 we can observe a gap between windows (20s), but we worked in Matlab only the cells where the wind turbine stopped producing.

We selected 17 and August 31 because they presented very different wind speeds 5.6 m / s and 13 m / s respectively.

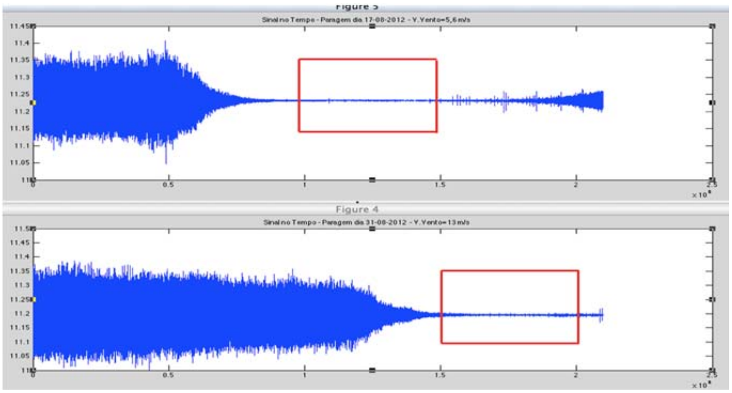


Figure 10 – Registration of the signal in time for 81.92 s - red window 20s after stopping

Figure 11 shows the spectrum of the sensor's response placed at the highest point of the tower (3), in the y direction, amplitudes of responses are compared in level 3 on 17 and 31 August.

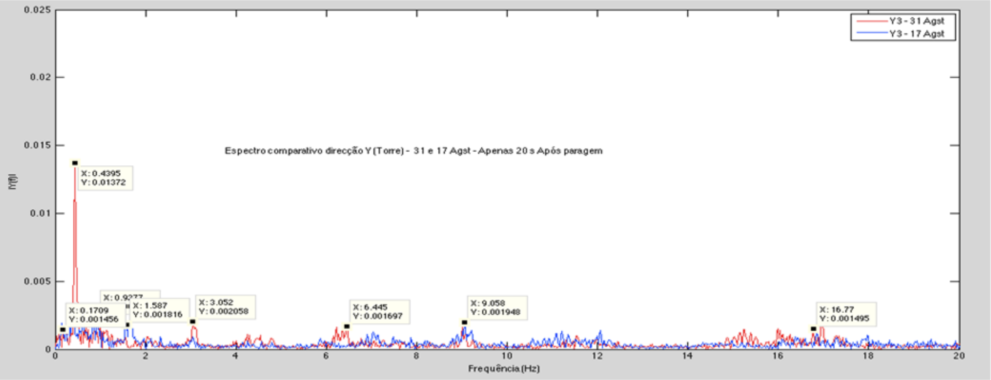


Figure 11 – Comparison of amplitudes level Y3 on 17 and 31 August

Fig.12 illustrates the comparing responses and is possible to observe that for the first natural frequency of 0.43 Hz, is presented with higher amplitude in the Y direction, the second to 3 Hz shows the largest responses in level 2 in X direction.

We also found some expression with amplitudes at 4 Hz, 6 Hz, 9 Hz, 11Hz and 16 Hz. These have higher amplitude at the highest point level 3.

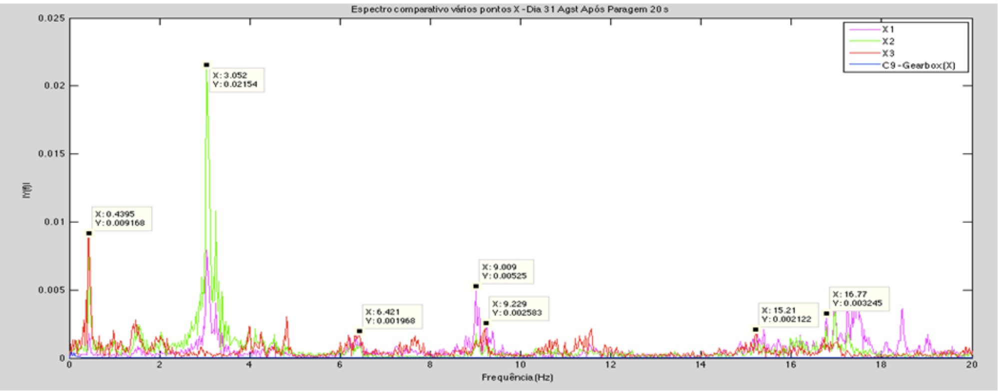


Figure 12 – Frequency spectrum after stopping in x direction

In Figure.13 it can be observed that the frequency response obtained in the tower appears in the spectrum obtained by the manufacturer of CMS (Bruel Kjaer), but these do not match with the kinematical data of mechanical components calculated previously, only the frequency of 12 Hz corresponds to the fundamental train frequency of main bearing, allowing to validate the information obtained in the previous spectrum of the presumed natural frequencies.

As can be observed in Figure.13 below red frequencies found in the response of the tower are marked.

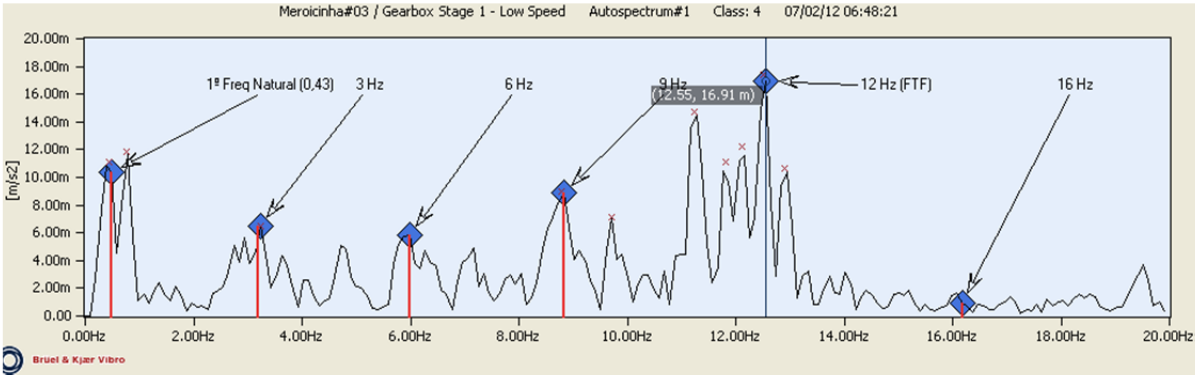


Figure 13 – First natural frequencies

If we compare frequencies obtained with the emergency stop, with the frequencies obtained by the manufacturer through modelling for automatic calculation, it can be observed that the values of the first two frequencies are very close.

Natural frequencies	Test	Manufacturer
1ª	0,43 Hz	0,37 Hz
2º	3 Hz	2,81 Hz
3º	9 Hz	8,27 Hz
4ª	16,8 Hz	16 Hz

Tab. 1 – Comparison of the frequency response between assay and manufacturer

4 CONCLUSION

The tests performed have allowed understanding that the first natural frequencies do not coincide with the operating frequency, avoiding unwanted resonances.

The vibrations generated in mechanical components such as gearbox are felt with some expression in the upper parts of the tower, the vibrations on the tower do? not affect the mechanical components but change the results of the CMS, causing false alarms, the frequency of defects is too close to a natural frequency (11.5 Hz).

This point will require monitoring and further progress, once due to the parameterization in cms manufacturers have not recorded the presence of these frequencies.

It is extremely important to know these frequencies, as they will allow to link and separate the information obtained through the CMS.

The aim of this work was focused on the evaluation of online monitoring systems for mechanical vibrations, these seem quite reliable but need to adjust the alarm values thus avoiding early replacement of some components.

It was observed that the behavior of the support tower of the mechanical components influence the response of the CMS, even with relatively low wind speeds.

Through these tools, we will be able to detect the fault at an early stage, to know its origin and calculate its expected lifetime.

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