Vibration Analysis of an Outdoor Air Conditioner Unit using BK Connect Software: A case study

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1. ABSTRACT

Improving the efficiency of Air Conditioner units requires better monitoring and fault detection of its electrical fan motors. This study focuses on analyzing the vibration generated by electrical motors of the outdoor unit. First, a tachometer was used to measure the RPM value and then vibrations were measured using BK Connect software from the top four corners and the bottom four corners of the unit in x, y, and z directions. After using an FFT analyzer to transform the time-domain data to the frequency domain, a graph was obtained from each corner for further analysis. There was almost an 80% decrease in the vibration of the bottom corners to the top four corners. That is because of the insulation which was used at the bottom and because of the weight of the unit. It cannot be differentiated since the unit was an existing one and it cannot be unplugged. In addition, the top four corners' graphs were analyzed to determine the motors' faults. Finally, by using insulation and taking the necessary steps (changing the cage and parts of the motors) for the faults, the efficiency of the motors and the unit was increased.

Keywords: Electrical motors, Vibrational analysis, FFT analyzer, faults identification

2. INTRODUCTION

In vibration analysis, there are three things to be considered; frequency, amplitude, and period. Frequency is the number of cycles of a repeating event per second, and the unit is Hz. The period is the duration of time of a cycle in a repeating event. Therefore, the period is the reciprocal of the frequency. Amplitude is the maximum extent of the repeating event[1]. The speed value for rotating machines is measured in RPM.

Amplitude can be measured in three types of physical quantities; displacement, velocity, and acceleration. Velocity is most commonly used in the analysis of electrical motors[2]. There are two ways of displaying the vibration signal. The first one is the time waveform or time domain view and the second type is the spectrum or frequency domain view. All the amplitudes of frequencies in the time waveform are made separately in the frequency domain[3]. According to Fourier analysis, any physical signal can be transformed into a number of discrete frequencies or a spectrum of frequencies over a continuous range[4].

The cause of the vibration can be identified by analyzing and monitoring the vibration in different places of the motors. It is important to identify and solve the problems in time to avoid long-term damages or immediate failure of the unit. Fault detection and diagnosis are very important in system safety[5]. Vibration analysis requires lots of knowledge regarding the type of vibration, the source, the cause of vibration, the forces which appear, and other relevant factors. Electrical causes and mechanical causes are the two categories of causes which affect motor vibrations. Electrical causes are flux variation around the stator that produces a variety of attractive force between the stator and rotor, broken rotor bars, or short circuits of a part of the winding. Mechanical causes are motor unbalance, improper base, and usage of wear bearings[6].

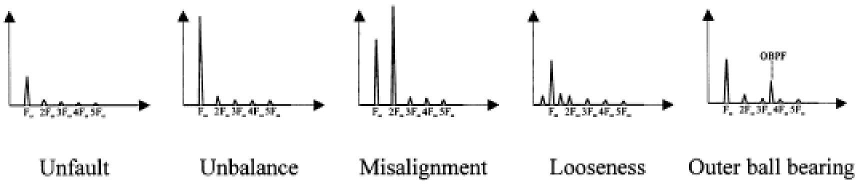

Figure 1: Qualitative Vibration Spectra in Unfaulty Condition and in Presence of Some Typical Faults

Figure 1 shows the vibration spectrum patterns when there are no faults and when the defects occur[7]. It means that if there is a fault in the motor, there is a specific condition in the peak values[8]. If there are no faults, then the 1st peak value comes under the shaft rotating frequency (fω).

This study focuses on monitoring and analyzing the vibration of the electrical motors of an Air Conditioner outside unit. The cause of the vibration can be identified by analyzing and monitoring the vibration in different places of the motors. It is important to identify and solve the problems in time. Otherwise, long-term damages or immediate failure can occur. Fault detection and diagnosis are very important in system safety.

The main objective of the study is to analyze the vibration of the electrical motors of the AC outside unit. Also, figure out the faults of the motors and improve the efficiency of the motors of the AC outside unit.

3. METHODOLOGY

The methodology of the study contains three main steps; measurements, data collection, and data analysis. First, the functions of the BK Connect software were studied. Then the RPM values of the two motors of the AC unit were taken with a tachometer. Then the accelerometers were connected to the sensor box through x, y, and z directions.

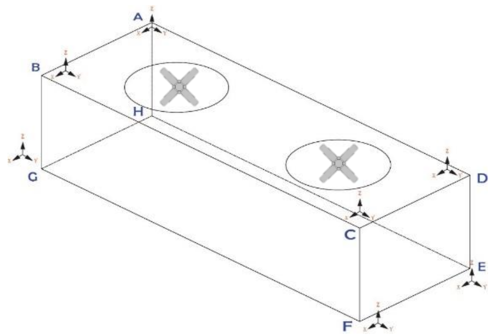

Figure 2: The Sketch of the AC Unit

The vibration data were taken from the top four corners and bottom four corners through x, y, and z directions with the sensor box through the BK Connect software. The readings were taken under a normal working day condition. Nine readings for every corner were taken in every direction for the study. Velocity (mm/s) vs Time (s) was taken as the readings and it was converted to the Velocity vs Frequency with the FFT analyzer of the BK Connect software. Then a graph from every nine readings was taken for further analysis.

Then the seven peak values (amplitudes of velocity) were taken from the graphs. Then the top and bottom corner values were analyzed separately. Averages of the seven values of every corner and direction were analyzed to figure out the reduction of vibration due to the insulation which is installed at the bottom. Then the values of the top corners are analyzed to figure out the faults of the electrical motors of the AC unit. There were no unfaulty AC unit values to compare the values of the motors. Therefore, the faults were identified as specified in literature review with probabilities.

4. RESULTS AND DISCUSSION

The measured RPM value for both motors is 720 and then the shaft rotating frequency of the motors (fω) is 12 Hz (720/60). The following figures (Figure 3, Figure 4, Figure 5) show the velocity FFT spectrums of the top four corners through the x, y, and z directions respectively. All the spectrums are obtained and analyzed with the BK Connect Software. Those spectrums show the peak values of the top four corners within the range of 0 Hz to 800 Hz. Every figure shows when the frequency is increased, the values of the peaks become low. It means when analyzing the vibration spectrums of electrical motors, it is better to see the peak values within a small range.

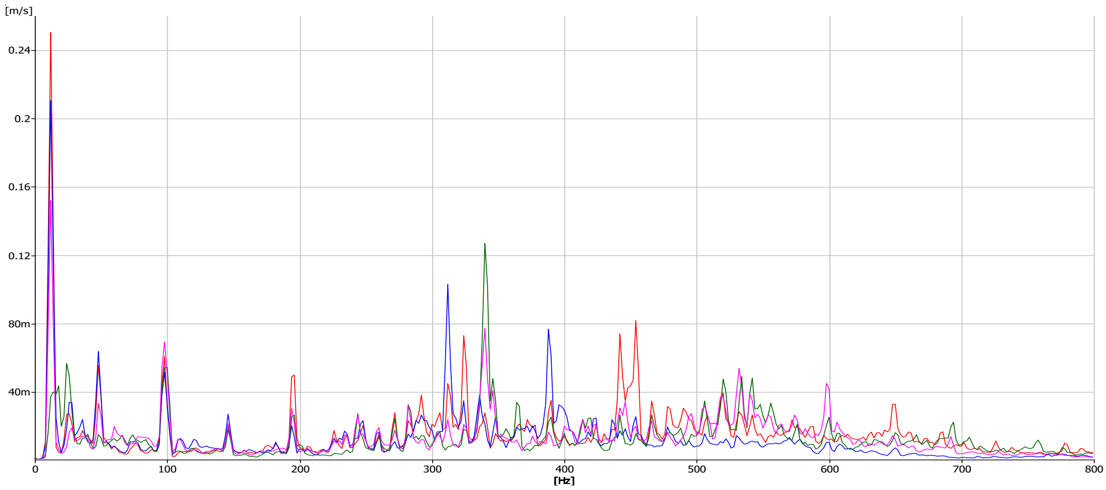

Figure 3: Velocity FFT spectrum of A(red), B(blue), C(green), D(purple) corners through x direction

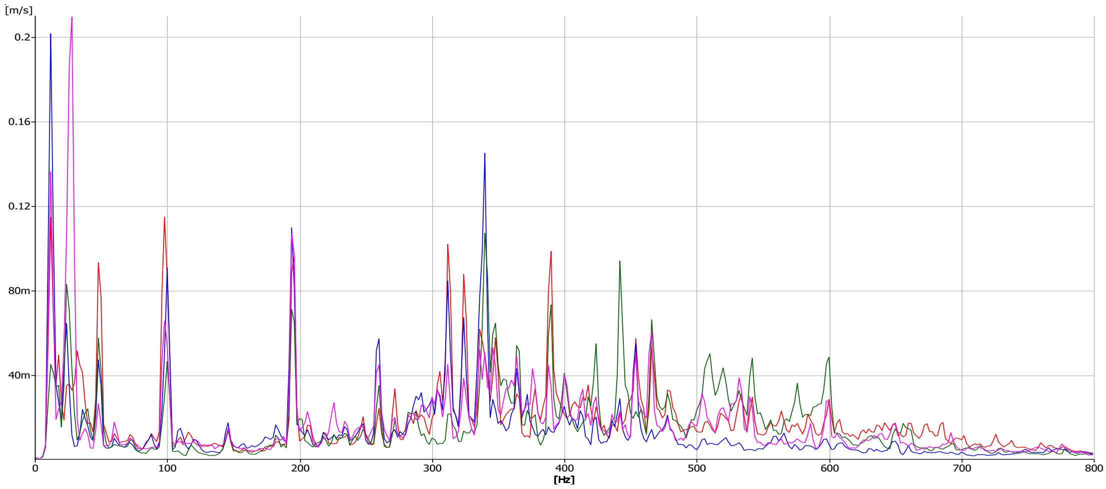

Figure 2: Velocity FFT spectrum of A(red), B(blue), C(green), D(purple) corners through y direction

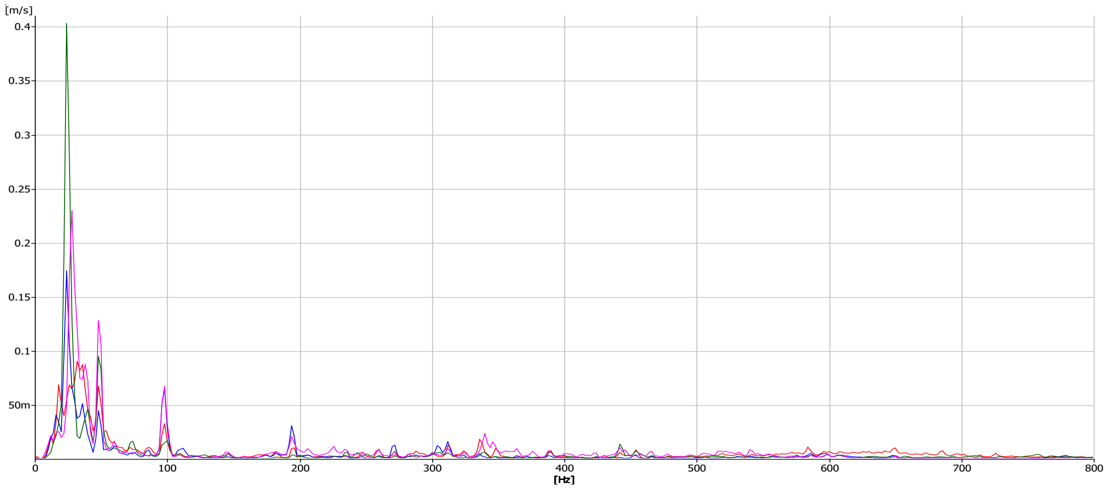

Figure 5: Velocity FFT spectrum of A(red), B(blue), C(green), D(purple) corners through z direction

Then the maximum seven peak values were taken from every corner (Top and Bottom) and direction (x, y, and z). The peak values were obtained with the BK Connect Software. Then the average values were calculated corner-wise using MS Excel. Table 1 shows the percentages of the reduction of the vibration. The reduction was calculated by getting the difference between the values of the top corners and the bottom corners and dividing it by the top corners' values. There is around an 80% reduction in vibrations at the bottom corners as compared to the top corners. Therefore, there is a huge reduction of the vibration and it helps to increase the efficiency of the motors as well as the AC Unit. The reasons of it cannot be differentiated since the unit was an existing one, it belongs to a particular company and cannot be unplugged.

Table 1: The Percentage Values of the Reduction of the Vibration

Corners	Average of Peak Values (Top) (mm/s)	Average of Peak Values (Bottom) (mm/s)	Reduction Percentage (%)
A and H	78.8 (A)	15.1 (H)	80.9
B and G	81.0 (B)	16.1 (G)	80.1
C and F	74.8 (C)	13.6 (F)	81.9
D and E	78.7 (D)	11.4 (E)	85.5

Since there is a huge reduction in the bottom corners, the peak values of the top corners were taken for identifying the faults in the motors of the AC Unit. Since there are no specific frequency values of an unfaulty AC Unit to compare the values which obtained with the AC Unit, the results were taken as probabilities of the faults that can occur.

Table 2: The Probability of Faults of the Motors that can occur

Possible Failure	Condition (Related frequency of peak values)	Count	Probability (%)
Unbalance	12 Hz	6	50.0
Electrical problems	12 Hz	6	50.0
Misalignment	24 Hz or 36 Hz	5	41.7
Looseness	12 Hz or less than 12 Hz	6	50.0
Bearing Problems	36 Hz to 48 Hz	1	8.3

The literature shows if there is a fault in the motor, then a specific peak value occurs in the FFT spectrum. Those studies were done with a single sensor which is mounted on the motor. But, in this study, the motors are inside of the AC Unit and the vibrations were measured from the AC Unit as well as there is 3-dimensional data for this study in the four corners. Therefore, there are twelve different data for identifying the faults. So, the specific conditions of the frequencies which have the peak values were studied and the faults were considered as the peak values. Table 2 shows the specific condition (where the peak should come) for the several faults that can occur in the electrical motors. Since there are twelve data, the peaks were counted and the faults were taken as probabilities (if there are specific peaks in all the twelve data, then the probability is 100%). Table 2 shows the probabilities of the faults that can occur in the electrical motors of the AC Unit. There is a 50% of maximum probability of occurring faults; unbalance, electrical problems, and looseness of the motors in the AC Unit.

5. CONCLUSION

The vibrations of the electrical motors of the AC unit were analyzed in the study. There is around an 80% reduction of the averages of the seven highest peak values (amplitudes) of the vibration at the bottom four corners of the mount with respect to the top four corners. It is because the insulation which is installed at the bottom. Use of an insulation material reduce the vibration and increase the efficiency of the motors. There are 50% chance of occurring unbalance, looseness and electrical problems in the motors of AC unit, 41.7% chance of occurring misalignment faults of the motors of the AC unit. Therefore, taking necessary steps (changing the cage and parts of the motors) for the faults can improve the efficiency of the motors as well as the AC Unit.

6. REFERENCES

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