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Gabriela Raţă, Mihai Raţă

System for Monitoring and Analysis of Vibrations at Electric Motors

The monitoring of vibration occurring at the electric motors is of paramount importance to ensure their optimal functioning. This paper presents a monitoring system of vibrations occurring at two different types of electric motors, using a piezoelectric accelerometer (ICP 603C11) and a data acquisition board from National Instruments (NI 6009). Vibration signals taken from different parts of electric motors are transferred to computer through the acquisition board. A virtual instrument that allows real-time monitoring and Fourier analysis of signals from the vibration sensor was implemented in LabVIEW.

Keywords: Vibration measurement, FFT, AC motors, DC motors, Sensors

1. Introduction.

The vibration is a dynamic phenomenon, which appears in the elastic mediums, due to local excitation. We can say that the vibration is a mechanical oscillation around a reference point which defines the motion of a mechanical system [1].

Vibrations are characterized by the following quantities:

- displacement

$$\mathrm{d} = \mathrm{D} \cdot \sin(\mu \cdot t)\,, \tag{1}$$

- velocity

$$\mathrm{v} = \frac{\mathrm{dd}}{\mathrm{dt}} = D \cdot \mu \cdot \cos(\mu \cdot t)\,, \tag{2}$$

- acceleration

$$\mathrm{a} = \frac{\mathrm{d}^2 d}{dt^2} = D \cdot \mu^2 \cdot \sin(\mu \cdot t)\,. \tag{3}$$

It is more advantageous to measure the acceleration, because the other two parameters can be obtained through integration with electronic circuits. The output of a vibration sensor gives a voltage proportional to the acceleration, velocity or displacement.

Since the appearance of the first industrial electrical machines, the engineers were interested in the vibration reduction or isolation. The need for accurate measurement and analysis of vibration has become more prominent [2]. In the last time, the vibration measurement technology was improved. This technology can provide a continuous oversight of electrical machines operating at high speeds. Using piezoelectric accelerometers for converting vibratory movements into electrical signals, the vibrations can be measured and analyzed.

The monitoring programs in industrial environments can provide an early warning of the problems that occur due to vibrations. In an industrial environment where the equipment efficiency is becoming increasingly important, the prevent of unexpected damages is extremely important. The electric motors as main equipment in all industrial sectors are a relevant example. Although are considered as very reliable due to construction techniques, they are subject to harmful conditions that can affect both their performance and their operational life [3].

Vibration monitoring on electric motors can be very beneficial. This determines a better reliability and improved performance for any predictive maintenance program. For example, on induction motors, in addition to the mechanical problems, such as misaligned couplings and unbalance, the vibration monitoring can detect electrical problems that cause mechanical vibrations. Some of them are: air gap variation, broken rotor bars and bearing fluting.

2. The proposed vibrations monitoring system.

The monitoring system of vibrations occurring at two different types of electric motors is presented in this chapter. Figure 1 shows the system block diagram.

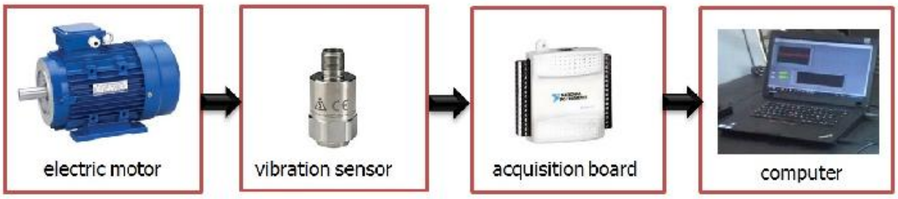

Figure 1. Block diagram system for acquisition, monitoring and vibration analysis.

As we can see from block diagram, a piezoelectric accelerometer (ICP 603C11), a data acquisition board from National Instruments (NI 6009) and a computer were used.

Accelerometers are precision measurement instruments that can provide the parameters: vibration acceleration, vibration velocity and vibration displacement. Many industrial accelerometers employ a sensing element with either a quartz or ceramic crystal. Quartz sensing elements are typically used because they are stable over time and have a small change in the output signal with temperature. Ceramic sensing elements provide excellent resolution and durability in noisy environments and can be designed to provide measurements at low and high frequency [4]. We also used a signal conditioner ICP-480C02 (from PCB Piezotronics). Installing the ICP sensor is magnetic, representing a convenient method for portable measurements, commonly used for vibration monitoring of electric motors. Accelerometers are typically placed at key locations on the motor. The sensor connection to the computer was achieved by using a NI USB 6009 acquisition boards. It has a USB interface with 4 inputs, 2 analog outputs, two digital inputs or outputs ports [5].

First, the vibration signals were acquired and analyzed from an induction motor. Through elastic coupling, the induction motor rotates a load which is made with multiple disks. The inertia moment of the load is established by the discs number used. One accelerometer, magnetically coupled and rotated around the motor to capture various data collection points, has been used. For this analysis, the experimental arrangement illustrated in Figure 2, has been made.

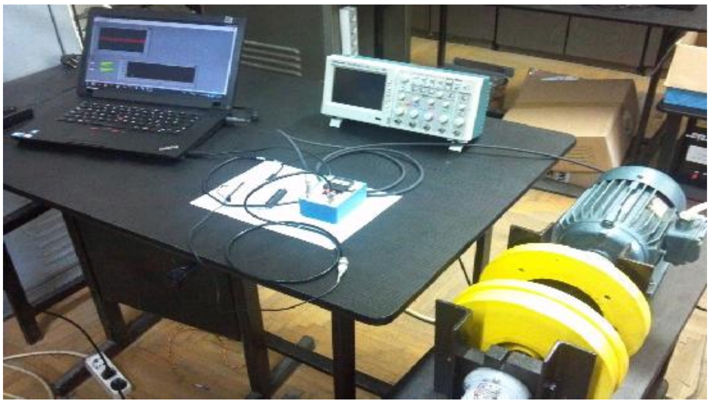

Figure 2. Experimental arrangement for acquisition, monitoring and vibration analysis at an induction motor.

The measurements were made in six distinct points (Figure 3) on the axis x and y:

- ✓ on x-axis: outboard motor bearing (1), inboard load bearing (3), outboard load bearing (5)
- ✓ on y-axis: outboard motor bearing (2), inboard load bearing (4), outboard load bearing (6)

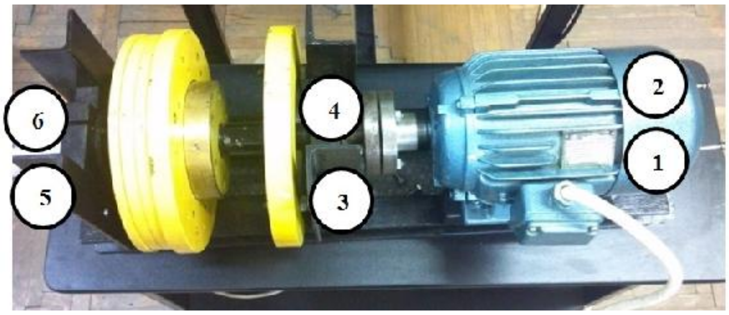

Figure 3. Vibrations measurement points.

Figures 4, 5, 6, 7, 8, 9 illustrate the front panel of the virtual instrument (VI) developed in LabVIEW 2013 for the vibrations analysis at an induction motor (for the six measurement points).

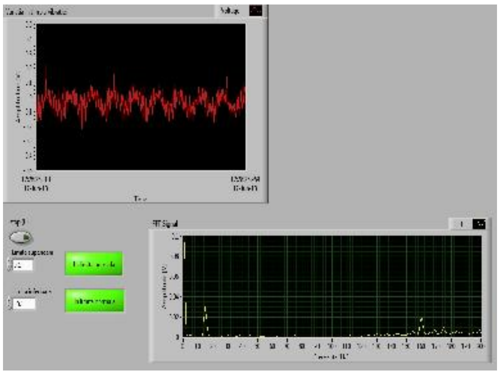

Figure 4. VI –vibrations in point 1 (900 RPM)

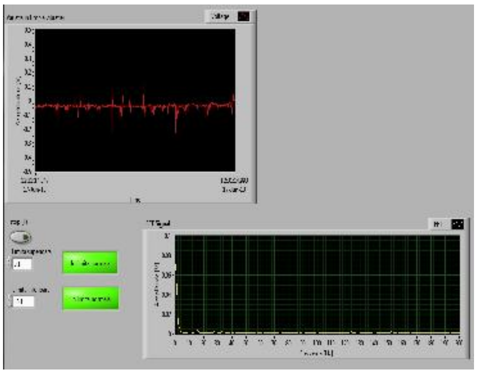

Figure 5. VI – vibrations in point 2.

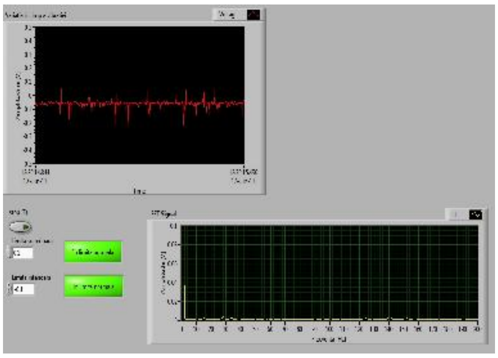

Figure 6. VI – vibrations in point 3.

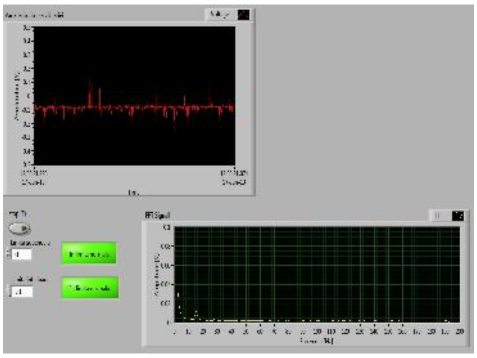

Figure 7. VI – vibrations in point 4.

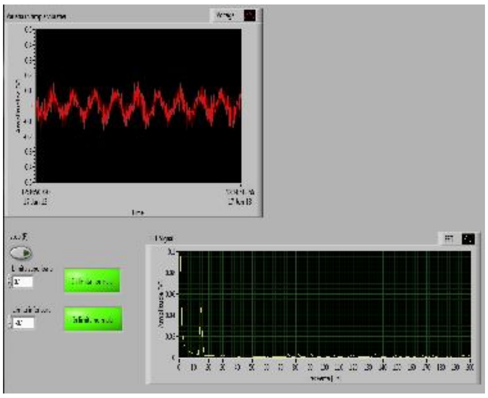

Figure 8. VI – vibrations in point 5.

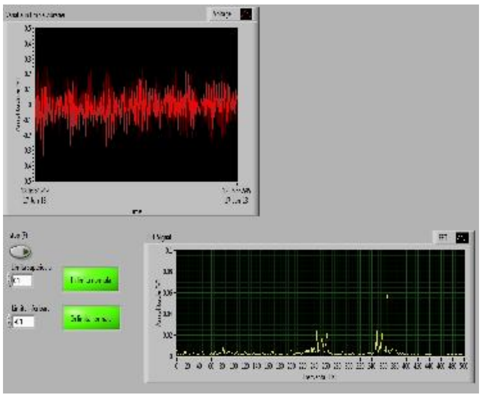

Figure 9. VI – vibrations in point 6.

This application allows the vibration signal acquisition through acquisition board, their real-time display and the spectral analysis using FFT. On the front panel we can set maximum and minimum values for vibration signals. If these limits are exceeded, optical signals appear. The measurements were done at a motor supply frequency of 15 Hz and 900 RPM. From this analysis it is observed that the maximum level of vibration is obtained at outboard motor bearing (1) and outboard load bearing (5). This is due to the fact that the load with disks is not balanced very well, sending vibrations to the ends of the electrical drive system. Figure 10 illustrates the VI front panel for the vibrations analysis on outboard motor bearing (1) at 1200 RPM.

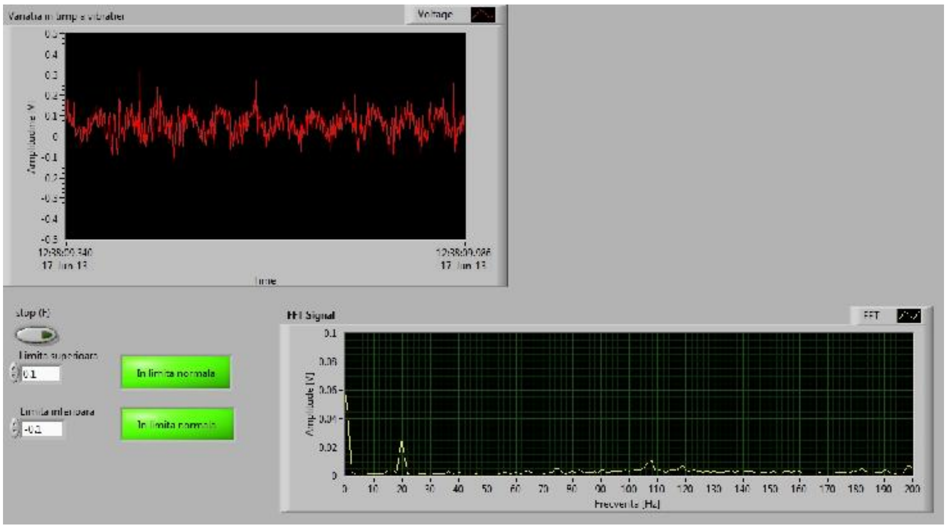

Figure 10. VI – vibrations in point 1 (1200 RPM).

From the spectral diagrams of the signals we can see an increase of the fundamental frequency once with electric motor speed increase.

In the following, a virtual instrument implemented for vibration analysis to a micro DC motor is presented. The experimental arrangement illustrated in Figure 11, has been made.

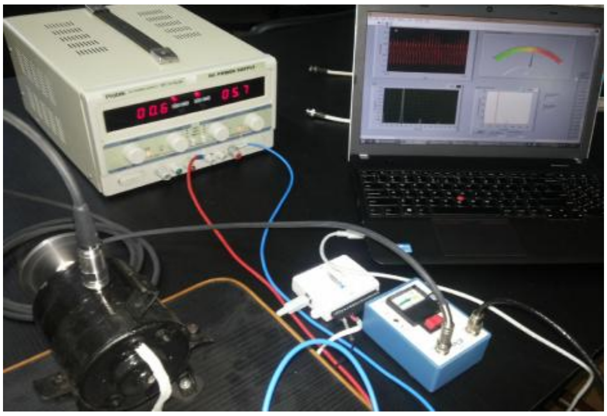

Figure 11. Experimental arrangement for acquisition, monitoring and vibration analysis at a micro DC motor.

The motor is powered at different values of the DC voltage so as to obtain different speeds. The vibration sensor is magnetically mounted on the motor housing. The signals from the sensor are transferred to computer. The virtual instrument takes the vibration signals obtained at different motor speeds.

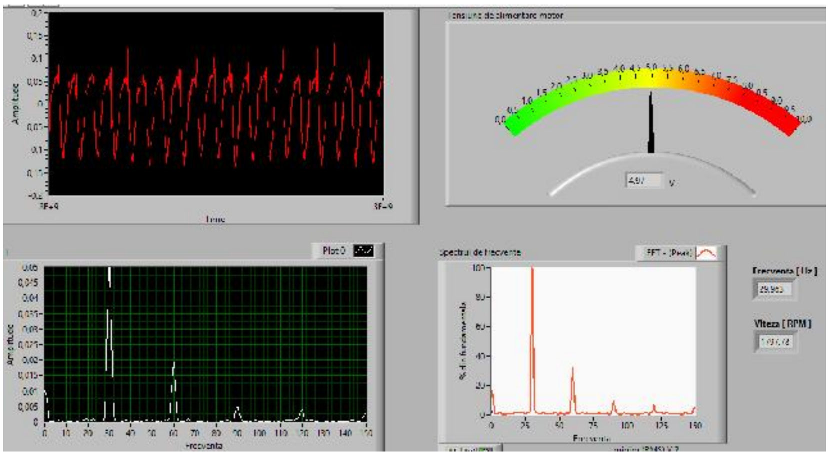

Figure 12. VI – Front Panel.

Figure 12 illustrates the virtual instrument front panel and Figure 13 shows the virtual instrument block diagram. Both the variations in real time of vibration signals and their spectral diagrams are shown on the VI front panel. Also, with the information obtained from the spectral diagram, the virtual instrument calculates the motor speeds. These were compared with the speeds measured using a digital tachometer from Chauvin Arnoux. The results are shown in Table 1. In order to verify the accuracy of the virtual instrument, the relative errors (also presented in Table 1) were calculated. As shown, the largest error obtained is 0.41%. This indicates a high precision of the virtual instrument.

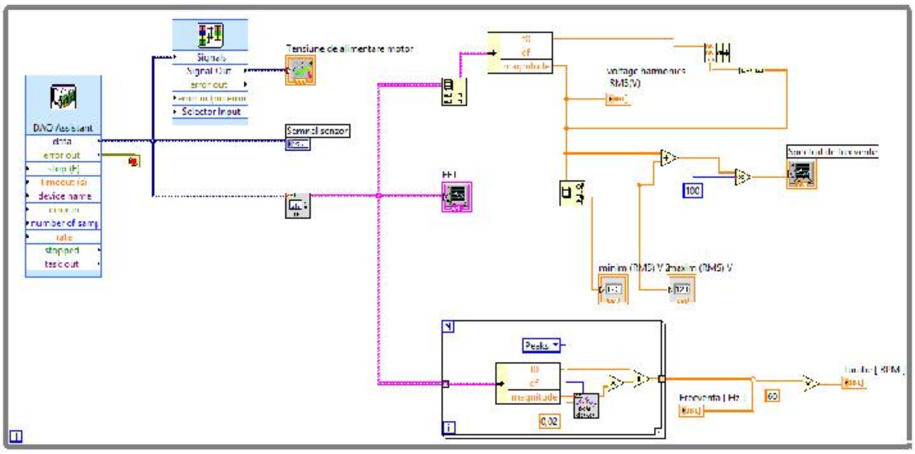

Figure 13. VI – Block Diagram.

Table 1. DC motor speeds

DC motor speed (VI) [RPM]	DC motor speed (tachometer) [RPM]	Relative errors [%]
1512	1510	0,13
1745	1742	0,17
1927	1930	0,15
2196	2187	0,41
2338	2330	0,34
2394	2400	0,25
2504	2500	0,16
2612	2620	0,30
2745	2740	0,18
2835	2840	0,17

4. Conclusion

A monitoring system of vibrations occurring at two different types of electric motors, using a piezoelectric accelerometer and a data acquisition board was presented in this paper. This system represents a very adaptable and reliable solution for vibrations analysis. A virtual instrument for the vibrations analysis was achieved in LabVIEW. In the control process, diagnostics and monitoring of electric motors is necessary to use the frequency spectrum of the vibrations. For this, the FFT analysis of the signals from the vibration sensor was made with the virtual instrument. The virtual instrument is flexible, can be easy change through programing and provides the necessary information in real time. This proposed system can be used to monitor vibrations in different technological processes to detect early defects that may occur during operation. Even if preventing defects with this measurement and vibration analysis equipment can be expensive, however it is cheaper than replacing electric motors damaged irreparably.

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Addresses:

- Assoc. Prof. Dr. Eng. Gabriela Raţă, "Stefan cel Mare" University of Suceava, Universităţii, nr. 13, 720229, Suceava, gabrielar@eed.usv.ro
- Assoc. Prof. Dr. Eng. Mihai Raţă, "Stefan cel Mare" University of Suceava, Universităţii, nr. 13, 720229, Suceava, mihair@eed.usv.ro