CHEAP WIRELESS MONITORING SOLUTION OF THE CONDITION FOR ELECTRIC MOTORS

Bogdan Sochirca, *Lecturer, University of Petrosani*
Aron Poanta, *Ph.D. Professor., University of Petrosani*

ABSTRACT. *In this paper is described a cheap and easy to use method of wireless monitoring and data interpreting concerning to the "health" condition for the electric motor. Is very important to know the condition because it can prevent future costly damages, save money, time, all that cause by the potentially damaging vibration found in electric motors.*

KEYWORDS: *wireless monitoring, Xbee, Arduino, MEMS accelerometer, FFT, electric motors.*

1. INTRODUCTION

Monitoring the vibration of the electric motor and use this information in order to obtain the "health" state, is very important because can save a lot of money by preventing and intervene to a future fault or can prevent damaging to other machine. If an electric motor is regular monitored, can be detected some potential problem that can be easy corrected in an early stage when an intervention is very simple, cheap and fast. The vibrating state can occur in several condition like: improper balanced, fault shaft misalign, worn, improper driven machine component, excessive clearance, some loose of the fixing bolts, and even the resonance at a particular rate.

2. PROBLEM FORMULATION

The simplest acquisitions solution of the vibration is with an MEMS accelerometer (Microelectromechanical systems). An accelerometer can be used to measure vibration or acceleration of motion of a subject. In these days an accelerometer can be found in many devices like: phones, tables, digital camera, and others. Accelerometers can be used in motion detection, orientation sensing, image stabilization, device integrity in laptops, etc. Depending the application the accelerometer specification can vary: the number of axes, the amplitude range, shock limits, temperature range, frequency range, sensitivity, resolution, amplitude linearity, and others.

The recording and the interpretation of the electric motor vibration, can make an idea about the severity of the vibration. The wireless acquisition of vibration is a good method for motors that cannot be reached easily. Imagine a motor that is placed 10 meters below earth with very hard access path, or a motor as a part of a very complex mechanism almost impossible to be reached. In all this cases a wireless solution will be very good to be implemented, and all with small cost.

On the market are a lot of solution for the problem with price that wary from 200-400 euro only for accelerometer and another 1000 euro for the station where the data are collected. We propose a very cheap and easy to use solution with almost the same results at a price of max 70 euro.

3. PROBLEM SOLUTION

As it was presented earlier, the easiest solution for monitoring the vibration of an electric motor is by using an accelerometer. For data transmission two possibility can be, wired and wireless. It is choose wireless solution because it benefit of mobility advantages. In this days exist a lot of wireless module with vary advantages and disadvantages. One viable solution is Bluetooth. The main advantages is that a lot of devices support Bluetooth connections, like computers and mobile phone, and the cost of the receiving data equipment will be almost zero, and also it assure a good speed for data transfer. The problem with Bluetooth is that can support only a master-slave connection, so only one motor can be monitored a time, so for future expansion will not be the greatest choice.

Another wireless solution on the market is the XBee radio module. The main reason that XBee is a better choice, is the distance, the cheapest XBee is XBee 1mW Chip Antenna - Series 1 with a range of 100m outdoor. The longest distance that an Xbee can transmit and receive is XTend 900 1W RPSMA, with almost 65 km outdoor. In the test phase it is used an XBee Pro 60mW Wire Antenna - Series 1 with the range of 1.5km. For the indoor distance was tested and achieved a distance of 25 meters with 3 walls with 50cm concrete thickness. Xbee also support point to point (a form of mesh networking) and point to multipoint connections. The mesh network is a type of network where each node can serve as a router for other node. If the coordinator can't reach directly to a node for gathering information, it can access that node through another node, so all collaborate for data propagation in the network. The Xbee is suitable for monitoring multiple electric motors or other devices/parameters.

The microcontroller board chose is an Arduino Mega based on the ATmega1280 microcontroller. It is chose because the programming environment is free, the schematic and reference design for the board is also free, so is very easy to develop own devices around this board. It has 54 digital input/output, 16 analogs pins, and runs at 16 MHz, more than enough for the application.

The accelerometer used is ADXL 335, a 3 axis accelerometer with low level noise and a low power consumption (320uA). It offer excellent temperature stability, and is used for motion and tilt sensing, widely spread in mobile devices, gaming systems, disk drive protection, image stabilization, sport and health devices and many more, with a minimum full scale range of ±3g.

The schematic connection between microcontroller board, Xbee and accelerometer can be observed in figure 1.

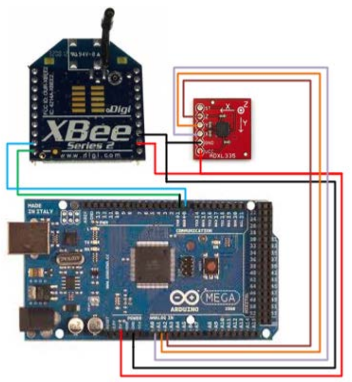

Fig. 1. The schematic drawing of the acquisition system.

Was made several measurements. On the same electric motor, first time when was new, was taken some measurement to have a reference value. The motor speed was controlled using an inverter, at various speed like: 60Hz, 50Hz, 40Hz, 30 Hz, 20 Hz, 10 Hz, and 5 Hz. In the paper is present only at 60 Hz and 30 Hz. The acceleration recorded is passed to a computer where it convert the signal to a velocity signal. To the velocity signal is applied mathematical calculation FFT (Fast Fourier Transform). For each individual measurement is displayed the wave of the accelerometer on axes X and Y, and the FFT of the signal. For each graphical representation was took 1024 value with 1ms between samples.

After the motor was used for a period of the measurement are repeated and apply the FFT on the velocity waves obtained. In order to be accurate it must take in consideration some aspect like: mount the accelerometer as close as possible to a bearing, the accelerometer need to be firmly attached, place it on the same spot on different measurement, the correct orientation of the accelerometer. In the next figures it can be observed the FFT and de acceleration at different speed and on booth x and y axes.

Figure 2 represent the graphic of the acceleration on x axes at motor supply frequency of 60 Hz, when the motor was new.

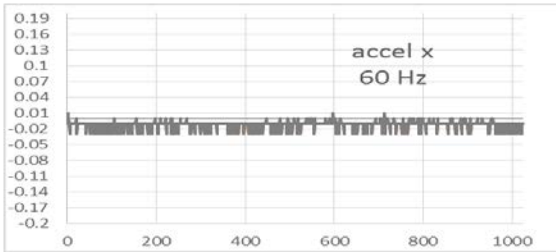

Fig. 2. Acceleration diagram for x axes at motor supply frequency of 60 Hz

For the acceleration represented before, is applied the FFT and was obtained the graph represented in figure 3 where can be observed that the max value of the amplitude is around 1.

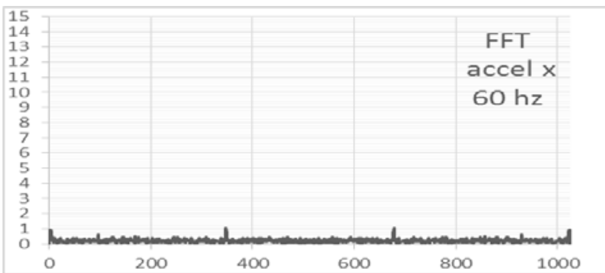

Fig. 3. FFT for motor supply frequency of 60 Hz on x axes with motor in good condition.

Figure 4 represent the graphic of the acceleration on y axes at motor supply frequency of 60 Hz, when the motor was new.

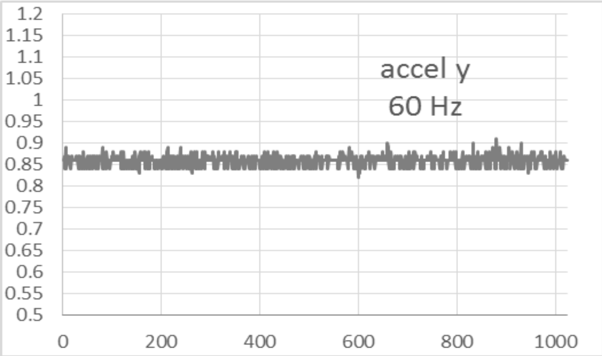

Fig. 4. Acceleration diagram for y axes at motor supply frequency of 60 Hz

Again is applied the FFT and obtain the value of the amplitude with max value around 2.5. (Fig 5)

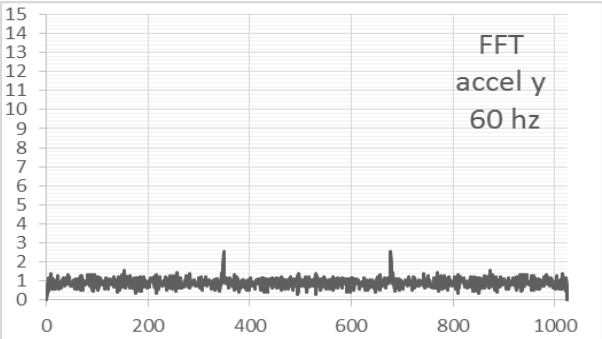

Fig. 5. FFT for motor supply frequency of 60 Hz on y axes with motor in good condition.

The measurements are repeated on the x and y axes this time at motor supply frequency of 30Hz. The acceleration representation can be observed in figure 6 for x axes and 8 for y axes and the corresponding FFT representation in fig 7 for x axes and 9 for y axes with maximum amplitude value of 0.5 and 1.5.

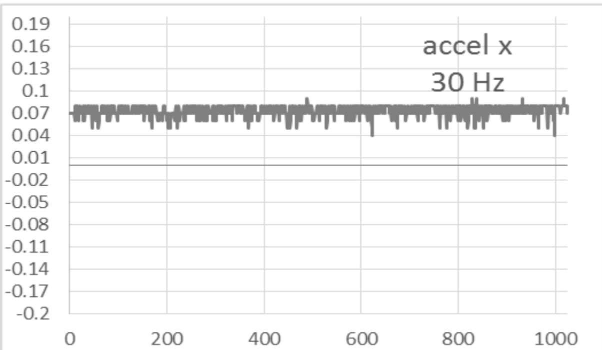

Fig. 6. Acceleration diagram for x axes at motor supply frequency of 30 Hz

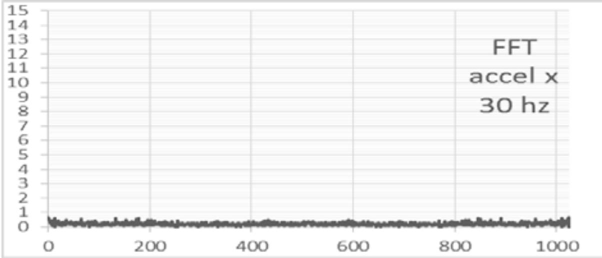

Fig. 7. FFT for motor supply frequency of 30 Hz on x axes with motor in good condition.

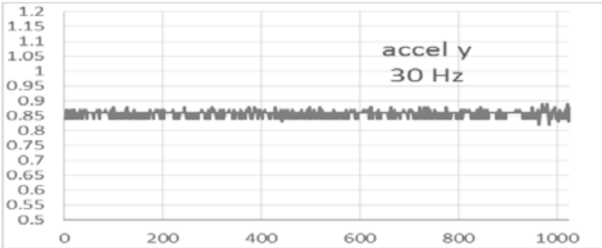

Fig. 8. Acceleration diagram for x axes at motor supply frequency of 60 Hz

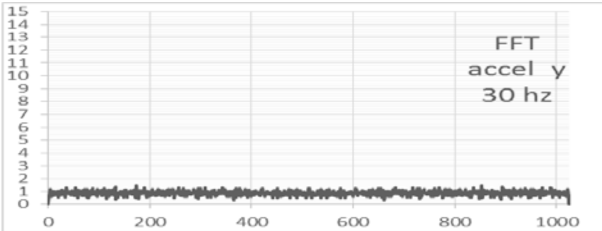

Fig. 9. FFT for motor supply frequency of 30 Hz on y axes with motor in good condition.

These data are from a larger set made at vary motor supply frequency in total more than 100.000 data was acquired. After the motor was used and wear appear, the measurement are repeated for the same axes, at the same motor supply frequency, with the accelerometer in the same positions.

For the motor supply frequency at 60 Hz and x axes the FFT corresponding is represented in figure 10. The maximum amplitude is 15 and if is compared with the maximum obtained at the same condition but at different wear, from figure 3, can conclude that a significant wear appear in the electrical motor.

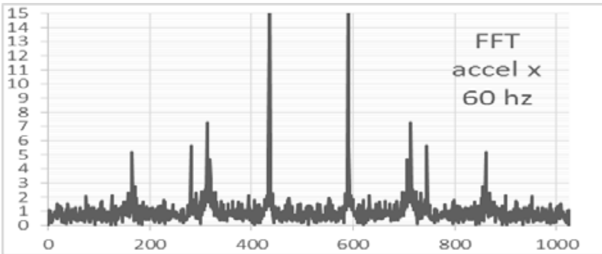

Fig. 10. FFT for motor supply frequency of 30 Hz on y axes with motor in bad condition.

The FFT for y axes at motor supply frequency of 60 Hz on y axes reveal the maximum amplitude around 9.5, significantly increased from 2.5 when was in good condition (figure 5)

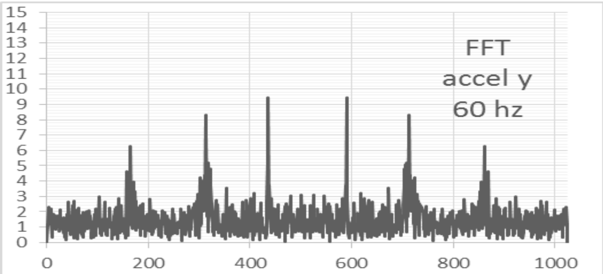

Fig. 11. FFT for motor supply frequency of 60 Hz on y axes with motor in bad condition.

The comparing between maximum amplitude on x (figure 12) and y (figure 13) axes at motor supply frequency of 30 Hz when wear appeared with those obtained previously (figure 7 and figure 9), shows that a degree a wear exist.

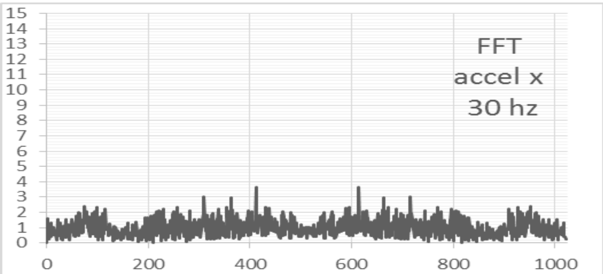

Fig. 12. FFT for motor supply frequency of 30 Hz on x axes with motor in bad condition.

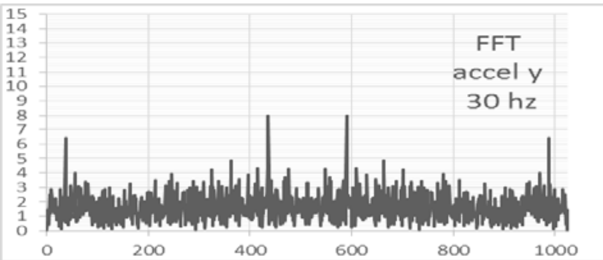

Fig. 13. FFT for motor supply frequency of 30 Hz on y axes with motor in bad condition.

For all other measurement was obtained encouraging results what prove that the system proposed obtain good performance at a tenth part from a dedicated system.

By analyzing the maximum amplitudes of the FFT in time, can be observed a moment from where the motor need to be replaced in order to assure a safety functioning of the system. The entire system is showed in figure 14.

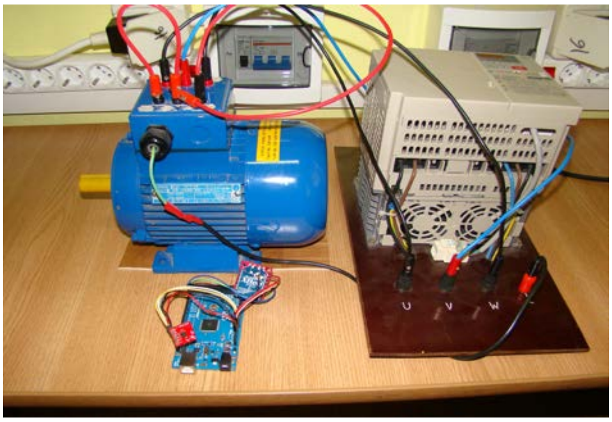

Fig. 14. The equipement used for testing.

4. Conclusion

In the future, taking advantages of the Xbee solution can be extend the monitoring solution to a large number of motors not only one, how is presented in the paper. In the future all the calculus will be made in the microcontroller and data will be transmitted over the internet or over the GSM for a better visibility, not only from a computer where is installed the Xbee explorer.

Another research direction will be over a smartphone, to use the accelerometer from that, and only need to touch motor for 5 seconds every week (or maybe more frequently) to see if the motor work properly.

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