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INDUSTRIAL MOTOR VIBRATION DETECTING SYSTEM FOR PREDICTIVE MAINTENANCE

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ABSTRACT

Motor Vibration Detecting System is very important and useful tool for Predictive Maintenance in industry. The basic aim of this research study is to design a low cost device to determine the present working state or condition of the single or three phase induction motor of the industry. The idea behind that is, predicts the present working condition of the any motor by analyzing its vibration characteristics or properties. Actually, it is not measuring the vibration directly and hence the acceleration of the vibration is measured instead of the vibration by using ADXL345 accelerometer. It is measured the acceleration produced by the motor when it is running. SMT32F103 Cortex-M3 core Microcontroller collects the data of acceleration with 1000Hz sampling rate. Then the collected data set is analyzed with the Fast Fourier Transform Technique (FFT). As the result of the FFT, the magnitude of the fundamental wave form is varied with the vibration pattern of the relevant motor. The amplitude of the resultant wave form is varied in between 1 to 43 LSB and vibration frequency goes up to nearly 500Hz. So that maximum RPM can be used to monitor is 30000RPM.

Keywords: Predictive maintenance, Vibration Analyzing, Fast Fourier Transform

1. INTRODUCTION

The basic principle of predictive maintenance is to take measurements that allow for the prediction of which parts of the machine will break down and when. The Predictive Maintenance concept is the most important and useful concept for the industry which is used to predict and prevent any failures of motor based machines. Continuous monitoring identifies the onset of component failures in advance, which means that maintenance is performed only when needed. By using this approach, unexpected downtime can be reduced or eliminated and the risk of catastrophic failure is mitigated up to some extent. In this study it is developed a device to monitor the working conditions of the industrial electrical motor especially helping for Predictive Maintenance as motors are widely used in many machines of many industries[1]. There are some monitoring devices commercially available at the market with unbelievable higher cost. Therefore this new proposed device will be more helpful for industry.

2. EXPERIMENTAL

The vibration detecting and monitoring are probably the most widely used predictive maintenance techniques with some modifications it can be applied to wide variety of rotating equipment such as motors, conveyers etc. Since the mass of the rolling elements is generally small compared to that of the machine, the velocities generated are generally small and result in even smaller movements of the bearing housing. In that case it is difficult to measure without having any device.

2.1. Vibration Monitoring and Analysis

Mechanical vibrating systems consist of elements such as a spring for storing potential energy, mass and inertia for kinetic energy, and damper for dissipating mechanical energy. The vibration process alternatively converts energy between its potential and kinetic forms. In its general sense the vibration is a periodic motion that repeats itself in all its details after a certain interval of time, called the period of vibration. Some energy must be replaced in each cycle of vibration from an external source to maintain the vibration.

All mechanical equipment in motion generates a vibration pole, or signature, that reacts its operating condition. This is true regardless of speed or whether the mode of operation is rotation, reciprocation, or linear motion. This motion is called periodic and harmonic and the relationship between the displacement of the mass and time is expressed in the form of a sinusoidal equation:

$X = A \sin (wt)$ -------- (1)

Where,

X = displacement at any given instant t;
A= maximum displacement; $\omega = 2 \Pi f$;
f = frequency (cycles/s hertz Hz); t = time (seconds) [2]

Depending on the application, a wide variety of hardware options exist in the world of vibration. Actually, it's hardware requirements are depend on several factors such as speed of the machine, on-line monitoring or off-line data collection, analysis needs, signal output requirements, etc. However any vibration program or device will require a sensing device (transducer) to measure the vibration of the motor and translates that measured information into some useful electronic or digital signal. Transducers are relatively small in size and can be permanently mounted or affixed to the monitoring location periodically during data collecting[1]. In addition it's required a device such as PC, Microcontroller to analyze the collected data. For this study it is used ADXL345 accelerometer and STM32F103 ARM Microcontroller to sense the vibration of the motor and analyze the data obtained by sensor.

2.2. OPERATION OF THE SYSTEM

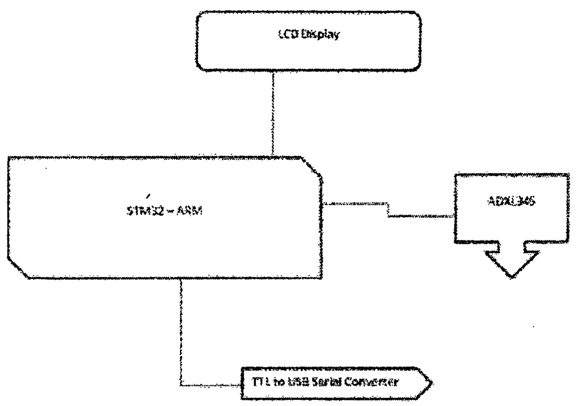

Figure 2: Block Diagram of the System

The accelerometer should be mounted on the motor and then when it running, the microcontroller collects the Time-Domain data from accelerometer and it collects data up to 1000Hz sampling rate. Then the Time Domain data is converted into Frequency-Domain data by microcontroller. Frequency-domain data are obtained by converting time-domain data using a mathematical technique referred to as a fast Fourier transform (FFT). Finally the output generated by the Microcontroller in order to results of the FFT.

The Fast Fourier Transform (FFT) is an algorithm for calculation of the Desecrate Fourier Transform DFT. It has revolutionized the modern experimental mechanics, signal and system analysis, acoustics, and paved the way for the introduction of modal analysis. The FFT algorithm applies only to signals comprising a number of elements which is equal to 2^m (e.g. 2^8= 256, 2^{10}=1024 etc.). Its main advantage is that it significantly reduces the computation time by a factor of the order m/log2m, i.e. more than 100 times for a sample of 1024 elements. In this study, 256 elements are collected by microcontroller due to memory limitation of the Microcontroller [3,4].

The procedure of FFT used in this project is illustrated in following block diagram (Figure:3).

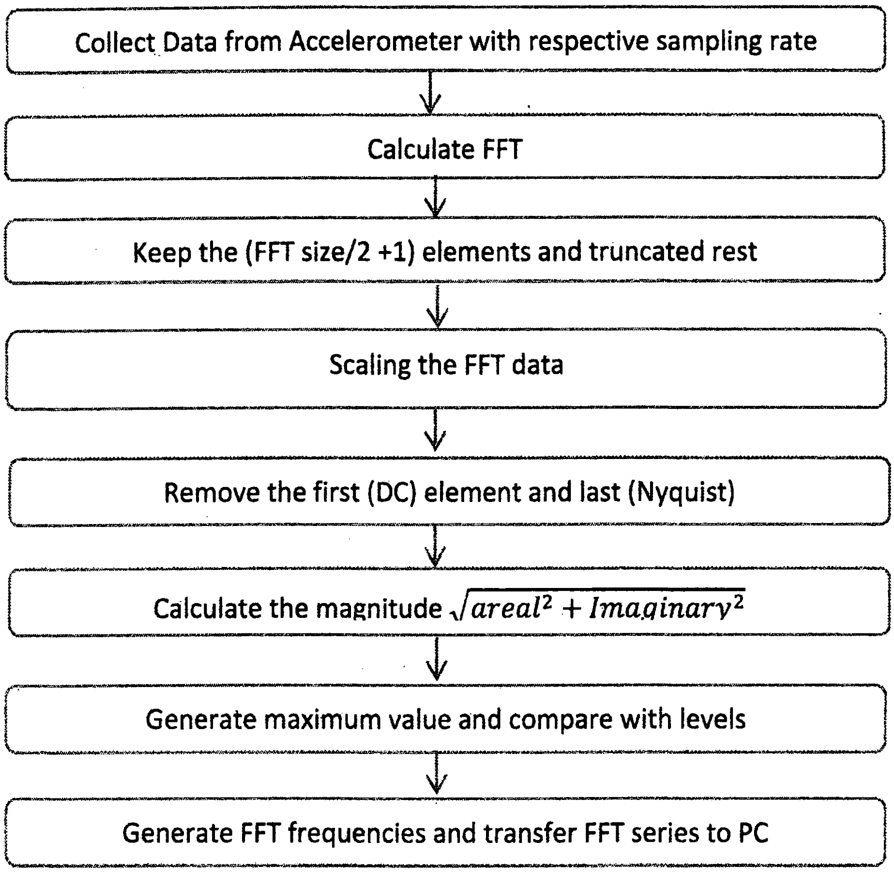

Figure 4: Algorithm for the FFT spectrum and producing a magnitude

Sampling frequency (Fs) = 1000Hz -- (2)

Number of Samples (NFFT) = 256--(3)

Therefore Maximum Frequency = (NFFT/2 – 1) x Fs / NFFT --------------(4)

Vibrating Frequency = RPM/60 --(5) [2]

3. RESULTS AND DISCUSSION

3.1. Results

The idea behind that study is developing a low cost Motor Vibration Detecting System for Predictive maintenance. The expected results could be obtained by using that system.

Output magnitude range 1 to 43 LSB, and frequency range 0 to 500Hz. Therefor the maximum motor RPM in measurable frequency range should be less than 30000 RPM.

The displacement, velocity and acceleration characteristics of vibration are measured to determine the severity of the vibration and these are often referred to as the 'amplitude' of the vibration. In terms of the operation of the machine, the vibration amplitude is the first indicator to indicate how good or bad the condition of the machine may be. Generally, greater vibration amplitudes correspond to higher levels of machinery defects[1].

FFT allows each vibration component of a complex machine-train spectrum to be shown as a discrete frequency peak. The frequency-domain amplitude can be the displacement per unit time related to particular frequency, which is plotted as the Y-axis against frequency as the X-axis. This is opposed to the time-domain spectrum, which sums the velocities of all frequencies and plots the sum as the Y-axis against time as the X-axis

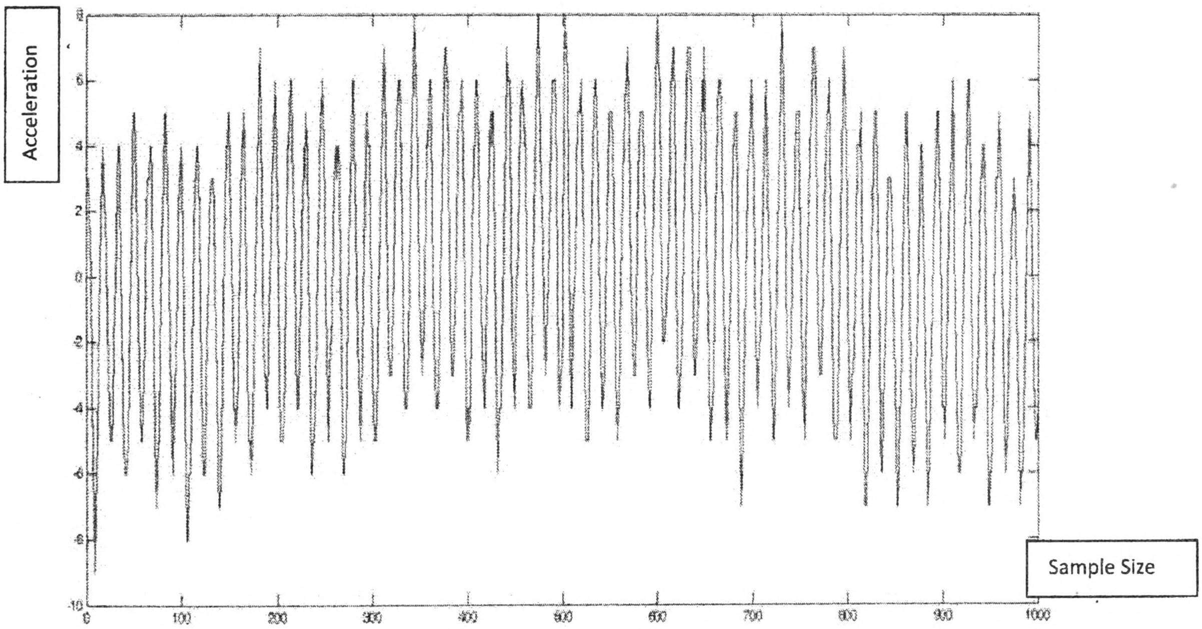

Figure 5: Variation of Time-Domain data

This figure shows the variation of 1000 acceleration samples. These values are proportional with the vibration frequency of the motor. By inspection this figure we cannot get any decision because it is same in everywhere. The following figure shows the FFT series of above data set.

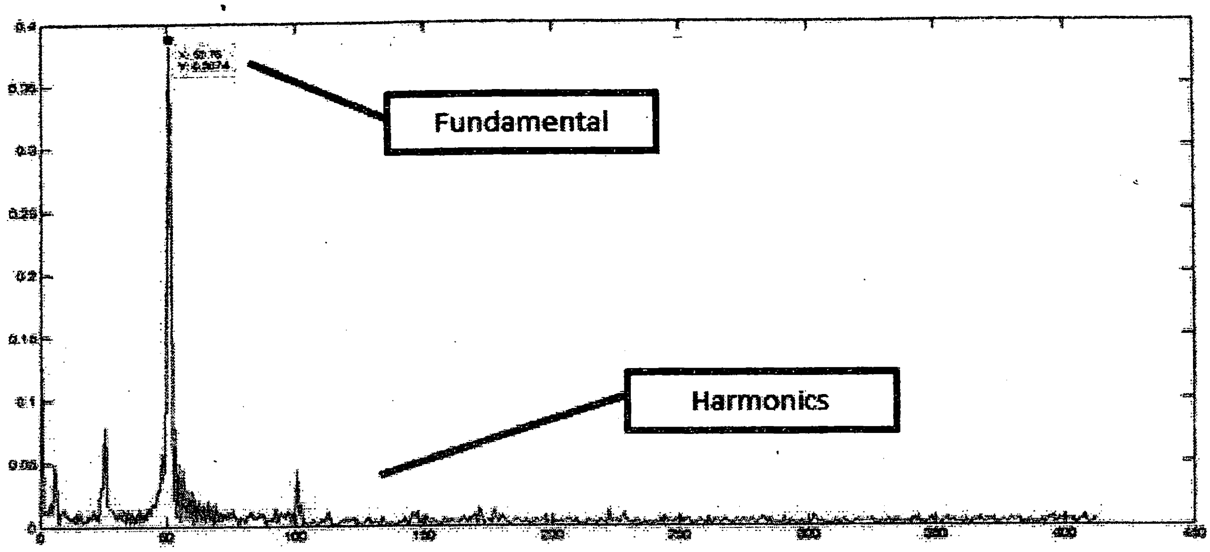

Figure 6: Fourier Series of Time-Domain data

By analyzing this figure we can clearly identify the fundamental wave and other harmonics with respective frequencies. The result from the FFT can be used to predict the current situation of the Motor because its natural vibration frequency of the motor changes automatically. So then the resulting wave pattern also changed.

Normally if there is any fault in a motor, it getting vibrate with high frequency than its natural frequency. Therefore fundamental frequency of the FFT series goes higher level. By using that change we can decide that there is a fault.

By analyzing this figure we can clearly identify the fundamental wave and other harmonics with respective frequencies. As mentioned before if there is any fault in the motor vibrates with high frequency than normal operation because that the accelerometer also vibrates with high frequency. Therefore readings of accelerometer getting high and finally the amplitude of the fundamental wave of the Fourier series is getting high. Then that change of the wave form is used to predict the current condition of the motor[1, 2, 3, 4].

4. CONCLUSION

For proper functioning of this device, we have to calibrate for different motors with different conditions. By connecting this device with different motors (from good to bad) we can measure the output. The by inspection those values with respective motor condition, we can predict the fault any unknown motor. After connecting sensor properly to the motor, it can be started the device. In initial state it allows you to set the fault level and warning level as well. After giving these values to the system through PC it starts the operation. It is detected any fault indicate and inform it through indicators and alarms and pre programmable setup can be activated. Furthermore the system is going to sleeping mode. This device can be connected with a PC and set values can be entered to the device by using its software. By using that software it could be see the spectrum view of the data. Here I have used 16X2 line LCD display to show some output data. But it is impossible to show all data such as Spectrum view in this LCD Display. It is more valuable if there is a large display and if so everything can be done using that display without connecting with a PC.

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