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Vibration Analysis of DC Motor with ADXL335 and MATLAB

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***Abstract*: -- Most of the failures in the industrial systems are due to motor faults which can be catastrophic and cause major downtimes. Hence, continuous health monitoring, precise fault detection and advance failure warning for motors are pivotal and cost-effective. The identification of motor faults requires sophisticated signal processing techniques for quick fault detection and isolation. This paper presents a real time health monitoring technique for induction motor using pattern recognition method. The proposed fault detection and isolation scheme comprises three stages: data acquisition, feature extraction and multiclass support vector machine classifier. This paper investigates single and multiple faults in single-phase induction motor including bearing fault, load fault and their combination. The test bed consists of 1⁄2 hp, 220V squirrel cage induction motor with load, vibration sensor, current sensor, data acquisition system and controller. Two features standard deviation and average value are computed for each sensor's data. Multiclass support vector machine classifier is implemented using a low-cost Arduino controller for fault detection and isolation. The performance analysis of the classifier with real-time sensor's data is presented which shows superior capabilities of the developed method.**

Keywords: Arduino, MATLAB, ADXL335

I. INTRODUCTION

Electric motors are electro-mechanical devices used for the conversion of electrical energy into mechanical energy.Motors are integral component of almost every electromechanical system and have wide range of industrial applications. Motors might be subjected to several electrical and mechanical faults during operation. The continuity of service with high level of reliability is an important characteristic of an industrial system that requires continuous monitoring of system and its components. This encouraged many scientists and engineers to carry out research on industrial machines in an effort to enhance reliability with incorporation of fault detection and isolation (FDI) techniques.A variety of fault detection and isolation methods have been reported in the literature that encompasses techniques based on model and data driven approaches[1]–[3]. Model based methodsutilize mathematical or graphical models for design of fault detection scheme such as Kalman filters and adaptive observer[4], multiple observer banks[5], and bondgraphs[6].The scope of model based fault detection and isolation methods is limited due to problem-specific design nature.Also, the performance of model based FDImethods degrades in the presence of uncertain industrial environment. On the other hand, data driven or signal based fault detection approaches are generic, independent of mathematical model that utilize process history/trends for FDI design. For instance,Bayesian, support vector machines (SVM) and neural network classifiers[4], [7], [8].Kolla and Altman [9]presented an artificial neural network (ANN)to identify external faults and no fault condition in a three-phase induction motor. Yuanet al. [10] presented power estimation based health monitoring and fault detection scheme. Their proposed method was based on performance degradation assessment of system components using sensor measurements and power efficiency calculations. However, the approach was problem-specific and incapable of multiple fault detection. Romero-Troncoso[11]presented FPGA based online detection of multiple faults in induction motors. A Reliable online machinery condition monitoring systemis very useful to a wide array of industries to recognize anincipient machinery defect so as to prevent machinerynon-fatal failure, malfunctions, or even catastrophic failures.An early fault warning can enable the establishment of a predictive maintenance program [1], which is critical tothose machines (e.g., airplanes, power turbines, andchemical engineering facilities) to which an unexpectedshutdown would cause serious economic or environmentalconsequences [2, 3]. Fault detection can be conducted basedon information carriers such as the acoustic emission,vibration frequency waveform, oil analysis, temperaturevariation, etc. However early fault warning based onvibration signal has proven track record of preventingcatastrophic failures; hence we will discuss about that indetailed manner in this paper [1]. Vibration, speed, acceleration and frequency spectrum. The measures which characterize themovement (vibration) of the system that is the displacement,speed and acceleration are defined according to the relations(1), (2) and (3):

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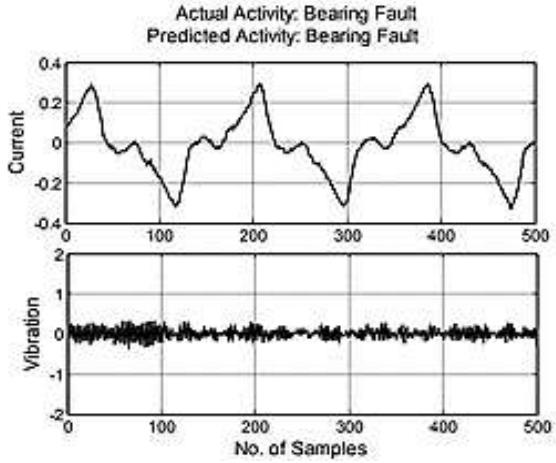
d=DSin(wt) -(1)
v=d/dt (DSin(wt)) -(2)
$a=d^2/dt^2$ (DSin(wt)) -(3)
$a=d^2/dt^2$ (DSin(wt)) -(3)

1.1 Vibration Monitoring

All electric motors generate noise and vibration, and analysis of produced noise and vibration can be used to give information on the condition of motor. Even very small amplitude of vibration of machine frame can produce high noise. Noise and vibrations in electric machines are caused by forces which are of magnetic, mechanical and aerodynamic origin. For stationary signal MCSA best but for non-stationary signal it‟s not convenient option for non-stationary signal vibration monitoring is generally used. Four vibration properties are crucial to understanding and resolving the machine problems. These include Amplitude, which indicate the level of severity of the measured condition. Frequency, which indicates the repetition rate of the contributing source or sources of the measured condition; Phase, which presents the timing relationship between two signals contributing to the measured condition; Modulation, the process by which the response amplitude at some frequency is varied by a lower frequency excitation response. With the help of this we can get detail information about asymmetry in motor [4].



1.2 Balanced Condition

Inernational Journal of Advanced Computer Research (ISSN (print): 2249-7277 ISSN (online): 2277-7970) Volume-3 Number-4 Issue-13 December-2013 First of all I create a balanced condition; here I create a balanced condition by setting same voltage of each phase. Means this is nothing but a healthy condition of motor. After that I take FFT of that balanced condition to extract the features which are sensitive to the presence of fault.Fig.7and8.

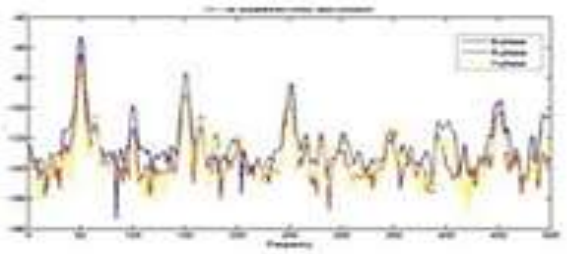


Figure 9: FFT (Unbalanced Supply)

After classifier training, testing data is used for performance evaluation. Similar to the training stage, features are extracted from sampled data. Depending on motor health condition and extracted feature values a particular point is assigned in the feature space. The trained classifier categorizes the health status of the system by recognition of the location of the point in feature space and subsequent class label assignment. The real time fault detection and isolation results with predicted and actual activity happening in the testing stage are shown in fig. For h ealthy (fault-free), bearing fault, load fault and combined load and bearing faults.

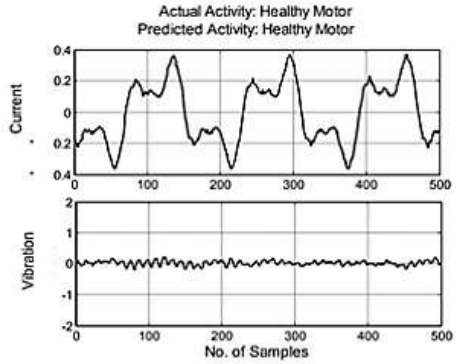


Figure : 5. Results of fault detection and isolation for healthy motor condition

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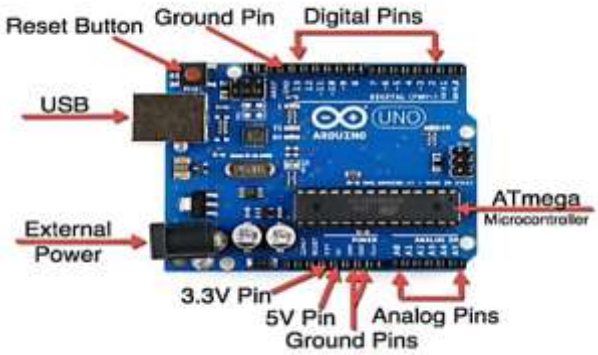
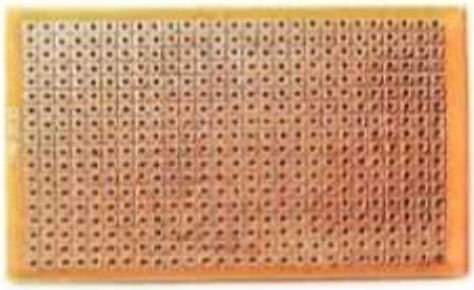
5V Spdt relay:
These are high quality Single Pole - Double Throw (SPDT) sealed relays. Use them to switch high voltage, and/or high current devices. This relay's coil is rated up to 12V, with a minimum switching voltage of 5V. The contacts are rated up to 5A (@250VAC, 30VDC).

ARDUINO UNO BOARD
A micro-controller is a small computer on a single integrated circuit Containing processor core, memory, and programmable input/output peripherals The important Part for us is that a micro-controller contains the processor (which all computers have) and memory, and some input/output pins that you can control. (often called GPIO –General Purpose Input Output



3.5 Printed circuit board
A printed circuit board (PCB) mechanically supports and electrically connects electronic components using conductive tracks, pads and other features etched from copper. sheets laminated onto a non-conductive substrate Components (e.g. capacitors, resistors or active devices) are generally soldered on the PCB. Advanced PCBs may contain components embedded in the substrate. PCBs can be single sided (one copper layer), double sided (two copper layers) or multi-layer (outer and inner layers). Conductors on different layers are connected with vias. Multi-layer PCBs allow for much higher component density.FR-4 glass epoxy is the primary insulating substrate. A basic building block of the PCB is an FR-4 panel with a thin layer of copper foil laminated to one or both sides. In multi-layer boards multiple layers of material are laminated together. Printed circuit boards are used in all but the simplest electronic products.



III. MODEL DESCRIPTION

The condition monitoring based simulation model is given in Fig-7 which has been designed using MATLAB/Simulink. The vibration data of class-III machine is used as a case study. If any problem is occurred in any position then the vibration of entire system increases. The magnitude of vibration is maximum in that bearing position where the problem is occurred. The four 'Max' blocks are used in this model. Four 'max' blocks are used to extract the maximum magnitude of vibration from four bearing positions of the system. The last 'max' block is used to extract the one maximum value from the five. The 'Embedded MATLAB function 1' block is used to check the maximum value. If the vibration is in 'unacceptable' range (> 11.2 mm/sec) then it stops the system by tripping the relay creating different buzzer sound and zero value is displayed in the display box. If the value is less than 11.2 then the data goes to second 'Embedded MATLAB function 2' block for condition checking. If vibration is in 'unsatisfactory range then a message is displayed in the computer screen with a computerised buzzer sound to alert everybody otherwise the system is on. The alert message is shown in Fig-8. In 'unsatisfactory' and 'unacceptable' condition it displays the serial no. Of defective bearing to find out the problematic source. The 'Sound Generator' is used to create the sound. A 'light bulb' is used to indicate that the vibration range is high. An accelerometer is a device that measures proper acceleration ("g-force"). Proper acceleration is not the same as coordinate acceleration (rate of change of velocity). Accelerometers have multiple applications in industry and science. Highly sensitive accelerometers are components of inertial navigation systems for aircraft and missiles. Figure 3 shows ADXL 335 accelerometer which is used in the experiment.

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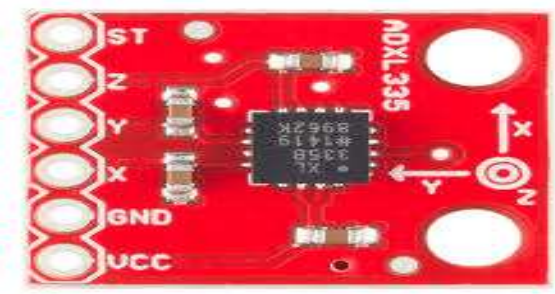
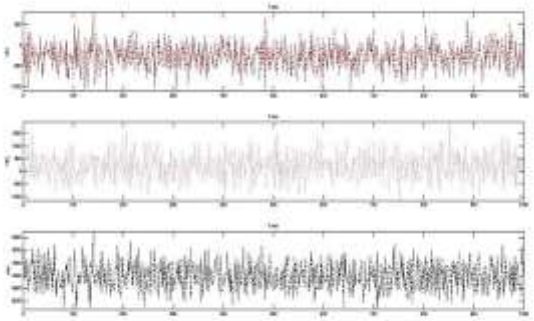


3.3 MATLAB

Matlab is a numerical computing environment that is built around an easy scripting language, which makes MATLAB perfect for quick testing and data analysis. First, we initialized the serial communication between MATLAB and the arduino slave, with the native function serial. Using this function, we created a serial object and set the parameters Data Bits = 8, Stop Bits = 1, Baud Rate = 115200. Serial Obj = serial(com Port); set(serial obj ='Data Bits', 8); set(serial Obj, 'Stop Bits', 1); set(serial Obj, 'Baud Rate', 115200); Then we implemented our protocol, see Appendix 7.2, into different functions that handled the serial communication. Below is the function read Waveform that reads a wave- form from an analog channel on the Arduino With only this simple code we are now able to perform tests and evaluate the performance of the ADXL335 accelerometer. Figure 4 shows the raw waveform obtained by the accelerometer placed near the A din tone generator playing a 60Hz sine wave. The sine wave was generated using onlinetonegenerator.com [14]. The collected waveform is then transformed from the time domain into the frequency domain,using fast fourier transform (FFT) [10], which is shown in figure 5. The 60 Hz signal is clearly distinguished from the background noise.

IV.RESULTS

Vibration of Induction motor for x, y, z axis using adxl335 sensor



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