ANN Based Health Monitoring Of Three Phase Induction Motor Using Vibration Analysis

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Abstract- *Induction motor especially three phase induction motors are the heart of the industry due to their advantages over other electrical motors. Therefore, there is a strong demand for their reliable and safe operation. The health monitoring of induction motor is an emerging technology for online detection of incipient faults. If the fault is about to occur in the motor, then there is change in vibration of the motor. By analysis the vibration of the motor fault can be detected before it actually occurs. The fault like bearing fault (Inner Race and Outer Race fault) and inter-turn fault induces significant change in vibration of the motor. The vibration signature of particular fault is different. The on-line health monitoring involves taking measurements on a machine while it is in operating conditions in order to detect faults with the aim of reducing both unexpected failure and maintenance costs. This project work is comprised of identification of bearing fault and inter-turn fault.*

Keywords- Health Monitoring, Online fault detection, Three phase induction motor, Vibration Signature etc.

I. INTRODUCTION

The Squirrel cage induction motors are most widely used electrical machines for industrial, domestic and commercial applications. These motors have advantages such as robustness, simplicity of its construction and highly reliable.

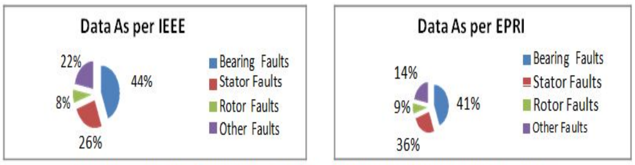


Fig. 1 Percentage (%) Component of Induction Motor Failure (Courtesy IEEE & EPRI)

According to the IEEE standard 493-1997, the most common faults and their statistical occurrences are shown in fig (1). A 1985 statistical study of the EPRI provides similar results as also shown in fig.1. From the fig 1 it may be clearly observed that the major occurrences of induction motor faults are bearing fault as well as stator winding fault i.e. inter-turn fault.

The health monitoring of the induction machine can be done by various techniques. Those monitoring techniques are:

(i) Vibration monitoring
(ii) Noise monitoring
(iii) Magnetic flux monitoring
(iv) Voltage monitoring
(v) Current monitoring

For this project vibration monitoring technique is used. This analysis is done using ANN (Artificial Neural Network) tool.

II. EXPERIMENTAL SETUP

This experimental setup of the project consists of 2 horse power, 1380 rpm, 3 phase induction motor having full load current of 3.8 A. It is base mounted motor coupled to DC shunt generator connected to resistive load bank for loading. In this experiment accelerometer ADXL 335 is used to capture the vibration data which is mounted on one end of the motor as shown in fig. In order to collect the data from the accelerometer it is coupled with ARDUINO UNO board (microcontroller) which compatible to MATLAB 2013 where data can be captured.

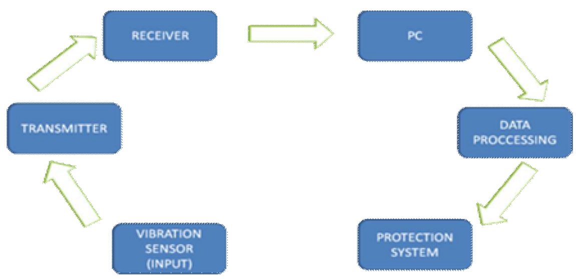


Fig. 2.1) Overall System Block Diagram

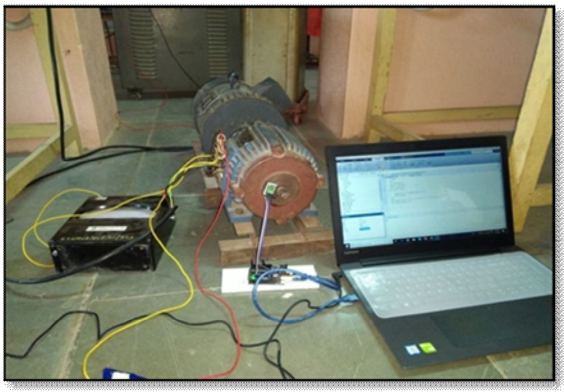
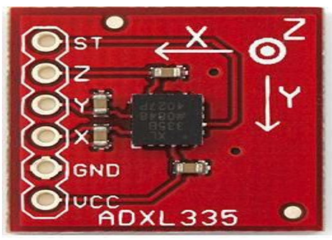


Fig. 2.2) Experimental Setup

A. Accelerometer (ADXL 335):

ADXL 335 is a three-axis sensor i.e. it senses vibration signal in X, Y, and Z directions. The vibrations observed in motor are different in different direction, but we obtained maximum vibration in Y direction. The accelerometer ADXL 335 has its own advantages such as it has good thermal stability and high shock absorbing capacity nearly about 10000g. It has good sensitivity it has bandwidth ranges from 0.5 Hz. to 1600 Hz. for X and Y axis and is 0.5 Hz. to 550 Hz. for Z axis



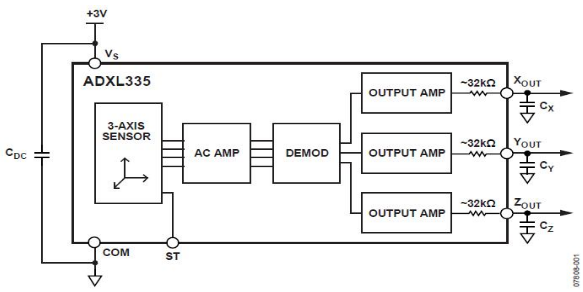


fig 2.3) Structure of ADXL 335

B. ARDUINO UNO board:

The arduino is an open source microcontroller board based on the Microchip ATmega328P microcontroller and developed by Arduino.cc. The board is equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards (shields) and other circuits. The board has 14 Digital pins, 6 Analog pins, and programmable with the Arduino IDE (Integrated Development Environment) via a type B USB cable. It can be powered by a USB cable or by an external 9 volt battery, though it accepts voltages between 7 and 20 volts

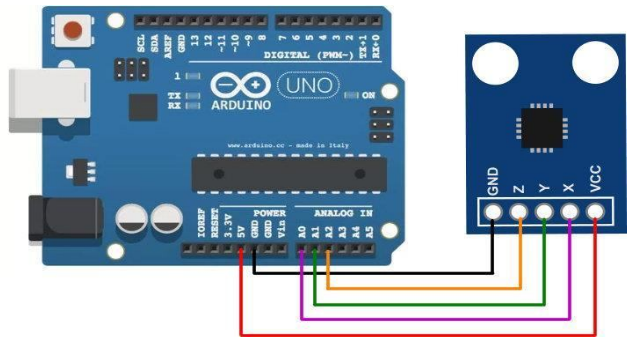


Fig 2.4) Arduino UNO Pin Diagram and interface with Sensor

C. Three phase induction motor:

This induction motor is coupled with DC shunt generator which is connected to resistive load bank as shown in fig. 2.2. This motor consists of bearing No. 6204 which is made damage to take the readings.

In this experiment 30 readings of healthy condition, 30 readings of bearing fault and 30 readings of inter-turn fault (10% turns short) is taken. Statistical parameters like RMS value, standard deviation, variance and skewness is calculated for each reading and excel sheet is prepared containing all these readings' parameters.

III. APPLICATION OF ANN FOR FAULT DETECTION

A) ANN Architecture:

ANN stands for Artificial Neural Network is program designed to solve any problem by trying to mimic the structure and the function of our nervous system. Neural networks are based on simulated neurons, which are joined together in a variety of ways to form networks. Neural networks resemble the human brain in two ways. First is a neural network acquires knowledge through learning and second a neural networks knowledge is stored within the interconnection strengths known as synaptic weight.

B) ANN structure:

ANN is two layered feed forward network with sigmoid hidden and softmax output neurons. The structural block diagram of ANN is as shown in fig.3.1.

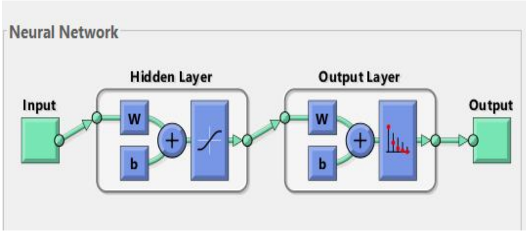


Fig. 3.1) Structure of ANN

The network is trained with scaled conjugate gradient back propagation. Back propagation is multi layer feed forward, supervised learning networks based on gradient descent learning rule. ANN is provided with inputs and outputs, the network compute, and then error (difference between actually and expected) is calculated. The idea of the back propagation algorithm is to reduce this error, until the ANN learns the training data. The excel sheet containing 90 reading and statistical parameter (Refer section II) of each reading is fed to ANN. Using this data ANN is learned and able to distinguished different healthy and fault conditions.

Total 90 sample readings are fed to the ANN out of which 62 numbers of samples (i.e. 70%) are used for the training purpose, 14 numbers of samples (i.e. 15%) for validation purpose and 14 numbers of samples (i.e. 15%) for testing purpose.

IV. EXPERIMENTAL FINDINGS

The pattern of vibration obtained is as shown in below figures.

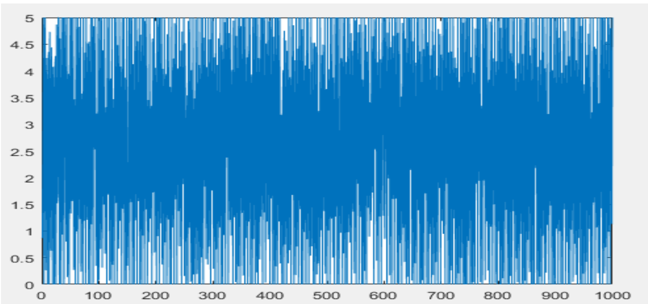


Fig. 4.1) Healthy Condition at No load

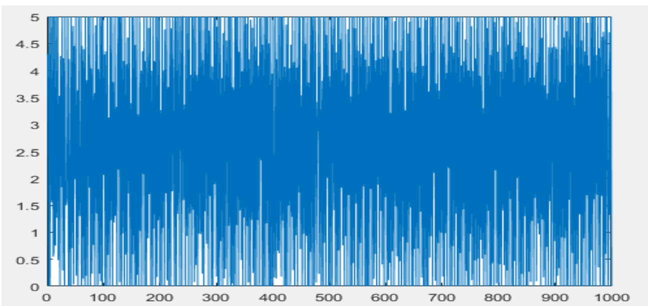


Fig. 4.2) Healthy Condition at Full Load

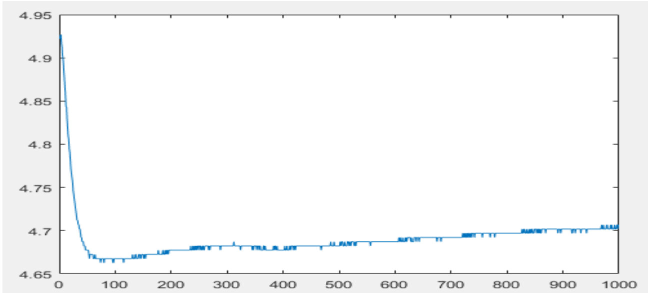


Fig 4.3) Bearing Fault at No Load

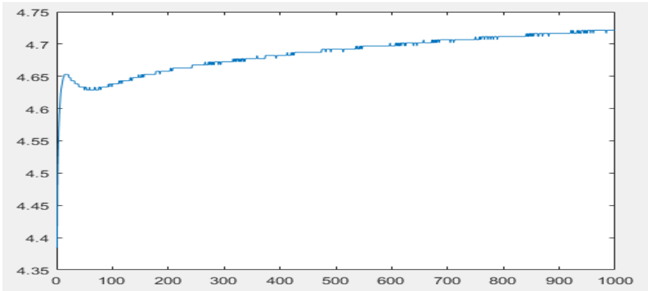


Fig. 4.4) Bearing Fault at Full Load

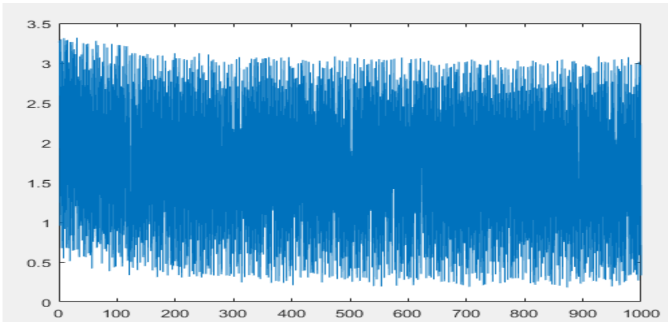


Fig. 4.5) Inter-turn Fault at No Load

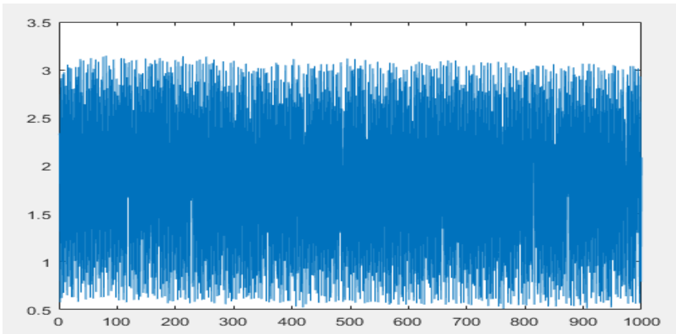


Fig. 4.6) Inter-turn fault at Full Load

Accelerometer gives output in the form of voltage. This voltage may vary from 0 to 5 volts. If more vibration is there then it gives reading nearer to 5 volts. The fault can be distinguished by calculating four parameter such as RMS value, standard deviation, variance and skewness which are distinguishing parameters for fault. These parameters are calculated for each reading and this data is used to train the

ANN network. For the healthy condition a constant vibration pattern is observed which is having rms value around 2.6 volts. There is not much difference in patterns is observed between the full load and no load condition. The vibration patterns are shown in fig 4.1 and fig 4.2.

For bearing fault, more vibrations are induced in the machine as shown in fig 4.3 and fig. 4.4. Accelerometer gives around 4.7 volts rms value. This indicates that vibration is increased. While for the inter-turn fault vibration is slightly less bearing fault and greater than healthy condition. It gives rms voltage around 3.1 volts. The patterns are as shown in fig. 4.5 and fig. 4.6. Similarly standard deviations, variance and skewness also shows particular pattern for the respective fault on that basis ANN can distinguished between normal and abnormal condition.

V. RESULT

When ANN is trained with data, it is able to distinguish between faulty condition and healthy condition. It's accuracy is 100% as shown in following confusion matrix (Fig 5.1). From this confusion matrix, it can be conclude that ANN does not have any confusion in faulty and healthy condition and it can identify with 100% accuracy,

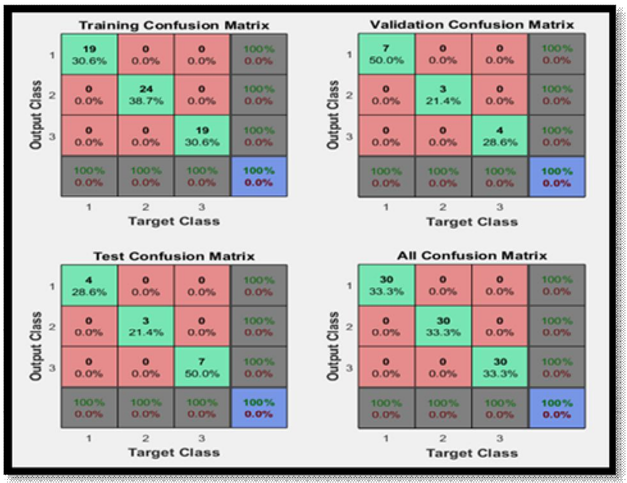


Fig 5.1) Confusion Matrix

When the test reading is fed to the ANN, it is identifying all these conditions whether the reading is of faulty or healthy motor and if faulty, which fault it is whether bearing fault or inter-turn fault, is also given by ANN. These results are as shown in figure 5.2, fig 5.3 and fig 5.4.

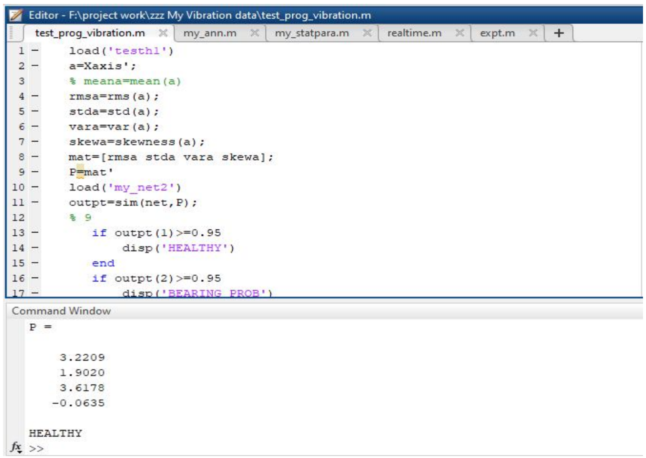


Fig 5.2) Healthy Condition

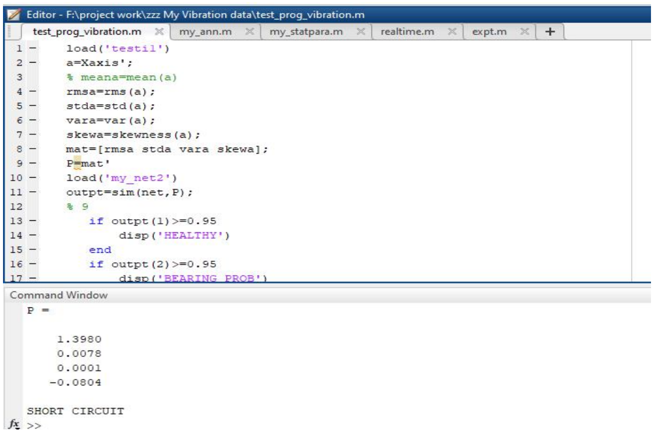


Fig 5.3) Inter-turn Fault Condition

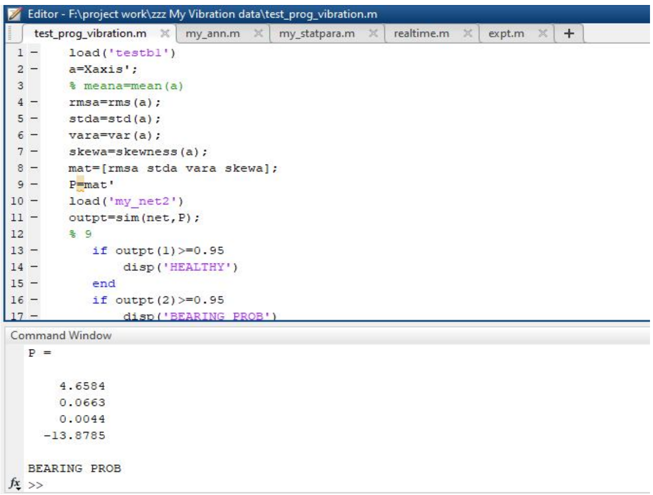


Fig.5.4) Bearing Fault Condition

VI. CONCLUSION

It is flexible and energy efficient health monitoring system for the three phase induction motor. The important point of consideration that is cost, it is a low cost protection profile for a single unit. Therefore, by using the accelerometer and

Arduino circuit assembly the vibration friendly faults such as bearing, inter-turn (which are experimented) are distinguished. It is much reliable method. So it is conclude that ANN based vibration signature can be used for the health monitoring of three phase induction motor.

VII. ACKNOWLEDGMENT

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