Bearing Fault Analysis of Single-Phase Induction Machine by using Vibration and Sound Signals

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Abstract

Induction machine plays a vital role in industry. The major advantages of induction machine are low cost, reliable operation, robust operation, simple in design, high starting torque, durability and low maintenance. Maintenance of induction machine is vital to keep up the complex process of industrial production. When any basic faults like bearing faults, gear box faults, mechanical unbalance, stator winding faults, air gap eccentricity, broken rotor bars, broken end rings, etc., occurs it may lead to the loss of production in industries. Bearing fault is one of the most common faults that occur in the induction machine. Therefore, machine condition should be monitored in order to protect the induction motor from damages. Currently a variety of methodologies are there for fault analysis. This paper is to analyze the fault by using vibration and sound signals because they are independent of the type of motor power supply and yields good results. Statistical features were extracted from the raw data of these signals and it is classified by K-Nearest Neighbour (KNN) classifier. The proposed work is implemented by using MATLAB.

Keywords - *Induction motor, Vibration and sound, K-Nearest Neighbour (KNN)*

I. INTRODUCTION

The induction motor plays a very important role and has found the applications in the field of medicine, industries, construction industries and military. The advantages of induction motor are low cost, low maintenance, durability. The induction motor works on the principle of electromagnetic induction. The electromagnetic field is induced in the rotor when the magnetic flux cuts the stationary rotor. The induction motor has high starting torque and the parameters of the motor do not change during operating conditions, but in practical applications the mechanical load parameters changes continuously with respect to time [1]. Therefore there is a chance for fault occurrence and it is mandatory to monitor the condition of machine in industries. Thus to monitor the condition, we are performing the analysis on the induction machine. The analysis may be of different types. They are motor current signature analysis (MCSA), Fast Fourier Transform spectral signature analysis, vibration analysis, temperature measurements, harmonic analysis of speed fluctuations, flux or air gap torque analysis, magnetic field analysis and sound analysis. The preferred analyzes is vibration and sound analysis because the sound and the vibration are the easiest and important parameters which can be detected accurately [9].

The vibration of any object in motion is characterized by variations of amplitude, intensity and frequency. And it is easy to identify, predict and prevent failures in rotating machinery. Vibration analysis has the advantage that its results are independent of the type of power supply and yields good results and its implementation requires using accelerometers as the basic sensors that must be placed on the geometrical axis of armature of the machine. Sound occurs due to mechanical and electrical faults. The analysis of sound signals for fault analysis on induction machine also has the advantage that the results are independent of power supply and standard microphone sensor is used as the primary sensor that can be placed anywhere near the machine under analysis and not necessarily in the direct contact [9].

Then these signals are given as the input to the one of the computing techniques, where the signals will be analyzed in MATLAB. Some of the computing techniques are Artificial Neural Network (ANN), Fast Fourier Transform (FFT), Continuous Wavelet Transform (CWT), the Hilbert transform, the Hilbert-Huang Transform, Discrete Wavelet Transform (DWT), fuzzy logic, K-Nearest Neighbour (KNN), fuzzy neural networks, the multiple signal classification (MUSIC), genetic algorithms, etc., [7]. In this paper K-Nearest Neighbour (KNN) is preferred for analyzes because KNN is a non-parametric algorithm. Non-parametric means there is no assumptions for underlying data distribution. This will be very helpful in practice where the most of the real world’s datasets do not follow mathematical theoretical assumptions. KNN is also known as simple algorithm which is easy to understand and it also gives accurate results.

Finally, the condition of the induction motor will be sent to the user through Simple Mail Transfer Protocol (SMTP) server using MATLAB.

II. PROPOSED SYSTEM

A. Block diagram

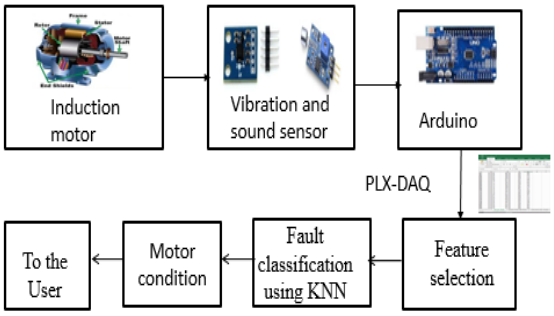

Fig. 1. Block diagram

Fig.1 shows the block diagram for the bearing fault analysis of an induction machine by using vibration and sound signals. The motor faults will be classified into two categories. They are internal and external faults. Further the internal faults can be classified as mechanical and electrical faults. The major sources of mechanical faults are rotor strikes, coil and lamination movement, bearing faults and eccentricity. Similarly, the major sources for electrical faults are dielectric failure, cracks in rotor bars and magnetic circuit faults. The external faults can also be classified as electrical, mechanical and environmental. The electrical fault sources are transient voltage, voltage fluctuations and unbalanced voltage. Environmental sources are humidity, temperature and cleanliness. The mechanical sources are pulsating load, over load and poor mounting [3]. The chances for the occurrence of faults in induction motor are the bearings. So therefore, this paper analyzes the condition of bearing in single-phase induction machine.

The bearing consists of two rings. They are inner ring and outer ring. The balls are present between the rings. The bearing faults may be of three types. They are inner race fault, outer race fault and ball defects. Bearing faults are due to overstress in bearings, spalling (flakes of materials break from the bearings), contamination (presence of dirt between the rings), corrosion, improper lubrication, improper installation and brinelling (when the balls in the bearings pushes the inner and outer rings, it creates a mark in the rings) [1]. When these types of bearing fault occur, it does not result in the smooth running of the bearings. So, it creates increased vibration and noise levels. When the bearing temperature increases it may also result in bearing failure [5].

Therefore, bearings of single-phase induction motor are analyzed by using vibration and sound signals. The block diagram explains that the vibration sensor and the sound sensor are kept on the motor which is programmed by Arduino. The vibration sensor is kept on the geometrical axis of the armature of motor and the sound sensor can be kept anywhere in the motor. The values from the Arduino are made to read in the excel sheet using Parallax Data Acquisition (PLX-DAQ) tool.

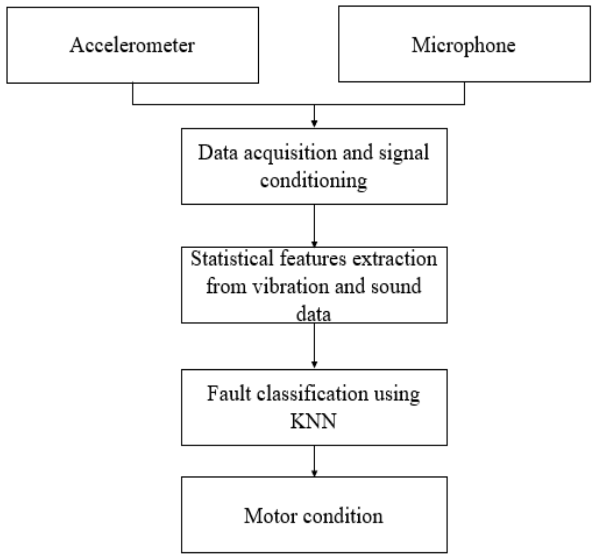

Fig. 2. The methodology flow chart

As per the Fig. 2, after the acquisition of vibration and sound data, statistical feature extractions are done. Some of the extracted features are

1. Average

$$Average = \sum_{i=1}^{n} \frac{x_i}{n}$$

2. Variance

$$S^2 = \frac{\sum (x - \bar{x})^2}{n}$$

3. Standard deviation

$$S = \sqrt{\frac{\sum (x - \bar{x})^2}{n}}$$

4. Mean

$$\bar{X} = \sum \frac{x}{n}$$

5. Median

$$Median = \left(\frac{n+1}{n}\right)^{th} term$$

One of the best feature is standard deviation which is selected by ranking selection method which gives accurate results. In this paper standard deviation is preferred. Then these results are given to the KNN classifier where the signals are analyzed in MATLAB and the condition of motor is obtained and it is sent to the user through mail.

B. K-Nearest Neighbour

KNN is a non-parametric algorithm. It is also called as lazy learning algorithm. Non-parametric means no assumptions are made for data distribution. This KNN algorithm will be very useful in most of the cases were data sets do not follow the theoretical assumptions. Lazy learning algorithm means training data points are not needed for model generation. All training data are included in testing phase. This will make training faster and testing slower. Testing phase is costlier because it takes more time to scan and requires a lot of memory for storage of these training datas.

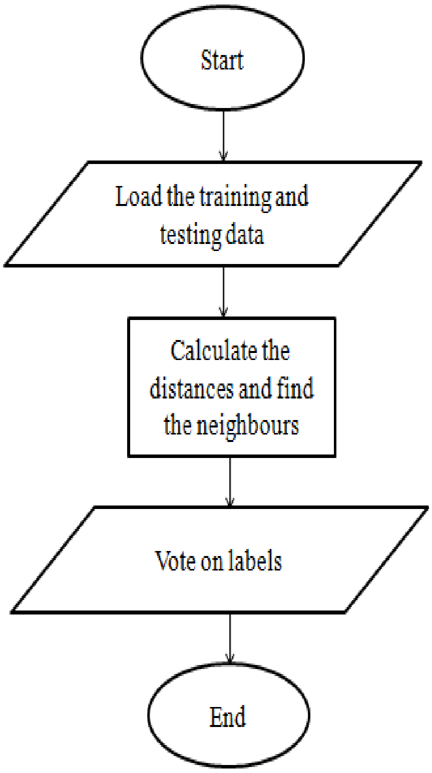

Fig. 3. Flowchart for KNN classifier

Fig. 3 explains the KNN classifier. First step of KNN algorithm is to load the training and testing data. Then, choose the K value. After that, find the distance for each point in the test data to all training data points. The distance measures are of many methods such as Euclidean distance, Hamming distance, Manhattan distance, cosine similarity and Minkowski distance. Euclidean distance is one of the most familiar and it is obtained by subtracting the training data point from the point to be classified.

$$E(x,y) = \sqrt{\sum_{i=0}^{n} (x_i - y_i)^2}$$

Then store the Euclidean distances in a list and sort it in the ascending manner. The first K points are selected. To each test point the classes are assigned based on the majority of classes present in the selected points.

The advantages of KNN are no assumptions are made in KNN algorithm for non linear data and it is an easy algorithm because it is easy to understand and interpret the result. It also gives highly accurate results. It is versatile because it is used for classification and regression process.

III. HARDWARE IMPLEMENTATION

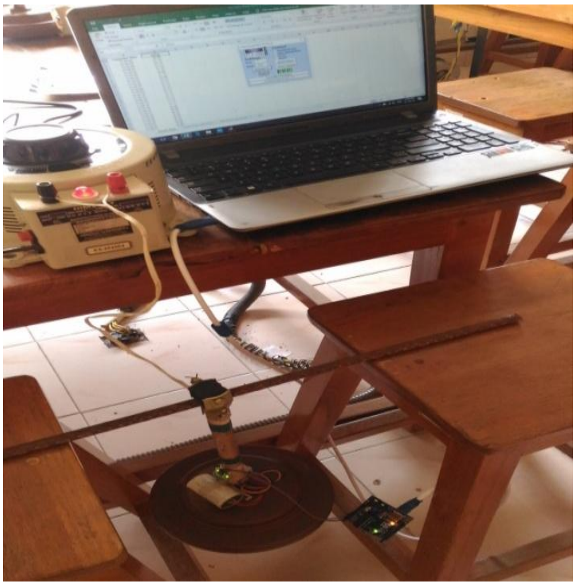

Fig. 4. Experimental setup of proposed system

Fig. 4 shows the experimental setup for the proposed prototype of single phase induction motor.

TABLE. 1. Specifications of single-phase induction motor

PARAMETERS	RATINGS
Voltage	220-240V
Power	66W
Frequency	50Hz

TABLE. 1 shows the specifications of single-phase induction motor. The supply voltage of 230V is given to the induction motor. The vibration and sound sensors are kept on the shaft where the shaft is connected with the bearings so that the bearing fault can be detected. Then the code for vibration and sound sensor is compiled and uploaded in Arduino. Next, the analog values from vibration and sound sensor are given as an input to the KNN classifier in MATLAB which classifies the motor based on the type of bearing conditions like faulty bearing, 25% fault, 50%fault, 75%fault and healthy bearing. After that the condition of induction motor is obtained and it is sent to the user in order to protect the induction motor from further damage.

TABLE. 2. KNN classification based on vibration and sound data

Vibration and Sound data	Speed	Bearing Condition
Low	High	Fair

Low	Medium	Good
High	Low	Bad
High	Medium	Good
Medium	Medium	Good
Medium	Low	Bad

TABLE. 2 explains the bearing condition with the help of speed, vibration and sound data. If the obtained vibration and sound signals values are between (0.15-0.18)V and (30.6-30.8)dB respectively it shows the bearing has damaged and when the corresponding values decrease to (0.25-0.26)V and (31.5-31.6)dB, it is 25%fault.When the vibration value is between (0.35-0.37)V and the sound value is between is (32.4-32.8)dB, it shows the bearing is 50% fault. And when it further decreases to (0.46-0.48)V and (33.3-33.7)dB respectively, the fault is 75% and when the vibration value is (0.55-0.56)V and the sound is (34-35)dB, the bearing is under healthy condition and the values are tabulated in the TABLE. 3.

TABLE. 3. Bearing conditions based on threshold value

Vibration Values(V)	Sound Values(dB)	Bearing Condition
0.15-0.18	30.6-30.8	Faulty bearing
0.25-0.26	31.5-31.6	25% fault
0.35-0.37	32.4-32.8	50% fault
0.46-0.48	33.3-33.7	75%fault
0.55-0.56	34-35	Healthybearing

IV. CONCLUSION

An experimental study for various fault conditions of induction motor and the effect of such changes on the vibration and sound produced has been measured and analyzed. This work dealt with the analysis of bearing fault occurred in an induction motor. Then the statistical features have been extracted from the acquired signals and the best feature from these extracted features is selected using ranker selection method. The selected features were given as an input for K-Nearest neighbour (KNN) classifier. By this way the bearing fault is analyzed in a single phase induction motor and the predicted condition is intimated to the user through Simple Mail Transfer Protocol (SMTP) server.

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