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Development of Intelligent System for Induction Motor Fault Diagnosis in Ceiling Fan

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A variety of fan faults occur in our day to day life such as electrical faults(winding faults), mechanical faults (broken rotor bars, eccentricity, bearing faults) etc. To detect the fault, many motor variables may be taken such as current, voltage, speed, sound, temperature and vibrations, so that the preventive action may be taken before the occurrence of faults in the fan. Current signature is useful for finding electrical faults such as stator faults etc. and acoustic signature is useful for finding mechanical faults such as rotor faults etc. In this paper, the on line current, voltage, rpm and temperature reading of faulty fan and healthy fan are recorded. These recorded signals are used to train a neural network so that it is able to detect the fault.

Keywords: *Wavelet, ANN, Ceiling Fan, Fault detection.*

1.0 INTRODUCTION

Induction motors are most commonly used electrical machines in fan because of their low cost, reasonably small size, ruggedness, low maintenance, and operation with an easily available power supply. Although these are very reliable, they are subjected to different kinds of failures/faults. These faults may be inherent to the fan itself or due to operating conditions. The inherent faults may be due to the mechanical or electrical forces acting on the fan enclosure. If a fault is not detected or if it is allowed to develop further it may lead to a failure A variety of machine faults have been studied in the literature [1] such as winding faults, unbalanced stator and rotor parameters, broken rotor bars, eccentricity and bearing faults. Several fault identification methods have been developed and been effectively applied to detect machine faults at different stages by using different machine variables, such as current, voltage, speed, efficiency, temperature and vibrations [2-3]. Thus, for safety and economic considerations, it is essential to monitor the behavior of fan of different sizes. Traditionally, maintenance procedures follow two approaches. The first one is to perform fixed time interval maintenance. However, making use of today's technology, new scientific approach has become possible for maintenance management. One of the key elements to this new approach is predictive maintenance through condition monitoring [4-7]. It is possible to give vital diagnostic information to operator before it fails catastrophically. To automate the diagnostic process, a number of soft computing diagnostic techniques have been proposed recently [8-9]. For condition monitoring and fault diagnosis many researchers used wavelet transform [10-11].

In manufacturing, fan reliability is critical for plant operation. For example, where fans serve material handling applications, fan failure immediately create a process stoppage. In

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industrial ventilation applications, fan failure will often forces a process to be shut down. Fan operation is essential to maintain a productive work environment. Fan failure leads to conditions in which worker productivity and product quality declines [12].

This paper proposes a fan fault diagnosis system using wavelet and artificial Neural Networks (ANN). There are certain limitations of ANN such as training difficulties, no fixed structure and configuration of ANN for different problem [11]. To overcome these difficulties generalized Neural Network has been proposed in the paper.

2.0 THE PROPOSED SYSTEM

Sound signature is useful for finding mechanical faults such as rotor faults, bearing faults, unbalanced wings. There are many faults; which may be broadly classified as electrical and mechanical faults. The paper mainly concentrates on mechanical faults i.e. bearing faults and electrical faults like winding faults or faults in rotor bars. A fault diagnosis system has been developed and implemented in real time. The block diagram used for the fan fault diagnosis system is shown in Figure 1. The diagnosis system consists of following blocks: fan system, data acquisition system, preprocessing of data, wavelet analysis and ANN. A real time healthy and faulty fan signals has been decomposed using wavelet. In wavelet we used db3 decomposition at level 5. All decomposed wavelet components are used for training of ANN and ANN is then used to predict the fault in fan system. To overcome the drawbacks of ANN such as-large training time, large training data and unknown ANN structure etc. use of GNN is proposed in this paper. Earlier GNN was used for modeling [11], controlling [11] and forecasting [11] applications.

2.1 Fan System

Crompton ceiling fan system has been taken for practical implementation. It has various parts such as stator (stator core, main and auxiliary windings), condenser, hanging arrangement, rotor core, rotor bars, blades, bearing etc.

Specification of Fan

Manufacturer– Crompton Greaves.

Power – 85 W

Voltage – 240 V

Frequency - 50 Hz

Speed – 300 rpm

Blades Length – 1200 mm

2.2 Data Acquisition System

The sound, current, temperature and speed signals of ceiling fan system are acquired through suitable sensors, interfacing device and computer. The signals have acquired for healthy and faulty fan system.

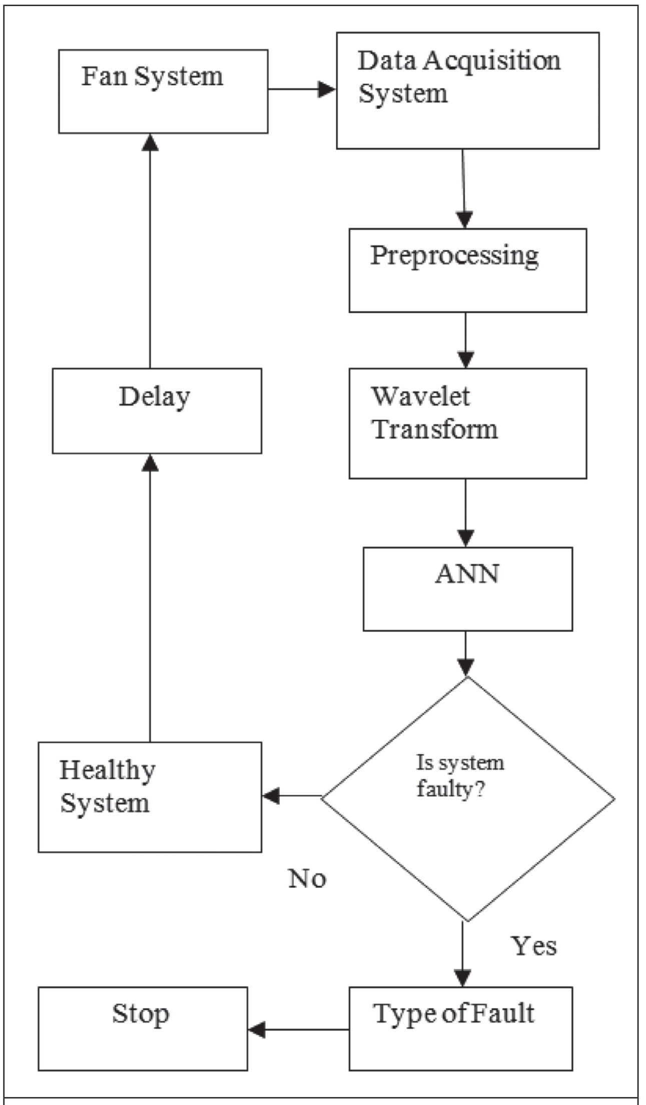


FIG. 1 BLOCK DIAGRAM OF THE PROPOSED FAULT DIAGNOSIS SYSTEM

2.3 Preprocessing

The real time signals acquired in previous section are de-noised and normalized in proper range. The de-noising of signals is done using suitable filters. If the observed signal is weak, we have to use amplifiers for amplifying the weak signals.

2.4 Wavelet Analysis

The processed signal is now analyzed with the help of wavelet 3-step decomposition of the signal at level 5. Wavelet decomposes this real time signal into one approximation (A5) and five detailed signals (D1 to D5) as shown in Figure 2.

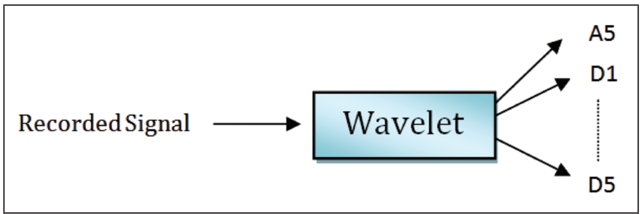


FIG. 2 DECOMPOSITION OF RECORDED SIGNAL USING WAVELET

2.5 Artificial Neural Network (ANN)

All decomposed components of faulty signals have become compared with healthy signal. If there is an error the system display the faulty state of fan system and will stop. If this is healthy then the loop will continuously check the fan system after a periodic delay as shown in Figure 3.

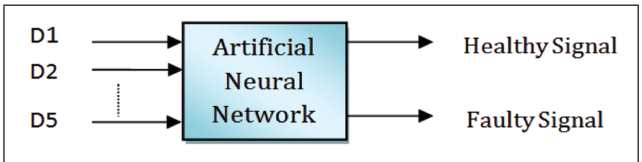


FIG. 3 NEURAL NETWORK SYSTEM FOR FAULT DIAGNOSIS

Figure 4 shows the internal details of the fan system such as capacitor, shaft, ball bearing primary and secondary windings.

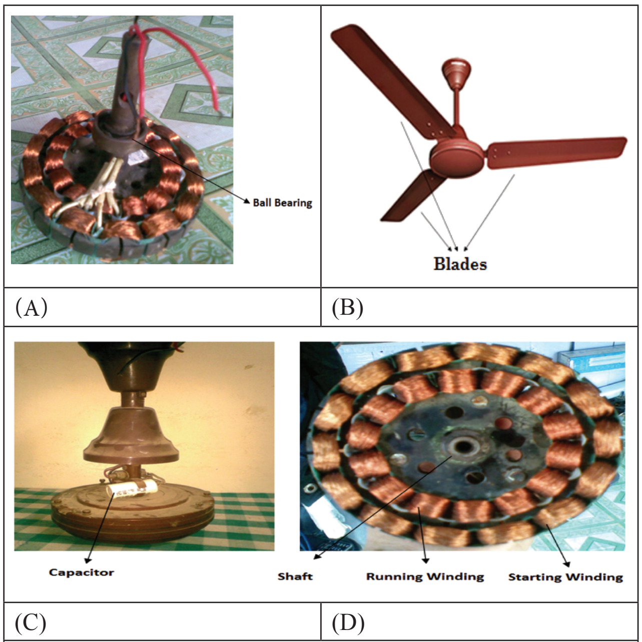


FIG. 4 INTERNAL DETAILS OF FAN SYSTEM

3.0 EXPERIMENTAL SETUP

The experimentation has been done in Electrical Engineering Lab at Faculty of Engineering, Dayalbagh Educational Institute (Deemed University) Agra, India. The laboratory model shown in Figure 5, is consisting of a fan, a laptop preloaded with MATLAB software and Aplab software, an auto transformer, a capacitor, a shunt, a transformer for amplification and isolation, an oscilloscope, an ammeter, a laser tachometer, a thermal imaging camera and mobile phone for sound recording.

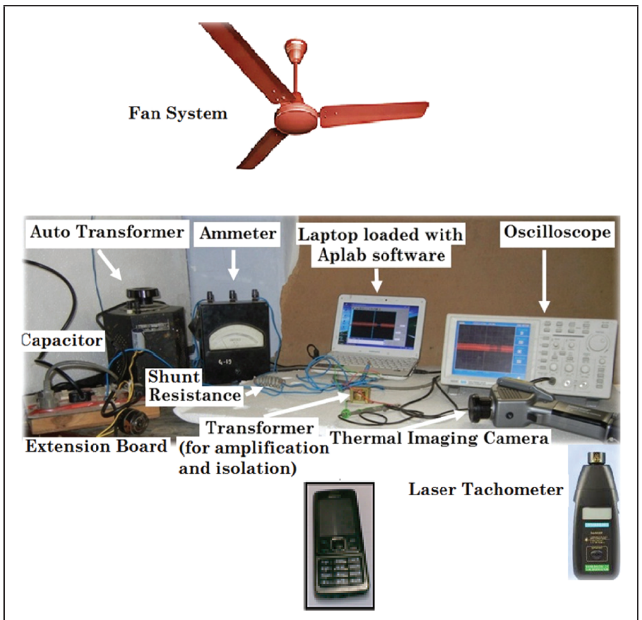


FIG. 5 TEST BENCH FOR FAN SYSTEM

4.0 EXPERIMENTAL RESULTS

The sound signals for faulty and healthy fans are recorded and shown in Figure 6-7, and their wavelet decompositions are given in Figures. 8-13.

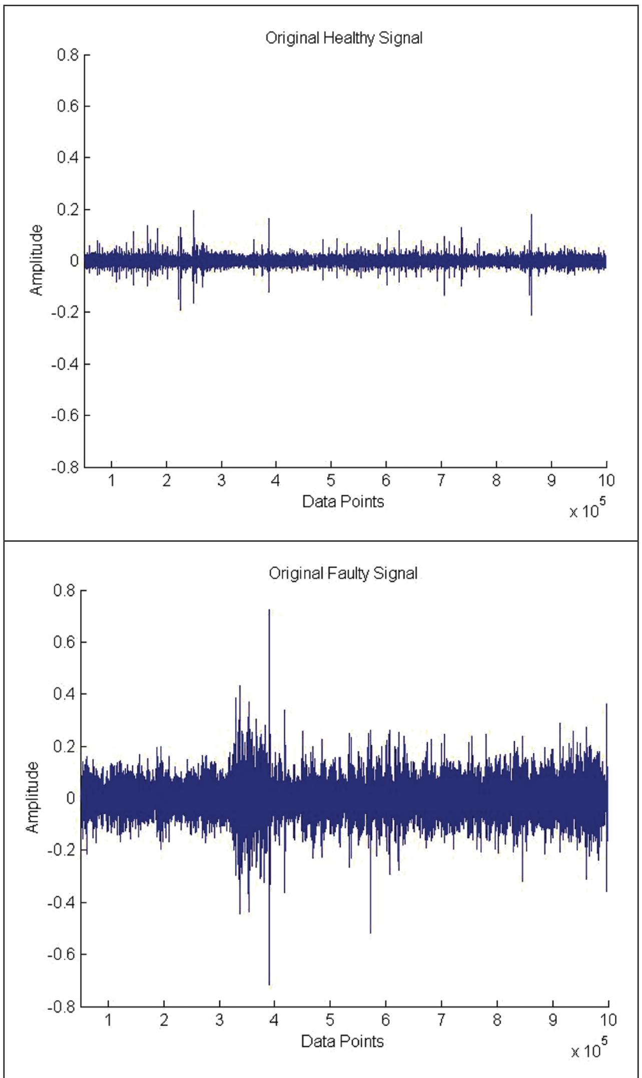
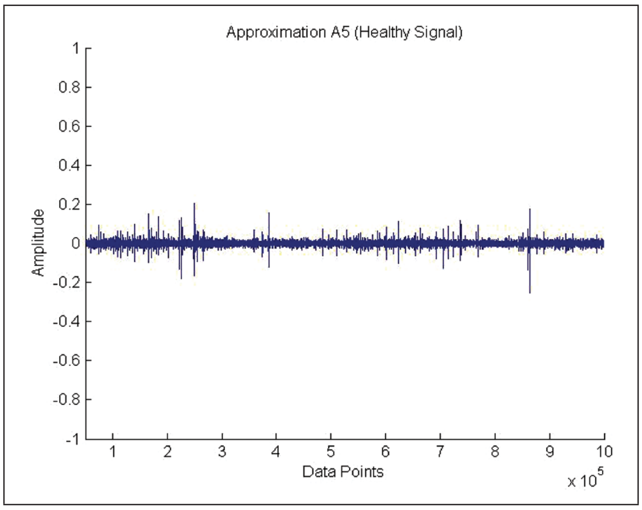


FIG. 6 SOUND SIGNAL



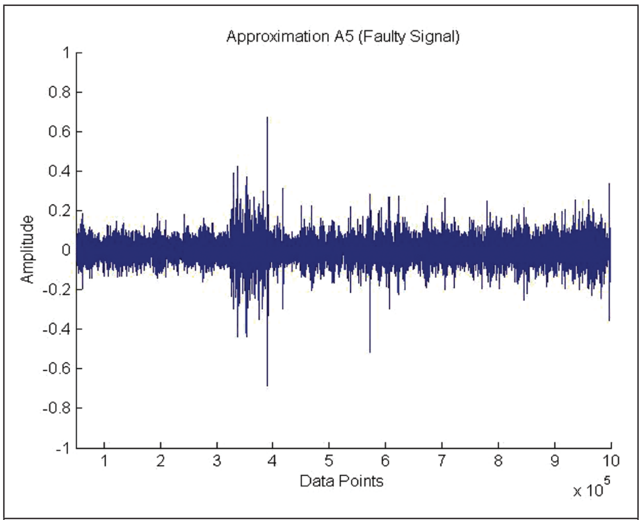


FIG. 7 APPROXIMATION A5 SIGNAL

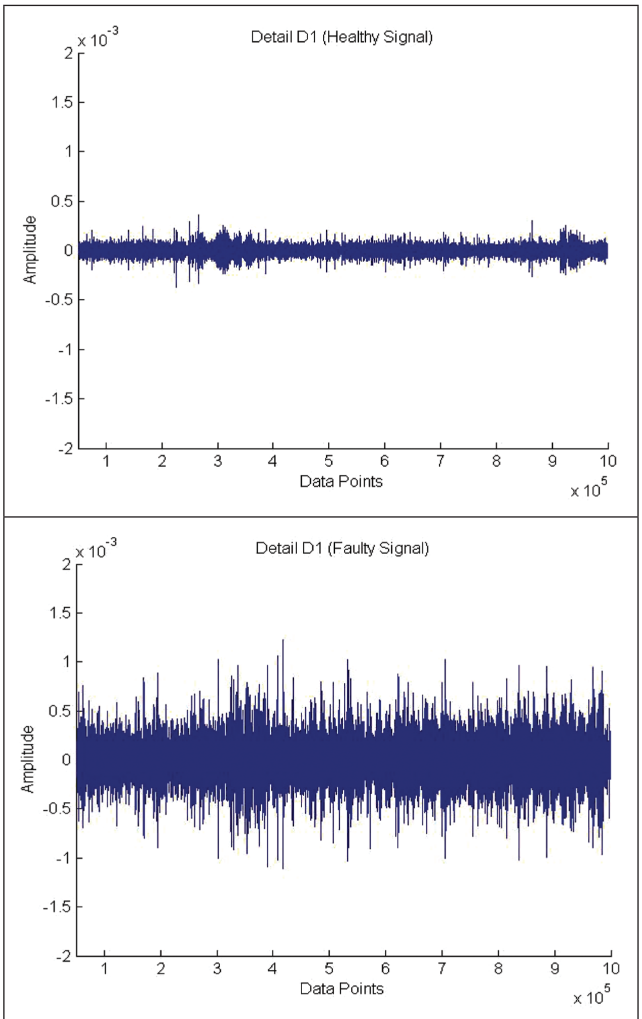


FIG. 8 DETAIL D1 FAULTY SIGNAL

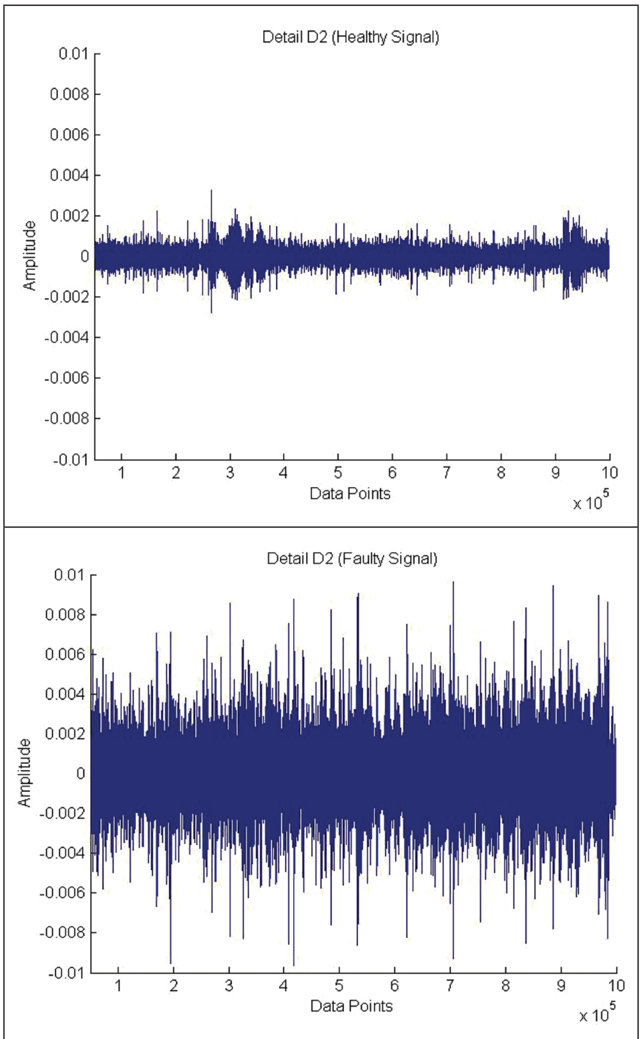
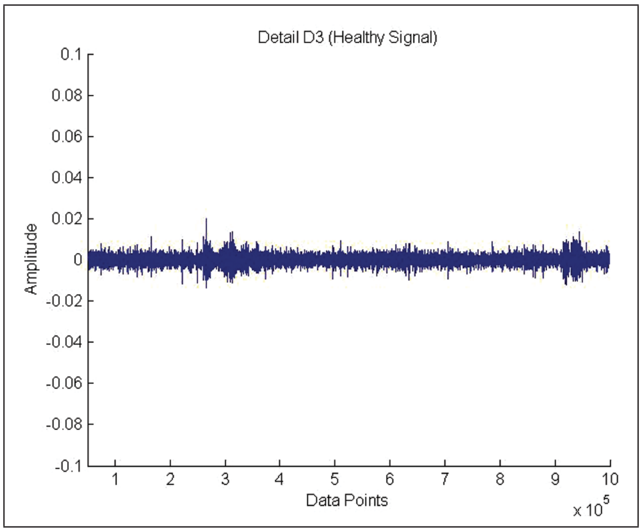


FIG. 9 DETAIL D2 SIGNAL



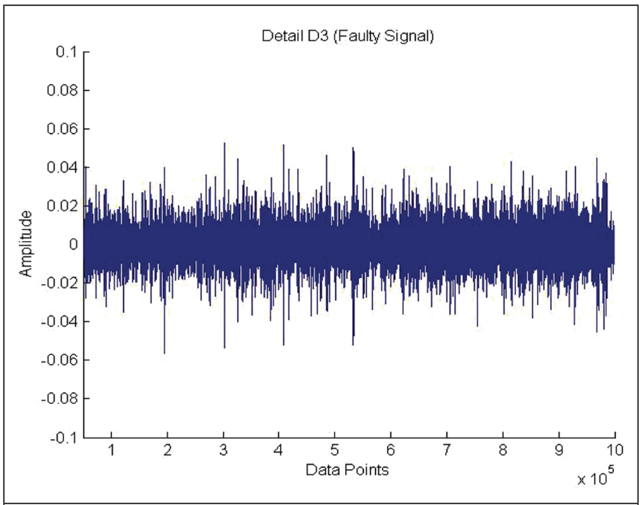


FIG. 10 DETAIL D3 SIGNAL

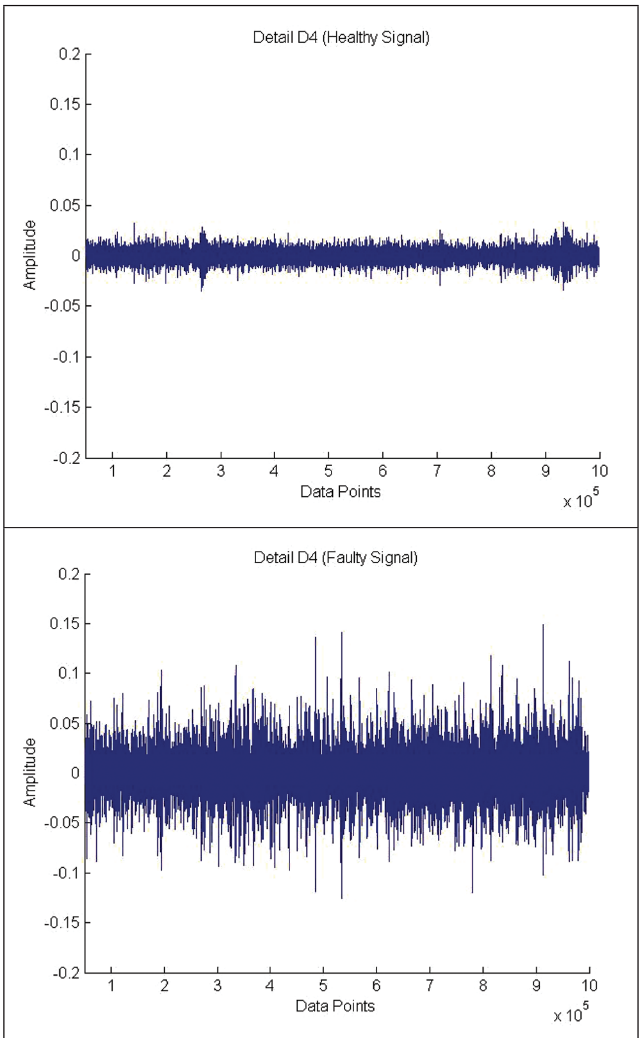


FIG. 11 DETAIL D4 SIGNAL

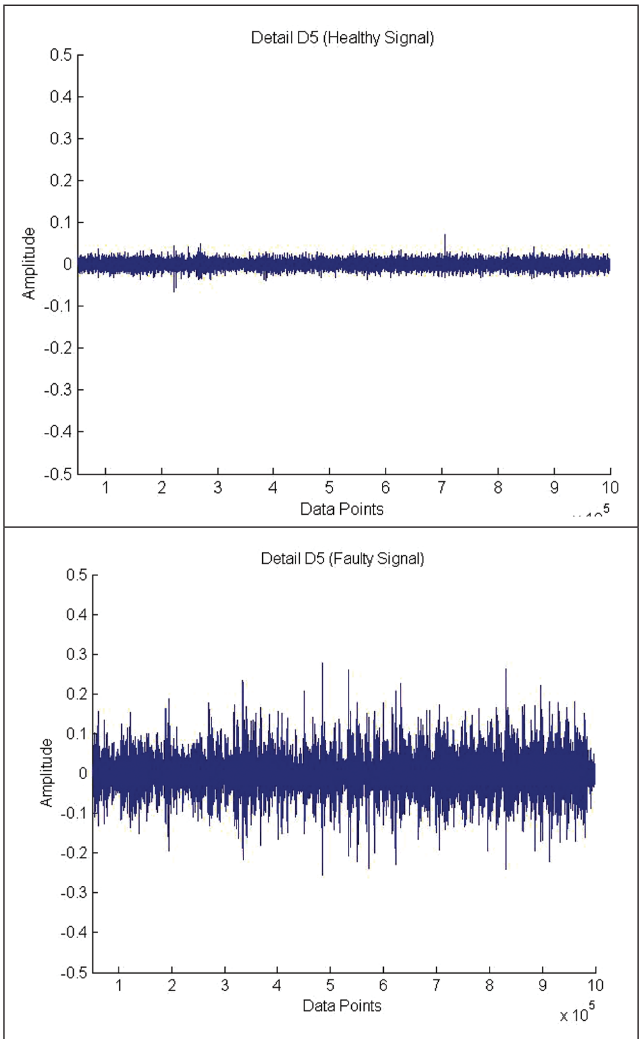


FIG. 12 DETAIL D5 SIGNAL

Clear difference may be observed in approximation component A5 and detailed components D1, D2, D3, D4, D5 of healthy and faulty fans.

From Table 1 and Figures 13-14 clearly show the difference in current and rotational speed (rpm) readings in healthy and bearing jam fault respectively for different voltages. It is observed that the current is minimum in case of weak capacitor fault and speed is zero in bearing jam at lower voltages. Also, the rpm is low in case of weak capacitor as compared to other faults.

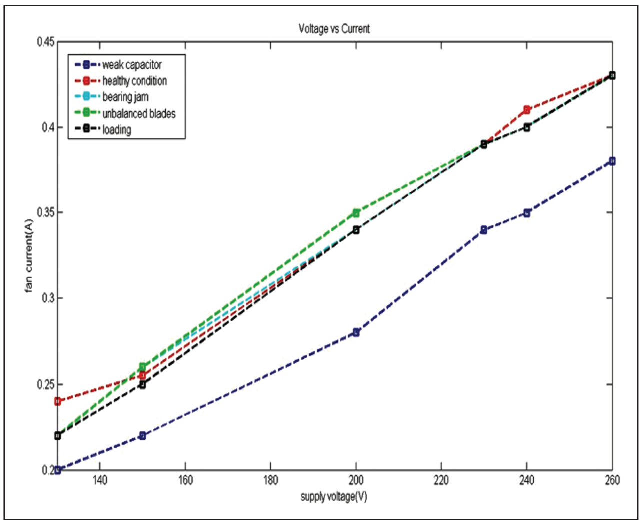


FIG. 13 VOLTAGE VS. CURRENT FOR DIFFERENT FAULT CONDITIONS

TABLE 1

COMPARISON OF WEAK CAPACITOR, BEARING JAM, UNBALANCED LOADING FAULT AND HEALTHY CONDITIONS

Weak capacitor			**Bearing jam**		**Unbalanced Loading**		**Healthy condition**	
SUPPLY VOLTS (V)	FAN CURRENT (A)	SPEED (RPM)	FAN CURRENT (A)	SPEED (RPM)	FAN CURRENT (A)	SPEED (RPM)	FAN CURRENT (A)	SPEED (RPM)
130	0.20	71.6	0.22	0	0.22	94	0.24	95
150	0.22	79.4	0.26	72	0.25	108	0.25	113
200	0.29	101.2	0.34	153	0.34	172	0.34	176
230	0.34	114.8	0.39	212	0.39	221	0.39	226
240	0.35	118.4	0.40	223	0.40	234	0.41	238
260	0.38	124.8	0.43	240	0.43	255	0.43	256

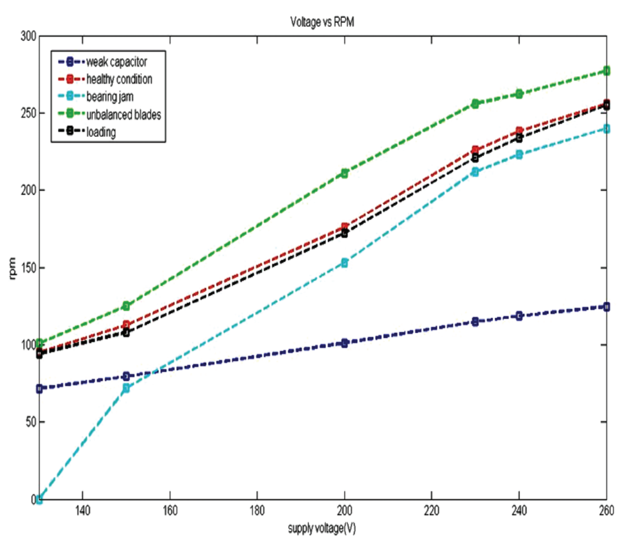


FIG. 14 VOLTAGE VS. RPM FOR DIFFERENT FAULT CONDITIONS

TABLE 2A			
READINGS WITH FAULTY AUXILIARY WINDING			
Volt. (main winding)	**Volt. (auxiliary winding)**	**Fan Current (A)**	**RPM**
230	0	0.33	41
230	100	0.33	113
230	140	0..345	135
230	180	0.36	170
230	220	0.37	210
230	260	0.38	218

TABLE 2B			
READINGS WITH FAULTY MAIN WINDING.			
Volt. (auxiliary winding)	**Volt. (main winding)**	**Fan Current (A)**	**RPM**
230	0	0.25	40
230	100	0.26	114
230	130	0.28	141
230	150	0.30	157
230	230	0.380	228
230	260	0.42	248

Table 2a and Table 2b show the current and rpm readings in faulty auxiliary winding and faulty main winding conditions respectively. The temperature under different fault conditions is given in Table 3.

The values of temperatures in Table 3 are the average of ten readings in each case. Each reading has been taken after half an hour operation of fan.

TABLE 3	
TEMPERATURE VARIATION IN DIFFERENT FAULTS	
Faults	**Temperature (°C)**
Unbalanced blades	57.6
Weak Capacitor	60.3
Healthy Condition	60.8
Loading	61.1
Bearing jam	62.6

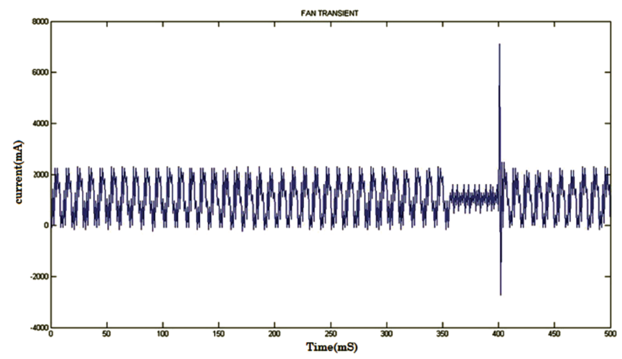


FIG. 15A STARTING FAN TRANSIENTS IN WEAK CAPACITOR CONDITION

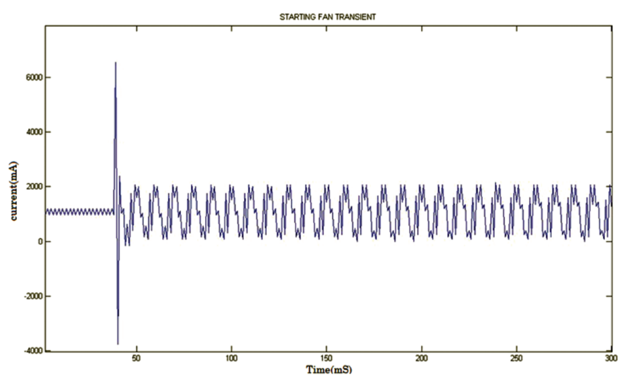


FIG. 15B STARTING FAN TRANSIENTS IN HEALTHY CONDITION

Starting fan transients were taken in healthy condition and in weak capacitor fault condition in Figure 15a and 15b and it is observed that the value of starting transient is less in weak capacitor fault as compare to in healthy condition.

5.0 GENERALIZED NEURAL NETWORK (GNN) FOR FAULT DIAGNOSIS

To overcome the drawbacks of ANN like selection of hidden neurons, large training time etc. the GNN is used in this paper. The GNN is consisting of single higher order neuron [10]. It is trained for wavelet components of experimental data (Signals) to diagnose the various types of fault. The inputs to GNN are wavelet components of sound signal, current signature, temperature, fan speed and output is fan state (i.e. either faulty or healthy). If fault is there which type of fault in the Fan system.

6.0 CONCLUSION

The paper deals with detection of faults in the ceiling fan system using wavelet components of real time sound signal and current, rpm and temperature. The wavelet components are clearly showing the difference between healthy and faulty fan system for bearing faults while other parameters are used to detect weak capacitor, unbalanced blades, winding and rotor bar faults. The ANN and GNN are trained to predict the faults.

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