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On line cooling system fault detection in induction motor

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Induction motors are popularly used as an electric drives are the critical component in industrial systems. Most of the faults in induction motor are because of excessive heat generated in the machine. In the industrial application a large rating of induction motors are used which produce a significant heat. The heat is produced in the motor due to the different losses accumulated in the machine. Hence a healthy cooling system is always required to dissipate the heat and maintain the motor temperature within acceptable limits. This paper deals with the problem occurred specially in the cooling system under different operating conditions and investigate them. The on-line information is gathered from the machine about temperature, current and vibration signatures at different operating condition and the health of the cooling system is analyzed. Soft computing techniques are utilized for this purpose.

Keywords: *Induction motor, cooling system, temperature, current signature, vibration, soft computing.*

1.0 INTRODUCTION

Induction motors are the workhorses of any industrial plant. Squirrel cage induction motors are widely used induction motor in modern industries as well as many domestic applications for different purposes like pumping of fluid, operating conveyors, ventilation purpose and many more. These motors are low cost, highly reliable, low inertia, compact, robust and high transient torque motors. For the small voltage (SV) and medium voltage (MV) induction motors, over heating is one of the vital causes of the stator winding insulation degradation process [1-2]. As one of the root causes to stator insulation failures, cooling system defect has drawn a lot of attention in the past several decades. This extremely high thermal stresses not only greatly reduce the mechanical performance of the rotor cage, but also lead to thermal expansion of the rotor cage and thus mechanical stresses on the rotor cage, which eventually leads to rotor cage failure. Therefore, to ensure the long lasting of the insulation life and for good health of the rotor cage, it is very important to monitor the temperature rise of induction motor. Thermal monitoring also protects the motor under thermal overloading conditions such as motor stall, jam, overload, unbalanced operation, and condition where the cooling ability of the motor is accidentally reduced.

So one healthy cooling system is very essential for a motor to maintain its temperature within its comfort limit. To maintain the cooling system healthy one on-line continuous monitoring is required [3-4]. Most of the faults in induction motor are due to excessive heat produced by it. Fortunately, high reliability and durability are one of the main constructive advantages of induction cage machines. However, they can work smoothly if their parameters are monitored properly. Although Induction motors are highly reliable industrial drive, these motors are often exposed to hostile environments during operation which leads to generate excessive heat. It may be the cause of faults and hence ultimately the failure of the motor. Faults and failures of induction

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machines can lead to excessive down times and generate large losses in terms of maintenance and lost revenues [5-6]. Even small excessive heating can causes increased losses, reduced efficiency, change in internal parameters and reduced the lubrication and bearing life span. Effective supervisory systems for the cooling system of the motor have two positive effects, one is lifetime of the machine can be prolonged and the other is efficiency of the machine will not be affected. Many more health monitoring of the cooling system for the induction motor are discussed past. They mostly consider the temperature rise of the machine only, but in our method, the on-line information is gathered from the machine about temperature, current and vibration signatures at different operating condition and the health of the cooling system is analyzed. Soft computing techniques are utilized for this purpose [7-8]

2.0 THE PROPOSED SYSTEM

The Proposed method is to monitor the health of cooling system and recognize the cooling system faults in 3-phase induction motor through the analysis of on line temperature characteristics, current and vibration signatures at different operating condition. It is a fault detection system for the cooling system which is provided in the motor itself for its cooling purpose. Though this is a one type of mechanical fault, but that can be realized by the three signals temperature, stator current and vibration of that motor. All the three factors are to be considered simultaneously to get final health declaration. The main advantage of this method is a noninvasive fault diagnosis in induction motor. Experiments on 3-phase induction motor for fault diagnosis of its cooling system was conducted to acquire all those three above said data. Separate experiments were conducted and separate sets of readings are noted for both faulty and healthy condition of cooling system of three phase induction motor. Proper cooling system signals and improper cooling system signals of that induction motor are analyzed through the use of software i.e. MATLAB™ 7.5 and the comparison graph is drawn for the better understanding of the health of the cooling system [9-10].This system needed an induction motor with cooling system provided in it, thermal sensor, speed sensor, vibration sensor, VIF meter, DAQ card with supporting VB software, one computer with MATLAB™ 7.5 [9,10].

3.0 EXPERIMENTAL SETUP

The experimentation is done in Electrical Engineering lab at Dayalbagh Educational Institute (Deemed University) Agra, India. The experiment setup is consisting of one induction motor having a healthy cooling system with the arrangement through which fault in the cooling system can be created. The specification of the motor are three phase Squirrel cage induction motor 230 V, 50 Hz, 3 HP, inbuilt fan type cooling. A voltage –current-frequency (VIF) meter, a temperature sensor (LM-35),one data acquisition system (DAS or DAQ) card is used to acquire the signal and interface with the computer. One vibration sensor, one current sensor and one computer with MATLAB™ software installed.

The real time data is acquired with the help of DAQ card for both healthy and faulty condition of the cooling system at different load conditions. For both the condition data are sent to computer. MATLAB™ imports these signals and graphs are drawn for all the parameters at faulty and healthy condition.

Graphical analysis is done for the final declaration of the health condition of the cooling system of that induction motor. Figure 1 shows the experimental setup of health monitoring system of cooling system of induction motor [5,11].

FIG. 1 EXPERIMENTAL SETUP

4.0 FLOW CHART FOR PROPOSED METHOD

A flow chart for proposed method is shown below in Figure 2.

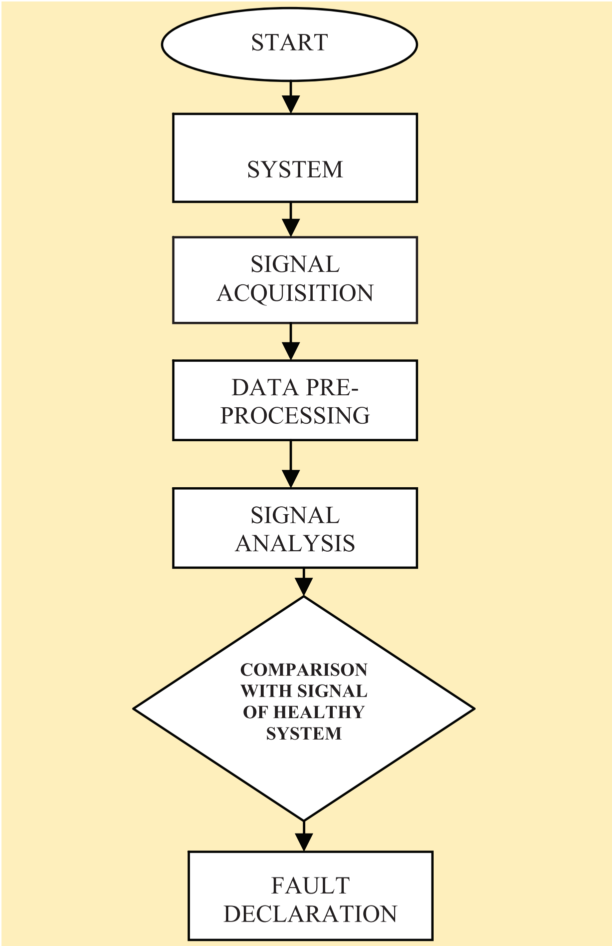

FIG. 2 FLOW CHART FOR PROPOSED METHOD

4.1 System

For the proposed method we have a system for the experimentation i.e. one induction motor with the facility that we can create the fault in the cooling system of that motor easily, when it is needed. First we acquired the data of temperature of the motor, current signature, vibration signature from the healthy motor that is when the cooling system is functioning properly. Then we create the fault in the cooling system of motor manually. Then we acquired the data of exactly same parameters by the same method for the faulty cooling system of the motor at different load conditions [12-13]. The experimented motor with its cooling system provided has shown in Figure 3 given below.

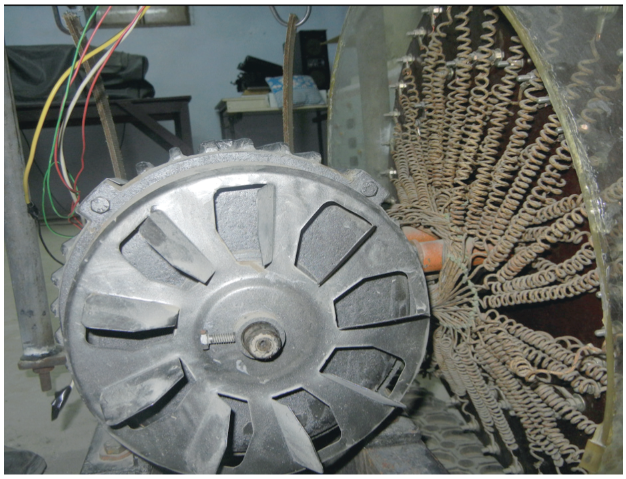

FIG. 3 COOLING SYSTEM OF EXPERIMENTED MOTOR

4.2 Signal Acquisition

The major part of the health monitoring of induction motor is data acquisition or signal acquisition. Basically three parameters are considered to analyze the health of the cooling system. They are temperature of the machine, vibration of the machine, stator current. Voltage and speed also are monitored. Speed is measured by a separate speed sensor kept in the front of the pulley of the machine. But the signal of the temperature, vibration, stator current and voltage are acquired by a DAQ or DAS (data acquisition system) card which is interfacing between the induction motor and the computer. Here DAQ card is playing a vital role to acquire the signal. Photo of the used DAQ card in this case is shown in Figure 4 and block diagram of the DAQ card is shown in the Figure 5. Four sensors are used to acquire the data; they are Temperature sensor (LM-35), vibration sensor, current sensor and voltage sensor. These sensors collect the data and these data are passed through a filter for leveling of data as the requirement. For the filtering purpose capacitor is fixed after each sensor. Initially those data which are collected and filtered by the sensors and filter respectively are in analog form. Analog to digital converter (A/D converter) is used in the DAQ card to convert those analog data in to digital form. One ADC T232CN GK 242115 is used in the DAQ card as A/D converter. After ADC one sample and hold circuit (S/H Circuit) is used to sample and hold the data [5, 14].

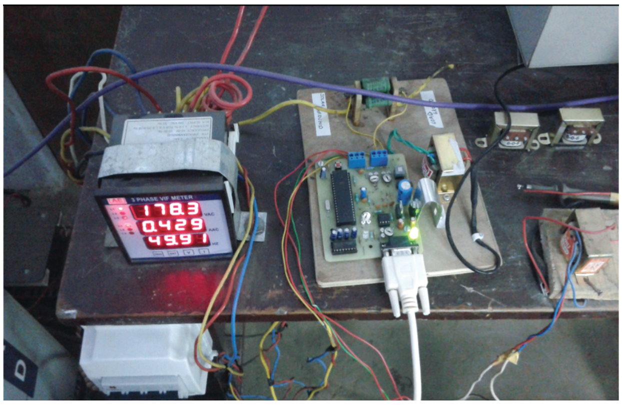

FIG. 4 PHOTO OF THE USED DAQ CARD IN THIS SYSTEM

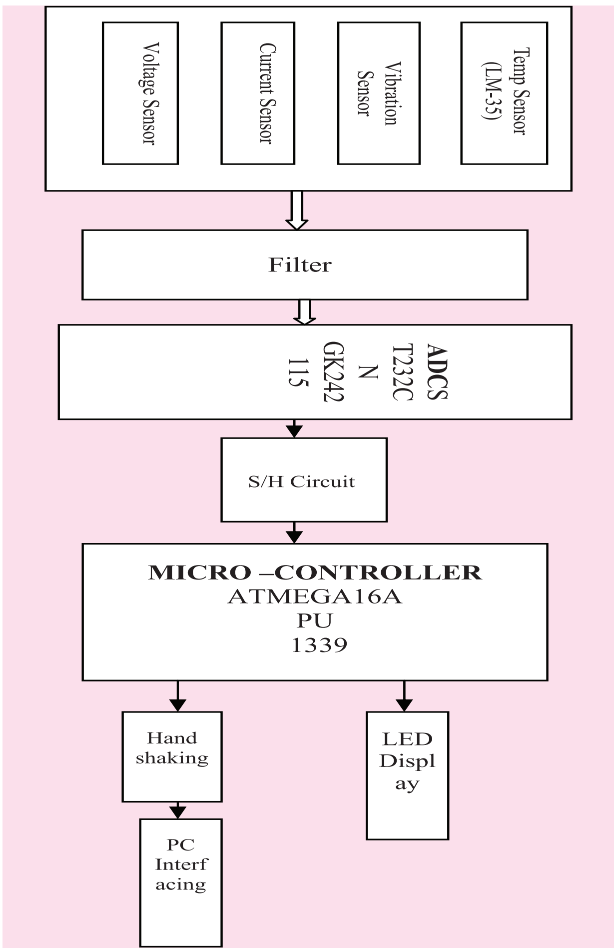

FIG. 5 BLOCK DIAGRAM OF THE DAQ CARD

As the name indicates, S/H circuit is a circuit whose function is to samples an input signal and holds onto its last sampled value until the input is sampled again. Sample and hold circuits are generally used in analogue to digital converts, communication circuits, PWM circuits etc. Then one microcontroller is used to communicate the data with computer. The microcontroller used in this DAQ card is MICRO –CONTROLLER ATMEGA16A PU 1339 [15-16]. Visual basic program is designed to save the digital data received from the DAQ card into computer in Microsoft office Excel Worksheet.

5.0 RESULT AND ANALYSIS

Mainly there are three reasons due that heat is generated in the induction motor. They are (i) Any type of mechanical friction inside the machine that may includes bearing faults (ii) I^2R losses in the machine which is variable with current(I), as R is a almost fixed parameter for any machine. (iii) Temperature rise due to unhealthy cooling system in the machine [3, 4].Here in our system one VIF (Voltage-Current-Frequency) meter is placed in the supply side to monitor a constant voltage and frequency in the supply. Three signals we are acquiring to detect the health condition of the cooling system of the tested induction motor at different operating conditions. Basically three parameters are considered to analyze the health of the cooling system. They are temperature of the machine, vibration of the machine, stator current. Voltage and speed also is monitored.

5.1 Vibration Signature Analysis

Vibration signature of the tested machine is acquired at different load condition that is on no load, quarter of full load and half of full load when cooling system is healthy as shown in Figure 6. The same step is repeated and acquired the vibration signature when cooling system is faulty as shown in Figure 8. PSD of vibration signature of induction motor at different load with healthy cooling system and faulty cooling system is shown in Figure 7 and Figure 9 respectively for the better understanding of the vibration signature.

At initial step when load is not applied, the machine vibration is high showing a high peak in vibration signature. When load is applied the vibration level is reduced showing a smaller peak in the vibration signature. The nature of the vibration signature is almost same for both, machine with healthy cooling system and machine with faulty cooling system. Those clearly indicate that the machine does not pose any type of mechanical friction inside and bearing faults which could be the reason for the overheating of machine [3, 4].

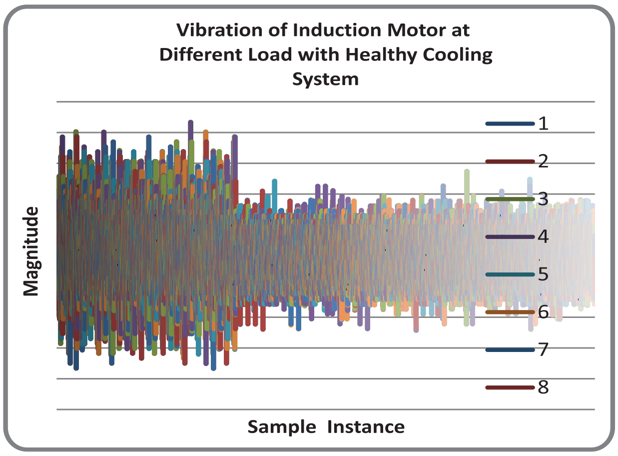

FIG. 6 VIBRATION SIGNATURE OF INDUCTION MOTOR AT DIFFERENT LOAD WITH HEALTHY COOLING SYSTEM.

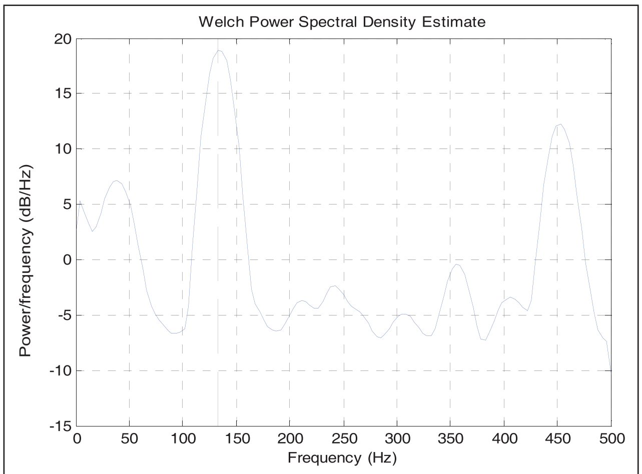

FIG. 7 PSD OF VIBRATION SIGNATURE OF INDUCTION MOTOR AT DIFFERENT LOAD WITH HEALTHY COOLING SYSTEM

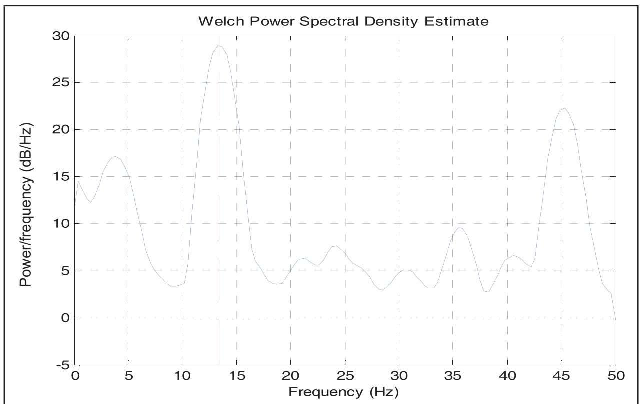

FIG. 8 PSD OF VIBRATION SIGNATURE OF INDUCTION MOTOR AT DIFFERENT LOAD WITH FAULTY COOLING SYSTEM.

5.2 Current signature analysis

Current signature of the tested machine is acquired at different load condition that is on no load, quarter of full load and half of full load when cooling system is healthy as shown in Figure 10. The same step is repeated and acquired the current signature when cooling system is faulty as shown in Figure 12. PSD of current signature of induction motor at different load with healthy cooling system and faulty cooling system is shown in Figure 11 and Figure 13 respectively for the better understanding of the vibration signature. At initial step when load is not applied, the machine current is low showing a low peak in current signature. When load is applied the current level is increased showing a larger peak in the current signature. The nature of the current signature is almost same for both, machine with healthy cooling system and machine with faulty cooling system. Those clearly indicate that the machine does not pose any type of winding faults inside for both the cases which could be the reason for excessive current drawn and hence overheating [3, 4].

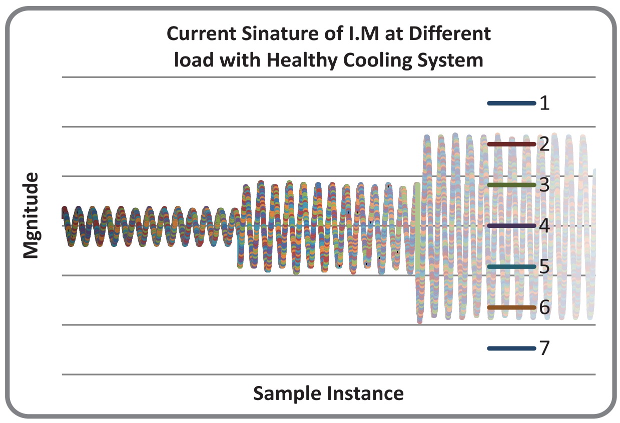

FIG. 9 CURRENT SIGNATURE OF I.M AT DIFFERENT LOAD WITH HEALTHY COOLING SYSTEM

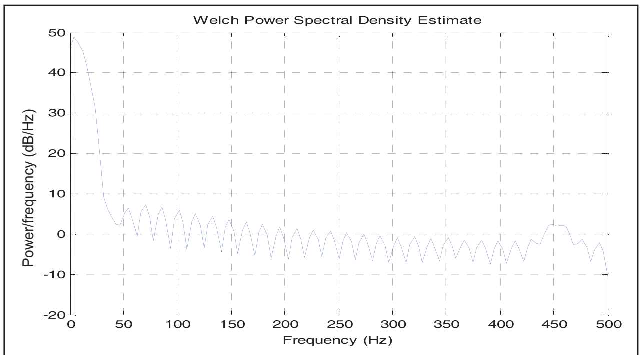

FIG. 10 CURRENT SIGNATURE OF I.M AT DIFFERENT LOAD WITH HEALTHY COOLING SYSTEM

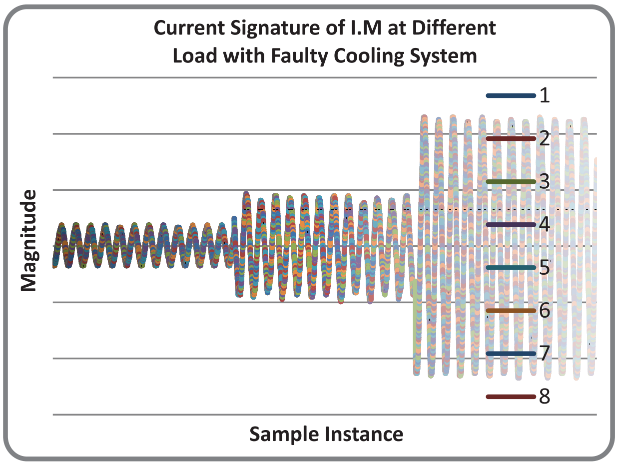

FIG. 11 CURRENT SIGNATURE OF I.M AT DIFFERENT LOAD WITH HEALTHY COOLING SYSTEM

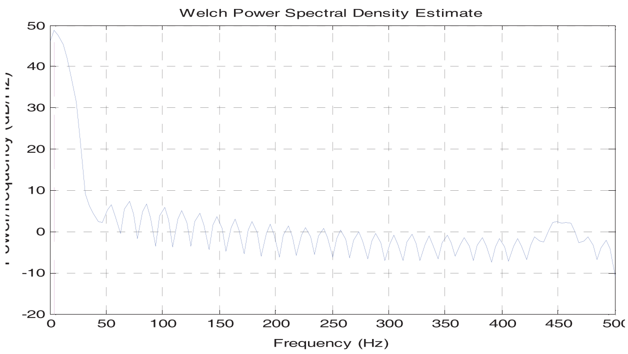

FIG. 12 PSD OF CURRENT SIGNATURE OF I.M AT DIFFERENT LOAD WITH FAULTY COOLING SYSTEM

5.3 Temperature Characteristics Analysis

Temperature Characteristics of induction motor at different load with healthy and faulty Cooling system is shown in Figure 14. In healthy cooling system temperature rise is very less where as in faulty cooling system temperature rise is more compare to healthy cooling system.

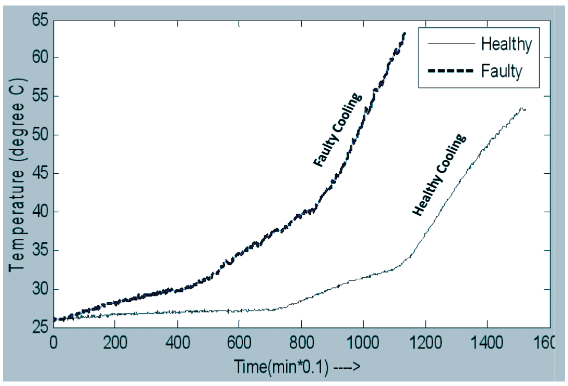

FIG. 13 TEMPERATURE CHARACTERISTICS OF I.M AT DIFFERENT LOAD WITH HEALTHY AND FAULTY COOLING SYSTEM

In the above system there is no change in vibration signature in both healthy and faulty condition of machines. So there is no frictional fault or bearing fault in the machine. There is no change in current signature for both healthy and faulty condition of machines. Therefore from the vibration and current signatures it is clear that frictional faults, bearing faults, winding faults are not present in the machine. But the temperature characteristics showing the excessive temperature rise in the machine. So the only reason left which can produce the heat in the machine is fault in cooling system. With that fact we can conclude that there is a certain fault in the cooling system [3, 4, 17].

1. If FM_V is low and FM_C is low and TR is very high then cooling system is Unhealthy.
2. If FM_V is low and FM_C is low and TR is Low then cooling system is healthy.

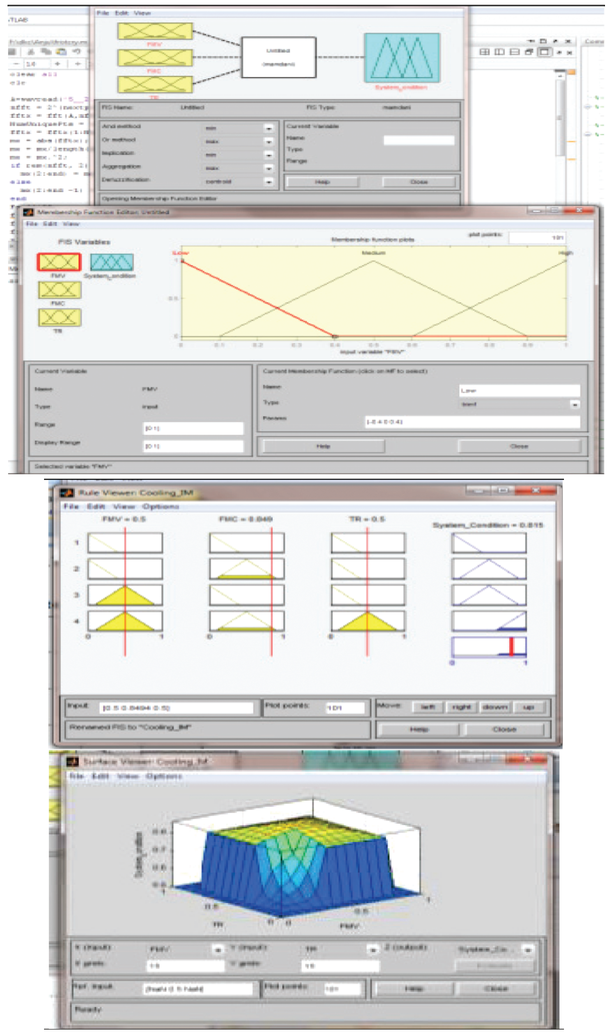

FIG. 14 FUZZY SYSTEM FOR HEALTH MONITORING USING MATLAB

One Fuzzy System for health monitoring using Matlab is shown in Figure 15 [2].

6.0 CONCLUSION AND FUTURE WORK

The purpose of this paper is to detect the on line fault condition of the cooling system of the induction motor. It is very much important for an engineer to monitor the cooling system of induction motor while it is working in a system because without the proper cooling system in induction motor windings of the motor may burn off and the situation will be very harassing. The paper deals with the soft computing techniques which are implemented to detect the fault of cooling system of induction motor on line. The analysis results show that the proposed method is able to monitor the health condition of the cooling system and detect its fault on line. This approach will help in monitoring the health of cooling system and protect from the critical failure of induction motor systems and the reliability and efficiency of motor can also be increased.

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