Advance in Electronic and Electric Engineering.
ISSN 2231-1297, Volume 3, Number 6 (2013), pp. 755-764

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Induction Motor Condition Monitoring Using Fuzzy Logic

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Abstract

Induction machines play a vital role in industry and there is a strong demand for their reliable and safe operation. They are generally reliable but eventually do wear out. Faults and failures of induction machines can lead to excessive downtimes and generate large losses in terms of maintenance and lost revenues, and this motivates the examination of on-line condition monitoring. The major difficulty is the lack of an accurate model that describes a fault motor. Moreover, experienced engineers are often required to interpret measurement data that are frequently inconclusive. A fuzzy logic approach may help to diagnose induction motor faults. In fact, fuzzy logic is reminiscent of human thinking processes and natural language enabling decisions to be made based on vague information.

Keywords: Induction Motor, Diagnosis, Fuzzy Logic, Stator Current Amplitudes.

1. Introduction

Typically, In the motor fault diagnosis process, devices are used to collect time domain current signals. The diagnostic expert uses both time and frequency domain signals to study the motor conditions and determines what faults are found. This paper applies fuzzy logic to induction motors fault detection and diagnosis. The motor condition is described using linguistic variables. Fuzzy subsets and the corresponding membership's functions describe stator current amplitudes. A knowledge base, comprising rule and databases, is built to support the fuzzy inference. The induction motor condition is diagnosed using a compositional rule of fuzzy inference.

2. Monitoring Techniques

These monitoring techniques have been classified into the following eight categories using different parameters are mentioned below.

1) Magnetic flux; any distortion in the air-gap flux density due to stator defects will set up an axial homopolar flux in the shaft, which can be sensed by a search coil fitted around the shaft. By using a minimum of four search coils located asymmetrically to the drive shaft, the location of shorted turn can be found out.

2) Vibration; the stator frame vibration is a function of inter turn winding faults, single phasing, and supply-voltage unbalance. The resonance between the exciting electromagnetic force and the stator is one of the main causes of noise production in electrical machines.

3) Current; the current drawn by an ideal motor will have a single component at the supply. The motor current signature analysis (mcsa) utilizes the results of the spectral analysis of the stator current of an induction motor to pinpoint an existing or incipient failure of the motor or the driven system. The diagnostic analysis has been reported by various researchers using the sequence components of current.

3. Statorcondition Monitoring Using Fuzzy Logic

This paper applies fuzzy logic to induction motors fault detection and diagnosis. The motor condition is described using linguistic variables. Fuzzy subsets and the corresponding membership functions describe stator current amplitudes. A knowledge base, comprising rule and data bases, is built to support the fuzzy inference. The induction motor condition is diagnosed using a compositional rule of fuzzy inference.

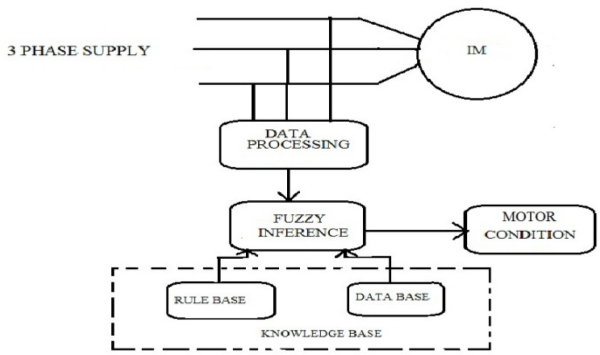

Fig. 1: Block diagram of motor condition monitoring system.

This paper applies fuzzy logic, to the diagnosis of induction motor stator and phase conditions, based on the amplitude features of stator currents. This method has been chosen because fuzzy logic has proven ability in mimicking human decisions [2] and the stator voltage and phase condition monitoring problem has typically been solved [1-3]. The generality of the proposed methodology has been experimentally tested on a

3hp squirrel-cage induction motor. The obtained results indicate that the fuzzy logic approach is capable of highly accurate diagnosis.

4. Fuzzy System Input-Output Variables

In this case, the stator current amplitudes ia, ib, and ic are considered as the input variables to the fuzzy system. The stator condition, cm, is chosen as the output variable. All the system inputs and outputs are defined using fuzzy set theory. For instance, the term set t (cm), interpreting stator condition, cm, as a linguistic variable, could be, t (cm) = {good, damage, seriously damaged}.Where each term in t (cm) is characterized by a fuzzy subset, in a universe of discourse cm. Good might be interpreted as a stator with no faults, damaged as a stator with voltage unbalance, and seriously damaged as a stator with an open phase. Similarly, the input variables ia, ib, and ic are interpreted as linguistic variables, with, t (Q) = {zero, small, medium, big}.

Where Q= Ia, Ib, Ic, Respectively.

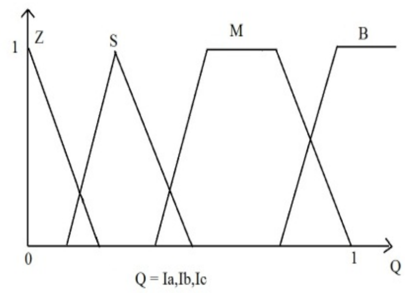

Fig. 2: Fuzzy membership functions for stator currents.

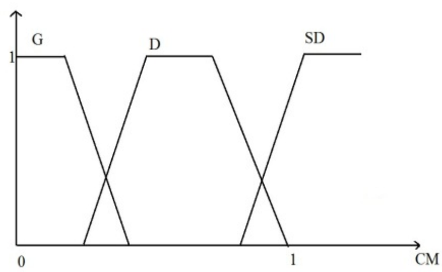

Fig. 3: Fuzzy membership functions for the stator condition.

For Our Study, We Have Obtained The Following 14 If-Then Rules.
Rule (1): If Ia is Z Then CM is SD
Rule (2): If Ib is Z Then CM is SD
Rule (3): If Ic is Z Then CM is SD

Rule (4): If Ia is B Then CM is SD
Rule (5): If Ib is B Then CM is SD
Rule (6): If Ic is B Then CM is SD
Rule (7): If Ia is S and Ib is S and Ic is M Then CM is D
Rule (8): If Ia is S and Ib is M and Ic is M Then CM is D
Rule (9): If Ia is M and Ib is S and Ic is M Then CM is D
Rule (10): If Ia is M and Ib is M and Ic is M Then CM is G
Rule (11): If Ia is S and Ib is S and Ic is S Then CM is G
Rule (12): If Ia is S and Ib is M and Ic is S Then CM is D
Rule (13): If Ia is M and Ib is S and Ic is S Then CM is D
Rule (14): If Ia is M and Ib is M and Ic is S Then CM is D

5. Simulation

In this figure the implementation of the stationary reference model of a three phase induction motor using simulink, which is shown below shows an overall performance of the induction motor in the stationary three-phase reference frame. The output of the simulink model is shown with the green colour in the circuit.

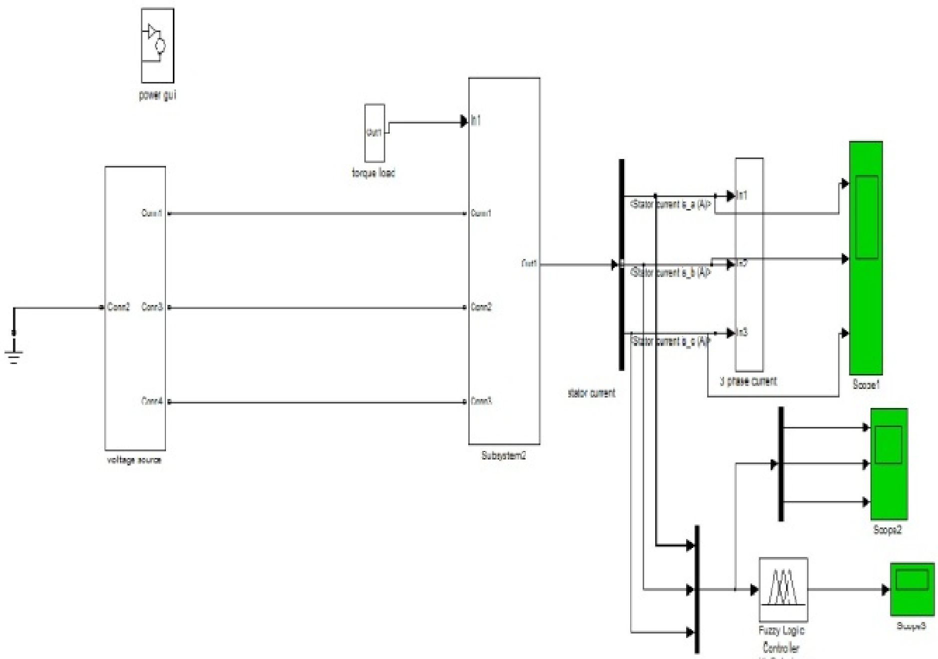

Fig. 4: Simulink Model of Condition Monitoring System.

6. Result

(1)Balanced full load condition

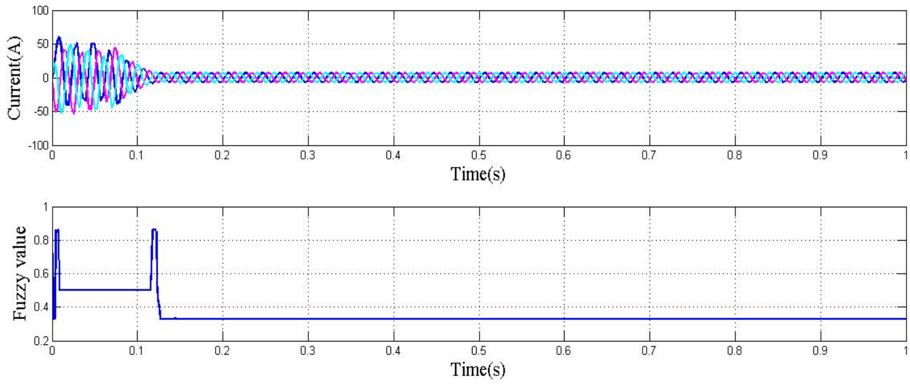

Fig.5: Stator current (ia,ib,ic) in balanced condition and output controller

(2)No load condition

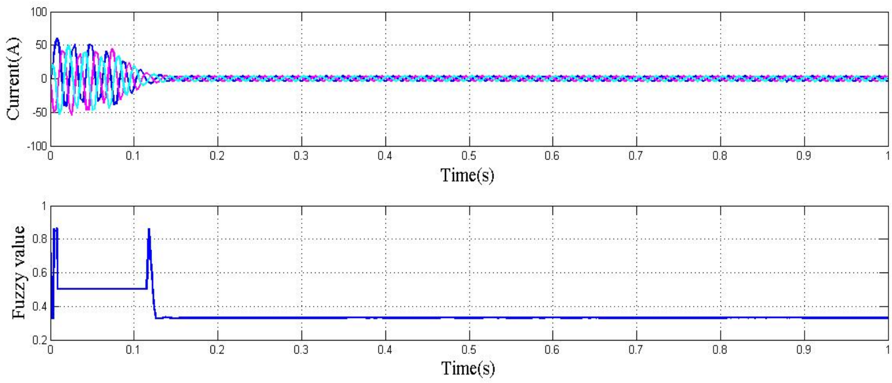

Fig. 6: Stator current (ia,ib,ic) in no load condition and output controller

In the model of induction motor is developed and simulated by matlab simulink tool box. The simulation results are given below for a 3hp motor [1].The results are taken during acceleration from stand still to full speed. Fig 5 shows the stator current and shows at 75% of rated load in open-loop circuit controller output. The normal condition is the same as in the fig. 6 which shows the no load condition is same as the result of the motor in the healthy conduction.

(3)Unbalanced supply full load condition

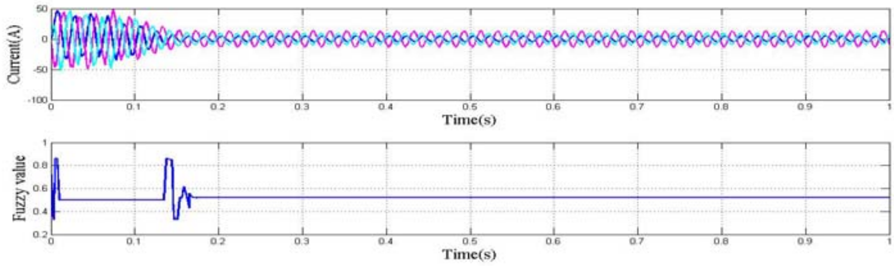

Fig. 7: Stator current and output controller unbalanced condition

(4)Unbalanced supply no load condition

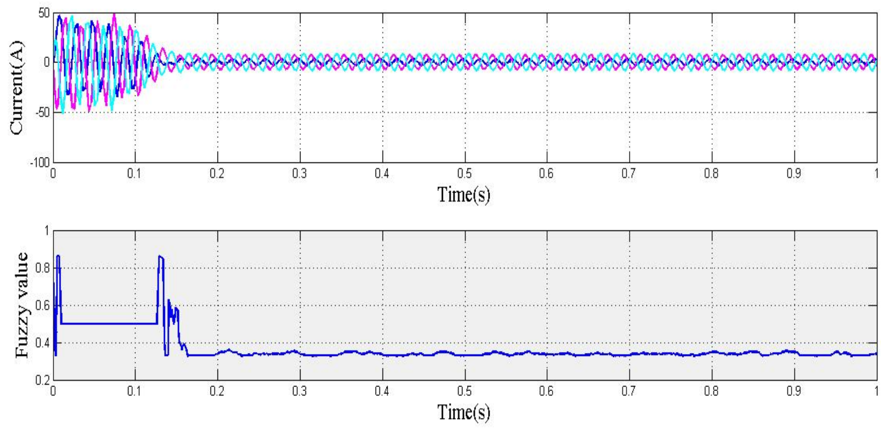

Fig. 8: Stator current and output controller unbalanced supply no load condition

In the fig.07 the result is damaged due to unbalanced condition at load but in the fig.8 the output is in the healthy condition due to unbalanced condition at no load.

(5)Open phase at full load condition

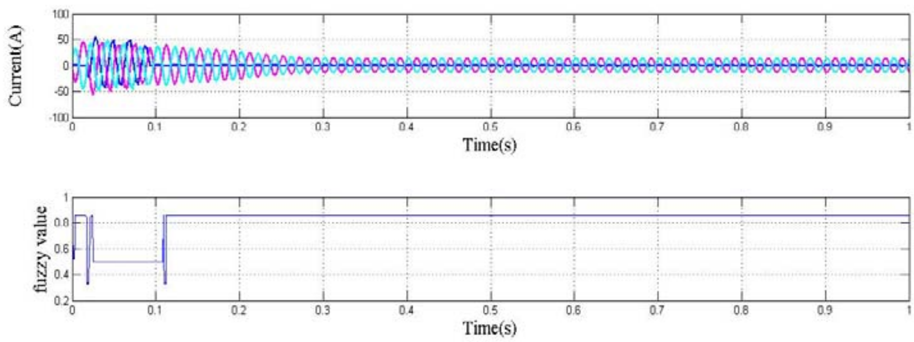

Fig. 9: Stator current and output controller open phase

(6) Open phase no load condition

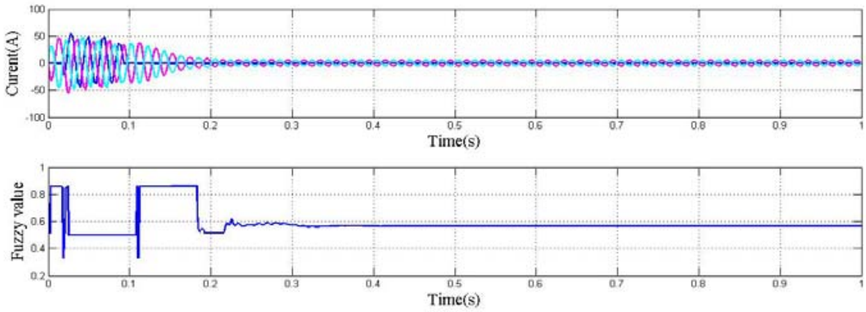

Fig. 10: Sataor current and output controller open phase no load supply.

When phase-A is open among the running condition the current magnitude is zero. Fig.9 shows the condition controller output is seriously damaged. Fig.10 shows the controller output condition of motor in damaged condition at no load.

7. Conclusions

A method using fuzzy logic to interpret current signal of induction motor for its stator condition monitoring was presented. Correctly processing theses current signals and inputting them to a fuzzy decision system achieved high diagnosis accuracy. There is most likely still room for improvement by using an intelligent means of optimization.

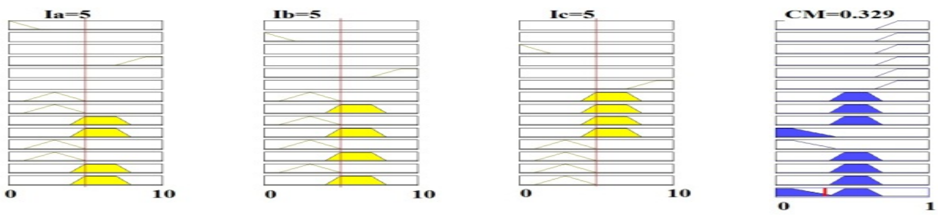

Fig. 11: Fuzzy inference diagram for a healthy motor.

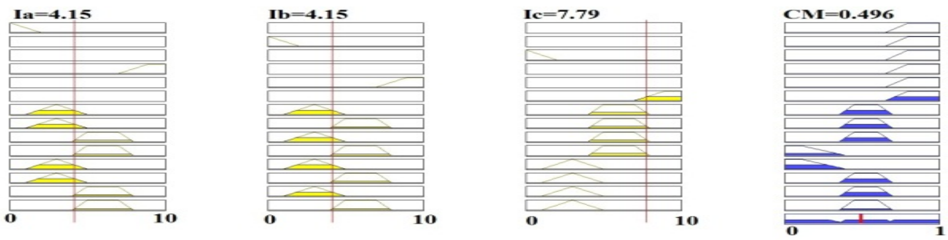

Fig. 12: Fuzzy inference diagram for a damaged motor.

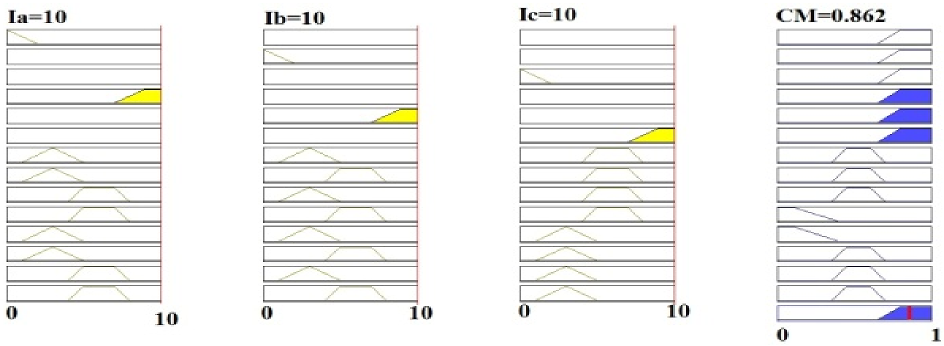

Fig. 13: Fuzzy inference diagram for a seriously damaged motor.

For Fig. 11, it is rule (10) that is solicited, in fact Ia = Ib = Ic = 5 A are small “S”. The motor is in this case supposed healthy (CM = 0.329). For Fig. 12, it is rule (8) that is solicited, in fact Ia = Ib = 4.15 A are small “S”, and Ic = 7.79 A is medium “M”. The motor is in this case damaged (CM = 0.496). Finally, for Fig. 13, it is rule (4, 5) that is solicited (Ia = Ib=10), or rule (6), in Ic = 10 A is big “B”. The motor is in this case seriously damaged (CM = 0.862).

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