Stator Interturn Short Circuit Fault Diagnosis using Fuzzy Logic

Mr. Adapa .S.S[1] Mr. Parmale. M. C[2]
[1,2]Assistant Professor
[1,2]MET BKC, IOE, NASIK, India

Abstract— Induction motors are widely used in process, mining, manufacturing industries and in almost every other field dealing with electrical power. These motors are simple, efficient, highly robust and rugged thus offering a very high degree of reliability. But like any other machine, these are also vulnerable to faults, which if left unmonitored, might lead to cascading failure of the machine in the long run. On-line condition monitoring of the induction motors has been widely used in the detection of faults. This paper presents a detailed analysis to detect induction motor faults using fuzzy logic. A fuzzy logic approach may help to diagnose induction motor stator faults. In fact, fuzzy logic is equivalent of human thinking processes and natural language enabling decisions to be made based on information.

Key words: Induction Motor Faults, Fuzzy Logic

I. INTRODUCTION

Induction motors are the mainstay for every industry. However like other machine, they eventually fail because of heavy duty, poor working environment, installation and Manufacturing factors etc. It is estimated that about 38% of the induction motor failures are caused by stator winding faults, 40% by bearing failures, 10% by rotor faults, and 12% by miscellaneous faults [1]. Bearing faults and stator winding faults contribute a major portion to the induction motor failures. Though rotor faults appear less significant than bearing faults, most of the bearing failures are caused by shaft misalignment, rotor eccentricity, and other rotor related faults. Besides, rotor faults can also result in excess heat, decreased efficiency, reduced insulation life, and iron core damage. So detection of mechanical and electrical faults is equally important in any electrical motor. In this paper we mainly concentrated on stator inter turn faults.

This paper applies fuzzy logic to induction motors fault detection and diagnosis. The motor condition is described using linguistic variables [4]. 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. The proposed system uses signal based method which uses condition monitoring systems assessing the machine's condition. Thus the key for the success of condition based maintenance is having an accurate means of condition assessment and fault diagnosis.

II. MONITORING TECHNIQUE

The current drawn by an ideal motor have a single component at the supply. The motor current signatures utilize the result 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.

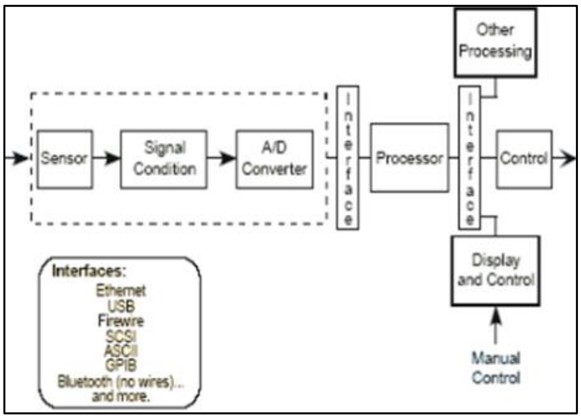

Fig. 1: Block Diagram of data collection system

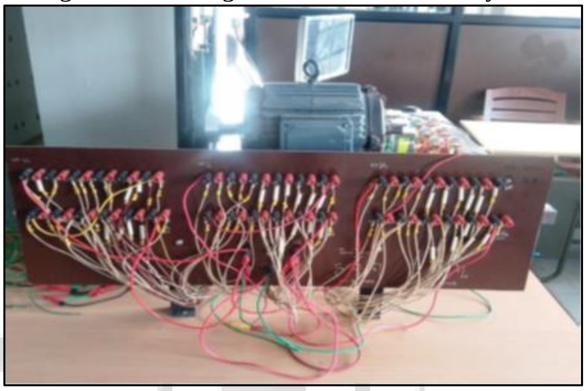

Fig. 2: Hardware Setup

III. INDUCTION MOTOR MODELING WITH MATLAB SINULINK

Three phase to two phase transformation can be obtained by using following equations [1].

$$\begin{bmatrix}V_{ds}\\ V_{qs}\end{bmatrix} = \underbrace{\begin{bmatrix}1 & -1/2 & 1/2\\ 0 & \sqrt{3}/2 & \sqrt{3}/2\end{bmatrix}}_{[A]} \begin{bmatrix}V_{as}\\ V_{bs}\\ V_{cs}\end{bmatrix}$$

Where Vas, Vbs, and Vcs are the three-phase stator voltages while Vds and Vqs are the two-axis components of the stator voltage vector Vs. In the two-axis stator reference frame, the current equation of an induction motor can be written as

$$\begin{bmatrix}i_{ds}\\ i_{qs}\\ i_{dr}\\ i_{qr}\end{bmatrix} = \int_{\tau=0}^{t} \left\{ \underbrace{\begin{bmatrix}L_s & 0 & L_m & 0\\ 0 & L_s & 0 & L_m\\ L_m & 0 & L_r & 0\\ 0 & L_m & 0 & L_r\end{bmatrix}}_{[B]}^{-1} \times \left(\begin{bmatrix}V_{ds}\\ V_{qs}\\ V_{dr}\\ V_{qr}\end{bmatrix} - \underbrace{\begin{bmatrix}R_s & 0 & 0 & 0\\ 0 & R_s & 0 & L_m\\ 0 & \frac{P}{2}\omega_0 L_m & R_r & \frac{P}{2}\omega_0 L_r\\ \frac{P}{2}\omega_0 L_m & 0 & \frac{P}{2}\omega_0 L_r & R_r\end{bmatrix}}_{[C]} \begin{bmatrix}i_{ds}\\ i_{qs}\\ i_{dr}\\ i_{qr}\end{bmatrix} \right) \right\} d\tau$$

As Matrix [A] and matrix [B] can be implemented by the 'Matrix Gain' block of SIMULINK, while matrix [C] can be implemented by four Function blocks of SIMULINK.

IV. FUZZY LOGIC CONTROLLER

Fuzzy rules and membership functions are constructed by observing the data set. For the measurements related to the stator currents, more insight into the data are needed, so membership functions will be generated for Negative Medium(NM), Negative Small(NS), Zero(Z), Positive Small(PS), Positive Medium(PM). For the measurement related to the stator condition, it is only necessary to know if the motor condition is Good, or Damaged or seriously damaged.

A. The Steps in Building Condition Monitoring System are

- Determine the fuzzy control input. The current is the input to the fuzzy controller.
- Determine the fuzzy control output. The output is the condition of the motor.
- Choose the word descriptions for the status of input and output.

B. Input Status Word Descriptions

1) Negative Medium (NM)
2) Negative Small (NS)
3) Zero (Z)
4) Positive Small (PS)
5) Positive Medium (PM)

C. Output Status Word Descriptions

1) Good.
2) Damaged.
3) Seriously Damaged.

The next step is to determine the degree of membership for both input and output variables. In the motor fault diagnosis process, time domain current signals are captured from sensors. The diagnostic expert then uses both time domain and frequency domain signals to study the motor condition and determines what faults are present. However, experienced engineers are often required to interpret measurement data that are frequently inconclusive. A fuzzy logic approach may help to diagnose induction motor faults. Fuzzy logic is reminiscent of human thinking process and natural language enabling decisions to be made based on vague information.

Fuzzy logic allows items to be described as having a certain membership degree in a set. While conducting fault diagnosis, there are several situations in which an object is not obviously "Good" or "Damaged", but may fall into some interior range. According to the fact that induction motor condition Interpretation is a fuzzy concept. Here the motor condition is described using linguistic variables. Fuzzy subsets and the corresponding membership functions describe stator current amplitudes.

A knowledge base, comprising rule base is built to support the fuzzy inference. The induction motor condition is diagnosed using a compositional rule of fuzzy inference. The obtained results indicate that the proposed fuzzy logic approach is capable of highly accurate diagnosis. Humans express knowledge. (Like an electrical machine referred as "somewhat secure", "little overloaded"). This linguistic input can be expressed directly by a fuzzy system. The internal structure of fuzzy controller. The stator current signal contains potential fault information. Fuzzy systems rely on a set of rules. These rules, allow the input to the fuzzy.

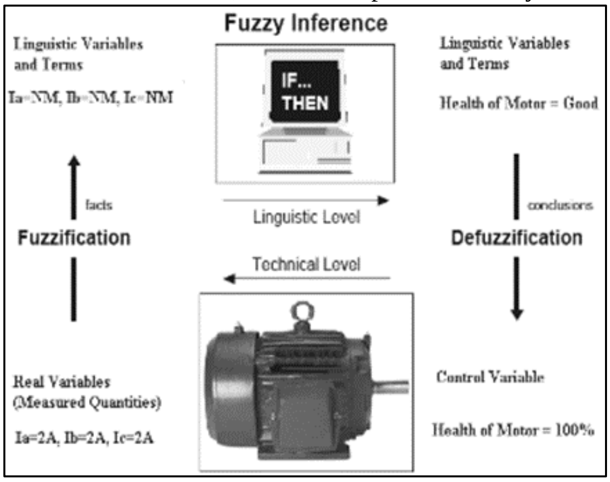

Fig. 3: Motor and fuzzy interface

V. RULE BASE

1) If Ia is NS then CM is Seriously Damaged
2) If Ib is NS then CM is Seriously Damaged
3) If Ic is NS then CM is Seriously Damaged
4) If Ia is PM then CM is Seriously Damaged
5) If Ib is PM then CM is Seriously Damaged
6) If Ic is PM then CM is Seriously Damaged
7) If Ia is NM and Ib is NM and Ic is NM then CM is Good
8) If Ia is NM and Ib is NM and Ic is Zero then CM is Damaged
9) If Ia is NM and Ib is NM and Ic is PS then CM is Damaged
10) If Ia is NM and Ib is Zero and Ic is NM then CM is Damaged
11) If Ia is NM and Ib is PS and Ic is NM then CM is Damaged
12) If Ia is Zero and Ib is NM and Ic is NM then CM is Damaged
13) If Ia is PS and Ib is NM and Ic is NM then CM is Damaged
14) If Ia is NM and Ib is Zero and Ic is Zero then CM is Damaged
15) If Ia is NM and Ib is Zero and Ic is PS then CM is Seriously Damaged
16) If Ia is NM and Ib is PS and Ic is Zero then CM is Seriously Damaged
17) If Ia is NM and Ib is PS and Ic is PS then CM is Damaged
18) If Ia is Zero and Ib is NM and Ic is Zero then CM is Damaged
19) If Ia is Zero and Ib is NM and Ic is PS then CM is Seriously Damaged
20) If Ia is PS and Ib is NM and Ic is Zero then CM is Seriously Damaged
21) If Ia is PS and Ib is NM and Ic is PS then CM is Damaged
22) If Ia is Zero and Ib is Zero and Ic is NM then CM is Damaged
23) If Ia is PS and Ib is Zero and Ic is NM then CM is Seriously Damaged

24) If Ia is Zero and Ib is PS and Ic is NM then CM is Seriously Damaged
25) If Ia is Zero and Ib is PS and Ic is Zero then CM is Damaged
26) If Ia is Zero and Ib is PS and Ic is PS then CM is Damaged
27) If Ia is Zero and Ib is Zero and Ic is PS then CM is Damaged
28) If Ia is PS and Ib is Zero and Ic is Zero then CM is Damaged
29) If Ia is Zero and Ib is Zero and Ic is Zero then CM is Good
30) If Ia is PS and Ib is PS and Ic is Zero then CM is Good
31) If Ia is Zero and Ib is PS and Ic is PS then CM is Good

Defuzzification is defined as the conversion of fuzzy output to crisp output. There are many types of defuzzification methods available. Here we used Center of Area (COA) method for defuzzification. Despite its complexity it is more popularly used because, if the areas of two or more contributing rules overlap, the overlapping Area is counted only once.

A. Output of Fuzzy Logic Controller

1) 1. Good 70 TO 100
2) 2. Damaged 30 To 70
3) 3. Seriously Damaged 0 To 30

The output of the fuzzy controller is used as the command signal for the closed loop operations. If the fuzzy controller output is good, then the program goes for next set of data to be acquired. Meanwhile if the operator wants, the data like three phase current, three phase voltage, frequency of input voltage, power factor, total harmonic distortion of both the current and voltage and the state of the motor can be stored in a file.

VI. SIMULATION AND RESULTS

By using a simulation stop time of 2.0 seconds, the motor was simulated during starting from rest with rated voltage applied and no mechanical load. Figure 4 shows the Stator current, Stator input voltage and torque, symmetrical components of stator current, symmetrical components of stator induced voltage, symmetrical components of stator input voltage are shown. From these results it can be concluded that after the transient period is over, the health of the motor is good, and there is no negative sequence Component in both stator induced voltage and stator current.

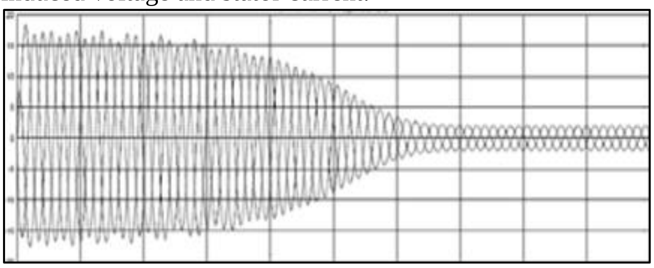

Fig. 4: three phase Stator currents of Induction motor

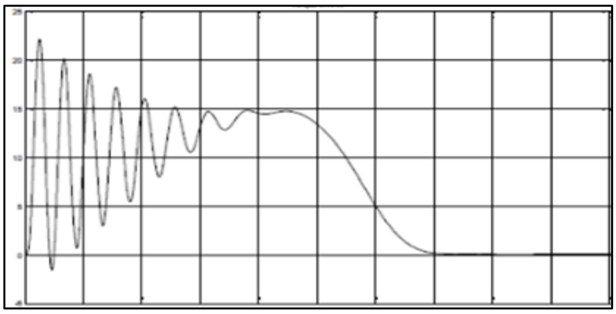

Fig. 5: Developed Torque and Speed of Induction motor

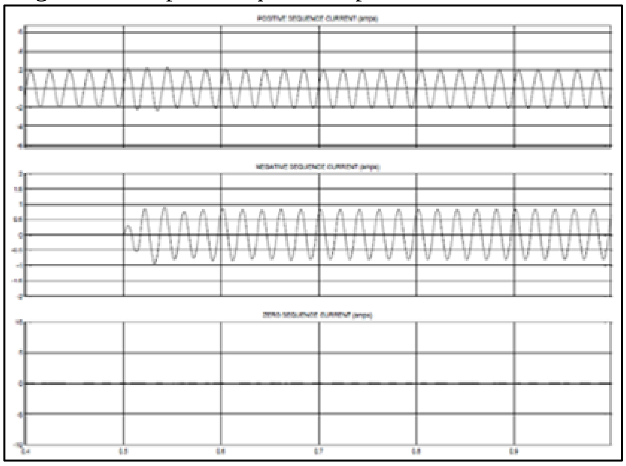

Fig. 6: Symmetrical component waveforms of stator current (Turn-Turn short)

From these results it can be concluded that during normal Operation (before fault), the health of the motor is Good, and there is no negative sequence component in both stator induced voltage and stator current. As soon as the fault is created the stator current becomes unbalanced, and the health of the induction motor goes seriously damaged and finally settles to Damaged state, and we can notice that there is presence of negative sequence component in both stator induced voltage and stator current waveforms during fault conditions.

1. Break in stator winding:

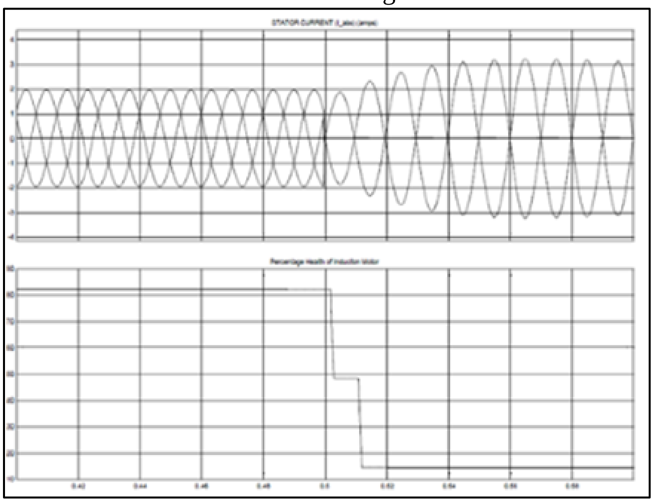

Fig. 7: Stator current and Percentage health of induction motor (Break in winding)

From these results it can be concluded that during normal operation (before fault), the health of the motor is Good, and there is no negative sequence component in both stator induced voltage and stator current. As soon as the fault is created the stator current becomes fully unbalanced, and the health of the induction motor goes seriously damaged and finally settles to the same state, and the presence of negative sequence component in both stator induced voltage and stator current waveforms during fault conditions can be noticed.

VII. Conclusion

Measurement and health evaluation system has been developed and implemented. This application allows fast failure state estimation. The more detailed investigation to point out the difficult conditions of the machine under different stator fault conditions of induction motor can be performed. This is a highly versatile technology for condition monitoring and fault analysis of motors. It solves the shutdown Problems and ensures safe working environment in continuous process industry.

References

[1] Neelam Mehela A PHD thesis on “Condition Monitoring and Fault Diagnosis of Induction Motor using Motor Current Signature Analysis” (2010).
[2] Krause PC (1986) Analysis of electric machinery. Mc-Graw Hill, New York.
[3] P S Bhimra “Generalized theory of electrical machine”.Mc-Graw Hill.
[4] H.A.Toliyat, T.A. LiPo,”Transient Stator, Rotor Bar and End rings Fault” IEEE Transactions on Energy Conversion, Vol. 10, 1995, pp.241-247.
[5] G. G Yen, K Lin,”Wavelet Packets Feature Extraction for Vibration Monitoring “IEEE Transactions on Industrial Electronics 2000.
[6] DONG Mingchui , CHEANG Takson , SEKAR Booma Devi†, CHAN Sileong “Fuzzy-Expert Diagnostics for Detecting and Locating Internal Faults inThree Phase Induction Motors” TSINGHUA SCIENCE AND TECHNOLOGY ISSN1007-021413/18pp817-822 Volume 13, Number 6, December 2008.
[7] F. Zidani M.E.HBenbouzid, D Diallo, M.S. NaitSaid ,”Induction Motor Stator Fault diagnosis by Current Concordia Pattern based Fuzzy Decision System . IEEE Transaction on Energy Conversion 2003 pp 469-475.
[8] Cusido J Rosero, JA Orlega, J a Garica, A.L.Romeral,” Induction Motor Fault Detection by using Waveletdecomposition on dqo components “Industrial Electronics 2006, IEEE Symposium on Publication date 9-13 July 2006 pp 2406-2411.

