Fault Diagnosis of Rotor of an Induction Motor using Fuzzy Logic Technique

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Abstract— This paper illustrates fuzzy logic technique, used for the detection of rotor of an induction motor. In this rotor fault identification methodology Simulation model of asynchronous induction motor has been constructed with the help of MATLAB/SIMULINK and second model is also introduced i.e. prototype model in which fault are inserted by changing the voltage supply frequency with no loads condition and output response has been obtained for both healthy and faulty motor model. With the help of chi square test both the healthy and faulty signal has been examined and which further help in formation of rule base in fuzzy logic technique. The proposed scheme works in a satisfactory way.

Key words: Fuzzy Logic, Induction Motor, Fuzzy Inference System

I. INTRODUCTION

Fault diagnosis of induction motor using fuzzy logic technique has been gaining large amount of researchers attention because of the utility of induction motor (IM) and during the last two and half decade an large amount of research has been done in this field of fault diagnosis of induction motor, resulting in a great variety of different techniques with increase acceptance in practice. Induction Motors are "Workhorse of the Industry". This is reason it is one of the most widely used motors in the world. It is used in transportation and industries, and also in household appliances, and laboratories. Induction Motors are cost effective, their installation use compared to DC and Synchronous Motors. Induction Motors are rugged in construction. There robustness enables them to be used in all kinds of environments. Induction Motors are very reliable. Also they have high efficiency of energy conversion [1,2]. Owing to their simplicity of construction, Induction Motors have very low maintenance costs. Induction Motors have high starting torque. This enables induction motor useful in specific applications where the load is applied before starting the motor.

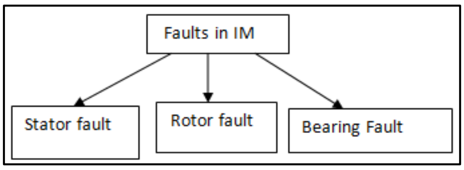

Fig. 1: Classification of faults in electric motor

Due to above stated reason induction motor is widely used in industries such as automotive, aerospace, and industrial equipment this is the reason their fault identification process acquiring lots of popularity. Condition monitoring and fault diagnosis of induction motor has increased because of the extensive use of automation and consequent reduction in direct human-machine interaction to supervise the motor drive system operation [1]. However, there are numerous reasons for the induction motor failure like operational environment, duty, and installation issues. Faults can occur in the stator, rotor, bearing, or the external systems connected to the induction motor. The faults of electrical motors can broadly be classified as the following [2]:

This paper is primarily focusing on the technique to identify rotor faults using fuzzy logic technique. From the survey it has recently been showed that 10% problems of total induction engine failures result from brake rotor winding. Induction motor brake disc faults are mainly cracked rotor bars as a result of pulsing load and direct online starting. It results in fluctuation of speed, torque pulsation, vibration, overheating, arcing in the rotor and damaged rotor laminations. Lately, in the motor for fault diagnosis purpose, sensors were used to collect time domain current signals. In recent years, with advancement in methodology the monitoring and fault detection of electrical machines have moved from traditional methods to artificial intelligence techniques (i.e., neural networks, fuzzy logics, and genetic algorithmic techniques require a minimum of intelligent configuration since no detailed analysis of the fault mechanism is necessary Such and no system modelling is required [3].The objective of This paper is to explore the field of condition monitoring and fault diagnosis for induction motors. This involves processing the signals produced by MATLAB simulation based model of induction motors and insertion of fault within induction motor model by changing the input ac frequency, and applying chi square test on those signals i.e. both healthy and faulty signals of motors to form the rule base of fuzzy logic techniques. Chi square test with the help of expert knowledge in the field of induction motor helps in formation of fuzzy technique based model on fault diagnosis of induction motor. Condition monitoring and fault diagnosis for induction motors consists of following steps: simulation model of induction motor, data acquisition from that model, signal analysis, signal processing with chi square test, fault detection fuzzy based model with the help of expert knowledge. Fault detection has to establish a relationship between the motor symptoms and the condition.

II. DIAGNOSIS OF INDUCTION MOTOR FAULTS

A. *Simulation of Induction Motor*

Constructing the simulation model of induction motor in MATLAB/SIMULINK is the basic and important step for fault diagnosis of induction motor. In Figure 2 implementation of three-phase asynchronous machine (squirrel cage induction motor) has been modelled in a selectable stationary reference frame. Stator and rotor windings are connected in wye to an internal neutral point. Parametric description has been given in Table 1. The inputs of an induction machine are three phase voltages, their fundamental frequency and load torque. The outputs of an induction machine are rms currents, rms voltage, rotor speed, and reactive power. The simulated IM model has given a satisfactory response in terms of the rotor speed characteristics. The model was tested at no load condition The results concludes that the MATLAB/SIMULINK is a reliable and sophisticated way to analyze and predict the behaviour of induction motor using the theory of reference frames drives

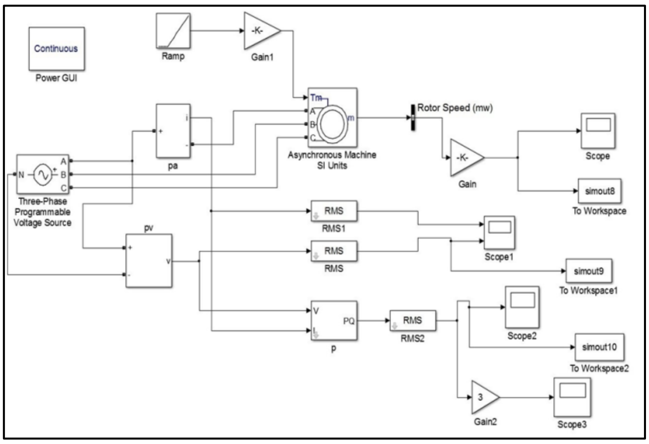

Fig. 2: Simulation model of induction moto

Symbol	Description	Value
Pn(VA)	Nominal power	4000
Vn(Vrms)	Voltage(line to line)	400
fn(HZ)	Frequency	50
Rs(ohm)	Stator resistance	1.405
Lls(H)	Stator inductance	0.005839
Rr(ohm)	Rotor resistance	1.395
Llr(H)	Rotor inductance	0.005839
Lm(H)	Mutual inductance	0.1722

Table 1: Parametric Description of Simulation Model

As given in [8], simulation of induction motor has high impact to both industry and academia due to the prevalence of these types of drives in various industrial settings as well as in the validation of design process of the motor-drive systems, eliminating inadvertent design mistakes and the resulting errors in the prototype constructions and testing. When we have proprietary software package such as MATLAB/SIMULINK, licensed by MathWorks which makes simulation design more efficient and easy to understand the operation of system than a programming-language implementation it is not required to create user-written software for dynamic model of induction motor. Several measurements were performed using the above described test bench and the computer programs. The squirrel cage induction motor was tested when it was considered healthy and with a provoked rotor fault.

The rotor fault was simulated by interrupting the fundamental frequency i.e. 50 Hz to 60 Hz. In both cases the induction motor was tested at no-load condition. Faults are inserted within in induction motor with the help of change in frequency. Output response are studied and saved in MATLAB workspace afterward chi square test has applied to both the healthy and faulty signals at different frequency. In chi square test faulty signal has been considered as observed signal and healthy signal has been considered as expected signal. According to chi square test in the final analysis, all signal values will be identified with particular limit for healthy and faulty signal. The chi-square test, being of a statistical nature, serves only as an indicator, and cannot be iron clad. In MATLAB chi square test has been implemented in MATLAB code, and observation has been studied and given in table II.

Pearson's chi-square test ($\chi 2$) is an analytical procedure whose result is examined by reference to the chi-square distribution. It tests a null hypothesis that the corresponding frequencies of occurrence of observed events follow a specified frequency distribution. In this research work, chi square test is applied in MATLB coding to compare the values of faulty and healthy signals and to examine the level of similarities between healthy and faulty signal. The results obtained from chi square test are further applied to the fuzzy inference system (FIS) to form rule base.

$$\chi^2 = \frac{\sum_{i=1}^{n} (O_i - E_i)^2}{E_i}$$

Here O_i is the observed signal and E_i is the expected signal, where n is the number of observation.

Parameter	Response	Response	Response
Frequency	**Speed**	**Voltage/current**	**Reactive Power**
30Hz	0.1132	0.1268	0.0587
40Hz	0.0783	0.0837	0.0533
60Hz	0.0782	0.0765	0.0745
70HZ	0.1456	0.1428	0.1976

Table 2: Result of Chi Square Test at Different Frequencies of Supply Voltage

III. FUZZY LOGIC APPROACH FOR ROTOR FAULTS DIAGNOSIS

A. Fuzzy System Input-Output Variables

Fuzzy systems rely on a group of rules. These rules, while superficially similar, allow the input to be, more like the natural way that humans express knowledge. Therefore, a power engineer might refer to an electric machine as "somewhat secure" or a "little overloaded". This linguistic input can be expressed directly by a fuzzy system. As a result, the natural format greatly eases the software between the engineer knowledge and the domain expert. Furthermore, infinite graduations of fact are allowed, a characteristic that accurately mirrors real life, where decisions are hardly ever "crisp". Figure 3 representing the block representation of fuzzy inference system.

As given in Figure 4 presents FIS for rotor condition monitoring where speedrpm, RMS1, power are input variable of fuzzy system and rc (rotor condition) is chosen as output variable. Boundaries of both three input variables are chosen from the table 2 which has been calculated in MATLAB coding by chi square test. Membership function for all three input variables which are speedrpm, RMS1, power are taken as ‘low’, ‘medium’, ‘high’. Membership function for output variable is taken as ‘working’, ‘damage’, ‘seriouslydamage’. Fuzzy system used for rotor condition monitoring is of mamdani type all the membership functions for input and output variables are further given in preceding figures. Figure 5 represent the membership function for speedrpm and boundaries of membership function are given according to chi square test.

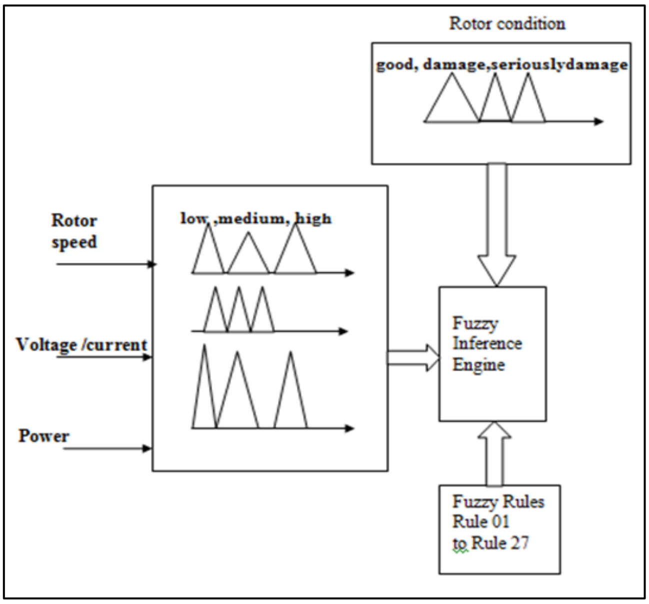

Fig. 3: Block Representation of Fuzzy Inference System

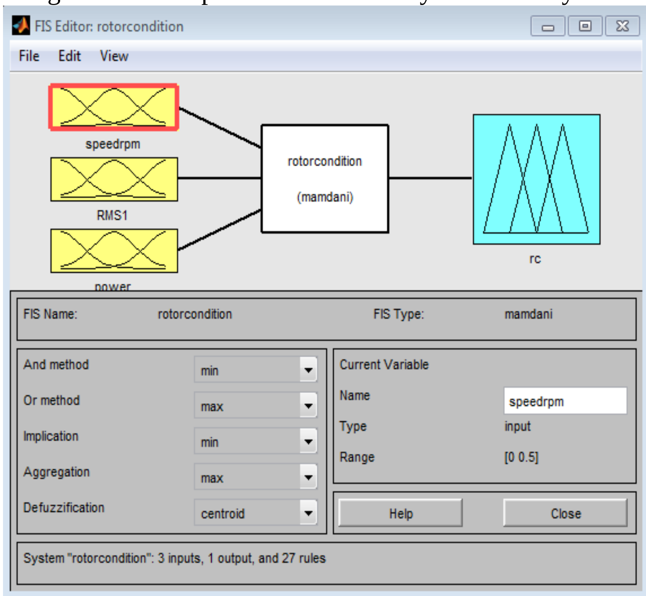

Fig. 4: Fuzzy model for Rotor condition monitoring

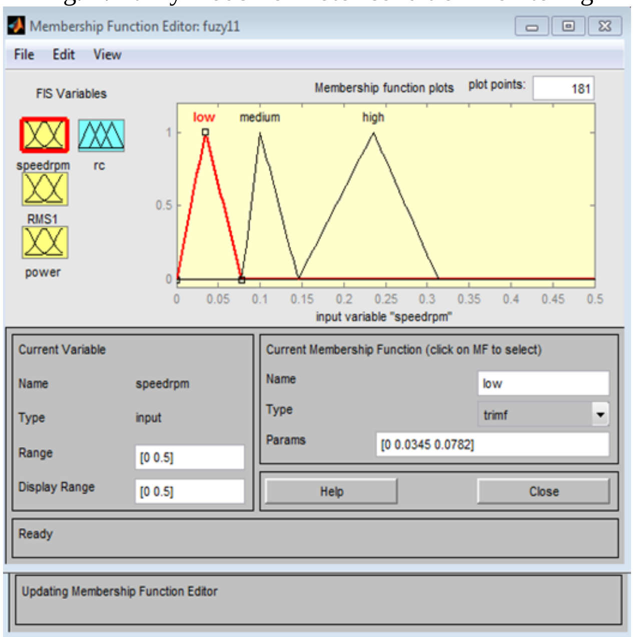

Fig. 5: Membership function for speed rpm

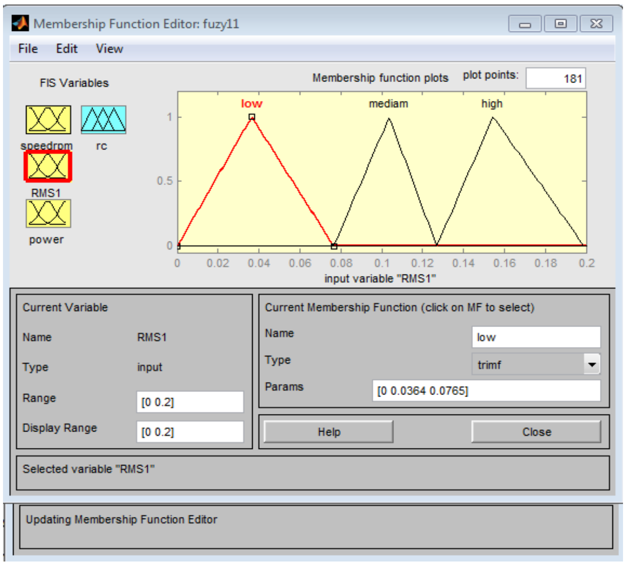

Fig. 6: Membership function for RMS1

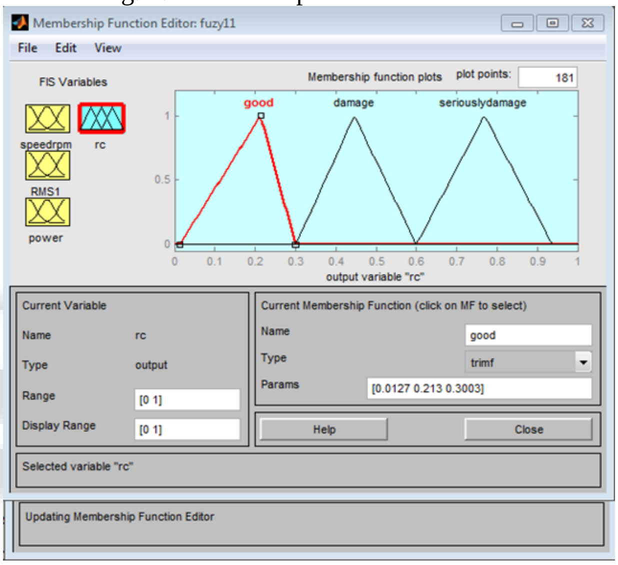

Fig. 7: Membership function for RC

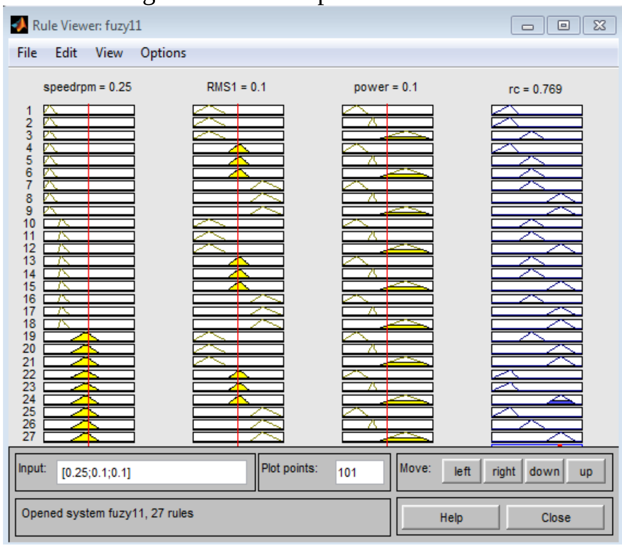

Fig. 8: Rule base for Rotor condition monitoring

IV. CONCLUSION

It is concluded that the rotor faults of induction motor are obtained by constructing the simulation model of asynchronous motor in MATLAB SIMULINK, and inserting fault in the simulation model by varying the frequency with respect to voltage supply and by applying chi square test to the faulty and healthy signals which will further used as a expert knowledge for formation of rule base in FIS. The problem in this research work is focused on the design of simulation model of induction motor for rotor fault diagnosis purpose. It is observed that induction motor is most efficient, rigid, cost effective and simple in construction as compare to other types of AC motors.

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