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FAULT DETECTION OF INDUCTION MOTOR USING SIMULINK

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ABSTRACT

Online monitoring of the electrical machines can reduces the costs of maintenance by allowing the early detection of faults, which could be expensive to repair.In this paper a simulink model is developed in Matlab/SIMULINK for Induction Motor using Fuzzy-logic Controller to analyze the performance under the turn-turn short in one phase winding, Unbalance in input voltage and open phase faults were simulated.

Keywords— Matlab/Simulink,Induction motor,Fuzzy logic

I. INTRODUCTION

Online fault detection of induction motor have been challenging for engineers. Induction motors are most widely used electrical machines for industrial automation, domestic and commercial applications. These motors have advantages such as robustness, simplicity of its construction and highly reliable [1].Althought this motors are reliable they are subjected to some stress that can cause fault leading to damage. Hence detection of initial fault can reduce the cost of maintance. Lot of research that are made which indicate that 35% of the fault is generated in the stator winding[2].For the past 20 years large amount of research into the creation of new monitoring techniques for Induction Motor This new methods have been developed and are being used in industries and research is continuing with the development of new and alternative on-line diagnostic techniques[6]. However it depends on the users who have to make the selection of most appropriate and effective monitoring technique to suit their particular Induction Motor drive systems.

II. MODELING OF INDUCTION MOTOR FOR VARIOUS FAULT CONDITION

Modeling is a process of analyzing a mathematical description that has the dynamic characteristics of a component in terms of parameters that can be determine in practice.Every model has parameters that are determined experimentally and then verified and validated. Verification involves mathmethical solution and underlining assumption. Validation involves in how adequately the model reflects pertinent aspects of the actual system[4]. Modeling and simulation are useful where the actual system does not exist, too expensive or time consuming.

In this modeling of induction motor there are certain assumption are being made whisc are as follows:-

1.Uniform air gap.

2. Balance stator and rotor winding

3. Saturation and parameter change are neglected.

2.1 Induction motor equation

The voltage equation for three phase induction motor is express as follows:

2.1.1 Stator equation

$$V_A = R_A i_A + \frac{d\lambda_A}{dt}$$
$$V_B = R_B i_B + \frac{d\lambda_B}{dt}$$
$$V_C = R_C i_C + \frac{d\lambda_C}{dt} \quad (1)$$

2.1.2 Rotor equation

$$V_a = R_a i_a + \frac{d\lambda_a}{dt}$$
$$V_b = R_b i_b + \frac{d\lambda_b}{dt}$$
$$V_c = R_c i_c + \frac{d\lambda_c}{dt} \quad (2)$$

2.1.3 Flux linkages due to interaction of stator and rotor winding are represented as

Stator:

$$\lambda_A = L_{AA} i_A + L_{AB} i_B + L_{AC} i_C + L_{Aa}\cos(\theta_r) i_a + L_{Ab}\cos(\theta_r + \frac{2\Pi}{3}) i_b + L_{Ac}\cos(\theta_r - \frac{2\Pi}{3}) i_c$$
$$\lambda_B = L_{BA} i_A + L_{BB} i_B + L_{BC} i_C + L_{Ba}\cos(\theta_r - \frac{2\Pi}{3}) i_a + L_{Bb}\cos(\theta_r) i_b + L_{Bc}\cos(\theta_r + \frac{2\Pi}{3}) i_c$$
$$\lambda_C = L_{CA} i_A + L_{CB} i_B + L_{CC} i_C + L_{Ca}\cos(\theta_r + \frac{2\Pi}{3}) i_a + L_{Cb}\cos(\theta_r - \frac{2\Pi}{3}) i_b + L_{Cc}\cos(\theta_r) i_c \quad (3)$$

Rotor:

$$\lambda_a = L_{aA}\cos(\theta_r) i_A + L_{aB}\cos(\theta_r + \frac{2\Pi}{3}) i_B + L_{aC}\cos(\theta_r - \frac{2\Pi}{3}) i_C + L_{Aa} i_a + L_{Ab} i_b + L_{Ac} i_c$$
$$\lambda_b = L_{bA}\cos(\theta_r + \frac{2\Pi}{3}) i_A + L_{aB}\cos(\theta_r) i_B + L_{aC}\cos(\theta_r - \frac{2\Pi}{3}) i_C + L_{ba} i_a + L_{bb} i_b + L_{bc} i_c$$
$$\lambda_c = L_{bA}\cos(\theta_r - \frac{2\Pi}{3}) i_A + L_{cB}\cos(\theta_r + \frac{2\Pi}{3}) i_B + L_{cC}\cos(\theta_r) i_C + L_{ca} i_a + L_{cb} i_b + L_{cc} i_c \quad (4)$$

2.1.4 Electromechanical torque equtation

$$T_e = -\frac{1}{2}\left[\begin{array}{l} i_A\left\{\begin{array}{l} i_a[L_{Aa} + L_{aA}]\sin(\theta_r) + i_b[L_{Ab} + L_{bA}] \\ \sin(\theta_r + \frac{2\Pi}{3}) + i_c[L_{Ac} + L_{cA}]\sin(\theta_r - \frac{2\Pi}{3}) \end{array}\right\} \\ + i_B\left\{\begin{array}{l} i_a[L_{Ba} + L_{aB}]\sin(\theta_r - \frac{2\Pi}{3}) + i_b[L_{Bb} + L_{bB}] \\ \sin(\theta_r) + i_c[L_{Bc} + L_{cB}]\sin(\theta_r + \frac{2\Pi}{3}) \end{array}\right\} \\ + i_C\left\{\begin{array}{l} i_a[L_{Ca} + L_{aC}]\sin(\theta_r + \frac{2\Pi}{3}) + i_b[L_{Cb} + L_{bC}] \\ \sin(\theta_r - \frac{2\Pi}{3}) + i_c[L_{Cc} + L_{cC}]\sin(\theta_r) \end{array}\right\} \end{array}\right] \quad (5)$$

2.1.5 Dynamic load equtation

$$T_e - T_L = J\frac{d\omega_r}{dt} + D\omega_r \qquad (6)$$

$$\frac{d\omega_r}{dt} = \frac{T_e - T_L}{J} \qquad (7)$$

$$\omega_r = \frac{1}{J}\int (T_e - T_L)dt \qquad (8)$$

2.1.6 Stator inductance

It is assume that the air gap in induction motor is uniformally distributed and all self inductance is identical.

$$L_{AA} = L_{BB} = L_{CC} = L_{ls} + L_{ms} \qquad (9)$$

Mutual inductance between any two stator winding is the is the same due to symmetry which is given by:

$$\begin{aligned} L_{AB} &= L_{BA} = -0.5L_{ms} \\ L_{BC} &= L_{CB} = -0.5L_{ms} \\ L_{CA} &= L_{AC} = -0.5L_{ms} \end{aligned} \qquad (10)$$

2.1.7 Rotor inductance

In the same manner the mutual inductance between the rotor is given by

$$L_{aa} = L_{bb} = L_{cc} = L_{lr} + L_{mr}$$

$$\begin{aligned} L_{ab} &= L_{ba} = -0.5L_{mr} \\ L_{bc} &= L_{cb} = -0.5L_{mr} \\ L_{ca} &= L_{ac} = -0.5L_{mr} \end{aligned} \qquad (11)$$

$$\begin{aligned} L_{Aa} &= L_{Bb} = L_{Cc} = L_{msr}\cos\theta_r \\ L_{Ac} &= L_{Ba} = L_{Cb} = L_{msr}\cos(\theta_r - 120^o) \\ L_{Ab} &= L_{Bc} = L_{Ca} = L_{msr}\cos(\theta_r + 120^o) \end{aligned} \qquad (12)$$

The mutual inductance between the stator and the rotor varies with the change in the rotor position.

III. SIMULINK MODEL OF INDUCTION MOTOR

In this section implementation of stationary reference model of three phase induction motor is done using simulink. This simulation uses all the equation which are listed in the previous section. Figure 1 shows the overall diagram of the three phase induction. Figure 2 shows the subsystem of the main block.

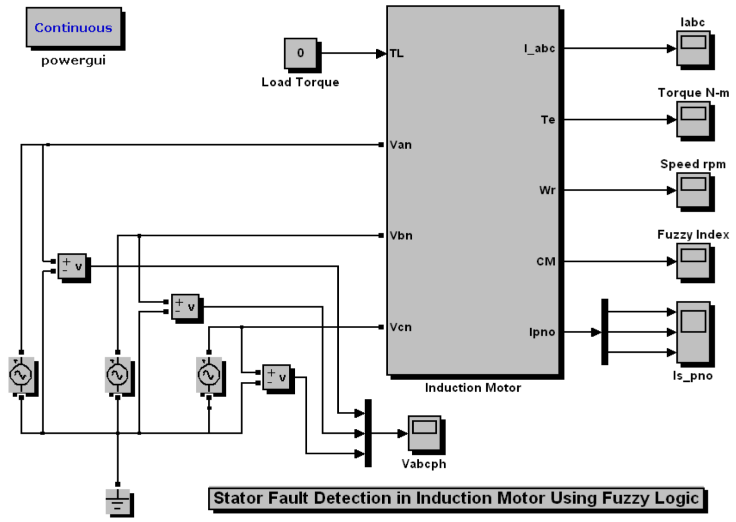

Fig 1 shows the simulink model of induction motor

In this model there are parameters that are stored in a m file. This parameters are accessed by this model while running this model.The parameters that are used in this model are as follows[8]:

Rated Voltage V=230v , Frequency f=50Hz Stator Resistence=15.3Ω, Rotor Resistance=7.46Ω. The stator and rotor self-inductances are equal to Lstator = Lrotor = Lleakage+Lmutual = .035+.55 = .585H, The mutual inductance between any two stator and any tow rotor windings is equal to Lss,mutual = Lrr,mutual = 0.5Lmutual = -0.275H.The mutual inductance between a stator winding and any rotor winding is equal to $L_{sr,mutual} = L_{mutual}$ =0.55H Number of Poles p = 4, Inertial constant J = 0.023kg.m^2

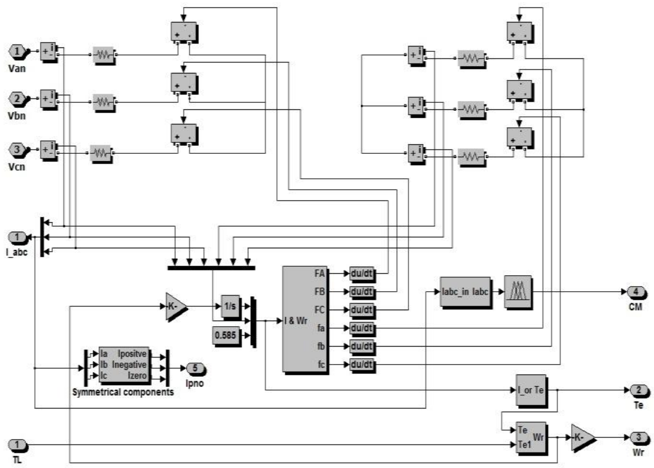

Fig2 shows the subsystem of the main block

IV. DESIGNING A FUZZY LOGIC FOR INDUCTION MOTOR

Fuzzy logic is a Boolean logic that is used in order to handle values between 0 and 1[3].Fuzzy logic is a tool that is used in controlling the complex industrial device and also household devices. It is a multivalued logic that defines value between 0 and 1 or yes and no etc. This notation are mathematically process by computer.This allows human ways of thinking in programming a computer[5]. This work require expert knowledge of different equtation in order to define a system.

4.1 Input Membership Function

Membership function is used to map the data in between 0 and 1.It consist of input and output membership function.In the input membership function consist of three input variables. They are Ia, Ib and Ic which is the stator current. In this trapezoidal and triangular membership function is used. The input variables are interpreted as Zero (Z), Small(S), Medium (M) and Big (B).The range of the input membership function is from 0 to 3.

4.2 Output Membership Function

The output membership function consist of one variable. This output is interpreted as Good, Damaged and Seriously Damaged.In this trapezoidal Membership Function is used. The range of output membership function is from 0 to 100.

4.3 Defuzzification and Fuzzy Rules

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.

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*.

Fig 3 Fuzzy rules

V. SIMILATION RESULTS

5.1 Normal Operation

The above simulation runs for 2.0 seconds. The motor is started from rest with rated voltage and no load. From the output of the fuzzy logic it is seen the health of the motor remains good after the transient time. Figure 4 and 5 shows the output of stator current and fuzzy logic output.

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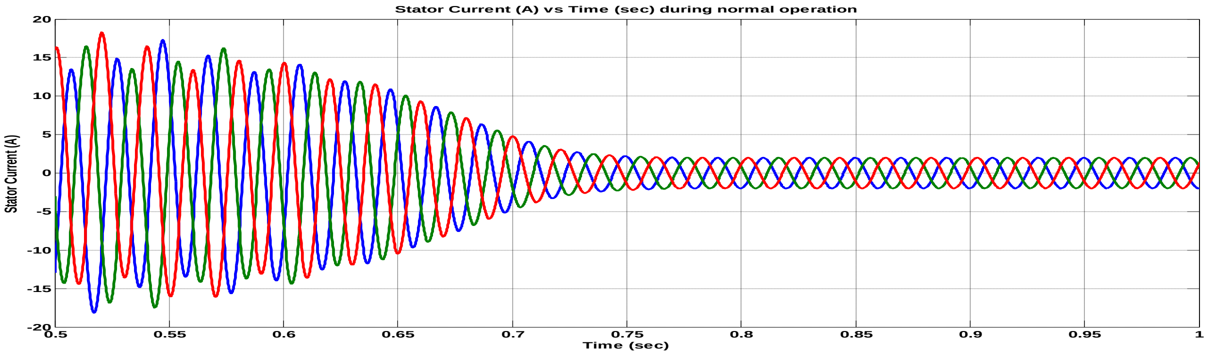

Fig 4 Stator current under normal operation

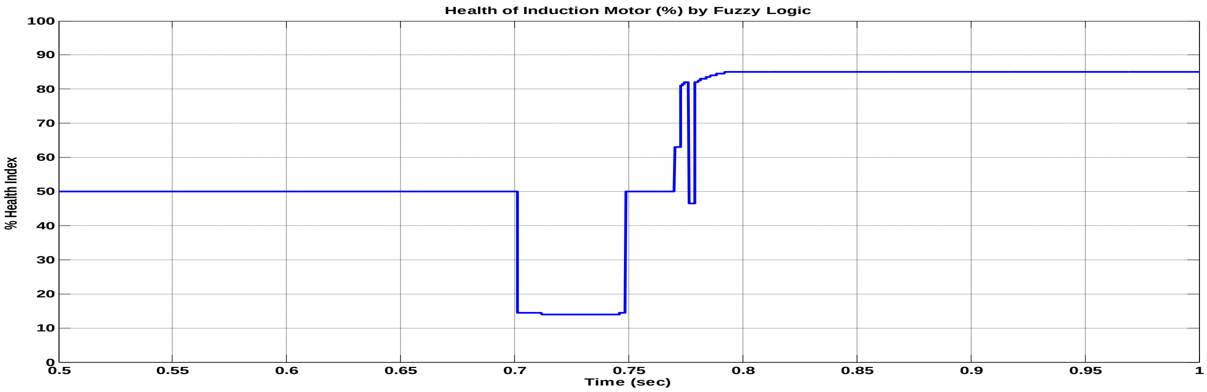

Fig 5 Fuzzy logic under normal operation

5.2 Turn-Turn short in one phase winding

After normal operation short circuit is being carried out in the R phase[7]. This can be done by placing a value at of stator resistance at short circuit fault is equal to Rstator, fault = 13.1Ω. Thus we can find the value of inductance at fault using the ratio of

$$\frac{R_{Stator,normal}}{R_{Stator,fault}} = n = \frac{L_{Stator,normal}}{L_{Stator,fault}}$$

$$\frac{15.3}{13.1} = \frac{0.585}{L_{Stator,fault}} \Rightarrow \therefore L_{Stator,fault} \approx 0.5H$$

In this simulation starts with normal state and then fault is created at 1 second. From this results it is see that after obtaining a steady state at 1 second turn fault is created by changing the above parameters. It is seen that the during normal operation that is before fault the health of motor is good. As soon as fault is created stator current is unbalanced and health of motor goes in damaged state and it settles in damaged state. Figure 6 and 7 shows the output of stator current and fuzzy logic output.

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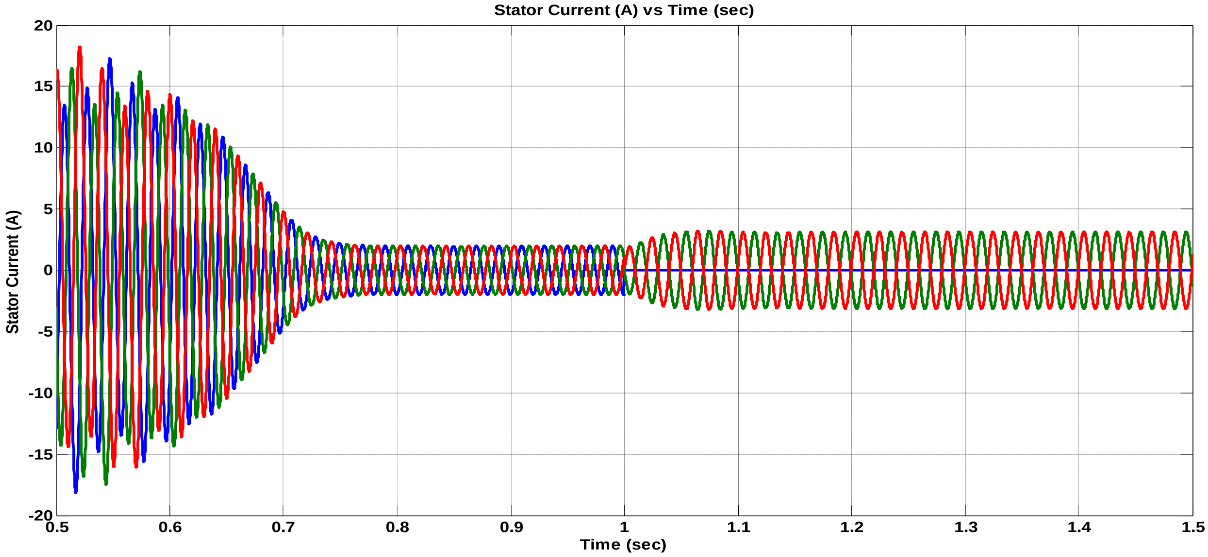

Fig 6 Stator current under turn to turn short in 1 phase

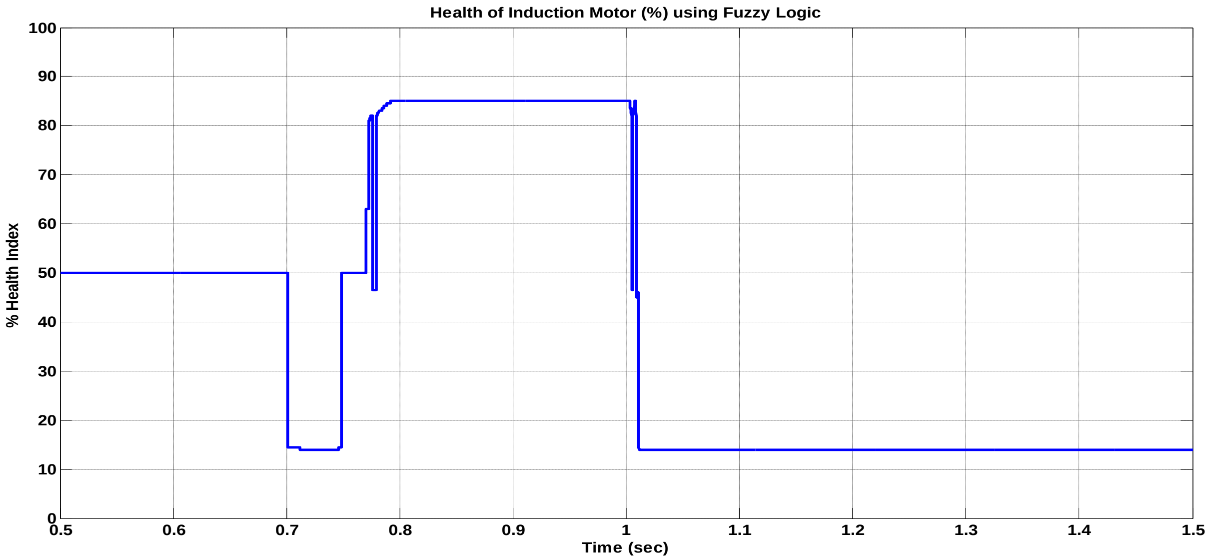

Fig 5 Fuzzy logic under turn to turn short in 1 phase

5.3 Unbalance in input voltage

The simulation of induction motor with voltage unbalance can be simulated by simply varying the voltage magnitude in any one of the phase. The fault has been created by changing the voltage of B phase.In this case a 6% of the rated voltage in C phase was reduced to create unbalance. In this simulation starts with normal parameters to obtain steady state at 1second.After that a fault is createdby changing the magnitude of B phase voltage. From these results it can be concluded that during normal operation(before fault), the health of the motor is Good, 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. . Figure 6 and 7 shows the output of stator current and fuzzy logic output.

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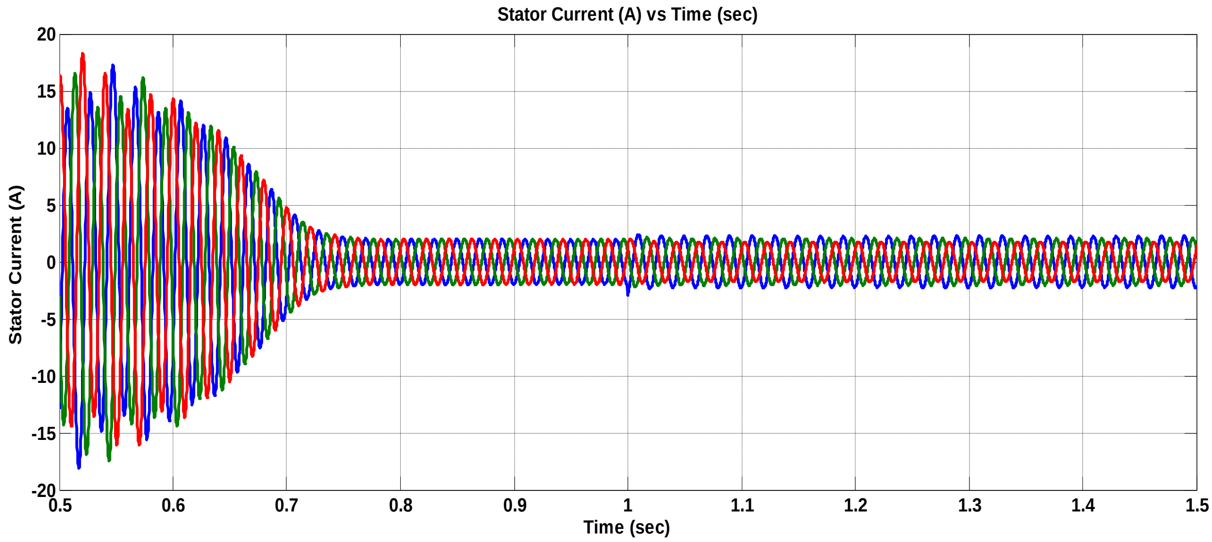

Fig 6 Stator current under unbalance in input voltage

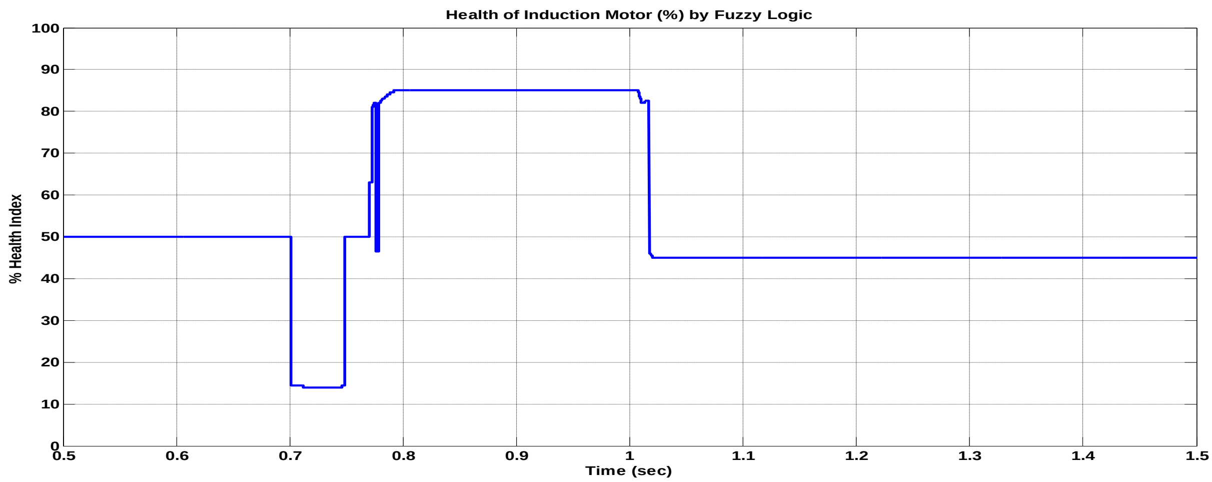

Fig 5 Fuzzy logic under unbalance in input voltage

VI. CONCLUSION

In this paper the induction motor was simulated by dynamic model. Afterwards, the equations were revisited by accounting faults in one of the phases. As for the issue of fault realization, the fuzzy logic was used. The advantages of this method are the high accuracy, easy implementation and independence to motor model during the fault detection process.

VII. ACKNOWLEDGMENT

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