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Stator Fault Detection using Fuzzy Logic

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Abstract: Identification of deficiencies in induction motors is getting to be progressively essential. The principle trouble in this assignment is the need of an exact investigative model to portray a faulty motor. A fuzzy logic approach may analyze induction motor faults. This method help in locating stator fault by monitoring the current amplitude. 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.

Keywords: Induction Motor, Fault Detection, Fuzzy Logic, Stator Fault.

I. INTRODUCTION

An induction motor is seen as the pulsating heart of the cutting edge industry because of its broad application, low support cost, simple control and additionally high dependability[1]. Lot of research that are made which indicate that 35% of the fault is generated in the stator winding[2]. In current mechanical groups, induction motor has been growingly getting consideration in different ventures including power station, car, petrochemical etc

II. MODELING OF INDUCTION MOTOR

To carry out a dynamic model of induction motor, we need to concentrate on the basic equations in induction motor. To do a dynamic model, it should be concentrated on the fundamental conditions of induction motor[4]. As has been specified in various references, dynamic conditions in a three-phase induction motor with a healty status with no faults in stator winding are as follows.

A. Stator Inductance

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

$$L_{AA} = L_{BB} = L_{CC} = L_{ls} + L_{ms} \qquad (1)$$

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

$$\begin{aligned} L_{AB} &= L_{BA} = -0.5L_{ms} \\ L_{BC} &= L_{CB} = -0.5L_{ms} \\ L_{CA} &= L_{AC} = -0.5L_{ms} \end{aligned} \qquad (2)$$

B. Rotor Inductance

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

$$L_{aa} = L_{bb} = L_{cc} = L_{lr} + L_{mr} \qquad (3)$$

$$\begin{aligned} L_{ab} &= L_{ba} = -0.5L_{mr} \\ L_{bc} &= L_{cb} = -0.5L_{mr} \\ L_{ca} &= L_{ac} = -0.5L_{mr} \end{aligned} \qquad (4)$$

$$\begin{aligned} L_{Aa} &= L_{Bb} = L_{Cc} = L_{msr}\cos\theta_r \\ L_{Ac} &= L_{Ba} = L_{Cb} = L_{msr}\cos(\theta_r - 120^\circ) \\ L_{Ab} &= L_{Bc} = L_{Ca} = L_{msr}\cos(\theta_r + 120^\circ) \end{aligned} \qquad (5)$$

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

Stator:

$$\lambda_A = L_{AA} i_A + L_{AB} i_B + L_{AC} i_C + L_{Aa}\cos(\theta_r) i_a + L_{Ab}\cos(\theta_r + \frac{2\Pi}{3}) i_b + L_{Ac}\cos(\theta_r - \frac{2\Pi}{3}) i_c$$

$$\lambda_B = L_{BA} i_A + L_{BB} i_B + L_{BC} i_C + L_{Ba}\cos(\theta_r - \frac{2\Pi}{3}) i_a + L_{Bb}\cos(\theta_r) i_b + L_{Bc}\cos(\theta_r + \frac{2\Pi}{3}) i_c$$

$$\lambda_C = L_{CA} i_A + L_{CB} i_B + L_{CC} i_C + L_{Ca}\cos(\theta_r + \frac{2\Pi}{3}) i_a + L_{Cb}\cos(\theta_r - \frac{2\Pi}{3}) i_b + L_{Cc}\cos(\theta_r) i_c \quad (6)$$

Rotor:

$$\lambda_a = L_{aA}\cos(\theta_r) i_A + L_{aB}\cos(\theta_r + \frac{2\Pi}{3}) i_B + L_{aC}\cos(\theta_r - \frac{2\Pi}{3}) i_C + L_{Aa} i_a + L_{Ab} i_b + L_{Ac} i_c$$

$$\lambda_b = L_{bA}\cos(\theta_r + \frac{2\Pi}{3}) i_A + L_{aB}\cos(\theta_r) i_B + L_{aC}\cos(\theta_r - \frac{2\Pi}{3}) i_C + L_{ba} i_a + L_{bb} i_b + L_{bc} i_c$$

$$\lambda_c = L_{bA}\cos(\theta_r - \frac{2\Pi}{3}) i_A + L_{cB}\cos(\theta_r + \frac{2\Pi}{3}) i_B + L_{cC}\cos(\theta_r) i_C + L_{ca} i_a + L_{cb} i_b + L_{cc} i_c \quad (7)$$

III. SIMULINK MODEL

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.

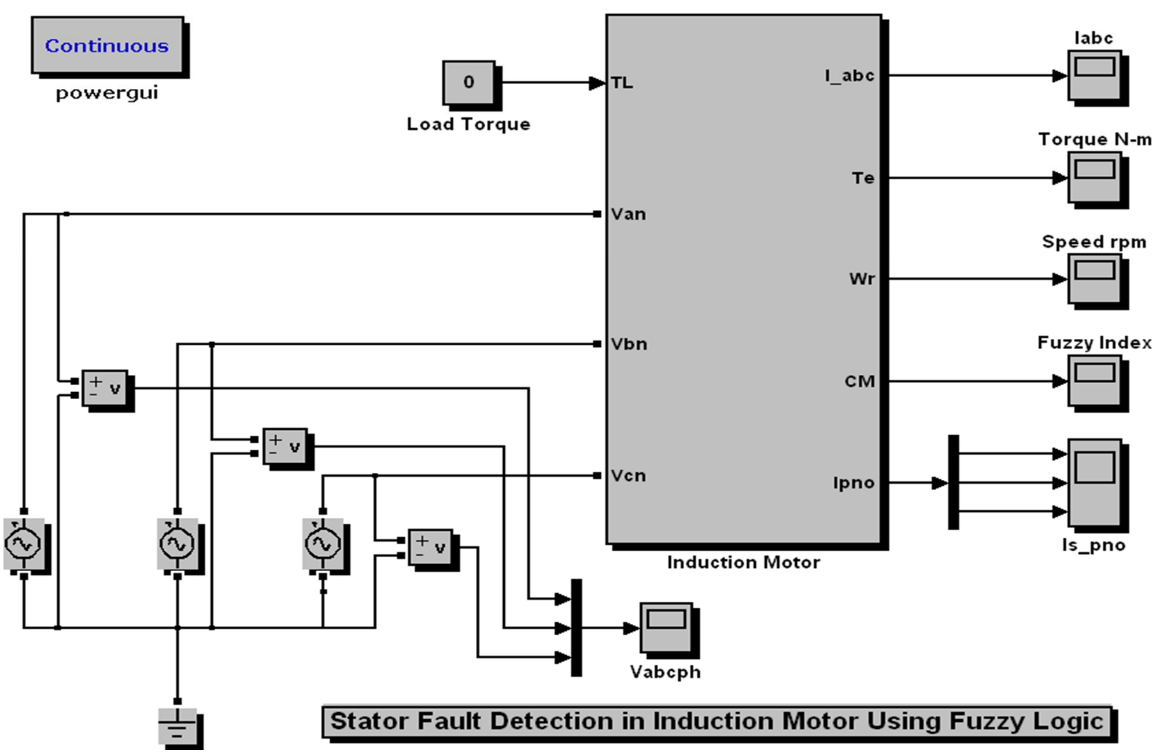

Fig 1 Shows The Simulink Model Of Induction Motor

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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

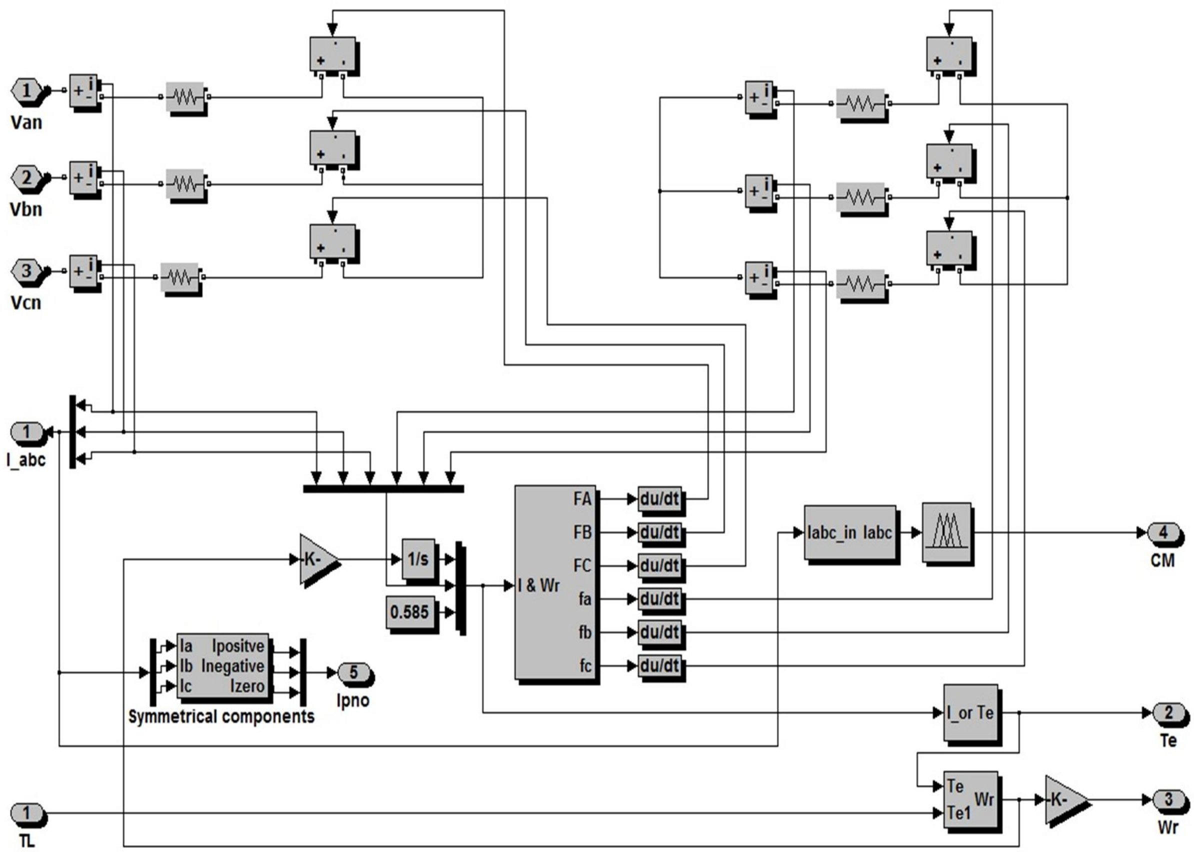

Fig2 shows the subsystem of the main block

IV. DESIGNING A FUZZY LOGIC FOR INDUCTION MOTOR

Fuzzy frameworks depend on an arrangement of tenets. These standards, while externally comparative, enable the contribution to be fuzzy, i.e more like the characteristic way that people express information. In this way, a power engineer may allude to an electrical machine as "to some degree secure" or "somewhat over-burden". This information can be communicated straightforwardly by a fuzzy framework. Along these lines ,the common organization incredibly facilitates the interface between the engineer information and the area master[3].

A. Fuzzy System Input-Output Variables

Induction motor condition can be derived by watching the stator current amplitudes as information factors. Elucidation of results is troublesome as connections between the motor condition and the current amplitudes . Along these lines, utilizing fuzzy logic, numerical information are represented as linguistic information. [51]. In this case, the stator current amplitudes *Ia*, *Ib*, and *Ic* are considered as the input variables to the fuzzy system. The motor condition, *MC*, is chosen as the output variable.

B. Linguistic Variables

For instance, the term set T(MC), interpreting motor condition, MC, as a linguistic variable, could be T(MC)= {Good, Damage, Seriously damaged}. Similarly, the input variables Ia, Ib, and Ic are interpreted as linguistic variables, with T(Q)= {Zero, Small, Normal, Big} where Q= Ia, Ib, Ic respectively.

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C. Fuzzy Membership Functions Construction

Fuzzy rules and membership functions are constructed by observing the data set. For the measurements related to the stator currents membership functions will be generated for zero, small, normal and big The optimized input and output fuzzy sets for this problem are shown in Fig.3 and Fig4.

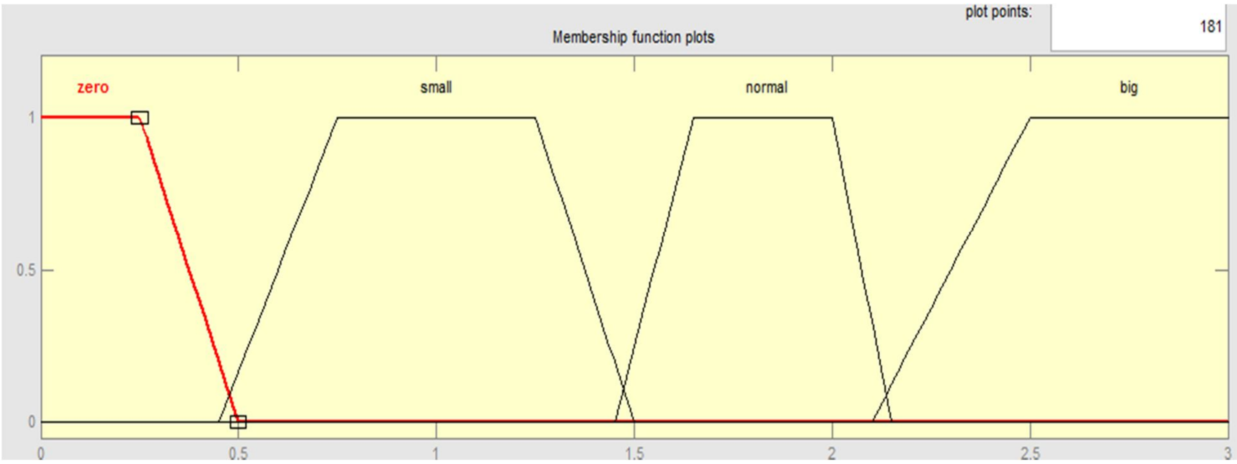

FIG 3 INPUT FUZZY SETS

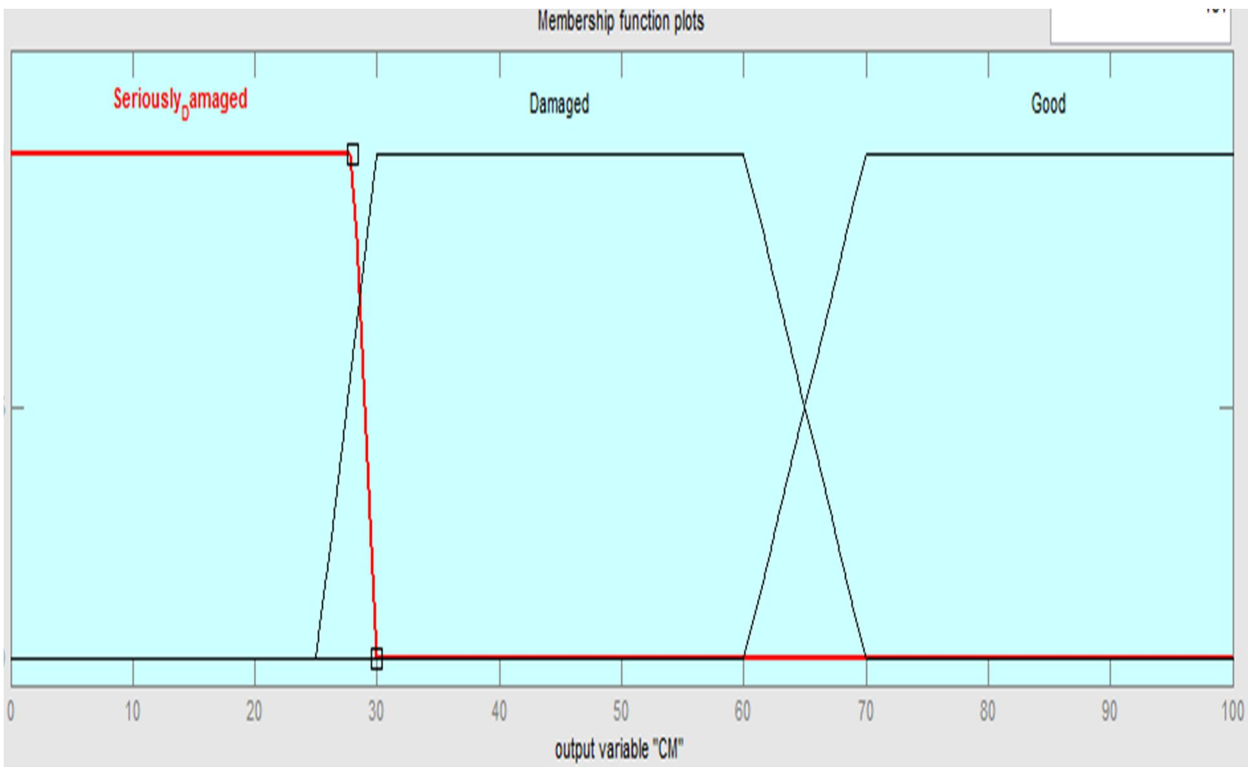

Fig 4 Output Fuzzy sets

V. SIMULATION RESULTS

A. 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 5 shows the output of fuzzy logic output.

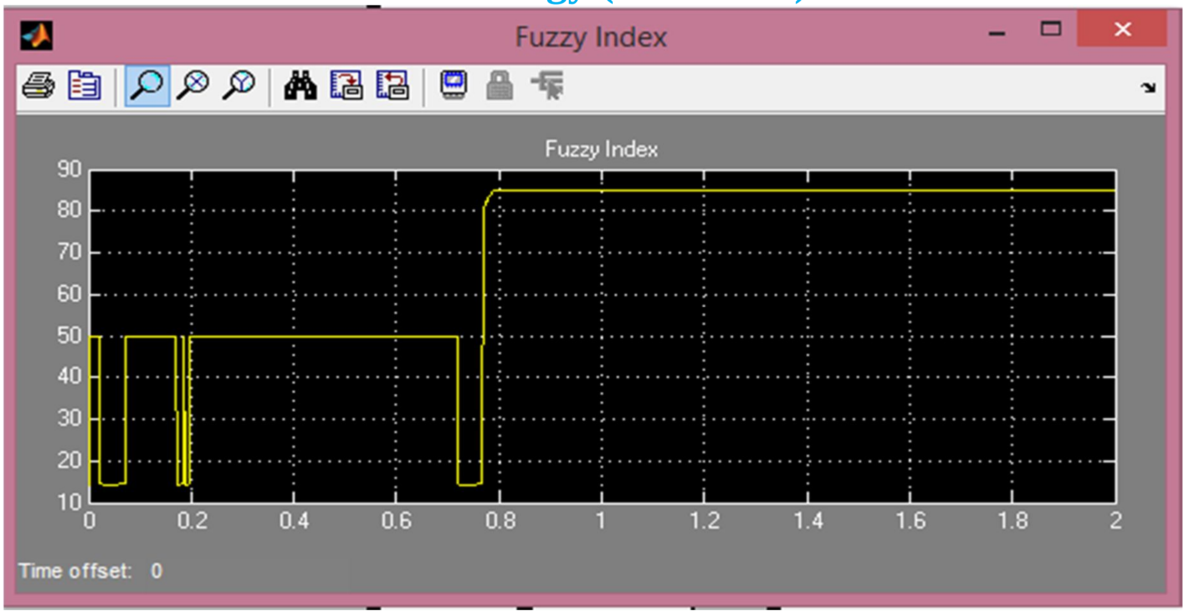

Fig 5 Fuzzy Logic Output For Normal Operation

B. Turn-Turn Short in One Phase Winding

Short circuit is being carried out in the R phase[7]. Which can be done by placing a value 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 seriously damaged state. Figure 6 shows the output of fuzzy logic output.

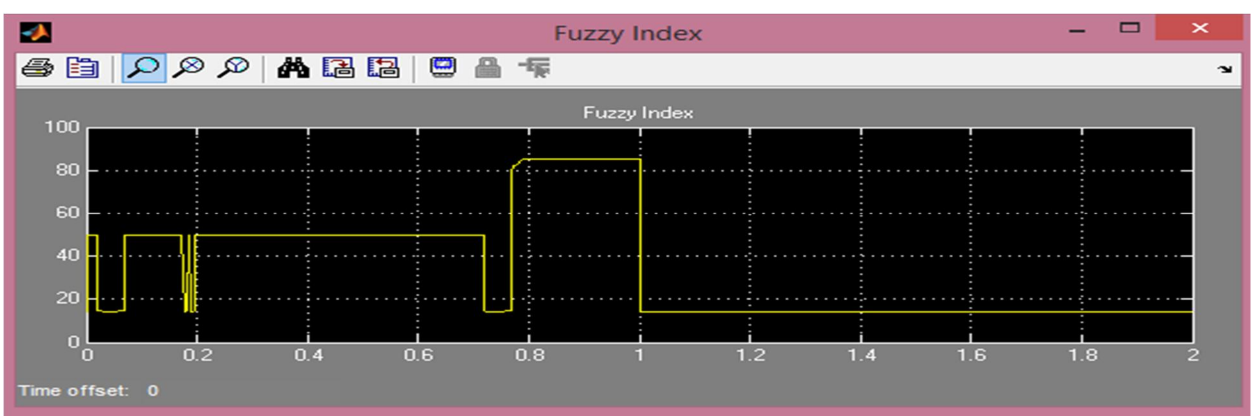

Fig 6 Fuzzy logic output for turn to turn short in one phase

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C. Open Phase Winding

In this case after normal startup, at 1 second, R phase was open circuited.. The corresponding fuzzy logic result is shown in Figure 7.

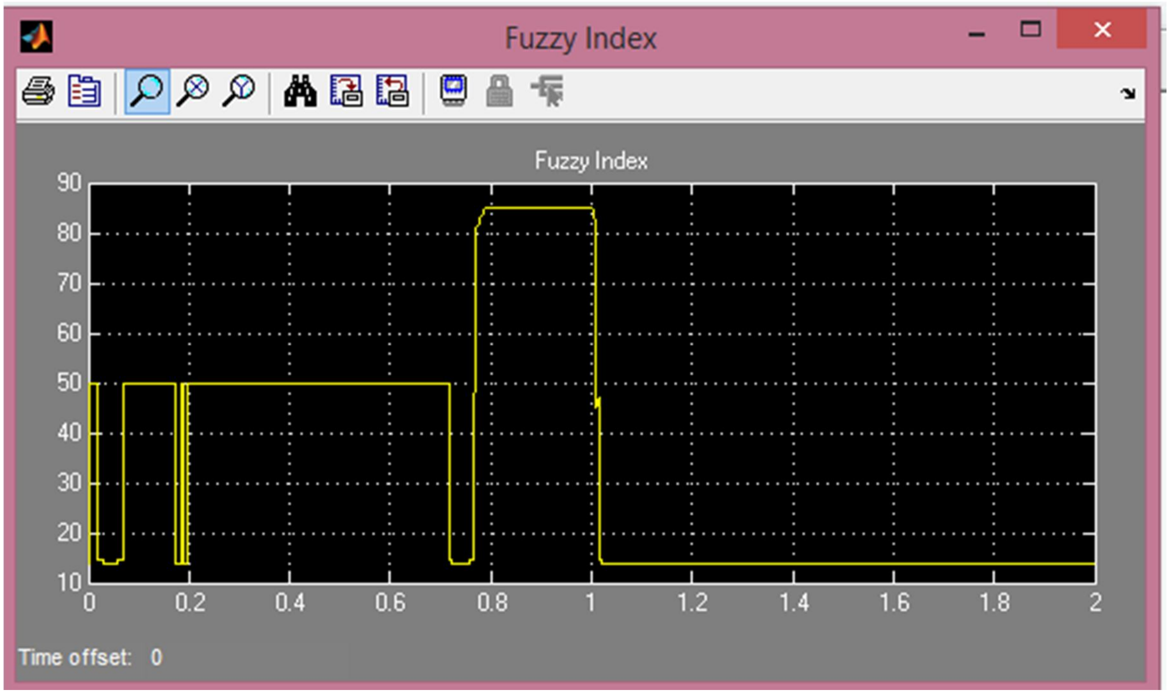

Fig 7 Fuzzy logic output for open phase winding

D. Unbalance in Input Voltage

The simulation of induction motor with voltage unbalance can be simulated by simply varying the voltage magnitude of B phase. In this case a 6% of the rated voltage in B phase is increased to create unbalance. In this simulation starts with normal parameters to obtain steady state at 1second. After that a fault is created by 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 to Damaged state. Figure 8 shows the output of stator current and fuzzy logic output.

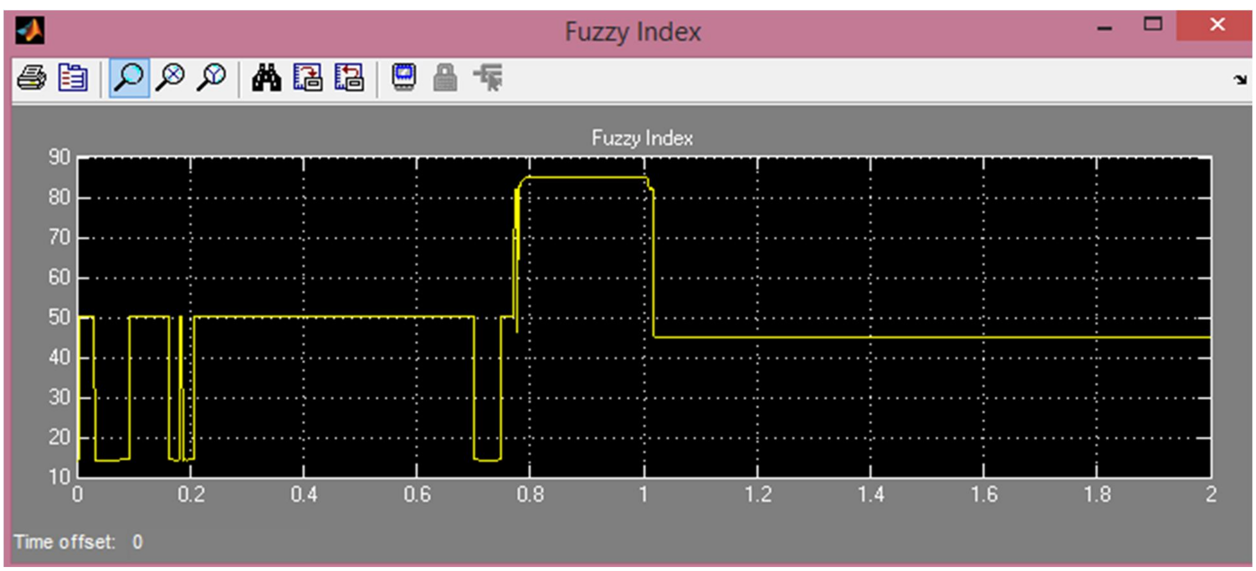

Fig 8 Fuzzy logic output for unbalance input voltage

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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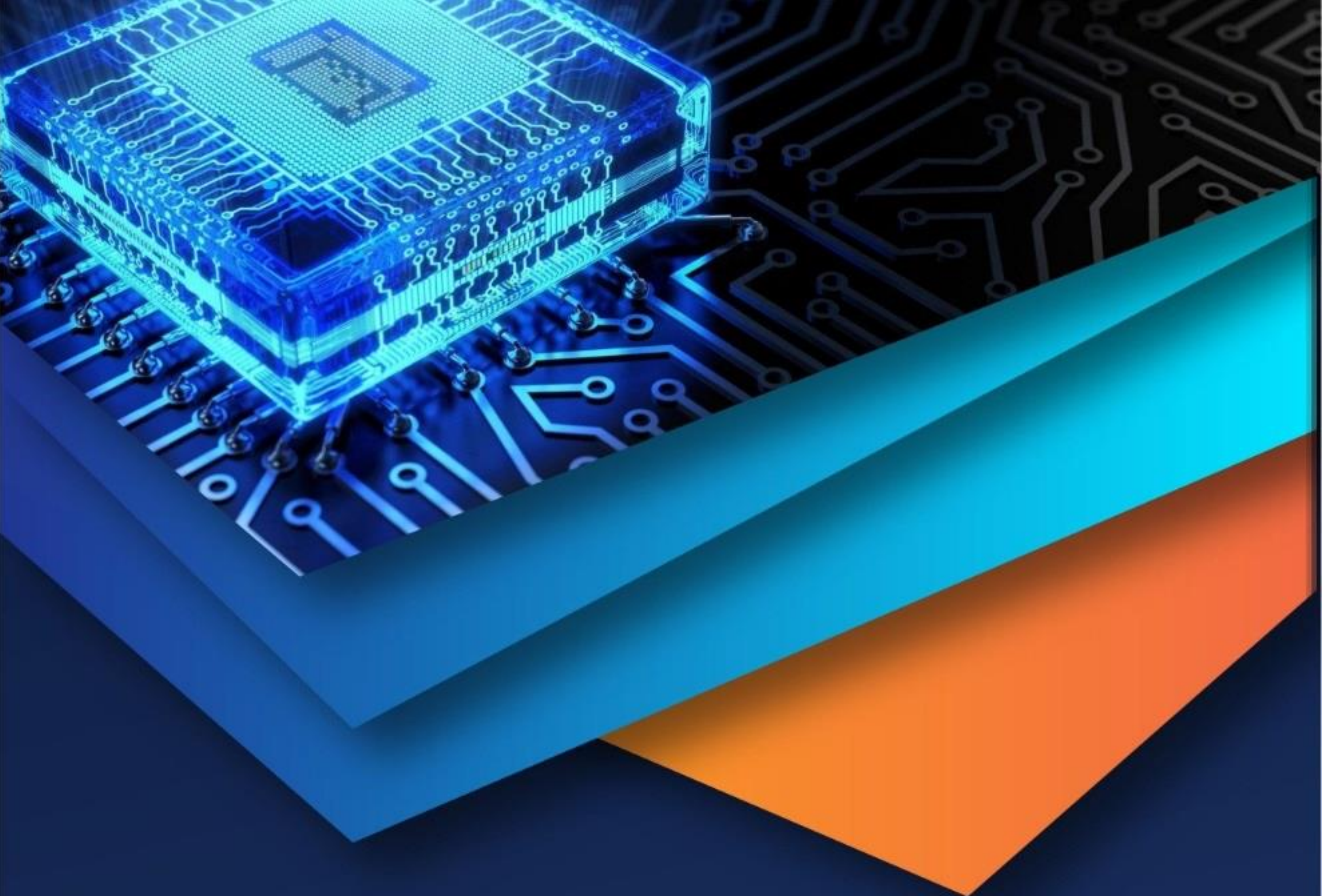

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