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Scalar Control of Induction motor using Fuzzy logic

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Abstract: The main objective of the paper is to control the speed of an induction machine with scalar control technique using Fuzzy logic controller. Here the PI controller is replaced with Fuzzy Logic controller. By using Fuzzy Logic controller there are wider range of operating conditions can be covered and easier to adapt. For Fuzzy Logic controller some rules are written which play major role to control the speed of induction motor in an effective manner. The errors are evaluated according to rules defined.
Keywords: Scalar Control, PI controller, Modulation index, Sectors, Fuzzy logic controller, Rule base, Membership functions.

I. INTRODUCTION

Induction motors are used in the past mainly in applications required constant speed. Squirrel cage Confine enlistment engines took care of VSI is standard in foot fold Applications. Scalar control Strategy controls the boundary of Amplitude of Voltage. Yield force of IM is subject to the square of terminal voltage. Presently to expand force an expansion in voltage is done in voltage control technique. The execution of both the speed and force is advanced by an adjusted PI regulator and V/F scalar control. The most broadly utilized IM is squirrel confine engine in view of its benefits like mechanical strength, basic development and less keep up. But the Issue is that terminal voltage has a cut off which is crosses will prompt an adverse consequence on protection and activity of Engine. Scalar control is a modest, yet stable control Technique. Use of scalar control is restricted to applications where the presentation necessities as far as powerful conduct of the framework are less rigid, fans, transporters and few sorts of machine apparatus. The speed of the engine can't be controlled correctly, on the grounds that the rotor speed will be marginally not exactly the coordinated speed and that in this plan the stator recurrence and subsequently the simultaneous speed is control variable.

A. *Objective*

The basic objective is to control the speed of induction motor using scalar control in MATLAB. Modelling the inverter and switching different sectors and finding out the angle alpha with the help of space vector pulse width modulation in MATLAB and interfacing with the v/f closed loop block and speed control block by varying voltage and frequency is the primary objective.

B. *Induction Motor Torque*

$$T = sE_2^2 \times \frac{R_2}{R_2^2 + (sX_2)^2} \times \frac{3}{2\pi n_s} N - m$$

ns is the synchronous speed in revolutions per second. So torque is directly proportional to square of the voltage and inversely proportional to the frequency.

C. *Torque Speed Characteristics*

The engine can be arrived behind schedule from 5% of the coordinated speed (NS) up to the base speed. The force created by the engine can be kept steady all through this district. At base speed, the voltage and recurrence arrive at the appraised values. We can drive the engine past the base speed by expanding the recurrence further.

The speed increase and deceleration of the engine can be constrained by controlling the difference in the inventory recurrence to the engine as for time.

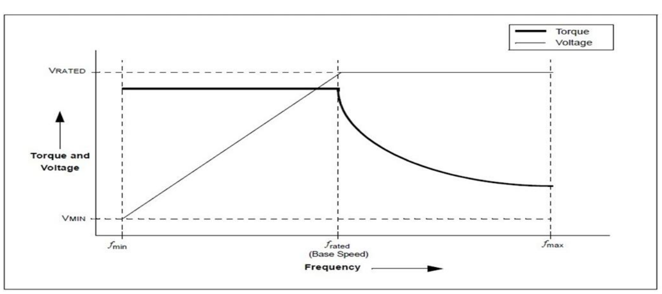

Fig. 1 Torque speed characteristics

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II. SCALAR CONTROL

Scalar control as the name indicates, is due to magnitude variation of the control variables only and disregards the coupling effects in the machine. For example, voltage of a machine can be controlled to control the flux, and the frequency or the slip can be controlled to control the torque. However, flux and torque are also functions of frequency and voltage respectively. Through SPWM fed Induction motor Drive, we will calculate the different parameters of IM such as rotor speed, electromagnetic torque, voltage and current. And after this calculation, one can do the d-q and a-b-c parameters of the system for PWM pulse generator. Now, compare obtained speed with the reference speed and if we get the desired speed which is equivalent to the obtained speed then we can calculate the THD.

A. V/F Control

V/F is abbreviated as voltage/frequency control. V/F control is an Induction motor control method which ensures the output voltage proportional with the frequency. So it maintains a constant motor flux, preventing weak magnetic and magnetic saturation phenomenon from happening. This method enables preventing reductions in the power factor or efficiency of a motor in a wide range of speed operation for changes in the frequency for speed control by outputting a voltage corresponding to the frequency set by a parameter in an Inverter.

III. SPACE VECTOR PULSE WIDTH MODULATION

A. Introduction

Space Vector Modulation (SVM) Technique has become the most popular and important PWM technique for three level voltage source inverters for the control of AC Induction , Brushless DC Switched Reluctance and Permanent Magnet Synchronous Motors. This work proposes a new software implementation for the three level inverter using Space Vector Modulation technique. Space Vector modulation (SVM) technique was originally developed as a vector approach to pulse-width modulation (PWM) for three-phase inverters. It is a more sophisticated technique for generating sine wave that provides a higher voltage to the motor with lower total harmonic distortion.

B. Space Vector Concept

In this modulation technique the three phase quantities can be transformed to theirequivalent 2-phase quantity either in synchronously rotating frame (or) stationary frame. From this 2-phase component the reference vector magnitude can be found and used for modulating the inverter output. The process of obtaining the rotating space vector is explained in the following section, considering the stationary reference frame. The principle of the SVM is that we use these switching states to compose the desired output voltage. Every switching state corresponds to specific output voltages which are equivalent to a vector on an α-β plane, using space vector transformation.

$$v_\alpha = \frac{3}{2} v_{RN}$$

$$v_\beta = \frac{\sqrt{3}}{2}(v_{YN} - v_{BN})$$

$$\begin{bmatrix} v_\alpha \\ v_\beta \end{bmatrix} = \begin{bmatrix} \frac{3}{2} & 0 & 0 \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} v_{RN} \\ v_{YN} \\ v_{BN} \end{bmatrix}$$

C. Sectors

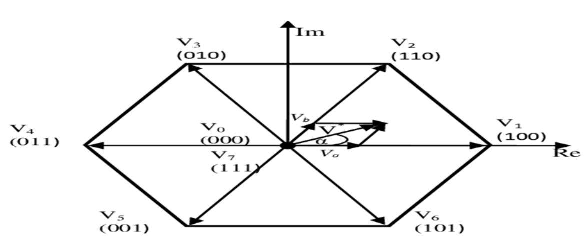

Fig.2 Space vector representation

There are 6 sectors as shown in the figure, V* is the reference voltage. Rotating voltage is sampled in every sub cycle to get 3 phase voltage. There are 8 possible states, out of which 6 are active states and 2 zero states are (000), (111). Each sector spreads about 60 degrees.

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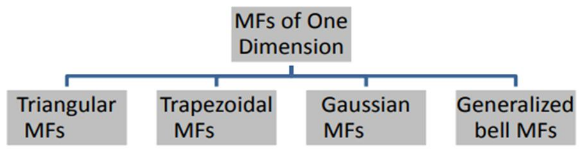
IV. FUZZY LOGIC CONTROLLER

A fuzzy control system is a control system based on a fuzzy logic, a mathematical system that analyses input values in term of logical variables that takes on continuous values between 0 and 1,in contrast to classical or digital value, which operates on discrete values of either 1 or 0(true or false) respectively. The main reason for using of Fuzzy Logic Controller is it works as a Human Being. It is simple and doesn't requires complex mathematics. It is easy to use apart from this the design is simple.

A. Formulating Membership Functions

Any membership function characterizes the complete fuzzy set, where it belongs to. Different shapes have been designed to choose the fuzzy membership function based on their choice.

Different types of membership functions commonly used are:



The most frequently used membership functions in day to day life are triangular and trapezoidal as there is less complexicity in representing these waveforms and require less time for computation.

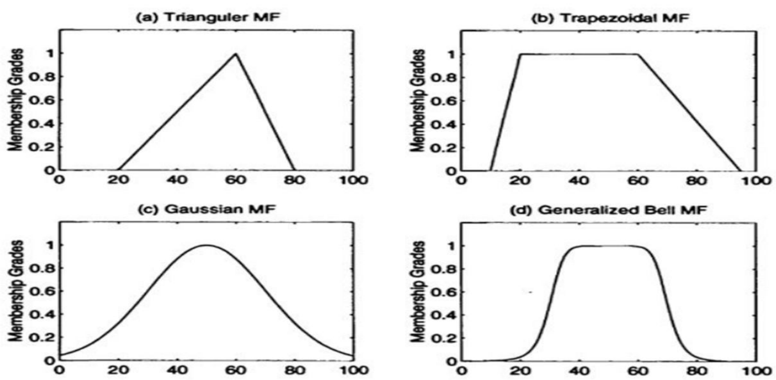


Fig.3 Membership functions

B. Components of FLC

The contributions to a fuzzy Logic controller are the prepared with the assistance of linguistic variables which thus are characterized with the guide of enrolment capacities. These are picked in a way that they cover the entire of the universe of talk. To stay away from discontinuity with respect to minor changes in the inputs, the nearby fuzzy sets must overlap each other. Because of a small time constant in Fuzzy Logic Controllers, this criterion is very vital role in the design of the similar.

1) *Fuzzification Block or Fuzzifier*: As talked about previously, rather than utilizing mathematical factors, fuzzy rationale utilizes phonetic factors for processing information. However, since the contributions to the FLC are as mathematical factors they should be changed over into linguistic variables. This capacity of changing over these fresh sets into fuzzy sets is performed by the Fuzzifier. The fuzzification method includes laying out the participation capacities for the inputs.

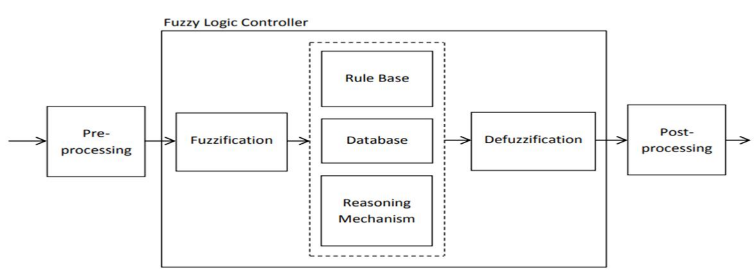


Fig.4 Fuzzy logic controller

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Volume 9 Issue VI Jun 2021- Available at www.ijraset.com

2) *Inference System*

This inference system of a Fuzzy Logic Controller consists of the following three patterns:

a) *Rule Base:* Rule Base FLC is a rule-based control system, so the basic rules are made to operate this system by input processing. Fuzzy rules are used within fuzzy logic systems to infer an output based on input variables. It comprises of various If-Then principles.

b) *Data Base:* It consists of user defined Information Attained, according to rules.

c) *Reasoning Mechanism:* It plays out the derivation on the guidelines and the information give a sensible yield. It is fundamentally the codes of the product which are measure the standards and the all the information dependent on a specific circumstance.

3) *Defuzzification Block or Defuzzifier:* Its Function is exact opposite of Fuzzifier. It transforms fuzzy variables to fresh sets. It is used to take fresh sets from the defuzzifier which is used as input to new systems. Even though the fuzzy sets resemble the human thought process, their functionality is limited only to the above processes. A defuzzifier is used for a very special role, when the Mamdani Fuzzy Model is utilized for planning a regulator.

There are five basic defuzzification strategies and they are defined as follows:

a) Centroid of Area (COA)
b) Bisector of Area (BOA)
c) Mean Of Maximum (MOM)
d) Smallest Of Minimum (SOM)
e) Largest Of Maximum (LOM)

V. SIMULATION LINK MODEL

In this MATLAB model the PI controller is replaced with Fuzzy logic controller to improve the output. That is the motor reaches to synchronous speed at a faster rate as modulation index reaches to 1 within less time when compared with PI controller. Here we take error and change in error as inputs and get speed control as output.

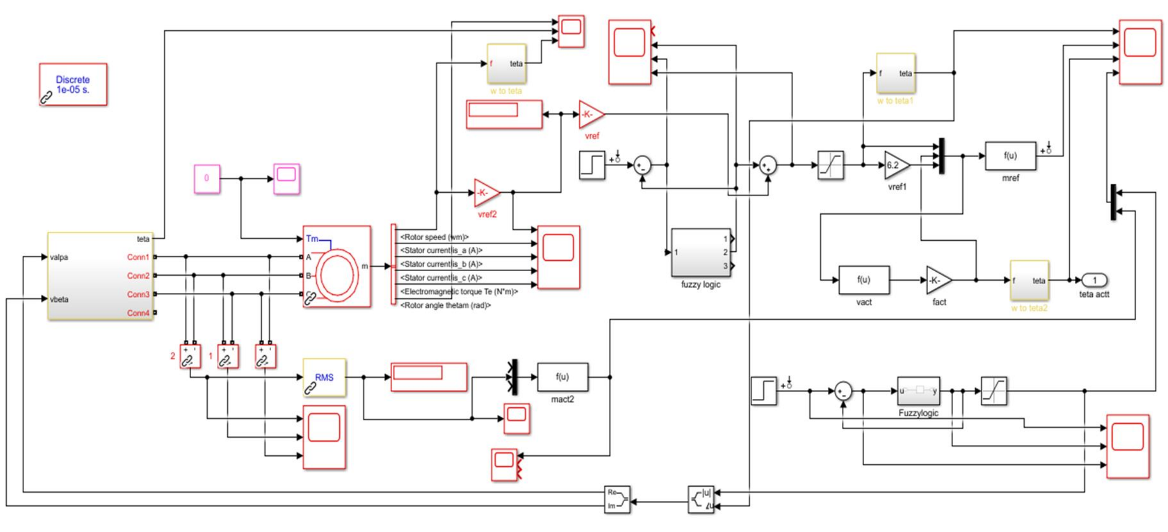

Fig.5 Simulation model

A. Modulation Index

The modulation index of an amplitude modulated signal is defined as the measure or extent of amplitude variation about an un-modulated carrier.

Modulation Index, m= peak value of modulating signal/peak value of carrier signal.

Modulation index is very important in speed control of induction motor. If modulation index value reaches to 1 in less time, then the induction motor achieves synchronous speed at a faster rate.

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Volume 9 Issue VI Jun 2021- Available at www.ijraset.com

B. Inverter

The basic operation of the inverter is to convert energy in the form of DC to energy in the form of a AC. There is a need of conversion of energy from DC to AC. Input voltage to inverter is DC voltage, with the help of gate pulses given at different instances we can convert it to AC . Here the swich used is IGBT connected in parallel to a diode.

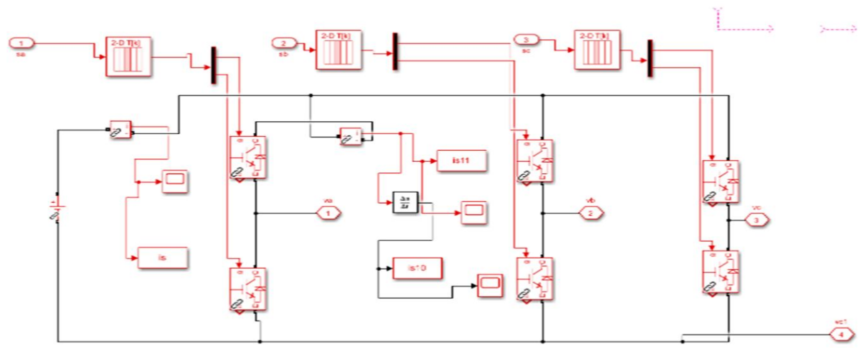

Fig.6 Three phase Inverter mode

C. Subsystem of Fuzzy Logic

With the reference speed and gave it to the unit delay block. Speed with delay and without delay are given to summing block and to saturation block. The speed is multiplied with required again to bring its range in (0,1).
The speed is given to Fuzzy Logic controller to improve the speed.

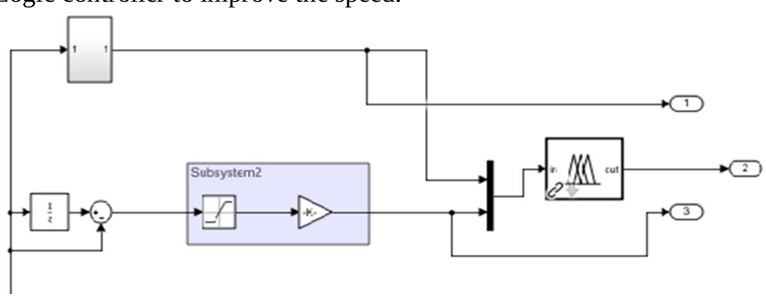

Fig.7 Subsystem of fuzzy logic model

D. Rule Base Design

Based on the variations in error and change in error we write the rule to get corresponding output which are observed in their respective waveforms.
These are the following rules used:

1) If (error is z) and (change_in_error is z) then (output is z) (1)
2) If (error is z) and (change_in_error is ph) then (output is z) (1)
3) If (error is z) and (change_in_error is pm) then (output is z) (1)
4) If (error is z) and (change_in_error is pl) then (output is z) (1)
5) If (error is ph) and (change_in_error is z) then (output is l) (1)
6) If (error is ph) and (change_in_error is ph) then (output is l) (1)
7) If (error is ph) and (change_in_error is pm) then (output is lm) (1)
8) If (error is ph) and (change_in_error is pl) then (output is lm) (1)
9) If (error is pm) and (change_in_error is z) then (output is l) (1)
10) If (error is pm) and (change_in_error is ph) then (output is lm) (1)
11) If (error is pm) and (change_in_error is pm) then (output is lm) (1)
12) If (error is pm) and (change_in_error is pl) then (output is m) (1)
13) If (error is pl) and (change_in_error is z) then (output is mh) (1)
14) If (error is pl) and (change_in_error is ph) then (output is lm) (1)
15) If (error is pl) and (change_in_error is pm) then (output is m) (1)
16) If (error is pl) and (change_in_error is pl) then (output is h) (1)

After writing the rules save the file with .fis extention.The .fis is now to be loaded in FIS editor to view membership function,rules and surface plot

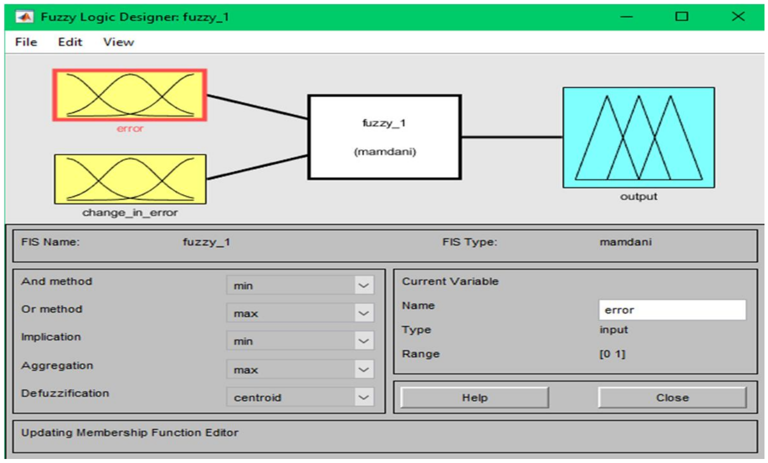

Fig.8 Fuzzy logic Designer

VI. SIMULATION RESULTS

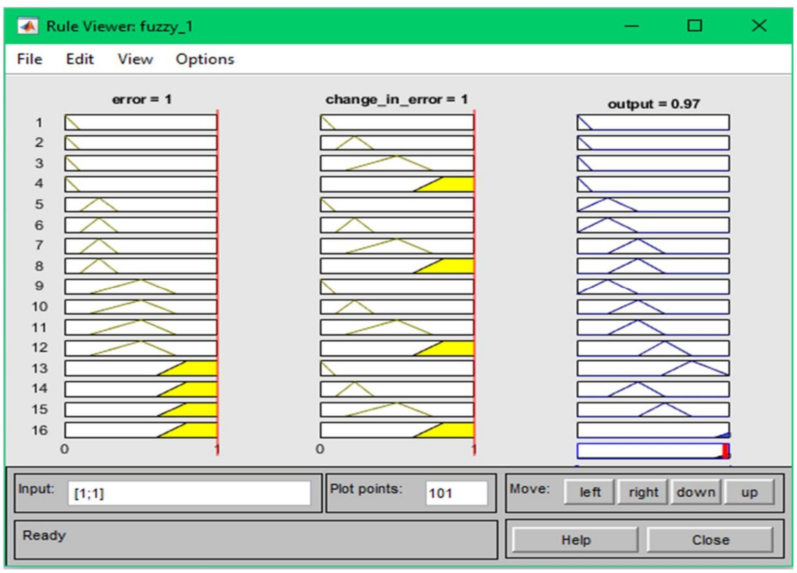

Fig.9 Rule viewer of fuzzy logic

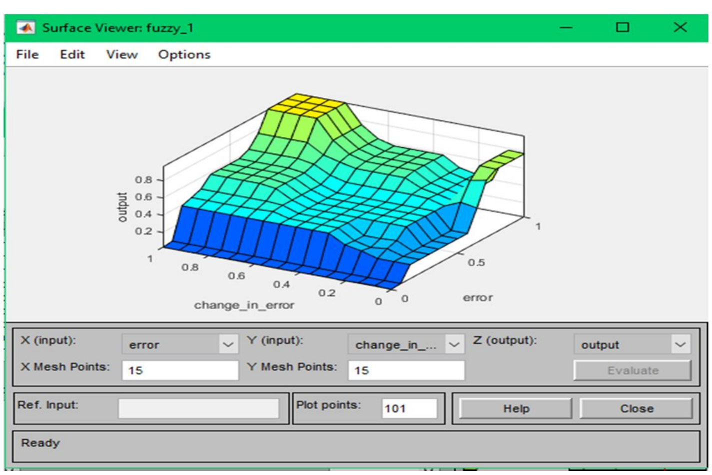

Fig.10 Surface view

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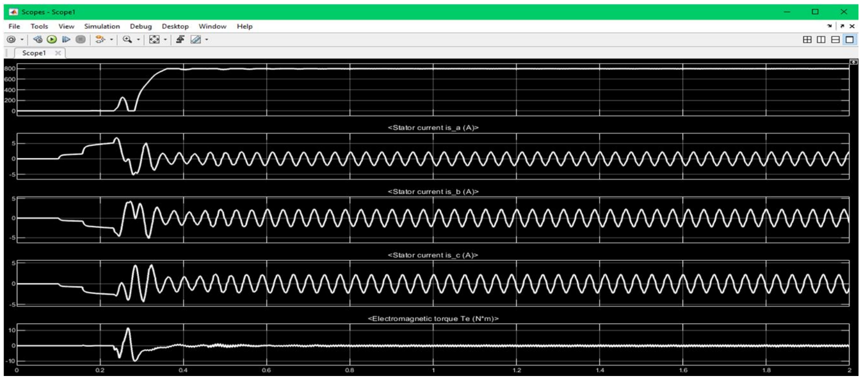
Fig.11 Waveforms of speed, current and EMT

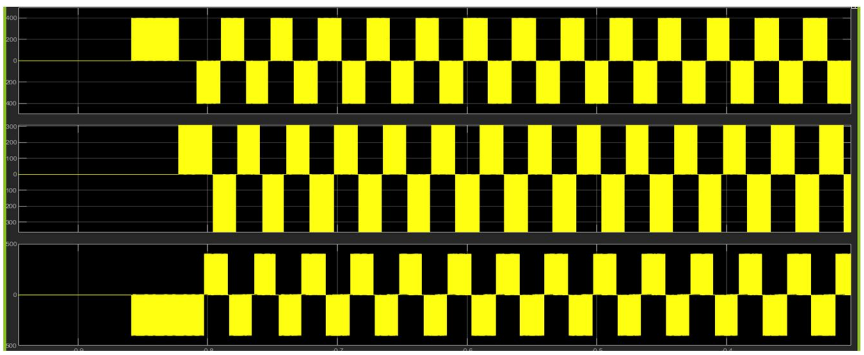
Fig.12 Three phase voltage waveforms

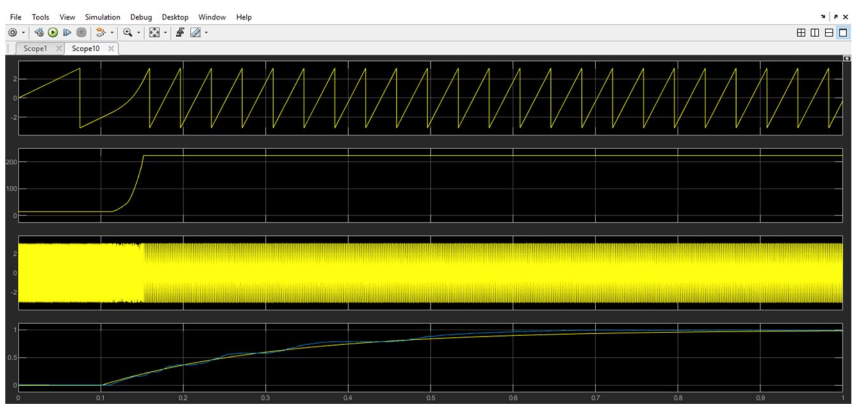
Fig.13 Modulation index and angle waveforms

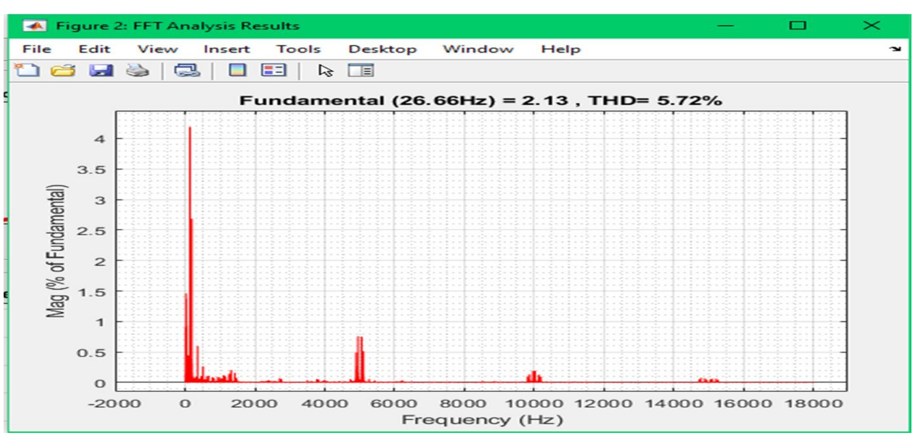

Fig.14 THD result analysis

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VII. CONCLUSION

By implementing scalar control by keeping voltage and frequency ratio constant we are able to bring the modulation index value to 1 at a faster rate .so we can bring the motor to operate at synchronous speed.In this project of speed control of induction motor using fuzzy logic, the PI controller is replaced with fuzzy logic controller to get improved results and to reduce the error present. The advantages of the Fuzzy Logic Controller used in the simulation is the speed tended to approach the reference speed even when it was higher than the base speed or very low as compared to the same, unlike the PI Controller.

VIII. FUTURE SCOPE

Simulation of the block diagram for speed control of induction motor has been performed in MATLAB/SIMULINK and the results have been studied. The Fuzzy logic controller was designed and tuned so as to achieve desirable results. This controller can be implemented in different practical applications of induction motors, the feasibility of the controller in the corresponding applications can be studied and changes can be made according to the requirement. Different strategies like Genetic Algorithm can also be applied for tuning the controller. Also, instead of just fuzzy controller, a neuro-fuzzy controller can be developed based on this project.

IX. ACKNOWLEDGEMENT

We would like to express our sincere thanks to our project supervisor Asst. Prof. T. Abhiram, Department of Electrical Engineering, Sreenidhi Institute of science and Technology for his constant support, timely help, guidance, sincere co-operation during the entire period of my work. We are grateful to him for providing all the necessary facilities during the course of project work, for the help provided during various stages of the project.

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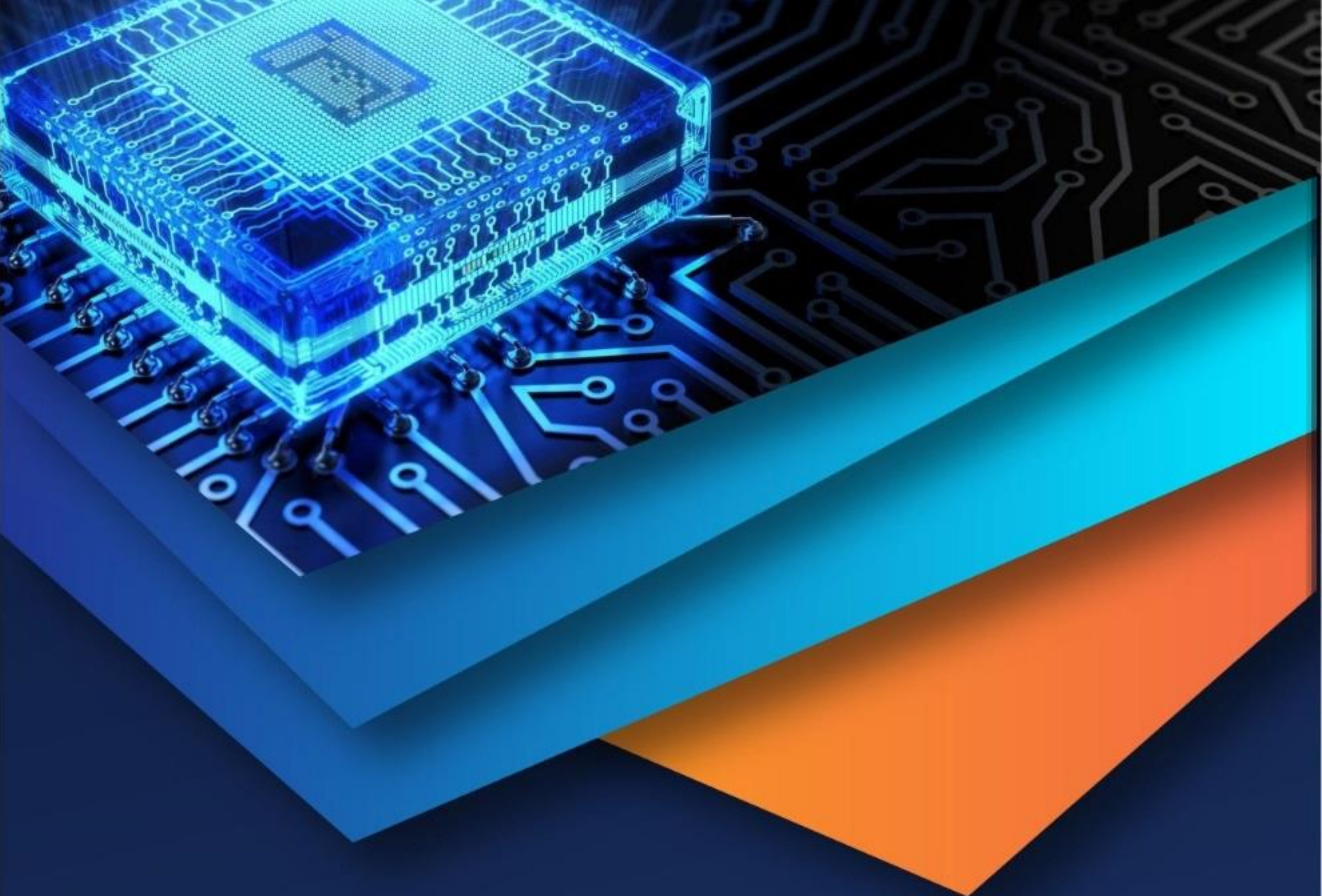

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