International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 3 Mar. 2021, pp: 782-789 www.ijaem.net ISSN: 2395-5252

Speed Control of an Induction Motor by Using Indirect Vector Control Method

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Submitted: 05-03-2021 Revised: 18-03-2021 Accepted: 20-03-2021

ABSTRACT: In this paper we have developed a model in which the speed of an induction motor will be controlled by the Vector Control or we can say by the PWM pulse generator. PWM Pulse modulator has been implemented in this model to generate the pulse which will be fed into the MOSFET inverter, PWM modulator is controlled by the FUZZY LOGIC Controller which will control the frequency of the pulse toggling. Pulse generated from the vector control block will go to the MOSFET Inverter which will convert the DC Voltage supplied to it into a AC Voltage source and its frequency will depend upon the pulse frequency generated by the vector control block or PWM Pulse Modulator. On the generation of the AC Voltage it will fed into the induction motor and hence it will ignite the motor. To start an Induction motor it is important to induce an initial current into it so that the coils will repel each other and hence the motor will start, however as the time elapses the motor starts rising or we can say it will gain more speed, MOSFET Inverter allows the motor to achieve higher speed in comparison to the IGBT Inverter which not only uses more power but also fails to cope up with the FUZZY LOGIC controlled vector controlled pulse. The motor flux is controlled by the direct-axis current reference id*. Block DQ-ABC is used to convert id* and ie* into three phase current references ip*, iq*, and ir* for the current regulator. Current and Voltage Measurement blocks provide signals for visualization purpose. Motor current, speed, and torque signals are available at the output of the 'Asynchronous Machine' block. Torque control management system has also been included in this model to keep the motor stable and vibrations free at the higher speed. It is also controlled by the FUZZY LOGIC controller to enhance the system capabilities and to make it more responsive and reliable.

Keywords- IM, FOC,PI, IVCIM.

I. INTRODUCTION

An induction motor is an asynchronous AC (alternating current) motor. The least expensive and most widely used induction motor is the squirrel cage motor. The interest in sensor less drives of induction motor (IM) has grown significantly over the past few years due to some of their advantages, such as mechanical robustness, simple construction, and less maintenance. These applications include pumps and fans, paper and textile mills, subway and locomotive propulsions, electric and hybrid vehicles, machine tools and robotics, home appliances, heat pumps and air conditioners, rolling mills, wind generation systems, etc. So, Induction motors have been used more in the industrial variable speed drive system with the development of the vector control technology. This method requires a speed sensor such as shaft encoder for speed control.

However, a speed sensor cannot be mounted in some cases such as motor drives in a hostile environment and high-speed drives[1]. In addition, it requires careful cabling arrangements with attention to electrical noise. Moreover, it causes to become expensive in the system price and bulky in the motor size. In other words, it has some demerits in both mechanical and economical aspects. Thus current research efforts are focused on the so called “sensor less” vector control problem, in which rotor speed measurements are not available, to reduce cost and to increase reliability. The control and estimation of ac drives in general are considerably more complex than those of dc drives, and this complexity increases substantially if high performances are demanded. The main reasons for this complexity are the need of variable-frequency, harmonically optimum converter power supplies, the complex dynamics of ac machines, machine parameter variations, and difficulties of processing feedback signals in the presence of harmonics. The selection of drive for motor control is based on several factors such as[2]:

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- One-, two- or four-quadrant drive,
- Torque, speed, or position control in the primary or outer loop,
- Single- or multi- motor drive,
- Range of speed control Does it include zero speed and field-weakening regions, Accuracy and response time,
- Robustness with load torque and parameter variations,
- Control with speed sensor or sensor less control,
- Type of front-end converter,
- Efficiency, cost, reliability, and maintainability consideration,
- And Line power supply, harmonics, and power factor consideration.

The performance at the high speed region is satisfactory but its performance at very low speed is poor. In many research, most of the methods are estimation of rotor flux angle and parameter tuning in field oriented vector control. The field orientation control, any controller is easily implemented and can approach desired system response. However, if the controlled electrical drives require high performance, i.e., steady state and dynamic tracking ability to set point changes and the ability to recover from system variations. Then a conventional PI, fuzzy and neural controller for such drives lead to tracking and regulating performance simultaneously and then compared each other [3]. The control and estimation of induction motor drive constitute a vast subject, and the technology has further advance in recent years. Induction motor drives with cage- type machines have been the workhorses in industry for variable-speed application in a wide power range that covers from fractional horse power to multi-megawatts.

Machines are so robust and inexpensive is that no external current is required inside the rotor to create the revolving magnetic field. An induction [4].The major reason why these machine consists fundamentally of two parts: the stator (the stationary part) and the rotor (the moving part). For a three-phase induction machine (this will be used in this thesis project), three-phase sinusoidal voltages are applied to the windings of the stator. This creates a magnetic field. Because the voltages differ in phase by 120 degree with respect to each other, a revolving magnetic field is created that rotates in synchronism with the changing dominant poles around the cylindrical stator.The rotor, which, for a squirrel-cage rotor consists of copper bars in a cylindrical format 'follows' the created revolving magnetic field. As a consequence, a voltage is induced in the rotor bars that are proportional to the relative angular speed of the magnetic field (this is referenced to the angular speed of the rotor). Because a voltage is induced, magnetic fields are created around the rotor wires[5]. The two generated magnetic fields (in the rotor and stator) interact to generate a force that is also proportional in magnitude to the relative angular speed of the magnetic field. Torque is equal to force multiplied by the radius of the cylindrical stator. Therefore, the resultant torque applied by the rotor is proportional to the relative speed of the magnetic field with respect to the speed of the rotor[6].

II. OVER VIEW OF DIFFERENT CONTROLLING SCHEMES FOR SPEED CONTROL OF THREE PHASE INDUCTION MOTOR

2.1 Scalar Control

Scalar control as the name indicates, is due to magnitude variation of the control variable only, and disregards the coupling effect in machine. For example, the voltage of machine can be controlled to control the flux, and frequency or slip can be controlled to control the torque. However flux and torque are also function of voltage and frequency respectively. A scalar controlled drive gives somewhat inferior performance. Scalar control is easy to implement. Scalar controlled drives have been widely used in industry, but the inherent coupling effect (both torque and flux are function of voltage or current and frequency) gives sluggish response and system is easily prone to instability because of higher order (fifth order) system effect. To make it clearer, if torque is increased by incrementing the slip (the frequency), the flux tends to decrease .it has been noted that the flux variation is also sluggish[7]. Decreases in flux then compensated by the sluggish flux control loop feeding an additional voltage. This temporary dipping of flux reduces the torque sensitivity with slip and lengthens the response time. However, their importance has diminished recently because of the superior performance of vector or Field orientated control (FOC) drives. To improve speed control performance of the scalar control method, an encoder or speed tachometer is required to feedback the rotor angle or rotor speed signal and compensate the slip frequency. However, it is expensive and destroys the mechanical robustness of the induction motor. So these are the limitation of scalar control which is overcome by Field orientated control (FOC) for induction motor drive[8].

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2.2 Vector Control or Field Oriented Control (FOC)

Blaschke in 1972 has introduced the principle of field orientation to realize dc motor characteristics in an induction motor derive.For the same, he has used decouploed control of torque and flux in the motor and gives its name transvector control. In DC machine the field flux is perpendicular to the armature flux. Being orthogonal, these two fluxes produce no net interaction on one another. Adjusting the field current can therefore control the DC machine flux, and the torque can be controlled independently of flux by adjusting the armature current [9]. An AC machine is not so simple because of the interactions between the stator and the rotor fields, whose orientations are not held at 90 degrees but vary with the operating conditions. We can obtain DC machine-like performance in holding a fixed and orthogonal orientation between the field and armature fields in an AC machine by orienting the stator current with respect to the rotor flux so as to attain independently controlled flux and torque. Such a control scheme is called flux-oriented control or vector control. Vector control is applicable to both induction and synchronous motors.

The cage induction motor drive with vector or field oriented control offers a high level of dynamics performance and the closed-loop control associated with this derive provides the long term stability of the system. Induction Motor drives are used in a multitude of industrial and process control applications requiring high performances. In high-performance drive systems, the motor speed should closely follow a specified reference trajectory regardless of any load disturbances, parameter variations, and model uncertainties. In order to achieve high performance, field-oriented control of induction motor (IM) drive is employed. However, the controller design of such a system plays a crucial role in system performance. The decoupling characteristics of vector- controlled IM are adversely affected by the parameter changes in the motor. So the vector control is also known as an independent or decoupled control [10].

2.3 Proportional Integral (PI) Control

In this project complete mathematical model of FOC induction motor is described and simulated in MATLAB for studies a 50 HP(37KW) induction motor has been considered .The performance of FOC drive with proportional plus integral (PI) controller are presented and analysed. One common linear control strategy is proportional-integral (PI) control.

The Maintenances of the systems. Therefore, preliminary results can be obtained within a short development period.Fuzzy control is based on fuzzy logic, which provides an efficient method to handle in exact information as basis reasoning. With fuzzy logic it is possible to convert knowledge, which is expressed in an uncertain form, to an exact algorithm. In fuzzy control, the controller can be represented with linguistic if-then rules [13]. Control law used for this strategy is given by

$$T = Kp\, e + Ki \int e\, dt$$

Its output is the updating in PI controller gains (Kp and Ki) based on a set of rules to maintain excellent control performance even in the presence of parameter variation and drive nonlinearity. The use of PI controllers for speed control of induction machine drives is characterized by an overshoot during tracking mode and a poor load disturbance rejection. This is mainly caused by the fact that the complexity of the system does not allow the gains of the PI controller to exceed a certain low value. At starting mode the high value of the error is amplified across the PI controller provoking high variations in the command torque. If the gains of the controller exceed a certain value, the variations in the command torque become too high and will destabilize the system. To overcome this problem we propose the use of a limiter ahead of the PI controller [11]. This limiter causes the speed error to be maintained within the saturation limits provoking, when appropriately chosen, smooth variations in the command torque even when the PI controller gains are very high. The motor reaches the reference speed rapidly and without overshoot, step commands are tracked with almost zero steady state error and no overshoot, load disturbances are rapidly rejected and variations of some of the motor parameters are fairly well dealt with[20]. In the next chapter we will discuss about the PI controller and designing of PI controller.

2.4 Fuzzy Logic Control

Due to continuously developing automation systems and more demanding small Control performance requirements, conventional control methods are not always adequate. On the other hand, practical control problems are usually imprecise. The input output relations of the system may be uncertain and they can be changed by unknown external disturbances. New schemes are needed to solve such problems. One such an approach is to utilize fuzzy control. Since the introduction of the theory of fuzzy sets by L. A. Zadeh in 1965, and the industrial application of the first fuzzy controller by E.H. Mamadani in 1974, fuzzy systems have obtained a major role in engineering systems and consumer's products in 1980s and 1990s. New applications are presented continuously. A reason for this significant role is that fuzzy computing provides a flexible and powerful alternative to contract controllers, supervisory blocks, computing units and compensation systems in different application areas[12]. With fuzzy sets nonlinear control actions can be performed easily.

III. MATLAB MODEL OF INDIRECT VECTOR CONTROL IN DRIVE

3.1 Hysteresis Current Regulator

The current regulator, which consists of three hysteresis controllers, is built with Simulink blocks. The motor actual currents are provided by the measurement output of the Asynchronous Machine block. The actual motor currents and reference current are compared in hysteresis type relay.

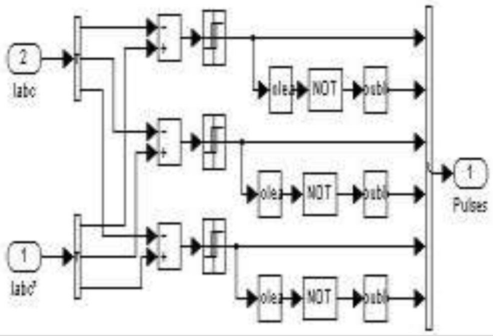

Fig. 3.1: Hysteresis Current Regulator

3.2 Universal Bridge

The Universal Bridge block implements a universal three-phase power converter that consists of up to six power switches connected in a bridge configuration. The type of power switch and converter configuration is selectable from the dialog box. Power Electronic device and Port configuration options are selected as IGBT/Diode and ABC as output terminals respectively. The DC link input voltage is represented by a 780 V DC voltage source. Set the snubber capacitance Cs to inf to get a resistive snubber [16].

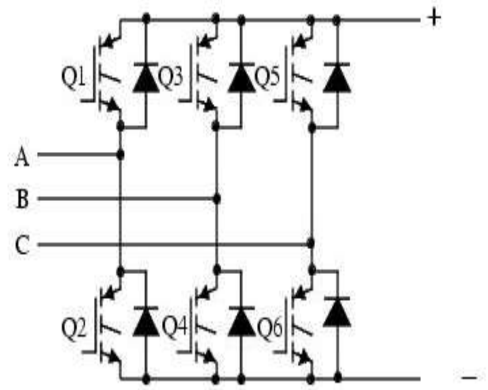

Fig. 3.2: Universal Bridge Block

3.3 Flux Calculation Block

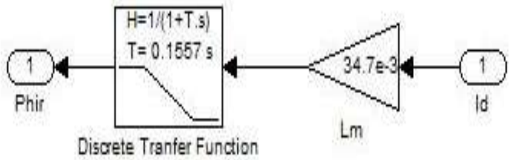

Fig. 3.3: Flux Calculation Block

Lr = Ll'r +Lm = 0.8 +34.7= 35.5 mH Lm = 34.7 mH Tr = Lr / Rr = 0.1557 sec Rr = 0.228Ω

then = Lm *Id / (1 +Tr .s)

3.4 Theta Calculation Block

The rotor flux position (θe) is calculated by the Theta Calculation Block.

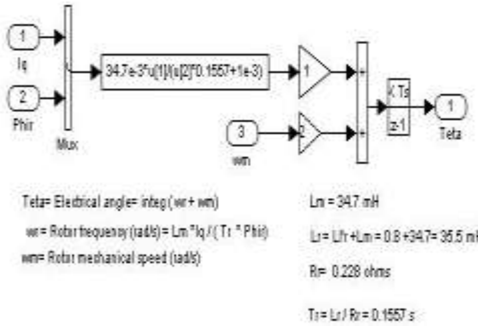

Fig 3.4: Theta Calculation block

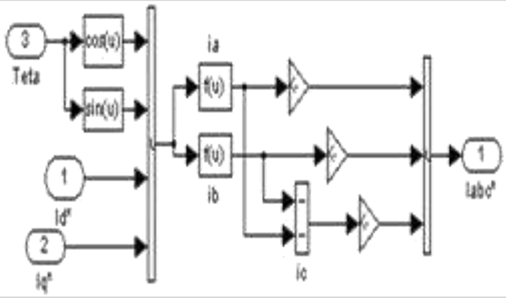

Fig 3.5: d-q to abc transformation blocks

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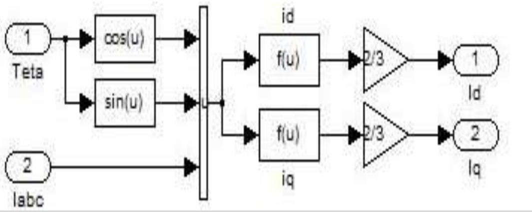

Fig 3.6: abc to d-q transformation blocks

3.5 MATLAB Simulation of IVCIM based on PI controller

We have simulated in matlab by use of Proportional - Integral controller based model as shown in figure. The reference speed 120 and feedback is given to summer, output of summer error given to PI controller which change the in output for better result[17].

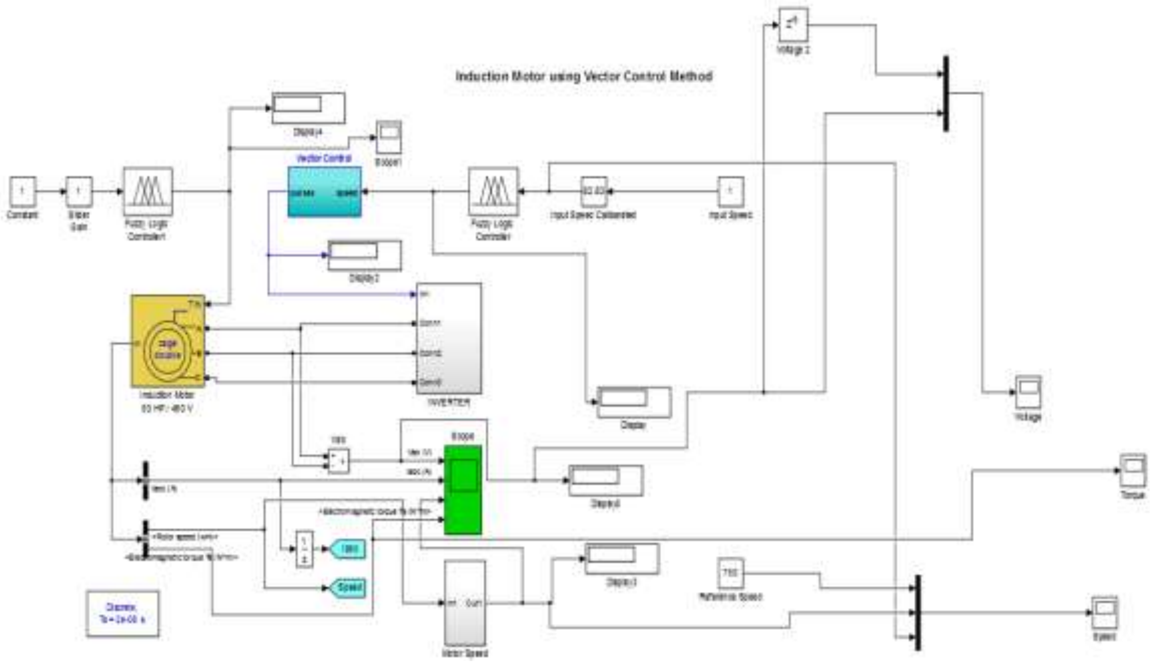

Fig 3.7 Matlab Simulink block diagram of indirect vector control using P-I controller

3.6 MATLAB Simulation IVCIM using Fuzzy Logic controller

We have simulated in matlab by use of Fuzzy Logic controller based model as shown in figure. Fuzzy logic controller block is used which have two input Error and rate of change in error and one output.

Induction motor is a useful asset for the machine engineering and as well as the electrical engineering field.

In this paper we have developed a model in which the speed of an induction motor will be controlled by the Vector Control or we can say by the PWM pulse generator.

PWM Pulse modulator has been implemented in this model to generate the pulse which will be fed into the MOSFET inverter, PWM modulator is controlled by the FUZZY LOGIC Controller which will control the frequency of the pulse toggling.

Pulse generated from the vector control block will go to the MOSFET Inverter which will convert the DC Voltage supplied to it into a AC Voltage source and its frequency will depend upon the pulse frequency generated by the vector control block or PWM Pulse Modulator.

On the generation of the AC Voltage it will fed into the induction motor and hence it will ignite the motor.

To start an Induction motor it is important to induce an initial current into it so that the coils will repel each other and hence the motor will start, however as the time elapses the motor starts rising or we can say it will gain more speed, MOSFET Inverter allows the motor to achieve higher speed in comparison to the IGBT Inverter which not only uses more power but also fails to cope up with the FUZZY LOGIC controlled vector controlled pulse.

The motor flux is controlled by the direct-axis current reference id*. Block DQ-ABC is used to convert id* and ie* into three phase current references ip*, iq*, and ir* for the current regulator. Current and Voltage Measurement blocks provide signals for visualization purpose. Motor current, speed, and torque signals are available at the output of the 'Asynchronous Machine' block.

Torque control management system has

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also been included in this model to keep the motor stable and vibrations free at the higher speed. It is also controlled by the FUZZY LOGIC controller to enhance the system capabilities and to make it more responsive and reliable.

IV. EXPERIMENTAL RESULT

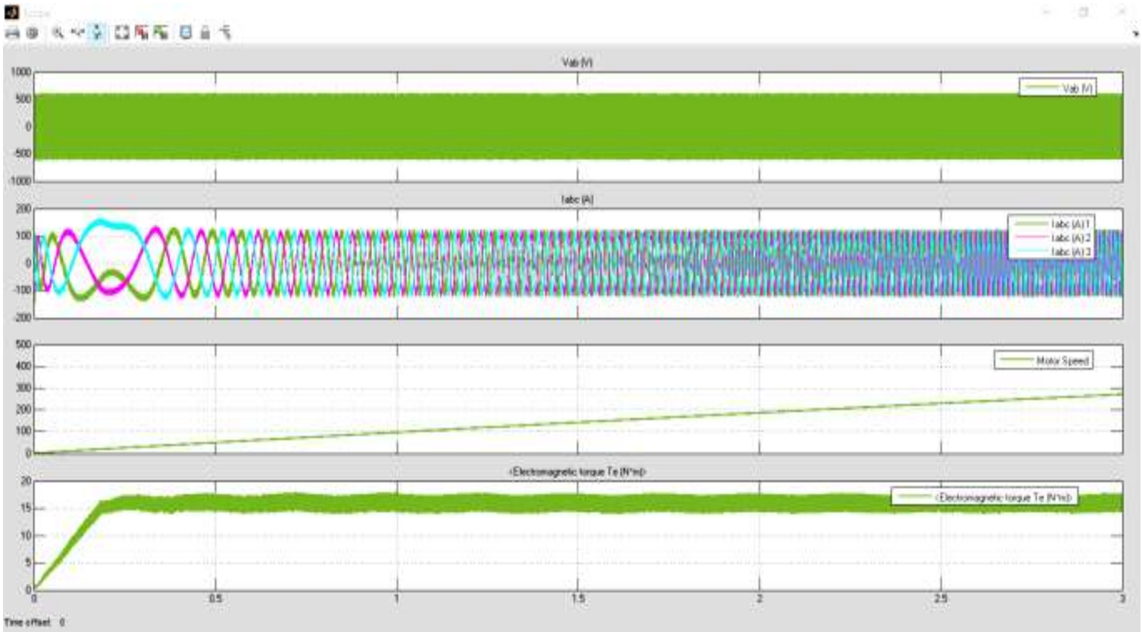

Fig 4.1: The graph shows the Voltage generated out from the inverter. Fig 4.2.2 shows the current output, fig 4.2.3 shows the speed of the motor. Fig 4.2.4 shows the torque which keeps changing itself to stabilize the motor at the higher speed it is controlled by the FUZZY LOGIC Controller.

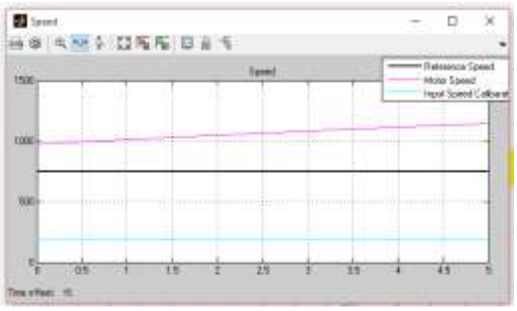

Fig 4.2: The speed graph above shows the speed acceleration on the reception of the current and the three phase voltage from the invertor.

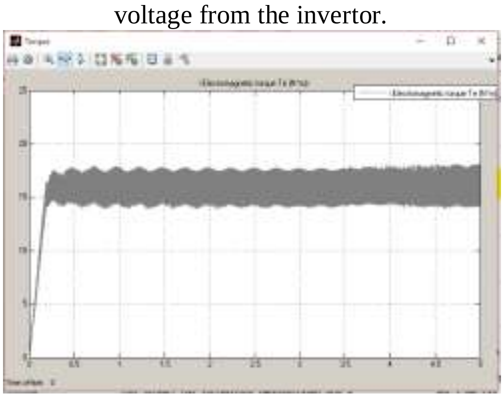

Fig 4.3: graph shows the Torque result.

V. CONCLUSION & FUTURE RECOMMENDATIONS

This project has successfully demonstrated and a properly designed PI, Fuzzy logic controller. We have study and compared two controllers for speed control of indirect vector control induction motor drive. At given result and their data of induction motor current, motor torque, and speed at no load and 100 N-m load performances are better with the Fuzzy logic controller Based on simulation results verification, the following conclusions are made.

• The Fuzzy logic controller is more robust than the PI and when load disturbances occurred.

- The Fuzzy logic controller performance when certain motor parameters (i.e. current and motor torque) were increased by a factor was still quite good and far better than the PI performance when the same parameters.
- The fuzzy logic controller base makes the superior to PI control techniques.

VI. FUTURE DIRECTIONS

1. With the help of other controller NARAMA-L2, Model Reference Control induction motor drives (VCIMDs) can be better controlled and compared these two controller performances.
2. To further develop an intelligent controller for better performance.
3. Study can be performed redial basis NN and recurrent NN etc. for speed control.

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International Journal of Advances in Engineering and Management
ISSN: 2395-5252

IJAEM

Volume: 03 Issue: 03 DOI: 10.35629/5252