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Performance Analysis of Induction Motor Using PI And FUZZY Controller

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Abstract—This paper represents the better speed regulation of induction motor by the help of indirect vector control technique and also by using other controlling techniques. Here speed of induction motor is regulated or controlled by using PI controller and fuzzy logic controller, by using PI controller it provides good regulation of speed but due to some drawback in it like high overshoot, oscillation of speed and torque at variation or change in load or due to external disturbances occur during running performance of induction motor drive that controller is replaced by fuzzy logic controller which provides more better running performance to the induction motor by regulating its speed in better way and tracking the actual running speed response easily and fast as compare to PI controller. The benefits of squirrel-cage induction motors are high robustness and low maintenance which make it widely used through various industrial modem processes, with growing economical and demands. In conventional FOC, PI controller is used to control the speed response of the induction motor drive. The use of PI controller induces many problems due to sudden changes in load and external disturbances. This behavior of the controller causes disturbance in drive running performance. To overcome this disadvantages an intelligent controller based on fuzzy logic is employed in the place of the conventional PI controller.

Keywords*-Induction motor; fuzzy logic controller (FLC); PI controller; Vector control.*

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I. Introduction

Induction motors are widely used in industrial areas due to its self starting and robust construction benefits and also due to less maintenance requirement, especially cage type induction motors are prefer in industrial areas because of no external resistance is required in it and many more advantages of it over wound type induction motor. Hence for smooth running performance of induction motor with variation in loads, external disturbances and change in voltage magnitude a control technique was introduce called field oriented control. As previously separately excited DC motor drives were used in industrial areas because of, it is simple in control due to its command in controlling torque and flux separately or independently that means when the torque is to be controlled there is no any dependency of flux in torque but there are some disadvantages in DC motor drives which will make it costly to estimate, that is frequent or time to time requirement of maintenance for commutator, brushes and brush holders. So the focus comes under AC drives like induction motor drive in which advantages like less maintenance requirement and robust in construction takes place but in induction motor control of magnitude of stator current to the phase coordination make its control quite complex and the electrical structure of AC machines are highly nonlinear and involve multivariable input and outputs. So, extra effort is required to linearize and decouple the control of AC drives. And the rotor flux linkages resolved along any frame of reference so that the position of the flux linkages at every instant must be required. Then only the AC drives control will be similar to the separately excited DC motor drives. Hence such type of control techniques are known as field oriented control method. [9][11]

The field oriented method or technique was firstly introduced by Blasckhe. He prefer that technique firstly for controlling torque and flux independently. The vector control method used two coordinate axis, one is used to control torque and another one is used to control flux. Hence field oriented control or vector control technique results to have good dynamic response to torque variation in a wide range of speed and also it can induce a high torque at zero speed. Many more research works were come under consideration to provide more better performance in controlling speed at variation in loads or in the presence of sudden change in load and external disturbances for providing smooth running performance of IM at any kind of disturbances. The better realization of vector control drive with modern control feature is made possible by using fast switching power devices and microprocessor technology. Hence PI controller is then introduced for controlling purpose and providing better running performance to IVCIM at different load disturbances. PI controller is most commonly used control method because of its simplicity but in this control method the accuracy depends on the mathematical model of the systems and the desired performance response is not obtained because of some disturbance occur in load. Due to such difficulties some other control technique were used or prefer that controlling method is FUZZY logic controller. By using that controller the performance of speed will have smooth transient response and reached steady state response and set down earlier than the PI controller response. [2][4][5][6][9][11][15]

II. MATHEMATICAL EQUATIONS USED IN INDIRECT VECTOR CONTROL TECHNIQUE

The indirect vector control method is essentially the same as the direct vector control, except that the rotor angle is generated in an indirect manner (estimation) using the measured speed and the slip speed. To implement the indirect vector control strategy, it is necessary to take dynamic equation into consideration and the following equations[5][10]

$$\theta e = \int \omega e = \int(\omega r + \omega sl) = \theta r + \theta sl \quad \text{.....................................(i)}$$

For decoupling control, the stator flux component of current ids should be aligned on the de axis, and the torque component of current iqs should be on the q^e axis, that leads to $\psi_{qr} = 0$ and $\psi_{dr} = \psi_r$ then:

$$\frac{L_r}{R_r}\frac{d\psi_r}{dt} + \psi_r = L_m i_{ds} \quad \text{.....................................(ii)}$$

The slip frequency is calculated from the stator reference current i_{qs}* and the motor parameters.

$$\omega_{sl} = \frac{L_m R_r}{\psi_r L_r} i_{qs} \quad \text{..(iii)}$$

It is found that the ideal decoupling can be achieved if the above slip angular speed command is used for making field-orientation. For a constant rotor flux ψr and $\frac{d\psi_r}{dt} = 0$

Substituting in equation yields the rotor flux set as

$$\psi_r = L_m i_{ds} \quad \text{..(iv)}$$

The stator quadrature-axis current reference i_{qs}* is calculated from torque reference T_e* as

$$Te = \frac{3}{2}\frac{P}{2}\frac{L_m}{L_r}\psi_r i_{qs} \quad \text{..(v)}$$

The stator direct-axis current reference i_{ds}* is obtained from rotor flux reference input $|\psi_r|$*

$$i_{ds} = |\psi_r|^* / L_m \quad \text{...(vi)}$$

Where, L_r is the rotor inductance, L_m is the mutual inductance of the stator, and $|\psi_r|_{est}$ is the estimated rotor flux linkage.
The speed cannot normally be treated as a constant. It can be related to torque as

$$Te = T_L + J(dwm/dt) = T_L + 2/P\ J(dwt/dt) \quad \text{..................(vii)}$$

T_L =load torque, J = rotor Inertia, and wm=mechanical speed [10]

III. METHODOLOGY

In this paper vector control also called field oriented control method is used in induction motor drive to transform it from nonlinear to linear plant system. In this control technique the stator current is divided into two orthogonal components of AC electric motor from which one component can control the magnetic flux and another one can control the torque. Vector control technique or field oriented control is used to control the AC synchronous and induction motors .It was originally developed for high-performance motor applications have high dynamic performance including fast acceleration and deceleration. However, it is more effectively perform for lower performance applications as well because of its tendency to reduce motor size, cost and power consumption. Here typically PI controller were used to keep the measured current components at their reference value.[1][5][6]

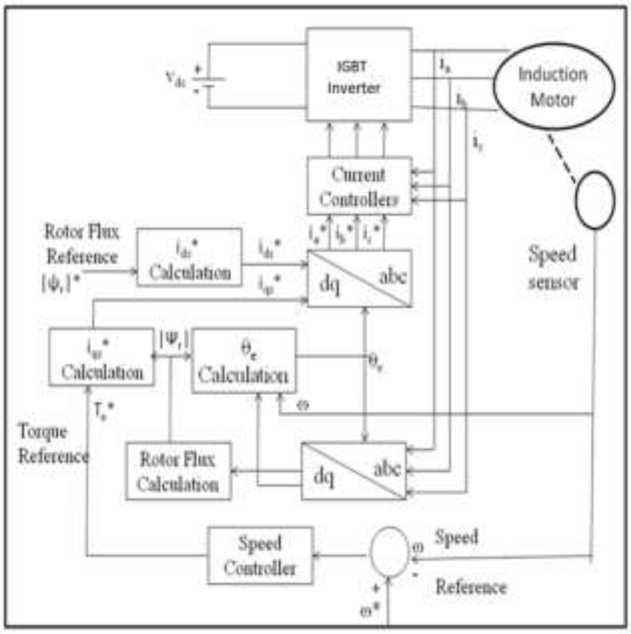

Figure 1.Block diagram for indirect Vector control of induction Motor

Proportional-Integral (PI) controller is one of the most common and simple method used in industrial areas. PI controller is the simple and most commonly used controller because of its simple construction, low cost, easy to tune, and robust nature. No exact model is needed in it and hence, it can be used for processes whose models are considerably difficult to be driven. There are some disadvantages also in this controller due to which that controller is not performing good in some of the cases like when the operating point is changed in that case system will processed in nonlinear system so the performance will become poor, also in the case of time varying parameters, and also in the case when the compensation of frequent and strong disturbances arrise [7][9]. Figure 2 shows the MATLAB simulink model of PI controller based indirect vector control of induction motor. In this simulation we observe that the actual running speed of induction motor is compared with the reference speed value and the difference of both the values cause to generate error and that error is fed to the PI controller to modify it to the better value so that the response obtained by the controller for running performance of induction motor drive will be smoothened. The output of the PI controller is used to obtain d-q axis stator current components by using mathematical modeling process that process is done by using three phase to two phase conversion and then by using two phase to three phase conversion from rotating reference frame to stationary reference frame. After that the actual stator current and measured stator current is then fed towards the current regulator or controller in which both the current difference is filtered in the hysteresis band where the values filtered and pass in the form of pulse and that obtained pulse is then fed towards the gate terminal of the three phase IGBT inverter which will run to provide supply to the induction motor and that supply is in controlled form so that the response of the speed is smooth and creates nearly negligible obstacle in running performance of induction motor drive when various different disturbances occur in the system. Since PI controller fixed gain may perform better in some of the operating situations but not in all conditions because the involve processes are in the general complex, time variant, with nonlinearity and model uncertainties. That drawback is overcome by using FUZZY logic controller by replacing conventional Pi controller in the system drive.[9]

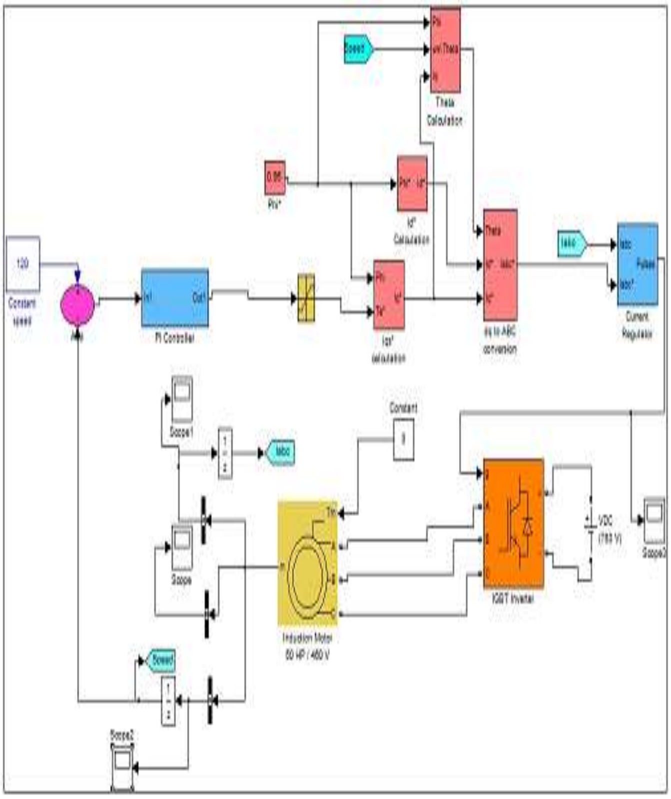

Figure 2.PI Controller based indirect Vector control of induction motor

In this paper Fuzzy logic controller and PI controller is used here for speed regulation of three phase induction motor. FUZZY logic controller is multi-valued logic that can be derived from fuzzy set theory to deal with reasoning that is approximate rather than precise. In contrast with "crisp logic", in which the binary sets has its own binary logic, fuzzy logic variables must have truth value that will ranges between 0 and 1 and is not constrained to the two truth values of classic propositional logic. when we use the linguistic variables, such degrees will be managed by specific functions.

Fuzzy logic is a very powerful method of reasoning when mathematical formulations are infeasible and input data are imprecise. Fuzzy logic is a powerful tool for designing the control system perfectly. To calculate a fuzzy rule from each i/o data pair, the first step is to find the degree of each data value in every membership region of its corresponding fuzzy domain. so that the variables are assigned to the region with the maximum degree. When each new rule is generated from the i/o data pairs, a rule degree or truth is assigned for that rule, where such rule degree is defined as the degree of confidence that the rule does in fact correlate to the function relating voltage and current to the angle. A degree will be assign in the developed method which is the product of the membership function degree of each variable in its respective region. Speed error is calculated with comparison between reference speed and speed signal feedback. The fuzzy logic controller is divided into three main sections they are fuzzification section, inference engine section and defuzzification section. In the section inside controller Fuzzification is the part which is used to calculate fuzzy input or to evaluate the input variables with respect to corresponding linguistic terms in the condition side. The fuzzification block thus matches the input data with the conditions of the rules to determine the matching capability of the rules to the input. The input variables are applied by the linguistic terms have individual degree of membership. Inference engine is used for calculating fuzzy output or evaluating the activation strength of every rule base and then combine their action sides. Deffuzzification is used to converts the fuzzy value obtained from composition in to a “crisp” value.[12][13][16]

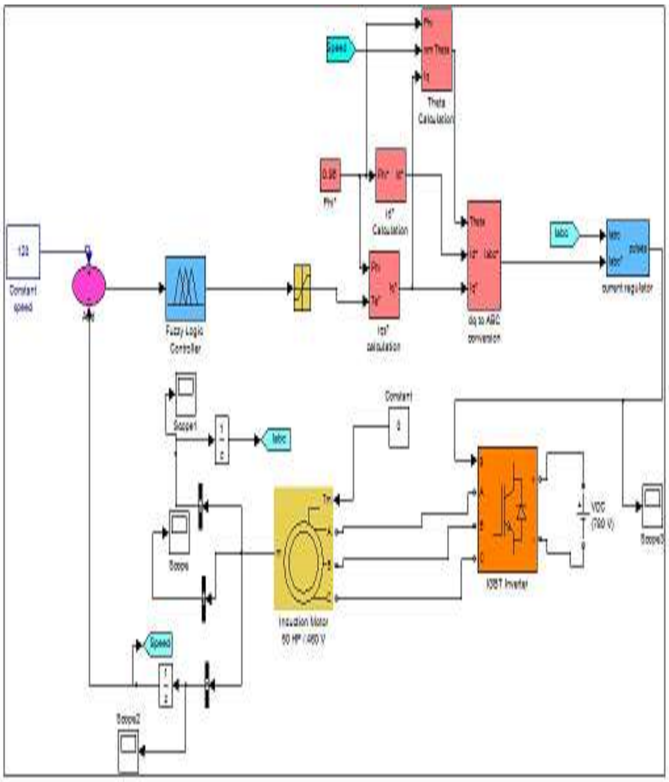

Figure 3.FUZZY Controller based indirect Vector control of induction motor

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IV. EXPERIMENTAL RESULTS

In this project many tests are performed to obtain the performance response from the proposed fuzzy logic controller based IVCIM drive system and PI controller based IVCIM drive system. The speed control loop of the IVCIM drive is also designed and then simulated with both the controllers to obtain the combined performance of FLC based and PI based IVCIM drive system for comparing them to analyse the better one. The performance response of speed, torque, and current is then obtained and observed at different operating conditions. All the results obtained at different disturbances in load and speed is presented in this section.

Performance of indirect vector Control induction motor using PI controller

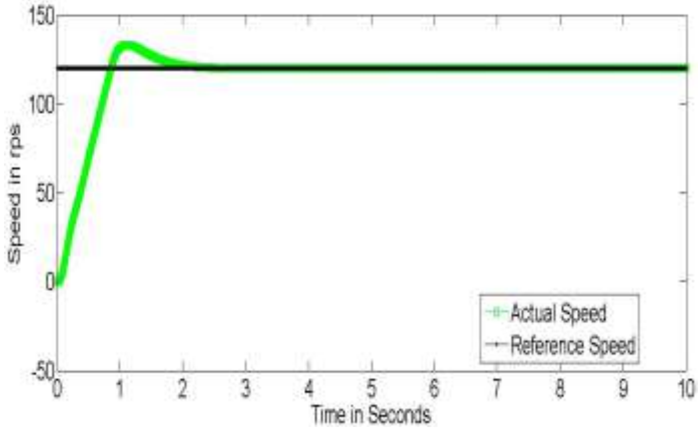

Figure.4(a)

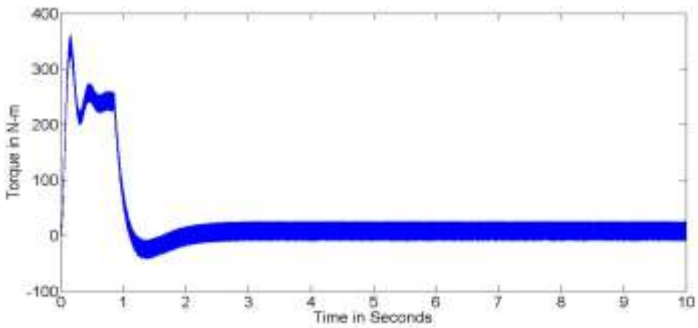

Figure.4(b)

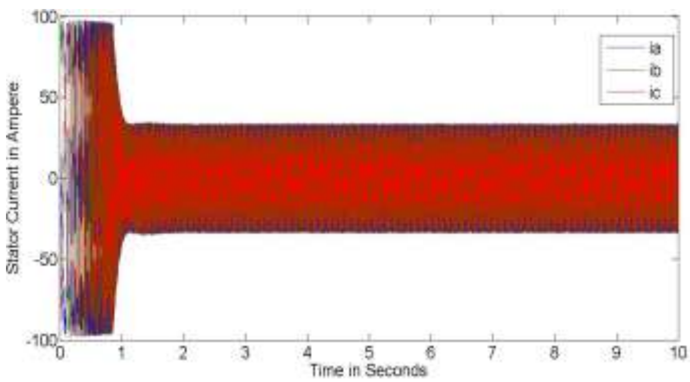

Figure.4(c)

Figure 4(a)(b)(c) are Speed, Torque, Current Performance of indirect vector control of induction motor using PI controller at no load with reference speed 120rps

Performance of indirect vector Control induction motor using fuzzy controller

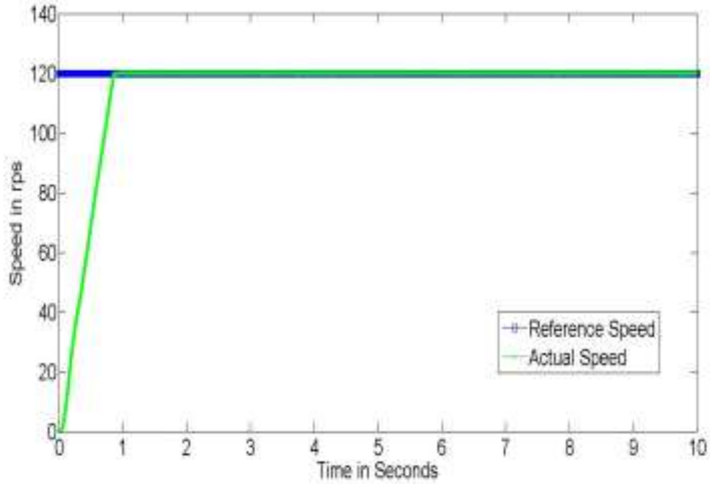

Figure5(a)

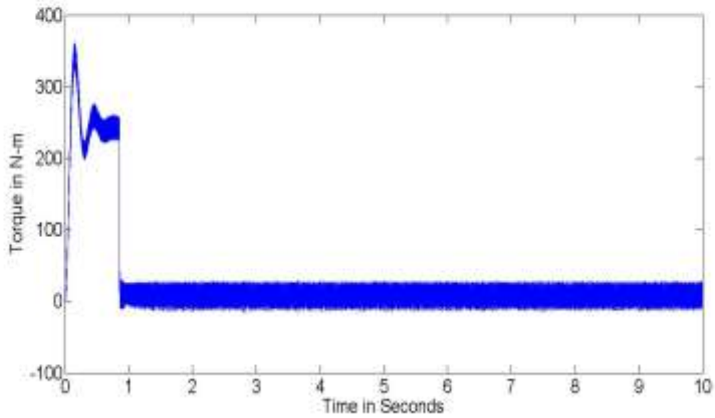

Figure5(b)

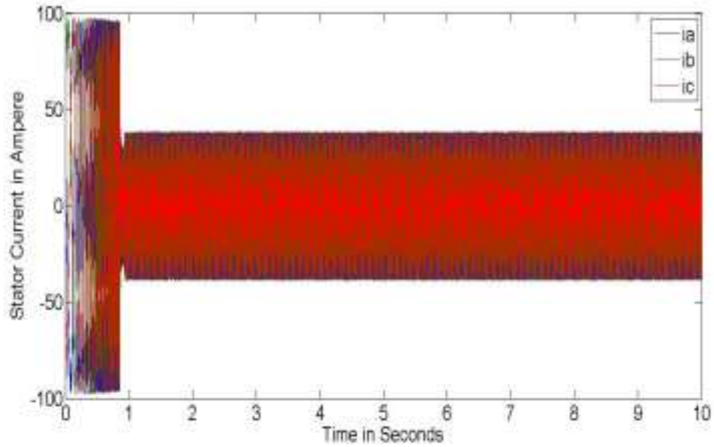

Figure5(c)

Figure 5(a)(b)(c) are Speed, Torque, Current Performance of indirect vector control of induction motor using Fuzzy logic controller at no load with reference speed 120rps

Comparing performance of indirect vector Control induction motor using PI controller and fuzzy controller

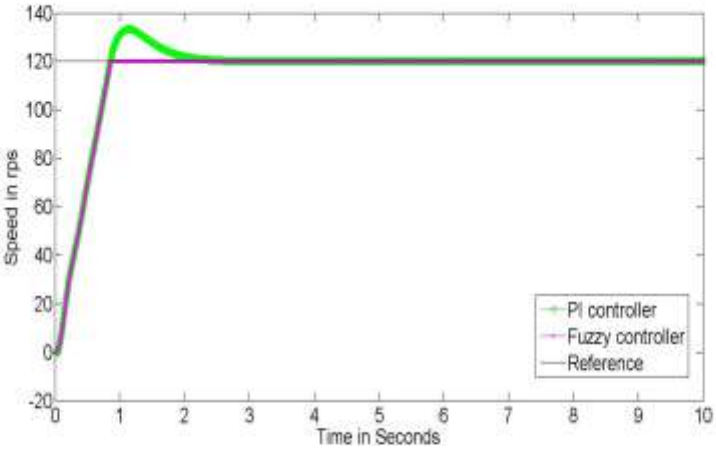

Figure6(a)

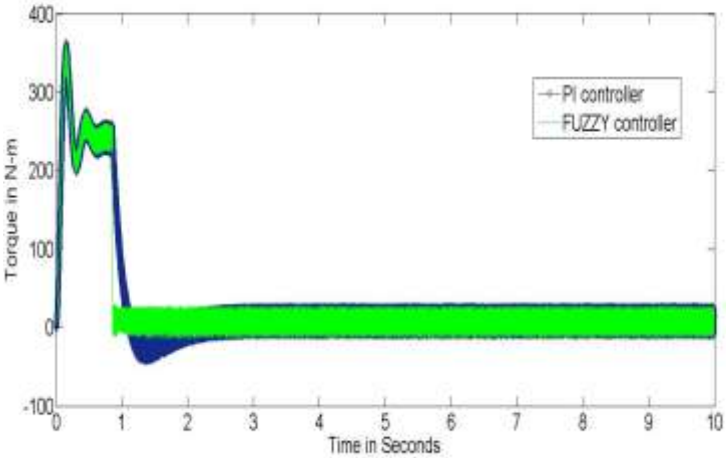

Figure6(b)

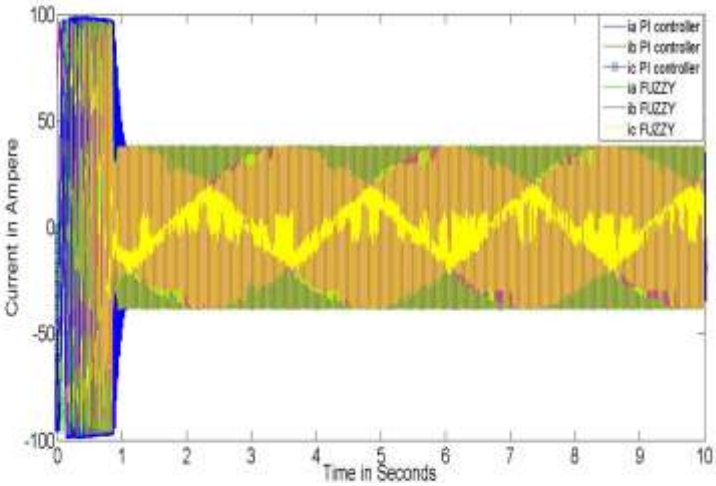

Figure6(c)

Figure 6 (a)(b)(c) are Speed, Torque, Current Performance of indirect vector control of induction motor using PI and FUZZY logic controller at no load with reference speed 120rps

V. CONCLUSION

In this paper fuzzy controller for controlling the speed of induction motor by using indirect field oriented vector control technique is used. The simulating result of both the speed controller model is then compared, through which we observe that the fuzzy controller response is superior than the PI controller response; as fuzzy controller eliminates the transient response errors during sudden change in speed due to sudden load disturbance as compare to the PI controller. The result obtained from both the controllers under the dynamic conditions are compared and analyzed. This simulation result is then represents that the FLC settles more quickly and has better performance than the result obtained by the PI controller. Fuzzy logic controller is more superior and better than conventional PI controller in the sense of its less sensitive nature with the variation in the parameters of the system, its robustness, its fast dynamic response provide best performance, its stiffness with speed regulation. In order to improve the controller performance, it needs to study about the auto-tuning fizzy controller or fuzzy adaptive controller in the future.

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