FUZZY BASED DIRECT TORQUE CONTROL OF INDUCTION MOTOR USING MATLAB/SIMULINK

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Abstract : The DTC approach was developed and commonly used in industrial applications as well as in literature studies. In most work the DTC was combined with the PI controller for speed management. PI controllers are considered the most commonly used controllers in industry due to their basic functional principles and ease of implementation. In this analysis, it was suggested the use of fuzzy controller to improve the accuracy of speed results as well as the ability of the fuzzy logic controller to respond to sudden changes and nonlinearity of the system.

Fuzzy controller has proved its reliability and good results when used with DTC control scheme. DTC regulation has also demonstrated its ability to keep track of target speed values with minimal cost and effort, in addition to rapid implementation. The method is a simple method with quantities of light calculation and no need for any transition or synchronisation of reference. The process does not mean regulating source voltage by a closed loop inverter. From the results we have obtained we can conclude that Fuzzy logic controller with DTC device is a very good choice in terms of low cost, usability and efficiency for controlling induction machines.

Keywords: Fuzzy Logic Controller, Direct torque Control, Induction Motor Drive.

I. INTRODUCTION

The induction motor in industrial and domestic applications is the most commonly used motor type. Due to its ability to self-start, simple and durable design, low cost and performance, this type of motors is favored. Also called asynchronous motors are induction motors because their mechanical speed is different from their electrical speed. The three-phase induction motor is a single motor with stator winding from three phase sources. An induction motor's rotor gains its energy through stator induction. The three-phase voltage creates a rotating magnetic field in the air gap; this rotating field interacts with the voltage and current induced by the rotor's windings. At a constant synchronization speed, the spinning field rotates. This causes the rotor to rotate at all speeds except for the synchronous frequency to produce mechanical torque. Induction motors cannot operate at synchronous speed, which is why asynchronous devices are also popular. Induction motors use a basic electromechanical energy conversion system. The rotor can not be reached under any circumstances in the squirrel-cage motors. No need for brushes as in DC machines; or slip rings as in AC machines that are synchronous and wound. This fact increases the use of motor induction in environments where there is a fire hazard. Because brushes and moving contacts cause sparks which can be a fire source. The lack of wiring in their rotors is another level of power in squirrel cage motors. Such rotors are made of solid bars that can withstand higher currents and work under extreme electrical and mechanical overloads. Due to the vital influence of speed on certain applications, speed control of industrial motors is a very important subject. While squirrel cage engines are cheap compared to other engine types, their control is a bit expensive. There are different methods for regulation of speed and torque for induction motors. Motor speed control means the use of electronic power converters to provide the desired control of various voltage and frequency parameters.

The control methods of an induction machine are different based on vectors. DTC is one of the best solution to regulate the torque and speed of induction motors on variable frequency drives. The torque and magnetic flux that have been developed in the engine are then measured by motor voltages and currents. The determined values are then used for the determination of the correct system torque and voltage. The applied voltage would allow the machine to operate with high accuracy, efficiency and low effort at the desired speed and torque. The mathematical definition is usually difficult in complex systems, if not impossible in certain situations. As a result, linear and traditional control mechanisms tend to be inadequate to ensure proper system control. It provides low effort and high efficiency by using conventional and nonlinear intelligent controllers as fuzzy logic controllers or Neural network controllers. Such a smart controller can predict the system's behavior without any knowledge of its mathematical model. Fuzzy logic is commonly used in various control and prediction systems, and it provides reliable results in high efficiency.

II. LITERATURE REVIEW

One of the earliest works related to fuzzy logic direct torque control of induction motor has been presented by Y.Lai. et.al [3]. They proposed a new hybrid fuzzy controller for direct torque control (DTC) induction motor drive consisting of proportional-integral (PI) control at steady state, PI-type fuzzy logic control at transient state, and a simple switching mechanism between steady and transient states was used, to achieve satisfied performance under steady and transient conditions. On comparison to existing methods the proposed method gives fast tracking capability, less steady state error, and robust to load disturbance while not resorting to complicated control method or adaptive tuning mechanism. Comparing the output of different control methods, including proportional-integral (PI) control, PI-type fuzzy logic control (FLC), proportional-derivative (PD) type FLC, and combination of PD-type FLC and I control, for DTC-based induction motor drives, will highlight the features of the proposed new hybrid fuzzy controller. Intensive experimental results will demonstrate the pros and cons of these controllers. F. Zidani et.al [4]. The input variables of the fuzzy logic controller were the input and output of the low-pass filter used to integrate the backemf. Simulation results, using Matlab/Simulink, comparing the fuzzy estimator and a classical integrator in a direct torque control scheme proved the superiority of the proposed approach. The stator flux locus was smoothed and therefore torque ripples were reduced. A step change has been applied in the stator resistance in a steady state to demonstrate the output of the proposed FLI. An improved direct torque controlled induction motor drive was proposed by K.B.Mohanty[5]. The prposed strategy is based on variable duty ratio control scheme to increase switching frequency, and adjust the width of hysteresis bands according to the switching frequency. The method minimizes torque and current ripples, improves torque response, and reduces switching losses in spite of its simplicity. Simulation results establish the improved performance of the proposed direct torque control method compared to conventional methods.

Y. Zhang et.al [6] proposed a sensorless three-level neutral-point-clamped inverter-fed induction motor drive. The authors suggested two kinds of modified schemes for three-level DTC Fuzzy logic control and the speed-adaptive flux observer (with novel gain and load toque observation) were introduced to enhance the performance of the system. The issue of large starting current is investigated and solved by introducing the technique of pre-excitation. M.Moattri et.al [7] have proposed an approach to control scheme for induction machine which makes DTC more applicable while it has lower torque ripple, lower flux ripple and almost fixed switching frequency rather than other DTC methods. Comparisons between simulation and practical results confirm that not any noticeable advantage of other developed DTCs is lost while it becomes more applicable. The possibility of utilizing high speed chips like FPGAs or low cost DSPs is the priority of the presented method. A developed DTC is being investigated and implemented in this journal. The DTC benefits addressed are low torque ripple, low flux ripple, and nearly fixed rate of switching. In this process, there are some functions that make it difficult and costly for ordinary microcontrollers to perform. The method results replaced by FPGA confirm that the presented neural networks save all the advantages of the developed DTC while building is easier and cheaper. Another goal of the theoretical neural networks is the prospect of using cheaper DSPs or neurochips. R. Sharma et. al [8] presented a simulation model using MATLAB/Simulink for the PMSM drives. In this paper, DTC technique for a two level inverter fed permanent magnet synchronous motor is explained and is simulated in MATLAB/Simulink environment. The simulation results are analyzed and found that the torque obtained from the motor is having a large amount of ripple content. N.Vekantaraman Naik and Dr. SP Singh [9] presented a direct torque control (DTC) using Bus clamped SVM (BCSVM). According to the authors, direct torque control gives more distortion in flux, speed and torque especially during speed or load changing conditions, and also gives more distortion in the current of the induction motor. Thus in order to improve the dynamic performance of the induction motor the Neuro Fuzzy(NF) is used to get the less THD in current as well as lesser distortion in speed, flux and torque. The transient and steady state performance of induction motor using NF based DTC is compared with the conventional DTC. DTC uses two level bus clamped SVM to control the speed of the induction motor. The DTC technique gives the induction motor drive more flux and torque distortion with significant current THD. The PI controllers were replaced by NF Cs to improve the performance of the induction motor drive. As a result, the NF-based DTC has less distortion of the induction motor's flux, torque and speed than the conventional PI-control method. Because, during transient as well as steady state operation, the NF control tuned the PI controllers well using the hybrid learning algorithm. Abderrahmane Ouchatti et. al [10] presented a sensorless direct control for induction motor using fuzzy logic controller used in electric vehicles. The work presented deals with a three-phase Induction Motor (squirrel-cage) speed-sensorless drive. The aim is to introduce an electrical traction system based on the power electronic converter operated use of 1M. This system enables vehicle speed, forward, backward and regenerative braking to be controlled. The operation of four quadrants is required. The control strategy developed is based on conventional Direct Torque and Flux Control (DTC). Both the rotor speed controller and the estimator of rotor speed are based on the Fuzzy logic controller (FLC). The performance of the control obtained is shown by simulation using MATLAB and its SIMULINK toolbox. The control obtained allows the start of coupled load while the current stator has not exceeded its preset value. We showed that in the zero-speed region, the DTC combined with the fuzzy logic speed controller ensures robust start and operation. It is possible to achieve adaptive control by estimating the resistance of the rotor. Amit K. Singh et.al [11] gave an FPGA implementation of direct torque control of induction motor Induction motors are currently being used in many applications of electric vehicles. As a result, a lot of attention has been paid to their control methods. Direct torque control is one of the efficient induction motor control methods. A development method for direct induction motor torque control was introduced in this paper. For implement the built DTC template on the Nexys 2 FPGA package, a Verilog hardware description language is used. Field programmable gate array (FPGA) has many consistent advantages such as fast response, reliable, flexible, robust against load variations, and architecture programmable. Using the Matlab / simulink method, the same algorithm is built and simulated. Finally, the experimental test is performed on different load torques showing a faster response and motor reaches its reference torque in very short time. Kamal Kishore Chouhan and G.B.Buch [12] presented direct torque control of induction motor. In many high-performance applications, induction motor control is most accurately required. Different control methods for controlling the induction motor were developed with the advancement in the power electronic sector. Among these, Direct Torque Control seems to be particularly interesting, independent of the parameters of the machine rotor and requiring no sensors of speed or position. It also allows good torque control in transient and stable conditions in addition to the simple structure. Several researchers have suggested various methods such as variable hysteresis band comparators, space vector modulation, predictive control schemes, and smart control techniques to solve these problems. Nevertheless, the key aspect of DTC, which is simple control structure, has been weakened by these methods.

III. System Implementation

The induction machine structure, the fuzzy logic controller structure and the direct torque control system for induction motor speed has been presented. The direct torque control system was discussed and presented as one of the most effective and simplest control techniques for induction machines. Instead of the standard PI controller, a fuzzy logic controller will be used to improve system stability in transient and stable machine states.

A Simulink model of three-phase induction motor is used to simulate the results.. The induction motor was supplied with the required power via three-phase power source, three-phase bridge corrector, chopper break and three-phase source voltage inverter. Figure 1 shows the general circuit layout for the simulation. The method for supplying DC voltage to a chopper is used. The chopper ensures that the voltage on the DC side of the rectifier or the inverter doesn't reach those limits. The inverter produces three Phase AC power voltages.There are some general steps for any image based system.

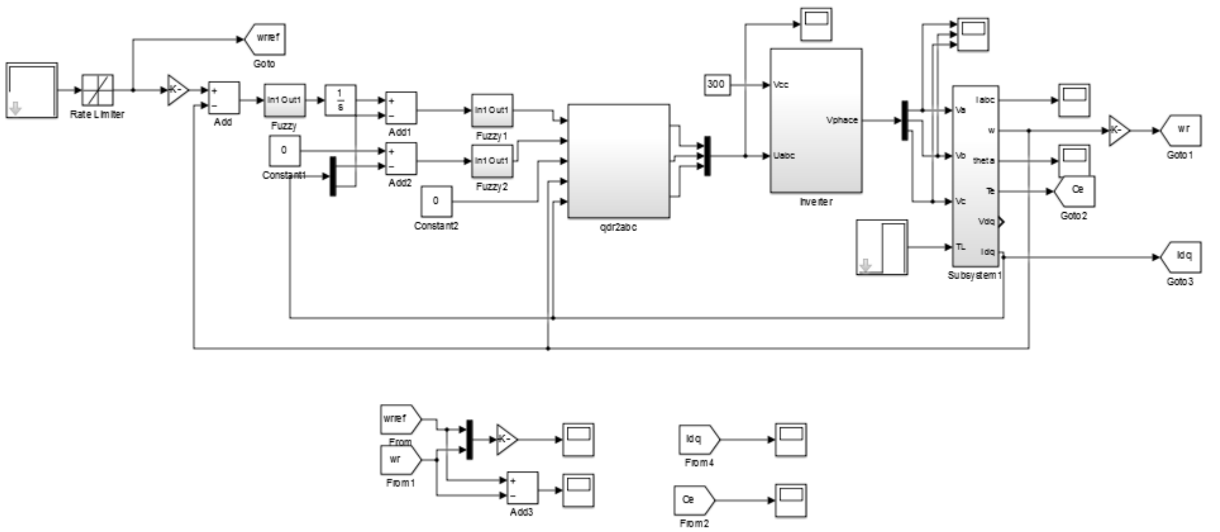

Figure 1: Block Diagram of Control Strategy

Two types of controller were used in this work, namely PI controller and Fuzzy logic controller. Such two regulators are used to control the speed of the induction motor as seen from Figure 2. Firstly, the reference speed slope is balanced to avoid any sudden changes in the distance.

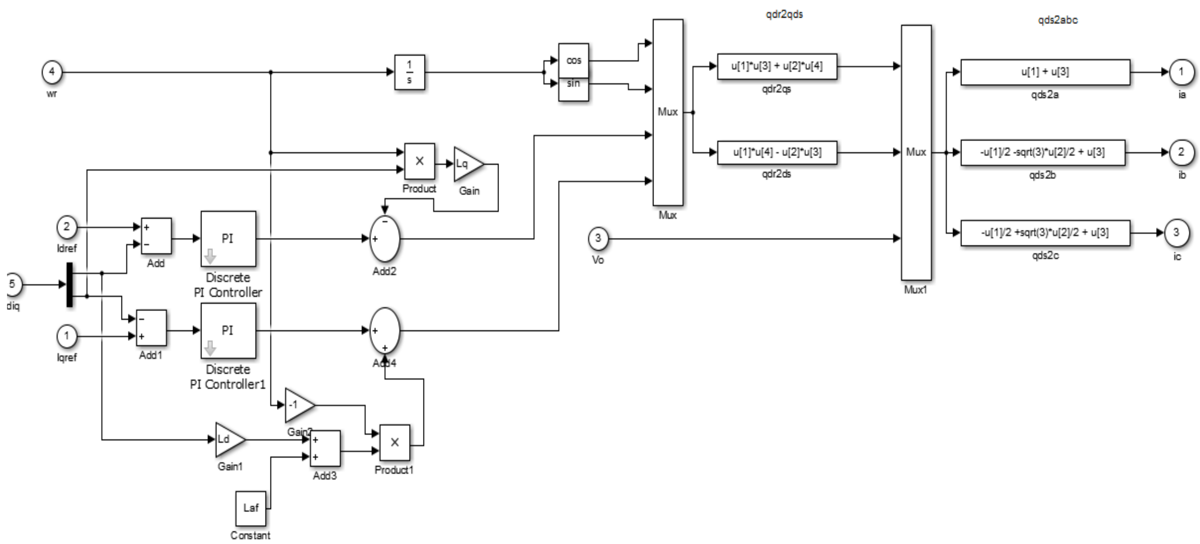

Figure 2: PI Control

Due to the slow reaction of the motors relative to other electronic devices, abrupt speed changes can not be obeyed. The reference speed is then compared with the motor's actual measured velocity to produce controller feedback. The error is then fed to the controller to produce the correct torque value to be generated by the motor to make the error zero.

The fuzzy rules defining the Fuzzy Logic Controller has been shown below:

- If (E is N) and (de is N) then (du is N)
- If (E is N) and (de is z) then (du is N)
- If (E is N) and (de is p) then (du is z)
- If (E is z) and (de is N) then (du is N)
- If (E is z) and (de is z) then (du is z)
- If (E is z) and (de is p) then (du is p)
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IV. SIMULATION RESULTS

The Simulink model of the control system used in this work has been described in this previous chapter. In this section the results has been shown with all the graphs and plots of various stages. Figure 5.1 shows the three phase Input Voltage Vabc.

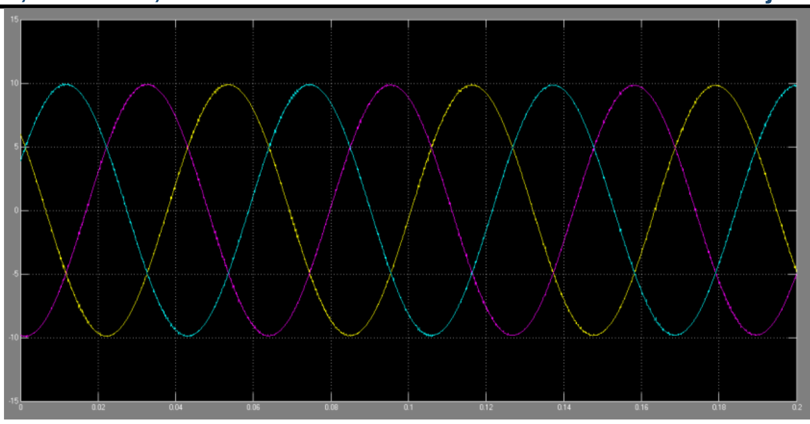

Figure 3: Three Phase AC input voltage waveform

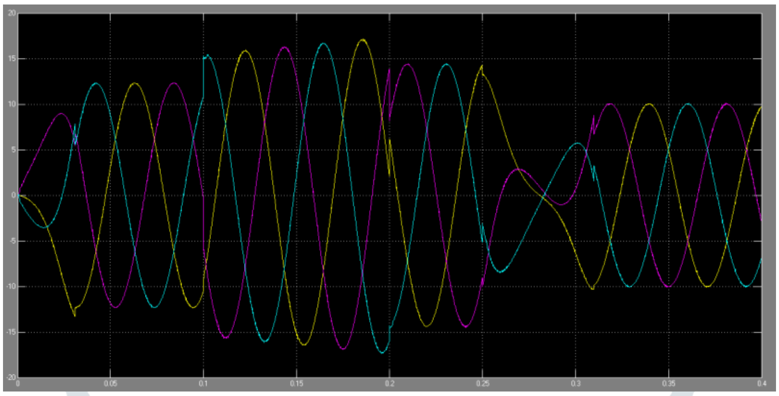

Figure 4: Three Phase input Current

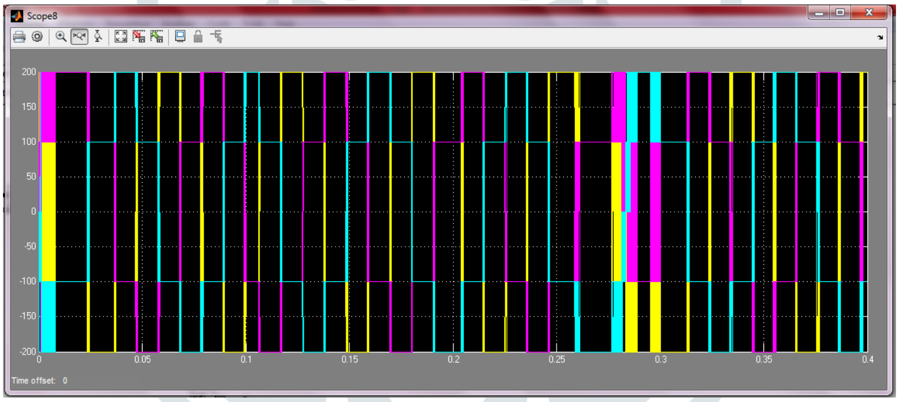

Figure 5: Voltage Source Inverter Output

Figure 5 shows the Output of Voltage Source Inverter. The inverter converts digital signals from the control unit into the voltages necessary for the rotation of motors.

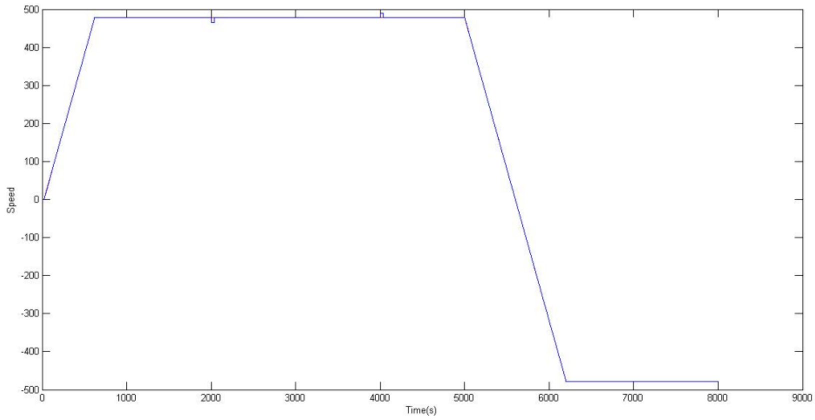

Figure 6: Speed vs time Characteristics of FLC

Figure 6 shows the Speed Characterstics of the Desired Speed and the actual Speed. The graph shows an efficient control using fuzzy logic control strategy.

Further functioning of Fuzzy Logic Controller has been verified by providing a step change at 0.25 second and it takes just 0.03 seconds for motor speed to reach the reference speed. The figure 7 below shows the change in speed with the applied input.

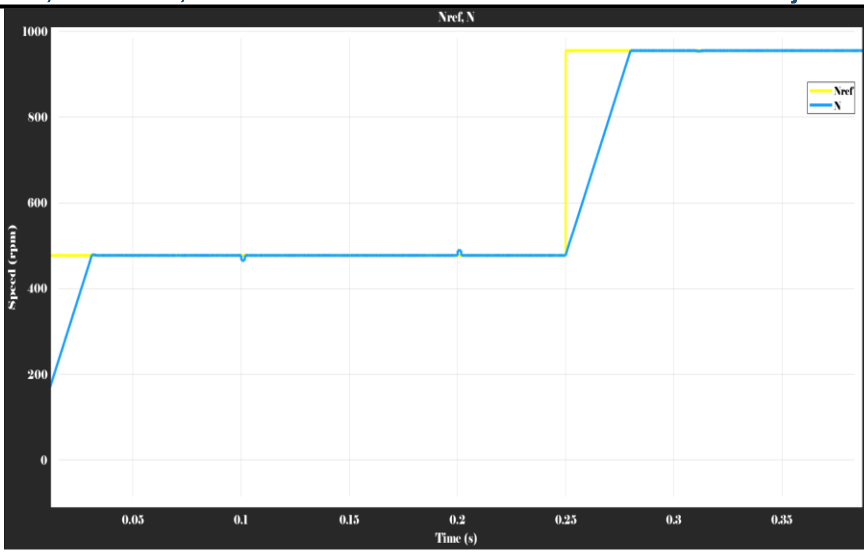

Figure 7: Step response of Stator Current

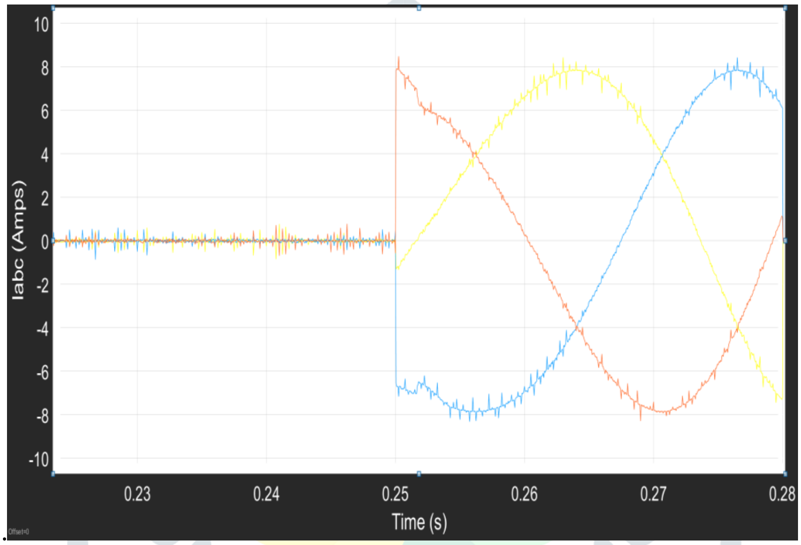

Figure 8 : Change in stator current corresponding to step change.

V. Conclusion

The research and analysis done in this work addressed control of induction motors with fuzzy logic controller method. The results obtained showed that use of the DTC control method is simple, efficient and the desired speed and torque values are achieved. The DTC method has been developed and commonly used both in industrial applications and in literature studies. In most research the DTC has been paired with the speed management PI controller. Because of their basic functional concepts and the ease of implementation, PI controllers are considered the most commonly used controllers in industry. In this study, the use of fuzzy controller was suggested to increase the accuracy of speed results as well as the ability of the fuzzy logic controller to respond to sudden changes and system nonlinearity.

When used with DTC control scheme, Fuzzy controller has proven its reliability and good results. In addition to quick implementation, DTC regulation has also demonstrated its ability to keep track of target speed values with minimal cost and effort. The method is a simple method with light measurement quantities and no need for any reference transformation or synchronization. The process does not mean a closed loop inverter regulation of the source voltage. From the results we have obtained we can infer that Fuzzy logic controller with DTC system is a very good choice for controlling induction machines in terms of low cost, simplicity and performance. The control has shown this method's ability to track different speed values with perfect response away from very low velocities. In this study, an improvement was achieved through controlling induction motor control using DTC control method. Improved results were obtained with sudden changes in the desired speed by replacing the conventional PI controller with a nonlinear Fuzzy logic controller.

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