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Speed Control of Induction Motor Drive Different Techniques-A Review

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ABSTRACT: This paper proposes design and simulation of a direct torque controlled induction motor drive system based on pulse width modulation (PWM) technique for ripple reduction. Direct Torque Control is a control technique used in AC drive systems to obtain high performance torque control. The principle is based on simultaneously decoupling the stator flux and electromagnetic torque. DTC drives utilizing hysteresis comparators suffer from high torque ripple and variable switching frequency. The proposed PWM based DTC reduces torque ripples and preserve DTC transient merits such as fast torque response. The basis of the PWM-DTC methodology is the calculation of the required voltage vector to compensate the flux and torque errors and its generation using the PWM at each sample period. The performance of this method is demonstrated by simulation using Matlab code /Simulink software. Simulation results presented in this paper show the torque, flux linkage and stator current ripple decreases with the proposed PWM-DTC algorithm.

KEYWORDS: Direct Torque Control, Field Oriented Control, Pulse Width modulation, Induction Motor.

I.INTRODUCTION

Induction Motors (IMs) are widely used in industrial, commercial and domestic applications as they are very simple, rugged, low cost and easy to maintain. Since IMs demands control performances: precise and quick torque and flux response, a large torque at low speed, wide speed range, the drive control system is necessary for IMs..In 1970s, field oriented control (FOC) scheme proved success for torque and speed control of induction motor. Decoupling of two components of stator currents (flux and torque producing components) is achieved as DC machines to provideindependent torque control. Hence the scheme proves itself superior to the DC machine. The problem faced by FOC scheme is complexity in its implementation due to dependence of machine parameters, reference frame transformation. Later DTC was introduced. The method requires only the stator resistance to estimate the stator flux and torque.

In conventional DTC, electromagnetic torque and flux are independently controlled by selection of optimum inverter switching modes. The selection of optimum inverter switching modes is made to limit the electromagnetic torque and flux linkage errors within the torque and flux hysteresis bands. The basic DTC scheme consists of two comparators with specified bandwidth, switching table, voltage source inverter, flux and torque estimation block. Like every control method has some advantages and disadvantages, DTC method has too. Some of the advantages are lower parameters dependency, making the system more robust and easier implements and the disadvantages are difficult to control flux and torque at low speed, current and torque distortion during the change of the sector , variable switching frequency, a high sampling frequency needed for digital implementation of hysteresis controllers, high torque ripple. The torque ripple generates noise and vibrations, causes errors in sensor less motor drives, and associated current ripples are in turn responsible for the EMI. The reason of the high current and torque ripple in DTC is the presence of hysteresis comparators together the limited number of available voltage vectors. If a higher number of voltage vectors than those used in conventional DTC is used, the favorable motor control can be obtained. Because of complexity of power and control circuit, this approach is not satisfactory for low or medium power applications. An another solution to minimize torque ripple is the space vector modulated DTC

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II. DIRECT TORQUE CONTROL

Direct torque control was presented by Manfred Depenbrock 1984. Induction motor (IM) Direct Torque Control (DTC) is based on the electromagnetic torque and stator flux hysteresis controls [5,6]. DTC provides very quick response with simple control structure and hence, this technique is gaining popularity in industries [7]. Though DTC has high dynamic performance, it has few drawbacks such as high ripple in torque, flux, current and variation in switching frequency of the inverter. A variety of techniques have been proposed to overcome some of the drawbacks present in DTC. Some solution proposed are: DTC with the Space Vector Pulse Width Modulation (SVPWM) use of artificial intelligence techniques, such as neuro fuzzy controller with SVPWM .However, the complexity of the control is considerably increased. To improve the performance of conventional DTC, a PWM technique is investigated in this paper.

III. PRINCIPLE OF CONVENTIONAL DTC

DTC principle is widely employed for induction motor drives with fast dynamics . The main notion of the conventional DTC is the rate of change of torque is proportional to the instantaneous slip between the stator flux and rotor flux under constant stator flux linkage DTC has been widely recognized for its fast and robust torque and flux control. The rotor flux linkage changes slowly compared to the stator flux linkage, as the rotor time constant of a standard squirrel-cage induction machine is very large. However, the rotor flux is almost unchanged during a short transient. Thus rapid changes of the electromagnetic torque can be produced by rotating the stator flux in the required direction, as directed by the torque command. On the other hand the stator flux can instantaneously be accelerated or decelerated by applying proper stator. Thus, the simultaneous and decoupled control of torque and flux is achieved by direct adjustment of the stator voltage in response to the torque and flux errors [7]. The DTC regularly applies the appropriate voltage vector in order to maintain the torque and stator flux within two hysteresis bands which results bangbang behavior and produces variation in witching frequency and significant ripple in flux, torque and current [8]. The basic configuration of the conventional DTC drive proposed by Takahashi is as shown in Fig. 1. It consists of a pair of hysteresis comparator, torque and flux estimators, voltage vector selector and a Voltage Source Inverter (VSI)

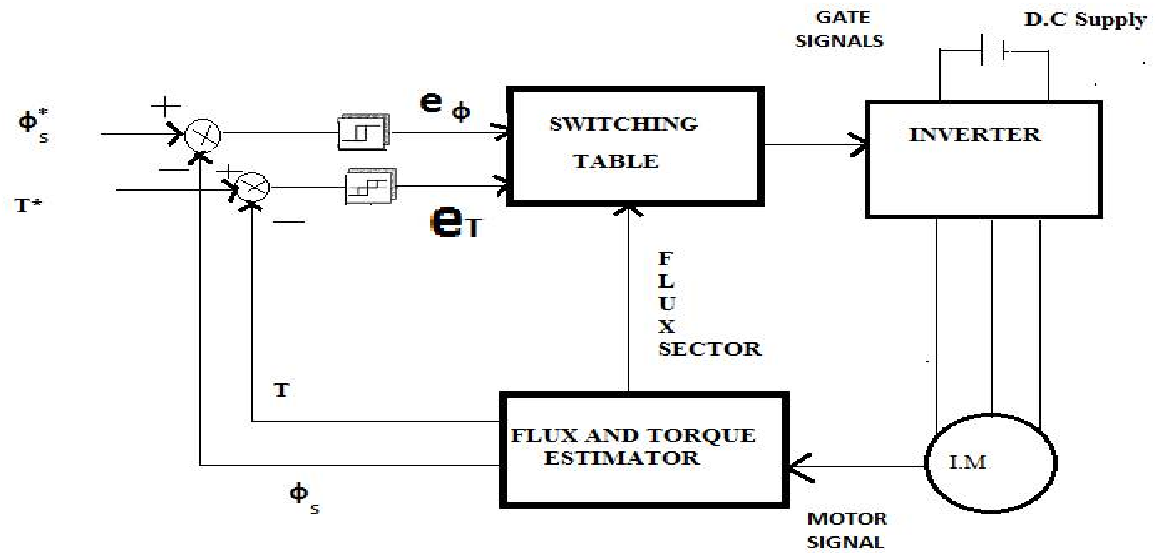

Fig 1.Block Diagram of the Conventional Direct Torque Control

Fig 1, shows schematic diagram of the basic functional blocks used in DTC induction motor drive using PI controller,in fig 1, the error between the estimated torque T and the reference Torque T^* is the input of a three level hysteresis comparator, whereas the error between the estimated stator flux magnitude ϕ_s and the reference stator flux magnitude ϕ is the input of a two level hysteresis comparator. Main features of the DTC [10] are direct control of flux and torque, indirect control of stator currents and voltages and it has the main advantage of absent of co-ordinate transformation,

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absent of voltage modulator block. In fig 2, shows MATLAB simulink implementation of the DTC induction motor drive using PI controller.

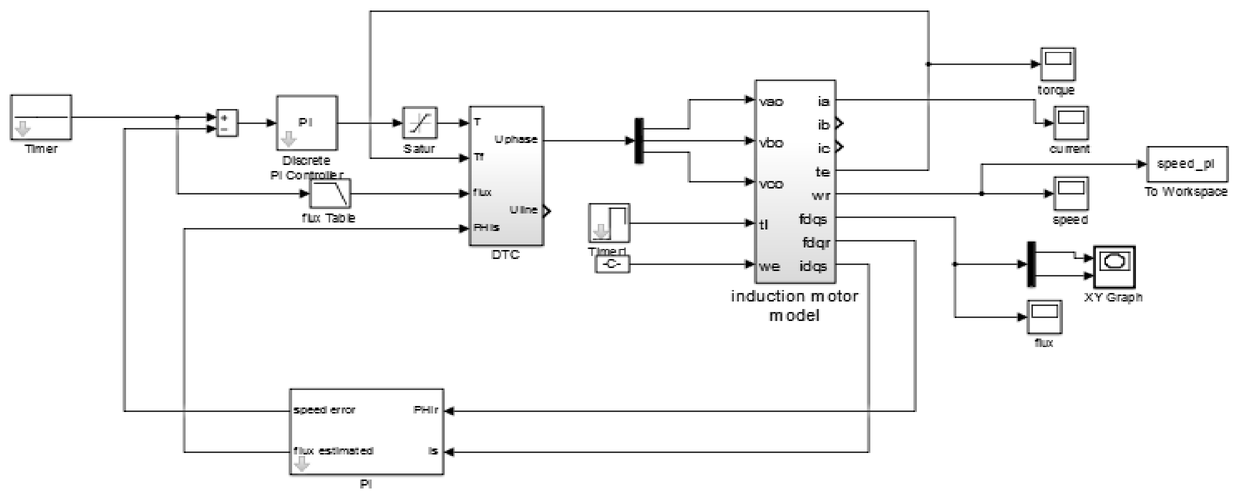

Fig 2.Simulink model of the Induction Motor with DTC-PI control

IV. PULSE WIDTH MODULATION

Pulse Width Modulation variable speed drives are increasingly applied in many new industrial applications that require superior performance. Recently, developments in power electronics and semiconductor technology have lead improvements in power electronic systems .A number of Pulse width modulation (PWM) schemes are used to obtain variable voltage and frequency supply. The most widely used PWM schemes for three-phase voltage source inverters are carrier-based sinusoidal PWM and space vector PWM (SVPWM). Pulse-width modulation (PWM) is the basis for control in power electronics. The theoretically zero rise and fall time of an ideal PWM waveform represents a preferred way of driving modern semiconductor power devices. the majority of power electronic circuits are controlled by PWM signals of various forms. The rapid rising and falling edges ensure that the semiconductor power devices are turned on or turned off as fast as practically possible to minimize the switching transition time and the associated switching losses.In PWM control The generation of gating signal is achieved by comparing the reference signal of the amplitude (Ar) with a triangular carrier wave (Ac)

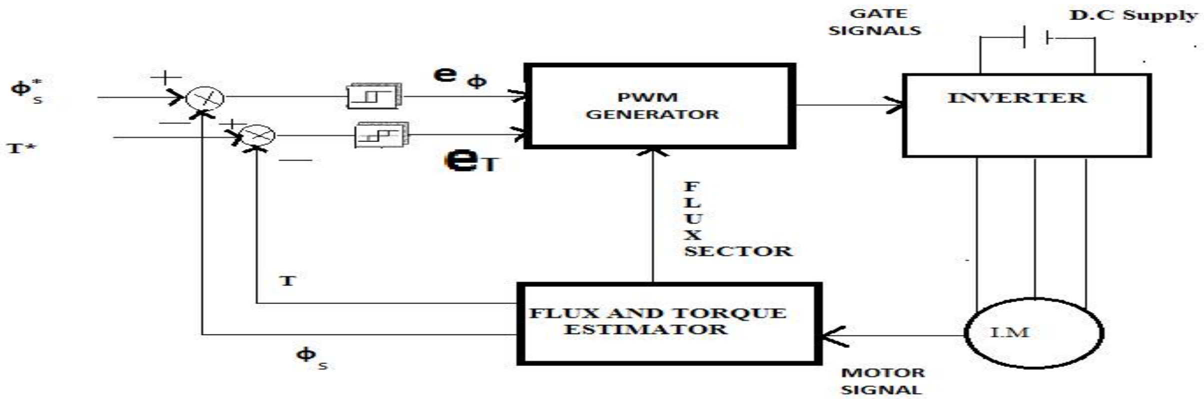

Fig 3.Block Diagram of the Pulse Width Modulation speed Control

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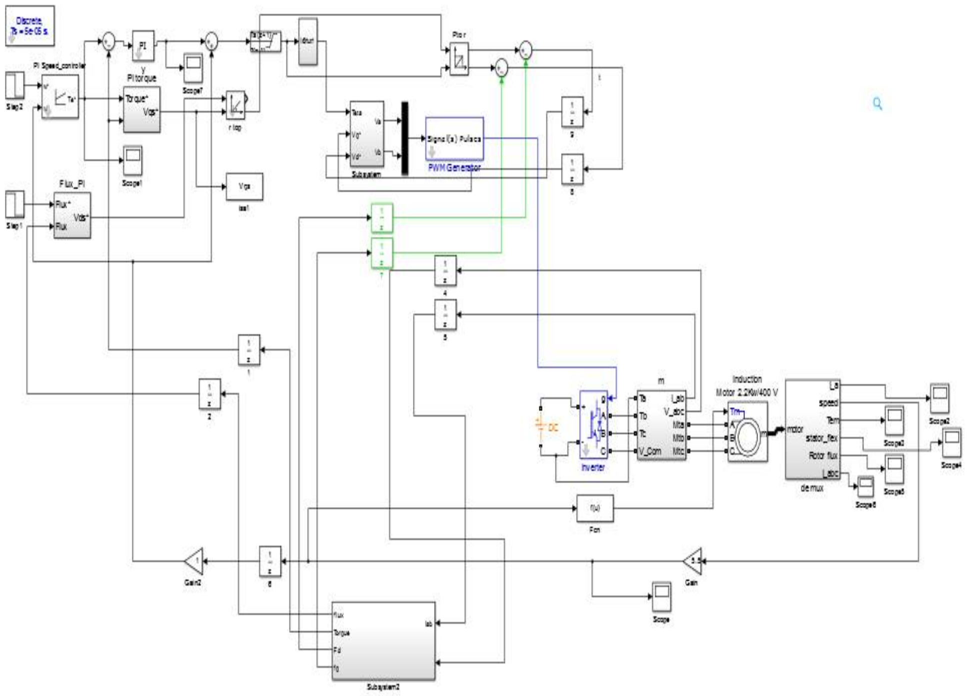

Fig 4.Simulink model of the Induction Motor with PWM control

Fig 3, shows schematic diagram of the basic functional blocks used in PWM controlled induction motor drive.the gating pulses for the inverter is obtained from the pulse width modulation generator. Fig 4, shows proposed MATLAB simulink implementation of the PWM control induction motor drive

V. RESULT AND DISCUSSION

The DTC with PI controller and PWM-DTC schemes for 2.2kw, 400v, 50Hz induction motor are designed using Matlab Simulink and their results have been compared..The results of both DTC and PWM controlled induction motor drive are compared and output wave forms are shown in the following figures.

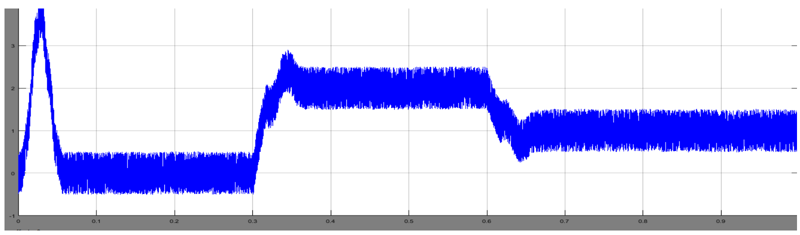

Fig 5.Steady state plot of torque for DTC I.M drive

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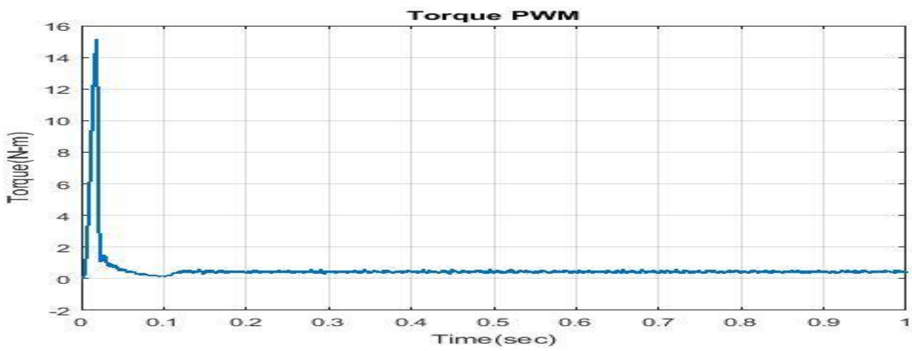

Fig 6. Steady state plot of torque for PWM I.M drive

In fig 5, fig 6 shows steady state plots of torque (N-m) Vs time (Sec) for DTC induction motor drive,PWM controlled induction motor drive respectively.

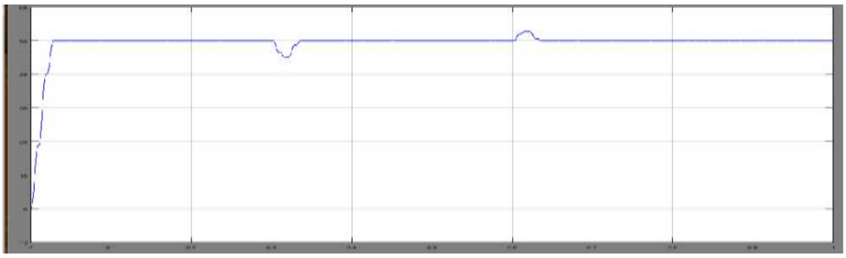

Fig 7.Steady state plot of speed for DTC I.M drive

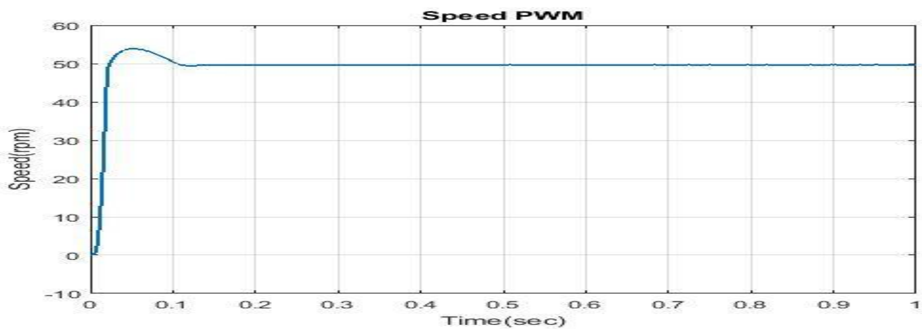

Fig 8.Steady state plot of speed for DTC-PWM I.M drive

In fig 7, fig 8 shows steady state plots of speed (rpm) Vs time(Sec) for DTC induction motor drive,PWM controlled induction motor drive respectively.

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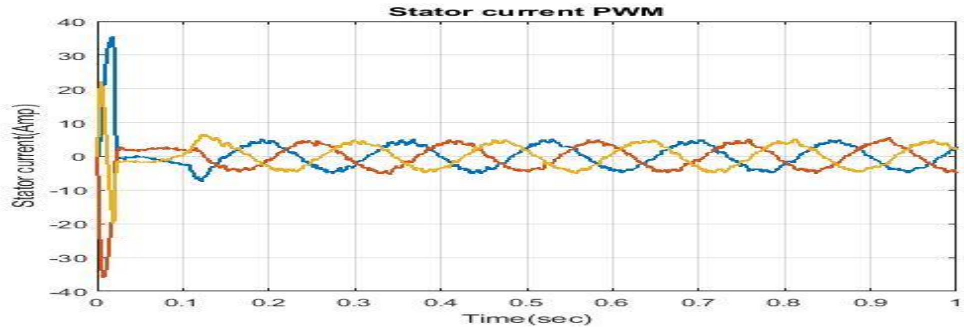

Fig 9.Steady state plot of Stator current for PWM I.M drive

In fig 9, shows steady state plot of stator current (Amp) Vs time(Sec) for PWM controlled induction motor drive.

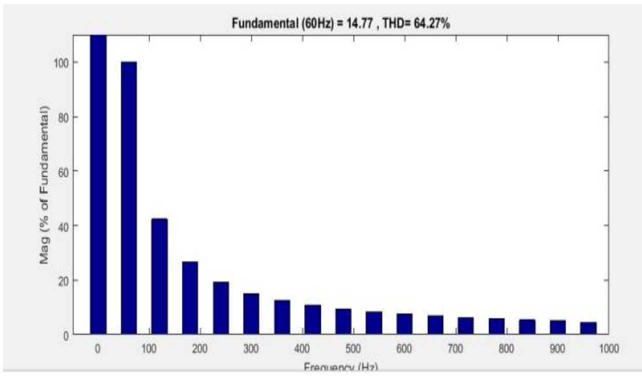

Fig 10.Harmonic Spectrum of Stator current ia for PWM controlled Induction Motor

In fig 10, shows Harmonic Spectrum of Stator current ia for PWM controlled Induction Motor at fundamental frequency of 60 Hz, Total Harmonic Distortion is 64.27%

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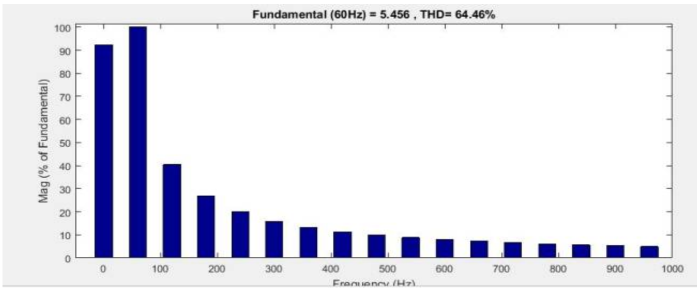

Fig 11.Harmonic Spectrum of torque for PWM controlled Induction Motor

In fig 11, shows Harmonic Spectrum of torque for PWM controlled Induction Motor at fundamental frequency of 60 Hz, Total Harmonic Distortion is 64.40%

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	speed (rpm)	t_p (sec)	t_r (sec)	Slew rate(v/sec)	t_S (sec)	overshoot
DTC-PI	3000	0.03	0.0103	758.033	0.005711	0.505%
PWM	3000	0.054	0.010100	714.037	0.012	8.103%

Table 1: Comparison table of peak time, rise time, slew rate, settling time and overshoot of DTC and PWM controlled I.M drive at 3000 rpm

In the table 1, shows peak time, rise time, slew rate, settling time and overshoot of DTC and PWM controlled I.M drive has been compared at the motor speed of 3000rpm.

	speed (rpm)	t_p (sec)	t_r (sec)	Slew rate(v/sec)	t_S (sec)	overshoot
DTC-PI	1500	0.019	0.007655	1.033	0.012843	6.989%
PWM	1500	0.032	0.007398	970.837	0.0146	15.698%

Table 2: Comparison table of peak time, rise time, slew rate, settling time and overshoot of DTC and PWM controlled I.M drive at 1500 rpm

In the table 2, shows peak time, rise time, slew rate, settling time and overshoot of DTC and PWM controlled I.M drive has been compared at the motor speed of 1500rpm.

	speed (rpm)	t_p (sec)	t_r (sec)	Slew rate(v/sec)	t_S (sec)	overshoot
DTC	1000	1.694	0.003992	2.458	0.018618	29.382%
PWM	1000	0.020	0.006406	1.109	0.0159	13.068%

Table 3: Comparison table of peak time, rise time, slew rate, settling time and overshoot of DTC and PWM controlled I.M drive at 1000 rpm

In the table 3, shows peak time, rise time, slew rate, settling time and overshoot of DTC and PWM controlled I.M drive has been compared at the motor speed of 1000rpm.

VI.CONCLUSION

This paper reviewed Direct Torque Control induction motor drive and PWM inverter-fed induction motor drive for speed control. It was observed that torque waveform of basic DTC scheme contains large amount of frequency ripples and the amount of stator current is also large.It is clear from the simulation results of PWM-DTC scheme, the torque and current ripples have been reduced and the amount of the setelling time (t_s) is also reduced to lower values as compared to the direct torque control method.

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