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# Reduction of Torque and Flux Ripple in the DTC Drive

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## ABSTRACT

***This paper presents a new controller for the direct torque control (DTC) of induction motor, which is considering one of the most advanced drive for the control of induction motor. DTC provides a simple structure and gives effective way of controlling the torque and flux in transient and steady state condition. This drive provides an independent control of torque and flux just like in D.C motor without the necessary of speed feedback. In the method, the induction motor torque and flux are to be estimated from the stator terminal voltages and currents, this estimation does not depend on any motor parameters except the stator resistance. The main drawbacks of the DTC are variable switching frequency because of presence of hysteresis controllers in the closed loop and high torque and flux ripple. In this report present a new controller for the classical DTC where the normal hysteresis controllers are replaced with a new controllers where approximately constant switching frequency is obtained and it has also obtained the reduced torque and flux ripple***

**Keywords**: Stator Voltages,classical DTC , Torque Ripple, Torque Controller, Flux Control

## 1.INTRODUCTION

In the year of 1986, a new control method for flux and torque is introduced by the Takahashi and Noguchi [1] later it's named as Direct Torque Control(DTC) of induction motor. DTC is an alternative to the Field Oriented Control(FOC) of induction motor which needs huge computational capabilities and considered as very sophisticated controller for the induction motor as of now [2]. The first proposed DTC is very simple as compared to other competitive vector control methods consists of two hysteresis controllers, torque and flux estimators, a switching table, and a voltage source inverter(VSI). Without the need of coordinate transform and current controllers [3] as other vector control methods needed DTC provides an independent control of torque and flux. The main disadvantages of the normal DTC are it generates high electromagnetic torque and flux ripple in the motor and irregular switching frequency in the voltage source inverter. It is found that these problems are mainly due to the presence of hysteresis controllers in the controlling loop [4]. Many researches have been done to solve these problems and improve the performance of the conventional DTC. Many changes and developments have been done to the original control scheme to transcend the limitations of the classical DTC. Which results in the complexity of the drive and controlling loop. This paper consists of a new controller for the conventional DTC which replaces the hysteresis controllers. This has shown the makes the and shown the improved performance without increasing the intricacy of the drive.

## 2. CLASSICAL DIRECT TORQUE CONTROL

In the classical DTC method one of the inverter voltage vector switching signals has to be applied to keep the stator flux and torque of an induction motor with in the hysteresis band about the reference values given to the controllers from the motor parameters. From the stator terminal voltages and current the torque and flux of induction motor is calculated. Figure 1. Shows the block diagram of the conventional DTC scheme.

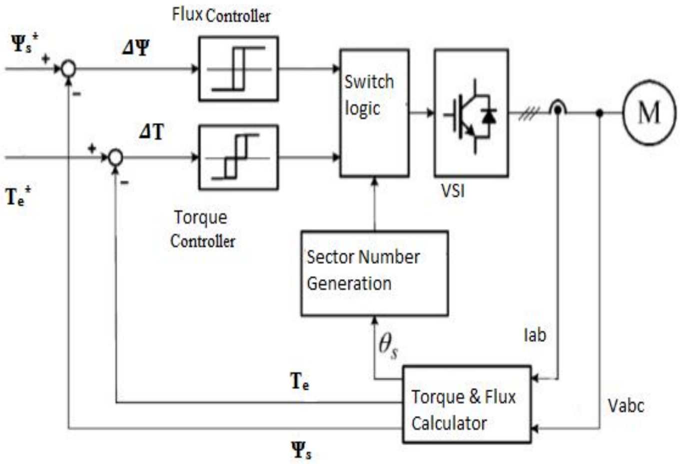



**Figure 1**.Block diagram of classical DTC method

The model was implemented using the d-q reference frame and space vector notation is used for the simulation DTC scheme of induction motor. Stator flux, Toque and sector information is calculated from the stator currents and voltages as follows [5].

$$\Psi_{ds}=\int (V_{ds}-R_s i_{ds})ds \qquad (1)$$

$$\Psi_{qs}=\int (V_{qs}-R_s i_{qs})ds \qquad (2)$$

$$|\Psi_s|=\sqrt{(\Psi_{ds}^2+\Psi_{qs}^2)} \qquad (3)$$

And sector information

$$\theta_s=Tan^{-1}\left(\frac{\Psi_{ds}}{\Psi_{qs}}\right) \qquad (4)$$

$$T_e=\frac{3}{2}P(\Psi_{ds}i_{qs}-\Psi_{qs}i_{ds}) \qquad (5)$$

Where
$V_{ds}$, $V_{qs}$ indicate the stator voltages d and q frame
$I_{ds}$, $I_{qs}$ indicate the stator currents in d and q frame
$\Psi_{ds}$, $\Psi_{qs}$ indicate the stator flux linkages in d and q frame
$R_s$ indicates the stator resistance
P indicates the no of pair poles

The calculated valves of the stator flux and torque from the calculator will be compared with reference quantities and the error signal will be fed to the hysteresis controllers. For the different combinations of the flux, torque errors and sector information different voltages vector switching signals will be fed to the inverter.

## 3. PROPOSED TORQUE AND FLUX CONTROLLERS

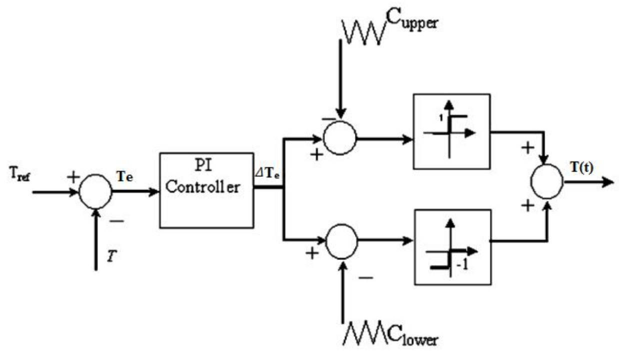
The hysteresis controllers are used in the torque and flux loop of the conventional DTC due to which torque and flux ripple is high in conventional DTC and inverter switching frequency is variable [1]. The replacement of hysteresis torque and flux controller by the proposed controllers has improved the output of the drive and got the reduced torque and flux ripple output of the induction motor [6]. The detailed explanation of these controllers are as follows:

### 3.1Proposed Torque Controller

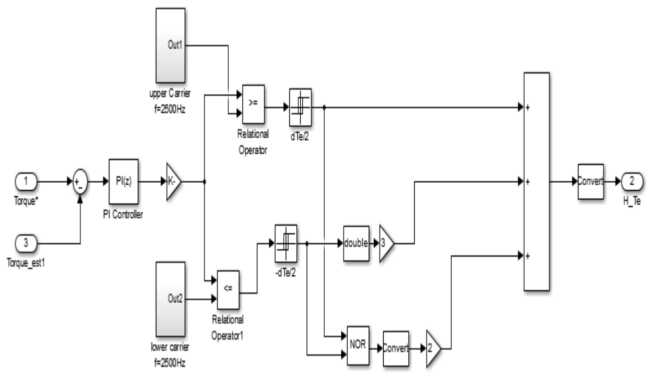
The new controller which has shown in Figure 2, consists of proportional integral(PI) controller, two comparators and two carrier waveform sources. The two carrier waveforms are shifted by $180^0$ and absolute values of the D.C offsets are set to half of the peak-peak values [7]. The controller output can be 1,0,or-1 which are same as hysteresis controller, so that the same voltage vectors lookup table of the conventional DTC could be used. The output of the controller which is indicated by T(t) is shown as following equation (6).

$$T(t) = \begin{cases} 1 \text{ for } \Delta T_e \geq C_{upper} \\ 0 \text{ for } C_{lower} \leq \Delta T_e \leq C_{upper} \\ -1 \text{ for } \Delta T_e \leq C_{lower} \end{cases} \quad (6)$$

Here T(t) is the controller output state, ΔTe is the error signal of torque.




(a)




(b)

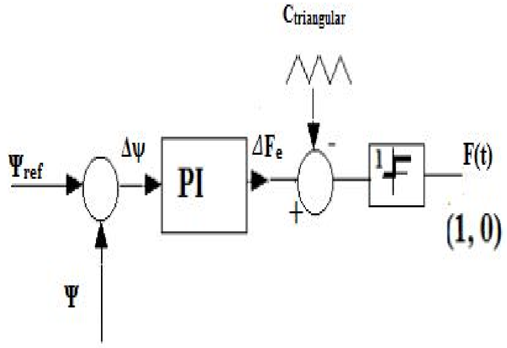
**Figure 2**.Improved torque controller

**3.2Improvement in Flux Controller**

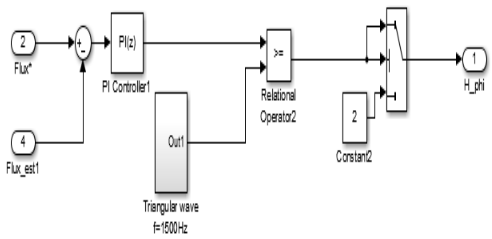
The new flux controller and its simulation model has shown in Figure 3, which consists of only one triangular carrier. The operation and working of the controller is same as waveform comparison. The Improved flux controller is a two-level controller and the output of the controller can be 1 or 0. The output of the controller is shown in the equation (7).

$$F(t) = \begin{cases} 1 \quad \text{for } \Delta F_e \geq C_{triangular} \\ 0 \quad \text{for } \Delta F_e < C_{triangular} \end{cases} \quad (7)$$

Here F (t) is the status of flux and $\Delta F_e$ is the error signal of the flux.




(a)




(b)

**Figure 3.**Improved flux controller

## 4. OUTPUT RESULTS

By the application of MATLAB/SIMULINK [8] the simulation of the conventional and improved DTC has done and also presented as to show the better performance of improved DTC. For the simulation purpose a 3-phase,3 HP,220V induction motor was used. All the simulations are carried under discrete environment and the same model is used for both the schemes. The only changes lie in the torque & flux controllers. Figure.4 shows The SIMULINK model of the DTC drive.

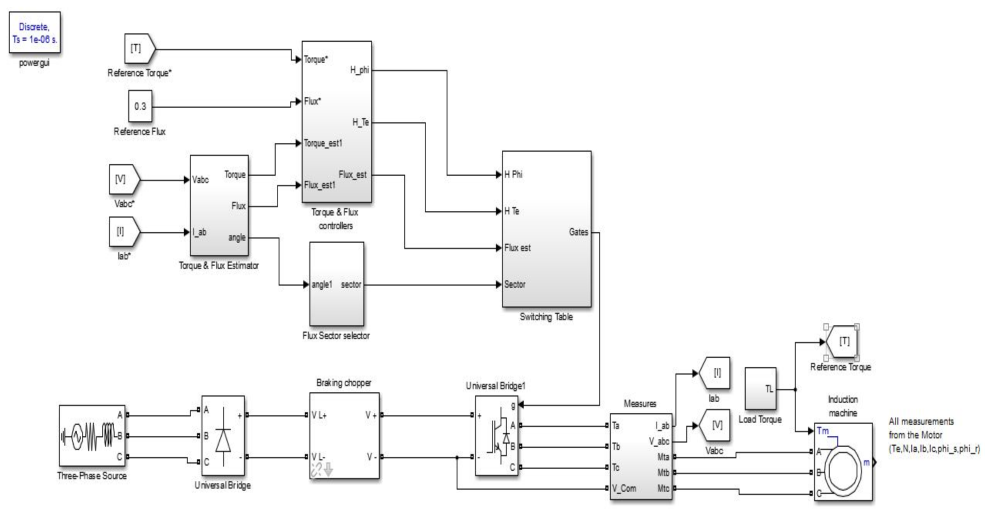



**Figure 4**. Block Diagram of MATLAB model for DTC drive

### 4.1Torque comparison

The applied load torque and it's set points for the induction motor are tabulated in table I. Figure 5 is showing the simulation results of the classical DTC and improved DTC. From the fig, it is shown that both the drives are tracking the reference value accurately and the improve DTC is tracking the reference value with reduce torque ripple.

**Table 1**: Torque reference set points

| S.No. | Time(second) | Torque (N-m) |
|---|---|---|
| 1 | 1 | 10 |
| 2 | 1.5 | 0 |
| 3 | 2 | 10 |
| 4 | 2.5 | 0 |

### 4.2 Flux comparison

The reference value of flux 0.3 web is given as input to flux controller. From the Figure 6 it can be show that the both the controllers are following the reference commands, where in improved direct torque controller scheme the flux ripple has reduced considerably.

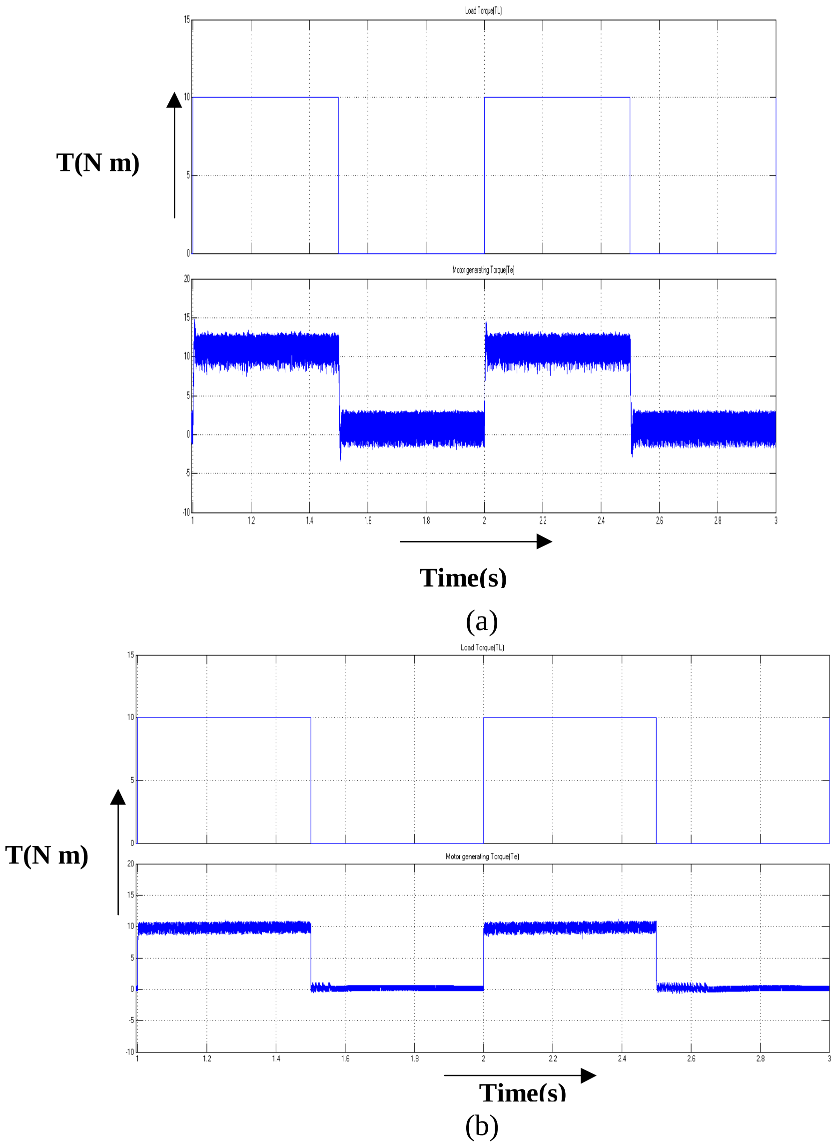



**Figure 5**.Torque (a) Classical DTC (b) Proposed DTC

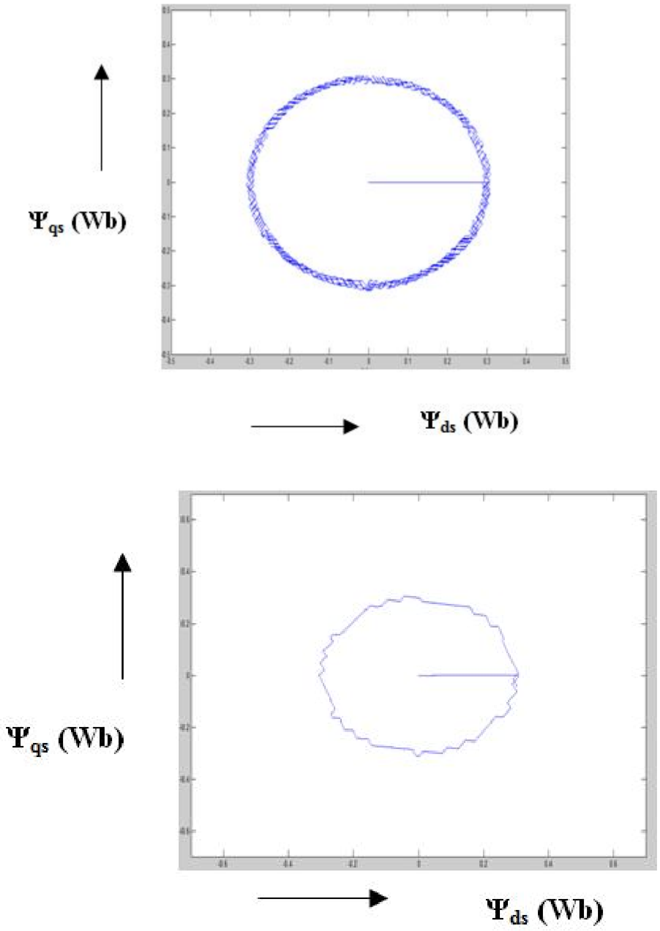
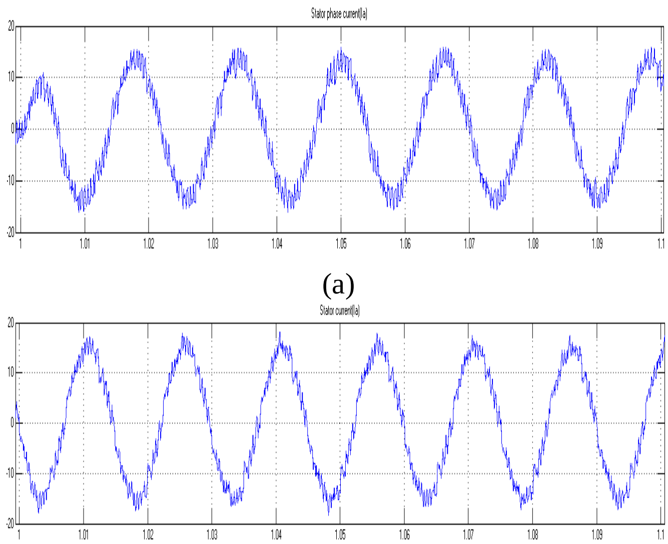



**Figure 6**.Stator flux (a) classical DTC (b) proposed DTC

**4.3 Stator currents and line-line voltage comparison**

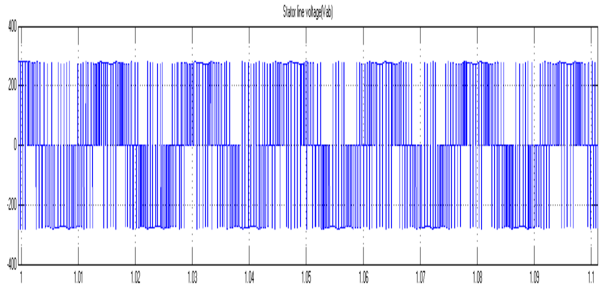
Figure 8. is showing the stator phase currents and line to line voltages of the inverter output. It is shown that the wave shape of currents and voltages has improved in proposed scheme compared to classical scheme.



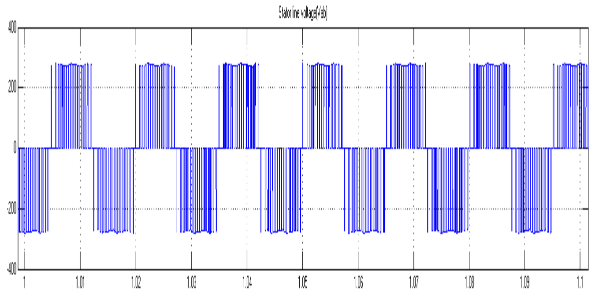
(a)

(b)

**Figure 7**. (a) Classical DTC (b) proposed DTC




(a)




(b)

**Figure 8**. (a)Classical DTC (b) Proposed DTC

## 5. CONCLUSION

In this paper presents the improved DTC in comparison with the conventional DTC with the help of MATLAB/SIMULINK software. Both the schemes simulated results are presented and also shown the improved direct torque control scheme has less torque ripple and flux ripple as compared to classical DTC. It also shown in the improved DTC scheme the inverter switching frequency can be changed by changing the carrier waveforms frequency in the loop.

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