Evaluation of High Performance Direct Torque Control Technique for Induction Motors

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***Abstract*— direct torque control technique is one of the excellent methods that used for torque control of induction machines. Direct torque control with simple control schemes, in the case of steady state and transient condition has good torque control among all control methods. The direct torque control scheme is determined by the lack of PI regulators, transformation, current regulators and pulse width modulated signal generators. In this paper the direct torque control technique based on space vector modulation is presented.**

***Index Terms*—** Direct torque control, Induction machine, Space vector PWM.

I. INTRODUCTION

Because of the most advantages of induction motors, such as reliability, low cost, low maintenance requirement and etc, are used in many commercial and industrial drive applications [1]. For induction motors drive control system is necessary.

Till now many studies has been developed on control of induction motor. In all of the methods, direct torque control provides powerful and fast torque responds [2, 3]. Many techniques are proposed to reduce the ripple of torque, but they each of them have some disadvantage. For example in [4] alternative inverter topologies, in [5] multilevel inverter are used. In this technique number of switches are increased thus they are more complex. In some paper to reduce the torque ripple, the switches frequency is increased [6], but this method increases the switching losses.

In this paper the direct torque control technique based on space vector modulation is presented. Direct torque control (DTC) has transpired as an alternative to field-oriented control (FOC) for high-performance ac drives, since it was first proposed in the mid-1980s. The key features of DTC compared to standard vector control include:

Manuscript received Aug 10, 2014

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- There is no current loops
- No need to coordinate transformations
- No separate voltage pulse width modulator
- Stator flux vector and torque estimation required.

Space vector pulse width modulation has important role in power conversion. Some of its advantages are as follow [7]:

- Less switching loss
- Easy implementation and less computational calculations

In the following sections the principle of direct torque control and after that simulation results is presented. The simulations are implemented by MATLAB-SIMULINK.

II. Direct torque control principle

DTC is popular technique in industry since the responds of DTC is very fast and its control structure is simple [8, 9]. In figure 1 the functional blocks of DTC is presented. The values of stator flux and torque are calculated from stator variable [10].

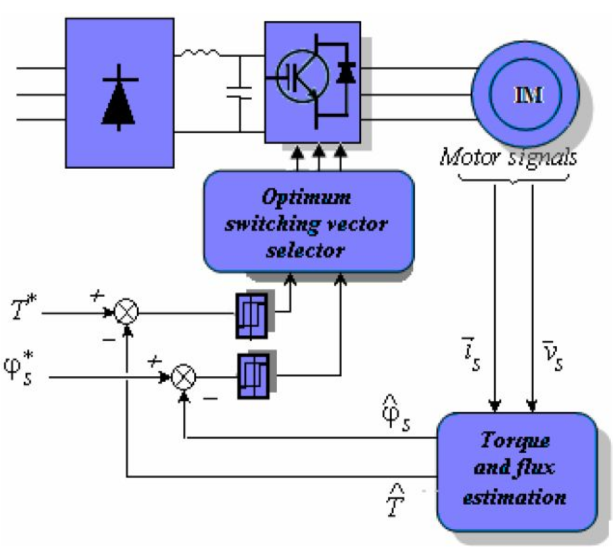

Fig.1: DTC scheme

In this technique, the estimated value of stator flux linkage $\hat{\emptyset}_s$ and the torque $\hat{T}$ are compared with the reference value of stator flux linkage $\emptyset_s^*$ and the torque T^* of the motor. If estimated values of flux and the torque, deviates from the reference values exceeding the tolerance value, the IGBT switches of the Variable Frequency Drive are turned OFF or ON, in other word,

the selection of the appropriate voltage vector is based on a switching table. So the flux and the torque error is form to return tolerant bands.
In DTC, the basic principle is determination of correct voltage vector using appropriate switching vector. In figure 1, the vector selector block provides the suitable control voltage vector. This selection is presented in following table.

Table 1: Switching table for inverter voltage vector

sectors		1	2	3	4	5	6
H_ϕ	H_T						
1	1	V2	V3	V4	V5	V6	V1
	0	V0	V7	V0	V7	V0	V7
	-1	V6	V1	V2	V3	V4	V5
-1	1	V3	V4	V5	V6	V1	V2
	0	V7	V0	V7	V0	V7	V0
	-1	V5	V6	V1	V2	V3	V4

Figure 2 shows the flux increment vector corresponds to inverter voltage vector.

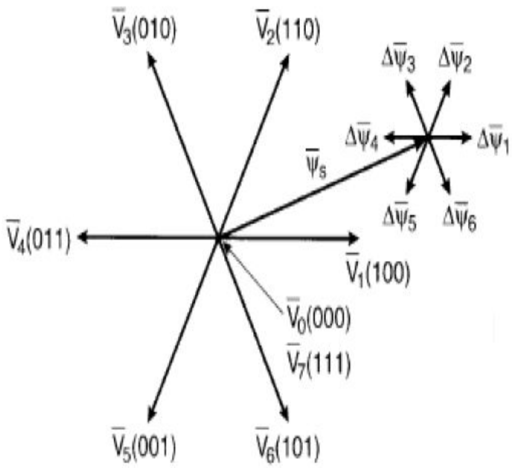

Fig.2: Stator voltage vectors and corresponding stator flux variation

III. Case study and simulation results

In this part the simulation results of direct torque control of induction motor is presented. Simulation is down by using MATLAB-SIMULINK. The Mathematical model of the induction machine is as follow:
Electrical system equations:
vs = Rs is + 1/wo (dfs/dt) + wk M(pi/2) fs (1)
vr = Rr ir + 1/wo (dfr/dt) + (wk - wm) M(pi/2) fr (2)
Where the variables i, v, and f are 2-dimensional space vectors; for instance
Is = [ids iqs] and so forth, wk is the speed of the reference frame, wm the rotor speed, and M (pi/2) represents a 90o space rotator namely M (pi/2) = [0 -1; 1 0].
The flux linkage current relations are:
fds = Ls ids + Lm idr (3)
fdr = Lm ids + Lr idr (4)
fqs = Ls iqs + Lm iqr (5)
fqr = Lm iqs + Lr iqr (6)
Ls =Lm +Lsl ; Lr = Lm +Lrl (7)
Mechanical system equations:
Te = 2H (dwm/dt) + Bm wm + Tl (8)
Where Te = fs (cross) is = M (pi/2) fs (dot) is = fds iqs - fqs ids = fs x is = M (pi/2) fs. Is = ir x fr = Lm (ir x is) = Lm/Lr (fr x is) = 1/Lm' (fr x fs)

Figure 3-7 shows the responds of simulation. Figure 3 shows the current of stator.

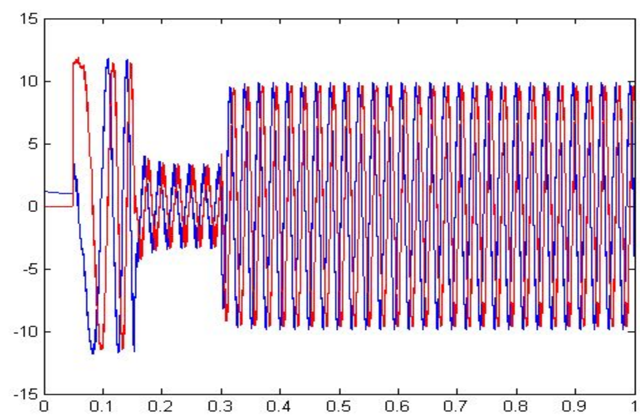

Fig.3 : Stator current

Figure 4 and 5 shows the rotor flux and stator flux respectively.

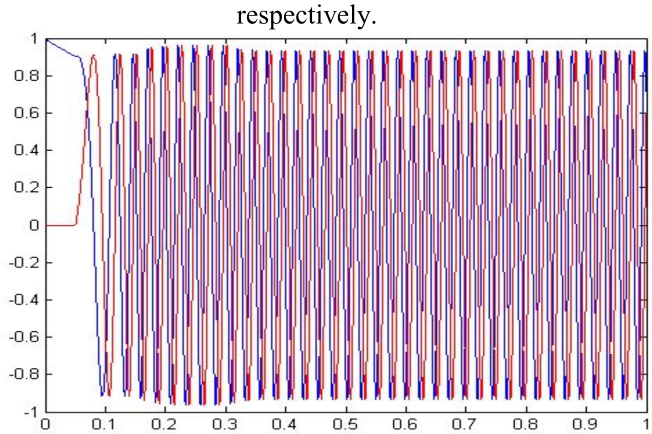

Fig.4: Rotor flux

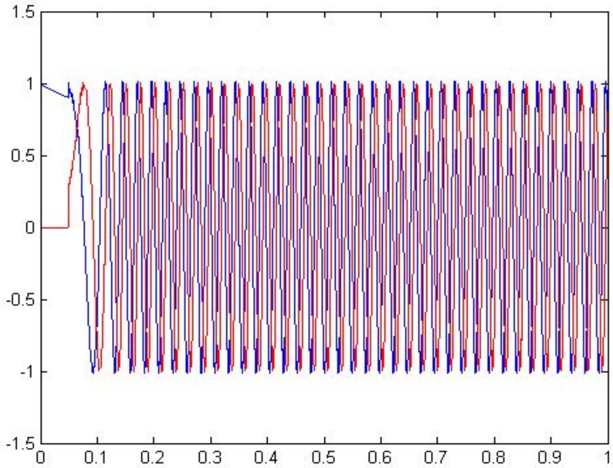

Fig.5: Stator flux

The respond of rotor speed is showed in figure 6 and figure 7 shows the torque respond of induction motor.

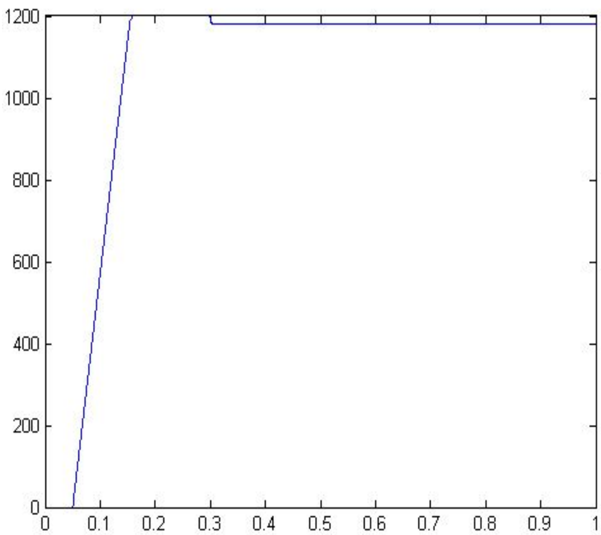

Fig.6: Rotor speed

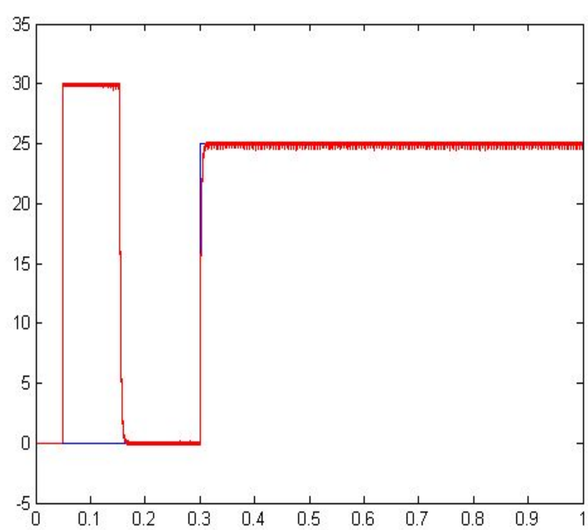

Fig.7: Electromagnetic torque

CONCLUSION

In this paper the direct torque control technique for induction motors based on estimation value of stator flux linkage and the torque is addressed direct torque control method allows the decoupled and independent control of torque and stator flux.. In this method, suitable selection of vector is the most important key. To this purpose, the flux and torque over switching period is calculated. This method has some advantages such as lack of PI regulators, transformation and etc. By using direct torque control technique, the torque has good control in steady state as well as transient operating conditions will be achieved.

Reference

[1]B. K. Bose, Modern Power Electronics and AC Drives. Englewood Cliffs, NJ: Prentice-Hall, 2001.

[2]Depenbrock M. 1988. Direct Self Control (DSC) of Inverter-Fed Induction Machine. IEEE Trans. Power Electronics. 3(4): 420-429.

[3]Isao Takahashi and Toshihiko Noguchi. 1986. A New Quick-Response and High Efficiency Control Strategy of an Induction Motor. IEEE Trans. Industry Applications. IA-22(5): 820-827.

[4]Isao Takahashi and Ohmori Youichi. 1989. High-Performance Direct Torque Control of an Induction Motor. IEEE Trans. Industry Applications. 25(2): 57-264.

[5]Casadei D, Giovanni Serra and Angelo Tani. 2001. The Use of Matrix Converters in Direct Torque Control of Induction Machines. IEEE Trans. Industrial Electronics. 48(6): 1057-1064.

[6]Peter Vas. 1999. Artificial Intelligence based Electrical Machines and Drives. New York: Oxford University Press.Wajiha Shireen, Srinivas Vanapalli, Hrishikesh Nene. 2006. A DSP Based SVPWM Control for Utility Interactive Inverters used in Alternate Energy Systems. IEEE Transactions on Industrial Electronics.

[7]H.F. Abdul Wahab, and H. Sanusi, "Simullink Model of Direct Torque Control of Induction Machine", American J. of Applied Sciences, Vol.5, No. 8, 2008, pp. 1083-1090.

[8]www.abb.fi/vsd/index.htm

[9]Takahashi, I. - Noguchi, T: A new quickresponse and high-efficiency control strategy of induction motor, IEEE Trans. On IA, Vol.22, N°.5, Sept/Oct 1986, PP.820-827.