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Direct Torque Control of Double Feed Induction Machine (DTC-DFIM)

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Abstract. This paper presents a performances study of a Direct Torque and Flux Control (DTC) for a double feed Induction Machine (DFIM). This method has become one of the high performance control strategies for AC machine to provide a very fast torque and flux control. The performance of DTC strongly depends on the quality of the estimated actual stator flux and torque. The simulation results show the effectiveness and the robustness of the proposed method in both dynamic and steady state response.

Keywords: Double Feed Induction Machine (DFIM), Direct Torque Control (DTC), Flux Estimator, Hysteresis comparator.

1. Introduction

The apparition of the field oriented control (FOC) made induction machine drives a major candidate in high performance motion control applications. However, the complexity of field oriented algorithms led to the development in recent years of many studies to find out different solutions for the induction motor control having the features of precise and quick torque response. The direct torque control technique (DTC) proposed by: I. Takahashi [1] and M. Depenbrock [2] in the mid eighties has been recognized to be a viable solution to achieve these requirements [1, 3]. The scheme, as the name indicates, is the direct control of torque and stator flux of a drive by inverter voltage space vector selection through a lookup table [2].

The three phase induction motor with wound rotor is doubly fed when, as well as the stator windings being supplied with three phase power at an angular frequency ω_s , the rotor windings are also fed with three phase power at a frequency. Under synchronous operating conditions, as shown in [5, 8], the shaft turns at an angular velocity, such that:

$$\omega_r = \omega_s + \omega_{rr} \tag{1}$$

The sign on the right hand side is (+) when the phase sequences of the three phase supplies to the stator and rotor are in opposition and (-) when these supplies have the same phase sequence. The rotational velocity of the shaft ω_r is expressed in electric radians per second, to normalize the number of poles.

2. Model of DFIM

The mathematical model for the electrical parts is written as a set of equations of state following:

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$$\frac{dX}{dt} = X^{\bullet} = AX + BU \tag{2}$$

Where X is the state variable and U is control variable.

The matrices A and B are given by:

$$A = \begin{bmatrix} \frac{-1}{T_s^{'}\delta} & \omega_r & \frac{1-\delta}{\delta M T_s} & \frac{1-\delta}{\delta M}\omega_r \\ -\omega_r & \frac{-1}{T_s^{'}\delta} & -\frac{1-\delta}{\delta M}\omega_r & \frac{1-\delta}{\delta M T_s} \\ \frac{M}{T_s} & 0 & -\frac{1}{T_s} & 0 \\ 0 & \frac{M}{T_s} & 0 & -\frac{1}{T_s} \end{bmatrix}$$

$$B = \begin{bmatrix} -\frac{1-\delta}{\delta M} & 0 & \frac{1}{L_r\delta} & 0 \\ 0 & -\frac{1-\delta}{\delta M} & 0 & \frac{1}{L_r\delta} \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{bmatrix}$$

The mathematical model for the mechanical parts is written as the following state equations:

$$C_{em} - C_r = j\frac{d\Omega}{dt} + f\Omega \tag{3}$$

Where ***j*** is the moment of inertia of the revolving parts, ***f*** is the coefficient of viscous friction, arising from the bearings and the air flowing over the motor, and $\boldsymbol{C_r}$ is the load torque. The equation of the electromagnetic torque is:

$$C_{em} = \frac{3pM}{2L_s}(\Phi_{s\alpha}I_{r\beta} - \Phi_{s\beta}I_{r\alpha}) \tag{4}$$

3. Direct torque control for the DFIM

Direct torque control is based on the flux orientation, using the instantaneous values of voltage vector. An inverter provide eight voltage vector, among which two are zeros .This vector are chosen from a switching table according to the flux and torque errors as well as the stator flux vector position. In this technique, we don't need the rotor position in order to choose the voltage vector. This particularity defines the DTC as an adapted control technique of ac machines and is inherently a motion sensorless control method [6, 8].

The block diagram for the direct torque and flux control applied to the double feed induction motors shown in figure1.The stator flux $Ø_{sref}$ and the torque Cem_{ref} magnitudes are compared with respective estimated values and errors are processed through hysteresis-band controllers.

Stator flux controller imposes the time duration of the active voltage vectors, which move the stator flux along the reference trajectory, and torque controller determinates the time duration of the zero voltage vectors, which keep the motor torque in the defined-by hysteresis tolerance band. Finally, in every sampling time the voltage vector selection block chooses the inverter switching state, which reduces the instantaneous flux and torque errors.

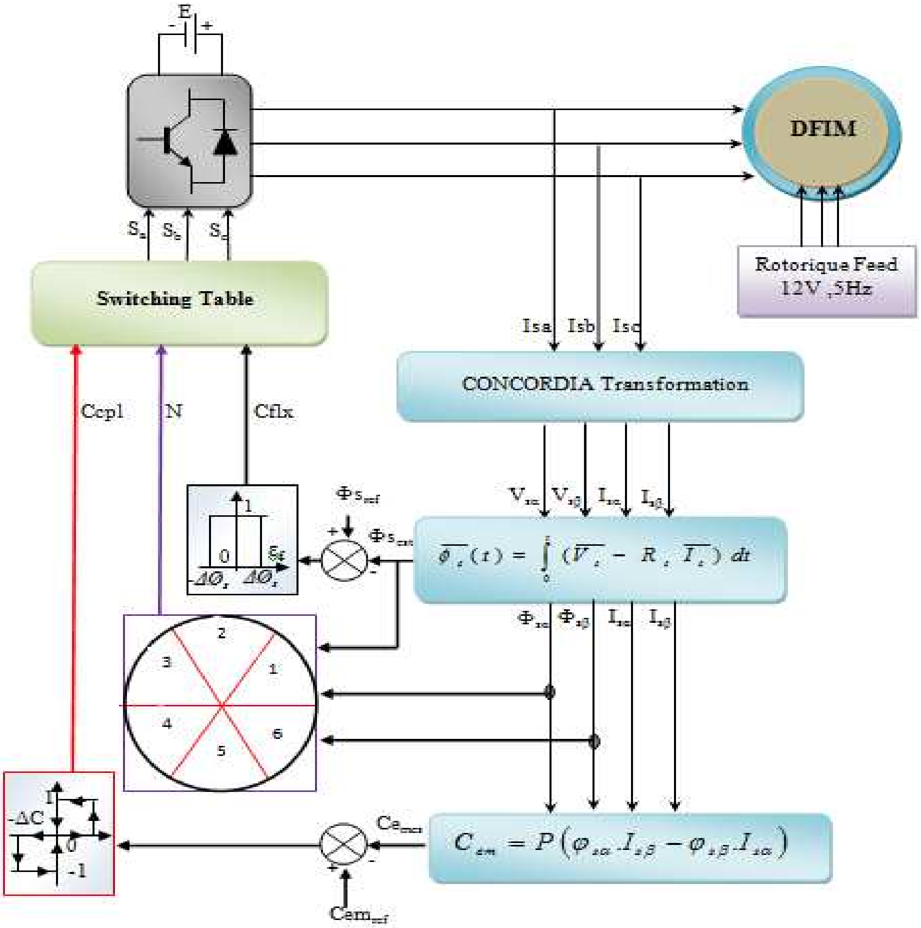

Fig. 1 DTC applied to double feed induction machine (DTC_DFIM)

4. Simulation results :

The Figure 2 shows in order, the variation in magnitude of the following quantities, speed, flux and electromagnetic torque obtained while starting up the induction motor initially under no load then connecting the nominal load. As can be seen during the starting up with no load the speed reaches rapidly its reference value without overtaking, however when the nominal load is applied a little overtaking is noticed and the command reject the disturbance. The excellent dynamic performance of torque and flux control is evident.

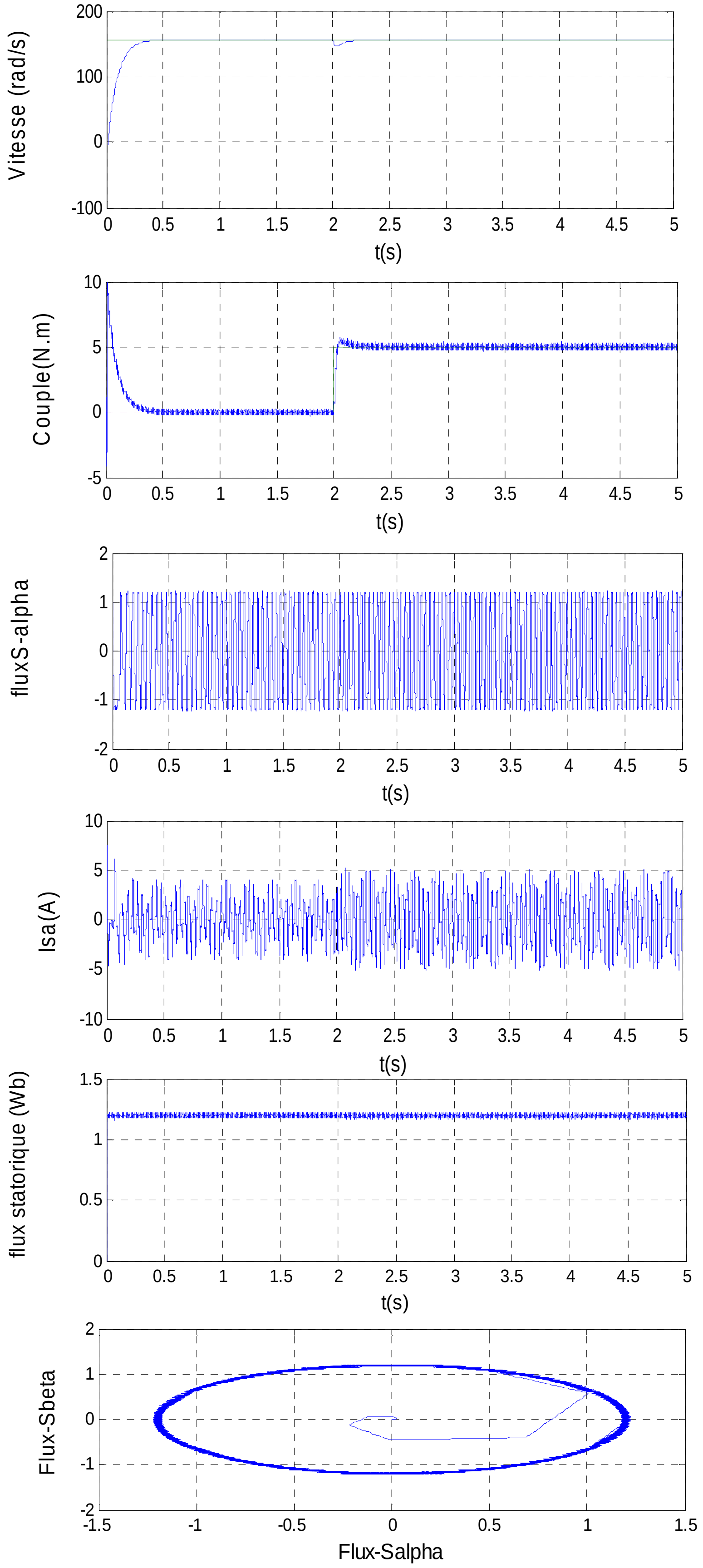

Fig. 2 Simulation results obtained with an IP

5. Robustness test

- ***Variable speed:***

The simulation results obtained for a speed variation for the values: (Ω_{ref}=157,130,157 rad/sec) with the load of 5 N.m applied at t=2s are shown in Figure3. This results show that the speed variation lead to the variation in flux and the torque. The response of the system is positive, the speed follow its reference value while the torque return to its reference value without error.

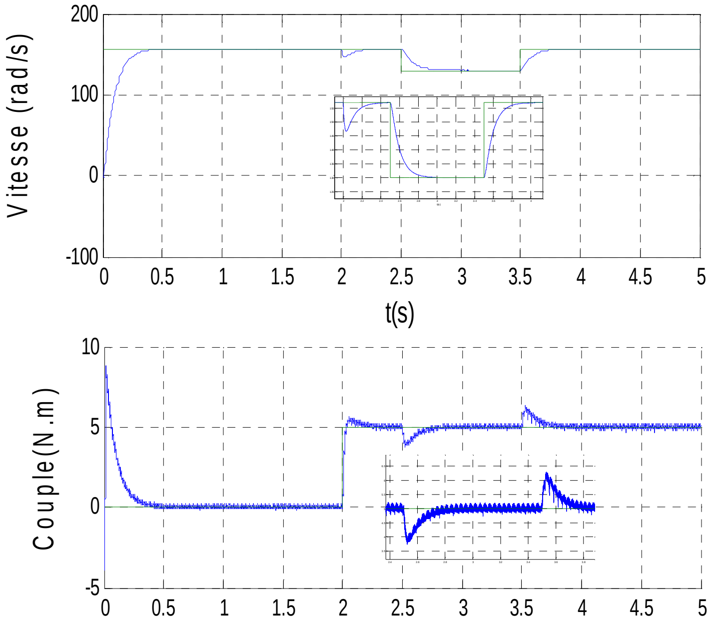

Fig. 3 Robust control under reversal

- ***Load variations:***

For a load variation (C_r = 3 N.m, 5 N.m), the simulation results obtained are shown in figure 4. As can be seen the speed, the torque and the flux are influated with the load variation. Indeed the torque and the speed follow their reference values.

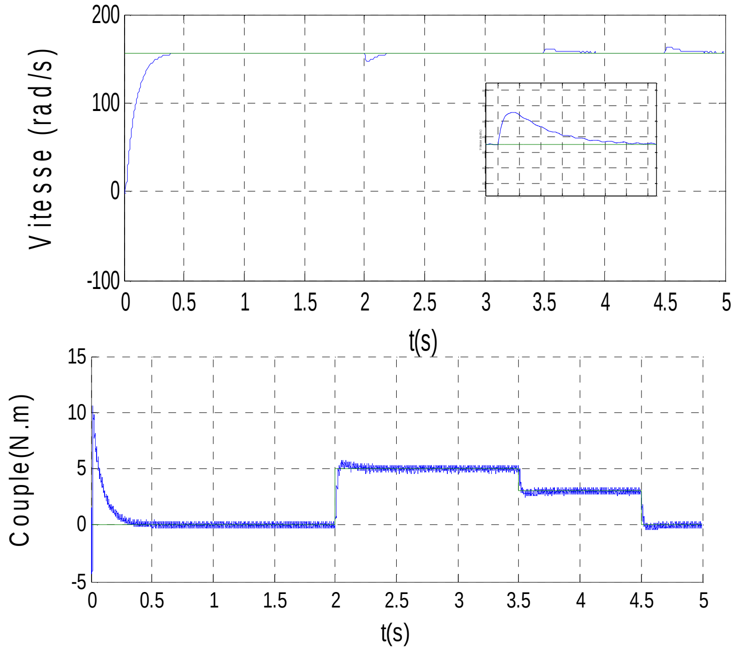

Fig. 4 Robust control under load

6. Conclusion

In this paper, the well-known classical DTC is detailed and applied to double feed induction machine to improve its performance. The control strategy of the double feed induction machine based on the direct control torque (DTC) use an IP regulator. The simulation results show that the DTC is an excellent solution for general-purpose induction drives in a very wide power range. The short sampling time required by the DTC scheme makes it suited to very fast torque and flux controlled drives in spite of the simplicity of the control algorithm. We believe that the DTC principle will continue to play a strategic role in the development of high performance motion sensorless AC drives.

7. References

[1] Q.W. Xiao, A. Steimel, "Direct Self Control of Induction Machines Fed by a Double Three-Level Inverter", IEEE Transactions on Industrial Electronics, Vol. 44, No. 4, August 1997.

[2] A. Chikhi1, M. Djarallah and K. Chikhil, "A Comparative Study of Field-Oriented Control and Direct-Torque Control of Induction Motors Using An Adaptive Flux Observer" SERBIAN JOURNAL OF ELECTRICAL ENGINEERING Vol. 7, No. 1, May 2010, 41-55

[3] D. Hadiouche, H. Razik and A. Rezzoug, "Stady and simulation of space vector PWM control of Double-Star Induction Motors", 2000 IEEE-CIEP, Acapulco, Mexico, pp 42-47.

[4] R.Toufouti, S. Meziane and H. Benalla, "Direct Torque Control for Induction Motor Using Intelligent Techniques" Journal of Theoretical and Applied Information Technology, 2007 JATIT.

[5] L. Dalessandro, S. D. Round, U. Drofenik, and J. W. Kolar, "Discontinuous Space Vector Modulation for Three Level PWM Rectifiers" IEEE Trans. Power Electron., vol. 23, no. 2, pp. 530-542, Mar. 2008.

[6] Takahashi, T. Noguchi, "A new quick response and high efficiency control strategy of an induction motor", IEEE Trans. Ind. Applicat., vol. IA-22, pp. 820.827, Sept./Oct. 1986.

[7] M. Depenbrok, "Direct self-control (DSC) of inverter fed induction machine", IEEE Trans. Power Electron. vol. PE-3, pp. 420.429, Oct. 1988.

[8] D. Zhou, R. Spée and A. K. Wallace, " Model reference adaptive speed control for doubly-fed machines",In Proceedings of International Conference on Industrial Electronics, Control and Instrumentation (IECON), volume 2. IEEE, 1993.

8. Appendix

Double Feed Induction Machine parameters:

$P_n = 0.8\ kW$
$U_n = 220/380\ V$
$F = 50\ Hz$
$I = 3.8/2.2\ A$
$Vr = 3\times 120\ V;\ 4.1\ A$
$\Omega = 1420\ tr/min$
$Rs = 11.98\ \Omega$
$Rr = 0.904\ \Omega$
$Ls = 0.414\ H$
$Lr = 0.0556\ H$
$M = 0.126\ H$
$P = 2$
$J = 0.01\ kg.m^2$
$f = 0.001\ S.I$