THE STABLE ALGORITHM BASED ON A MODEL REFERENCE ADAPTIVE CONTROL FOR THE DUAL STAR INDUCTION MACHINE DRIVES

LAAMAYAD TAHAR BELKACEM SEBTI
Department of Electrical Engineering, Kasdi Merbah University of Ouargla
30000, Email:laamayad tahar@yahoo.fr
Department of Electrical Engineering, University of Batna
Address,05000

Abstract: *This paper deals with the design and a simulations study of a Model Reference Adaptive Control speed adaptive controller used for control Dual Star Induction Machine, The developed controller is designed in accordance with Lyapunov stability theory. The technique proposed gives fast dynamic response with no overshoot, the simulation results show that the control.*

Key words: *DSIM Dual Star Induction Machine, Indirect Filed Oriented Control, Lyapunov Stability Theory, MRAC Model Reference Adaptive Control, Key parameters variation, Robustness.*

1.Introduction.

AC double star machines known as six phases machines have been used in many applications (such as pumps, fans, compressors, rolling mills, cement mills, mine hoists[1]) for their advantages in power segmentation, precision and electromagnetic torque pulsation minimization [1], [2], [3].

During the last decades, and thanks to the progress recorded in power electronics and Microprocessor technologies, various applications of the DSIM became possible whose interest lies mainly in the possibilities of speed control, In everyday language" adapted" means to change a behavior to conform to new circumstances .intuitively ,an adaptive regulator can change is behavior in response to changes in the dynamics of the process and the disturbances.(Fig.3.), [4], [5] can represent the adaptive control system. Let us now discuss the adaptive control of non-linear plants using the Lyapunov method, as an illustration of how to design and analyses an adaptive control system. This article is presented as follows: in section 2, the model of the motor is described. The design of the MRAC speed controller is presented in section 3. In section 4 the conception of the control of the DSIM is described. In section 5 simulation results are presented , finally section 6 is presents conclusion .

2.Machine Mode

A schematic of the stator and rotor windings for a machine dual three phase is given in Fig. 1. The six stator phases are divided into two wye-connected three phase sets labelled As1 Bs1 Cs1 and As2 Bs2 Cs2 whose magnetic axes are displaced by an arbitrary angle . The windings of each three phase set are uniformly distributed and have axes that are displaced 120 apart. The three phase rotor windings Ar Br Cr are also sinusoidal distributed and have axes that are displaced apart by 120 [6], [7].

The following assumptions are made:

_ The two stars have same parameters.
_ Flux path is linear.
_ Motor windings are sinusoidally distributed.

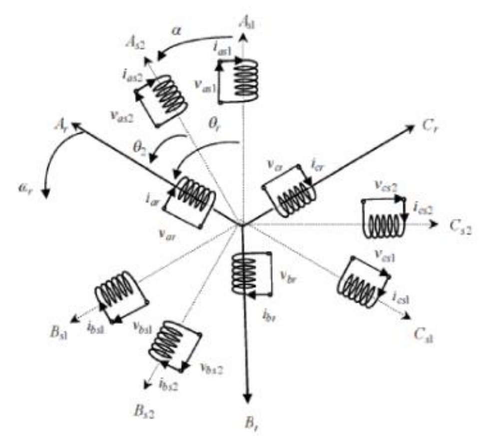

Fig.1. Schematic of the Dual Star Induction Machine

A. Model The Machine with axe d,q:

The expressions for stator and rotor flux are:

$$\begin{cases} \ddot{}_{ds1} = L_{s1} i_{ds1} + L_m (i_{ds1} + i_{ds2} + i_{dr}) \\ \ddot{}_{qs1} = L_{s1} i_{qs1} + L_m (i_{qs1} + i_{qs2} + i_{qr}) \\ \ddot{}_{ds2} = L_{s2} i_{ds2} + L_m (i_{ds1} + i_{ds2} + i_{dr}) \\ \ddot{}_{qs2} = L_{s2} i_{qs2} + L_m (i_{qs1} + i_{qs2} + i_{qr}) \\ \ddot{}_{dr} = L_r i_{dr} + L_m (i_{ds1} + i_{ds2} + i_{dr}) \\ \ddot{}_{qr} = L_r i_{qr} + L_m (i_{qs1} + i_{qs2} + i_{qr}) \end{cases} \quad (1)$$

With: $$\frac{3L_m}{2} = L_{ms} = L_{mr} = L_{sr} \quad (2)$$

In the induction machines, rotor windings has a short-circuited hence, i.e.

$v_{dr} = 0 , v_{qr} = 0$ (3)

The Park model of DSIM presents below in the references frame at the rotating field (d, q).

$$\begin{cases} v_{ds1} = R_{s1} i_{ds1} + \frac{d}{dt} \text{¨}_{ds1} - \mu_s \text{¨}_{qs1} \\ v_{qs1} = R_{s1} i_{qs1} + \frac{d}{dt} \text{¨}_{qs1} + \mu_s \text{¨}_{ds1} \\ v_{ds2} = R_{s2} i_{ds2} + \frac{d}{dt} \text{¨}_{ds2} - \mu_s \text{¨}_{qs2} \\ v_{qs2} = R_{s2} i_{qs2} + \frac{d}{dt} \text{¨}_{qs2} + \mu_s \text{¨}_{ds2} \\ v_{dr} = R_r i_{dr} + \frac{d}{dt} \text{¨}_{dr} - (\mu_s - \mu_r) \text{¨}_{qr} \\ v_{qr} = R_r i_{qr} + \frac{d}{dt} \text{¨}_{qr} + (\mu_s - \mu_r) \text{¨}_{dr} \end{cases} \quad (4)$$

B. Mechanical Equation

The mechanical equation is given by [8],[2].

$$\frac{J}{P}\frac{d\mu_r}{dt} = \text{ª}_e - \text{ª}_r - \frac{f_r}{P}\mu_r \quad (5)$$

With:

ª_e :Electromagnetic torque.

ª_r :Load torque.

μ_r :Mechanical pulsation.

P :Pair of the pole.

J :Moment of the inertia

f_r : Coefficient of the damping.

3. The Model Reference Adaptive Control:

The mechanical equation of the motor (process) represented by a differential equation as

$$\frac{d\mu_r}{dt} = b_p \text{ª}_{ref} - d_p \text{ª}_r - a_p \mu_r \quad (6)$$

In this step we accept that

$$\text{ª}_e = \text{ª}_{ref} \quad (7)$$

where a_p and d_p , b_p are constants motor parameters.

A. Parameters of the control:

In the adaptive control problem, the controller parameters k_r, k_y is assumed variable, let the desired performance of the adaptive control system be specified by a first-order reference model [9],[10],[11].

$$\frac{d\mu_m}{dt} = -a_m \mu_m + b_m \mu_{ref} \quad (8)$$

Where a_m and b_m are constants model following parameters, μ_{ref} is a bounded external reference signal.

b. Control Law:

As The first step in the adaptive control design, let us choose law to be:

$$\text{ª}_{ref} = k_r \mu_{ref} - k_y \mu_r \quad (9)$$

Where k_r, k_y are variables feedback gains, with this control law the closed-loop dynamics are:

$$\frac{d\mu_r}{dt} = b_p \left(k_r \mu_{ref} - k_y \mu_r\right) - d_p \text{ª}_r - a_p \mu_r \quad (10)$$

In the proposed controller, we have the system variables a defined as follows:

The error is given:

$$e = \mu_r - \mu_m \quad (11)$$

The derivative of the error:

$$\frac{de}{dt} = \frac{d\mu_r}{dt} - \frac{d\mu_m}{dt} \quad (12)$$

$$\frac{de}{dt} = b_p \left(k_r \mu_{ref} - k_y \mu_r\right) - d_p \text{ª}_r - a_p \mu_r + a_m \mu_m - b_m \mu_{ref}$$

(13)

After that we have

$$\frac{de}{dt} = \left(a_m - a_p - k_y\right)\mu_r - \left(b_p k_r - b_m\right)\mu_{ref} - \left(\mu_r - \mu_m\right)a_m \quad (14)$$

In adaptive control problem since k_r, k_y are variables , the adaptation law will continuously search for the right gains based on the Lyapunov theory to make μ_r tend to μ_m asymptotically

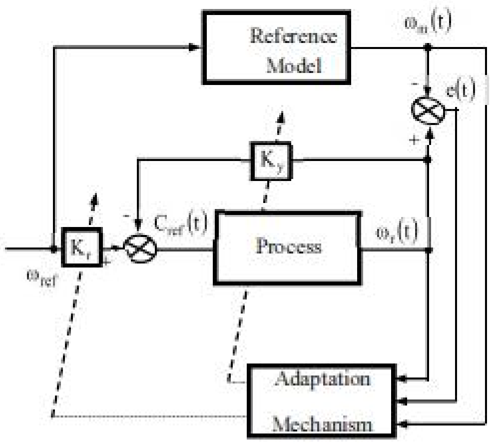

Fig.2: Schematic of the Controller

C. Adaptation law by using the Lyapunov:

Now select the adaptation law for the gains by using the stability Lyapunov method. We consider the function candidate:

$$V = \frac{1}{2}\left(e^2 + \left(\frac{1}{\text{¥}b_p}\right)\left(a_m - a_p - k_y\right)^2 + \left(\frac{1}{\text{¥}b_p}\right)\left(b_p k_r - b_m\right)^2\right)$$

(15)

The derivation of the Lyapunov function is negative, gives the following equation for assured stability of the control.

$$\frac{dV}{dt} = e\frac{de}{dt} + \left(\frac{1}{\text{¥}}\right)\left(a_m - a_p - k_y\right)\frac{dk_y}{dt} + \left(\frac{1}{\text{¥}}\right)\left(b_p k_r - b_m\right)\frac{dk_r}{dt}$$
(16)

We can obtained

$$\frac{dV}{dt} = -a_m e^2 + \left(\frac{1}{\text{¥}}\right)\left(a_m - a_p - k_y\right)\left(\frac{dk_y}{dt} - \text{¥}\mu_r e\right) + \left(\frac{1}{\text{¥}}\right)\left(b_p k_r - b_m\right)\left(\frac{dk_r}{dt} + \text{¥}\mu_{ref} e\right) \quad (17)$$

If the parameters of the control are updated as :

$$\frac{dk_y}{dt} = \text{¥}\mu_r e \quad (18)$$

$$\frac{dk_r}{dt} = -\text{¥}\mu_{ref} e \quad (19)$$

We get

$$\frac{dV}{dt} = -a_m e^2 \quad (20)$$

In the proposed law control is a method to systematically determine the parameters of the regulator; it is guaranteed the stability of the system.

4.Conception of The Control:

For command this machine, we propose a strategy MRAC for orientation the flux and regulation the speed, also control depends on two inverters one for stator1 and second for stator2, as Figure(3):

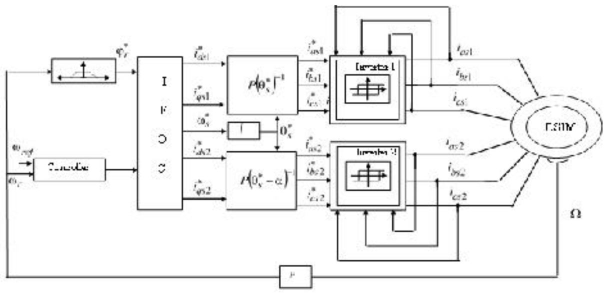

Fig. 3. Conception of the control Dual Star Induction Machine by using MRAC

5.Simulation Results :

In order to test the robustness of the method we can have studied the effect of the parameter changing during steady state on the performances of the speed control. Figure.4. illustrate the performances of control, we have simulated the starting mode of the motor without load, and the application of the load $^{a}{}_r = 14N.m$ at the instance t=1.5 s and it is elimination at t=3 s.

Figure.9. shows the tests of robustness realized with the MRAC in the case of variation of speed step of -100 (rd/s) at t=1.5 s . Moreover, the parameters variation in tests can be interpret in practice by the bad functioning conditions as overheating and variation of the inertia.

-Figure.8.Show variation of the gains for test of load.

-Figure.13. Show variation of k_y, k_r for test of speed. The decoupling of flux has maintained in permanent mode. The tests show that an increase of the torque load and the reference speed in steady state mode does not have any effects on the performances of the technique used, in consequent; the performances of speed control are approximately like the nominal case

A. Changing the torque

by Fig.4.,5,6,7,8 we present the DSIM response operated, respectively, at $^{a}{}_r = 0N.m$ with load $^{a}{}_r = 14N.m$.

B. Changing the rotation sense

By Fig 9.,10,11,12,13 we present the response of the DSIM with reference speed variations and with at t=1.5 (s) and -100 (rd/s) .

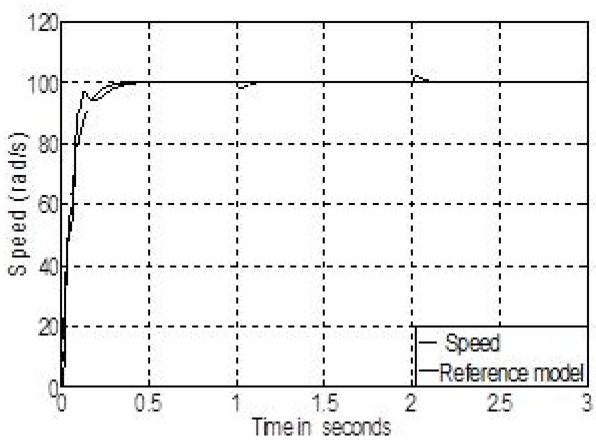

Fig.4.Simulation results of the control, response of Speed , when the machine operated under the variation of the load torque.

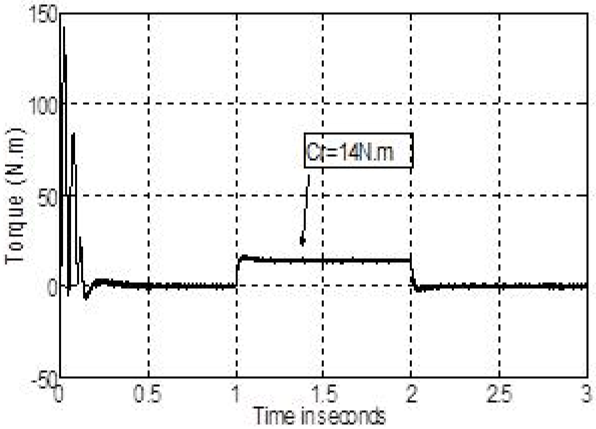

Fig. 5. Simulation results of the control, response of the electromagnetic torque, when the machine operated under the variation of the load torque

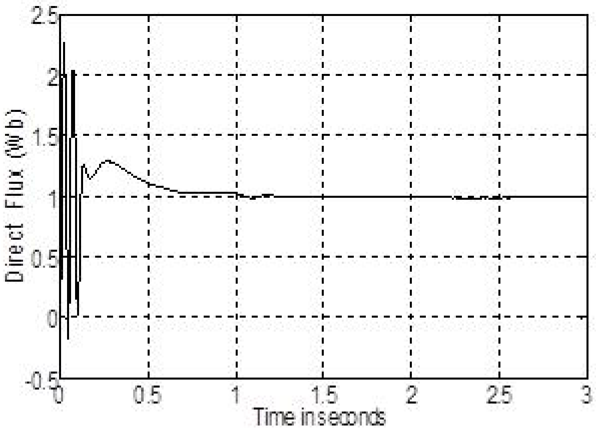

Fig 6. Simulation results of the control, response of the Flux ,when the machine operated under the variation of the load torque

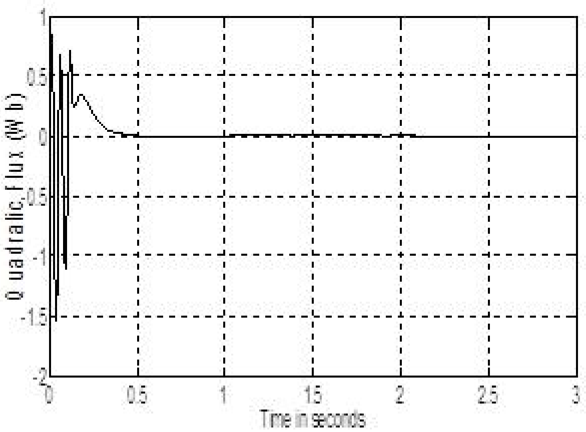

Fig 7. Simulation results of the control, response of the Flux ,when the machine operated under the variation of the load torque

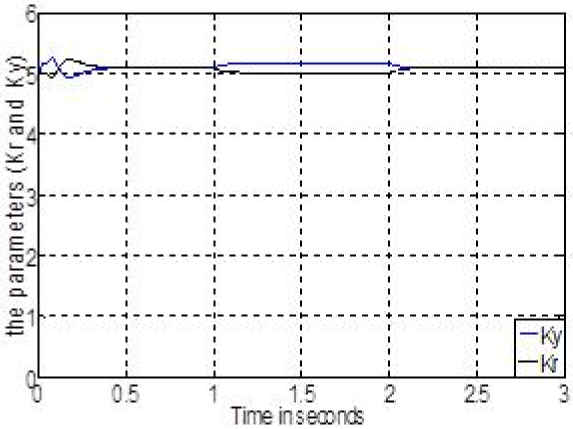

Fig. 8. The response of the gains kr; ky

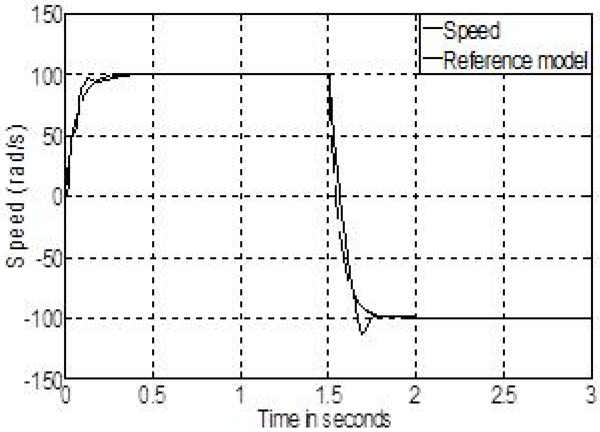

Fig 9. Simulation results of the control, response of the speed , when the machine operated under the variation of the speed reference

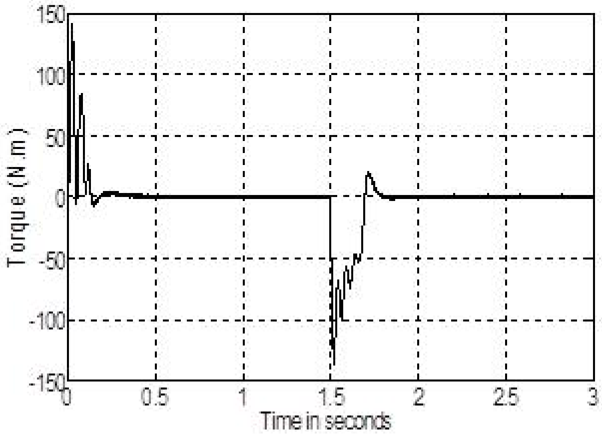

Fig10. Simulation results of the control, response of the electromagnetic torque ,when the machine operated under the variation of the speed reference

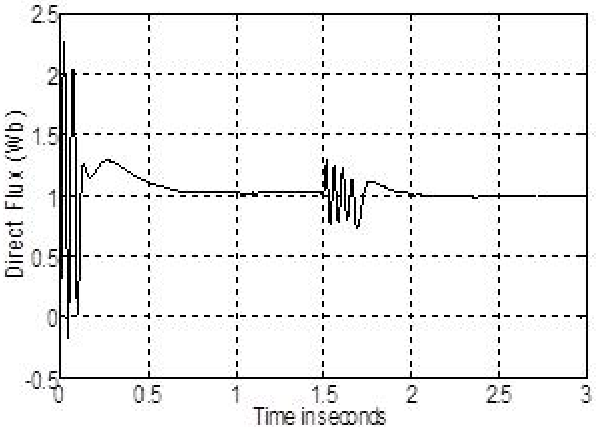

Fig 11. Simulation results of the control, response of the flux, when the machine operated under the variation of the speed reference

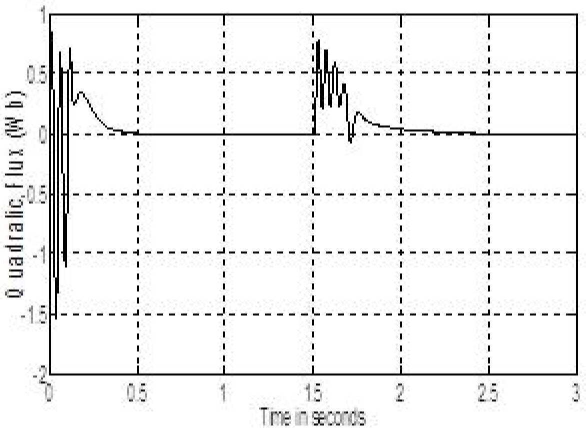

Fig 12. Simulation results of the control, response of the Flux ,when the machine operated under the variation of the speed reference

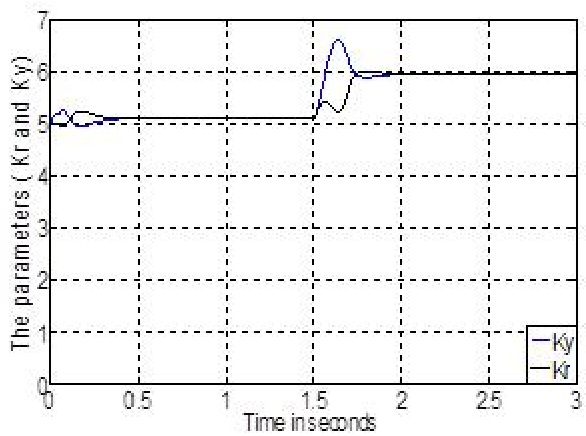

Fig 13. The response of the gains kr; ky

6.Conclusion

There have been a number of applications of adaptive control over 50 years. Most industrial processes are controlled by MRAC; also the control of the system is simulated using the software MATLAB for various parameters DSIM and reference model. All figures show that the proposed controller provides much fast and robust speed settling compared to classical PI controller to any load variation. This paper represents an interesting example of the use of MRAC control,

Another hand a speed control scheme of a dual stator induction machine with the adaptive control has been proposed. The principle of Lyapunov stability theory has been applied to the control design such that determine the parameters of the control and are dependent on the stability of control. Finally we can say that many other solutions can be applied when the system behavior is more known and this is at the same time the advantage and the limitation of MRAC control.

References

[1] Y. Zhao and T. A. Lipo, Space vector PWM control of dual three phase induction machine using vector space decomposition,. IEEE Trans.Ind.Appl., vol. 31, no. 5, pp. 11001109, September/October 1995.

[2] D. Hadiouche, Contribution ltude de la machine asynchrone double toile modlisation, alimentation et structure,. Thse de Doctorat.Universit Henri Poincar, Nancy-1, Soutenue le 20 Dcembre 2001.

[3] E. Levi, Recent developments in high performance variable-speed multiphase induction motor drives,. sixth international symposiumnikola tesla October 1820, 2006, Belgrade, SASA,Serbia.

[4] S. Filizadeh, L.M. Safavian , A. Emadi, Control of Variable Reluctance Motors ;A Comparison Between Classical and Lyapunov-based Fuzzy Schema,. Journal of power electronics, Vol 2, No 4,pp 305-311,2002.

[5] K. Johan Astrom, Adaptive Feedback Control,. Proceeeding of the IEEE,Vol.75, No.2, February 1987 .

[6] D. Hadiouche,H. Razik and A. Rezzoug, On the modeling and design of dual-stator windings to minimize circulating harmonic currents for VSI fed AC machines,. IEEE Trans. Ind. Appl., vol. 40,no. 2, pp. 506515, March/April 2004.

[7] G.K. Singh,K. Nam and S.K. Lim, A simple indirect field- oriented control scheme for multiphase induction machine,. IEEE Trans. Ind. Elect., vol. 52, no. 4, pp. 11771184, August 2005.

[8] H. Amimeur ,R. Abdessemed,D. Aouzellag,E. Merabet and F. Hamoudi A sliding Mode Control associated to the Field oriented Control of Dual stator Induction

Motor Drives,. Journal of Electrical Engineering ,Vol 10,Edit 3,No 2,pp7-13,2010, Romanie.
[9] I.D. Landau adaptive control the model reference approach,.Newyork,NY :Marcel Dekker, 1979.
[10] K.S. Narendra and R.V. Monopoli Applications of Adaptive control,. Newyoek ,NY :Academic press :1980.
[11] A. Balestrino ,G. Demarina ,A.S.I. Zinober Nonlinear Adaptive modelfollowing control,. Automatica, pp.559-568.1984.