COMMAND CHANNELS DECOUPLING CIRCUIT OF AN EMBEDDED VECTOR ORIENTED CONTROL SYSTEM

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Abstract: *In this paper a rotor-flux-oriented decoupled control system of an induction motor is presented. Because vector control involves a control of flux and torque, for decoupling these two command channels the synthesis of a field-oriented controller is developed. The simulation results show that the decoupling network is capable to obtain an independent control of the rotor flux and electromagnetic torque of the induction machine.*

1. Introduction

This article proposes a method for the command channels decoupling of a rotor flux oriented control system of an induction motor drive.
In spite of their non-linear, highly interacting multivariable control structure, the induction motors are an interesting alternative to others electrical machines used in variable speed drives. High dynamic performance in control systems with induction motors is achieved through the "vector control" [1].
In the paper, the following are regarded as variable parameters: the rotor resistance, the magnetization and dynamic inductances. Even though as a result of parameters variation effects a mismatch between actual and estimated values of flux space phasor and electromagnetic torque occurs, the decoupling network proposed here leads to an adequate vector control. The proposed decoupling controller is verified by simulation for a starting operating regime.

2. The Decoupling Circuit

The control structure of the simulated drive system is shown in fig. 1. First a mathematical model describing a squirrel-caged induction motor, derived in [2], [3], is used here.

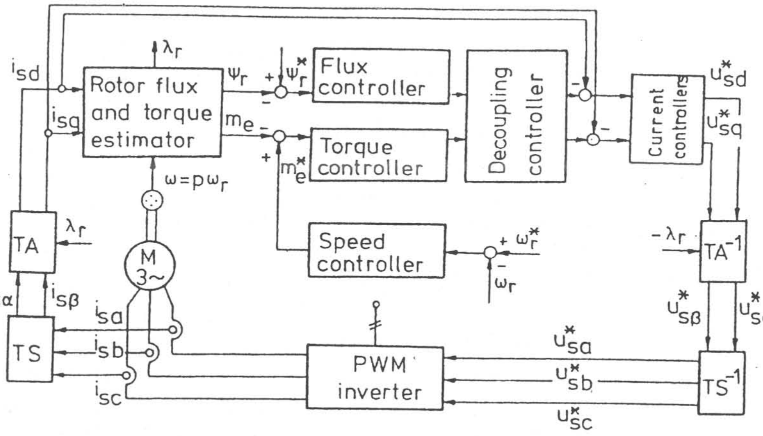

Fig. 1. The vector-controlled induction motor drive.

The rotor flux and electromagnetic torque estimator deduced in [2], [3] and used in this paper is an adaptive type which account for change in saturation level in the machine. The mathematical models of the rotor flux and speed control paths, including the stator current components control, are deduced in [4].

In the presence of magnetic saturation the decoupled control of the rotor flux and electromagnetic torque is lost. Consequently, a decoupling circuit is needed to obtain the separate vector control.

To obtain the mathematical model of the decoupling circuit, the equations describing vector control of the saturated induction motor deduced in [2],[3], can be rewritten as:

$$i^{\bullet}_{sd1} + A\frac{di^{\bullet}_{sd1}}{dt} = i^{\bullet}_{mr} + T_r'\frac{di^{\bullet}_{mr}}{dt} + B\frac{di^{\bullet}_{sq1}}{dt}, \qquad (1) \qquad\qquad i^{\bullet}_{sq1} = \frac{2L_r}{3pL_m}\cdot\frac{m^{\bullet}_e}{\Psi^{\bullet}_r}, \qquad (2)$$

where, the following notations were made [3]:

$$A = \frac{T_r}{L_m}\cdot\left[\frac{(L_{\sigma r} + L_{m1})\cdot L_m}{L_r} - L_{m1}\right], \qquad T_r' = \frac{L_{\sigma r} + L_{m1}}{R_r}, \qquad B = \frac{L_r}{R_r}\cdot\frac{L_{m2}}{L_m}. \qquad (3)$$

In the absence of magnetic saturation the following relations are valid [3]:

$$L = L_m, \qquad L_{m1} = L_m, \qquad L_{m2} = 0. \qquad (4)$$

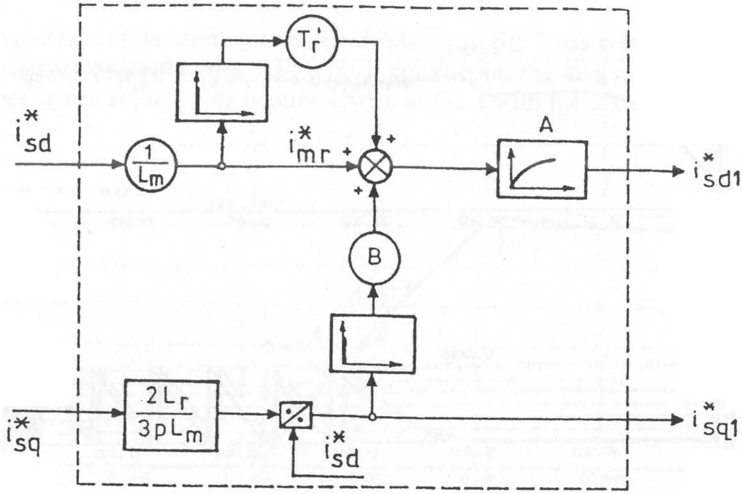

Fig. 2. The decoupling circuit for a field oriented controller.

Now the decoupling circuit equations are ready to be described by relations (1), (2) considering as inputs the command quantities of the flux and torque controllers as it is shown above in fig. 2.

3. Verification of the Decoupling Circuit Utilization

The results of simulations are presented in this section. Fig. 3 illustrates the commanded and actual rotor flux amplitudes with rated rotor flux as imposed value. The drive in fig. 1 is simulated without the decoupling network showed in fig. 2. As can be seen in fig. 3, the rotor flux is correctly settled during forced excitation within 0 - 0.2 s period of time.
But, during the acceleration of the drive, within 0.2 s - 0.4 s period of time, when the speed command is changed from 0% to 40% of its rated value, the flux command channel is influenced and the rotor flux amplitude is modified.
As is evident from fig. 4 during the starting transient a mismatch between actual and estimated values of the rotor flux space phasor angle occurs in absence of the decoupling circuit.
The same transient is analyzed when the decoupling circuit for a field-oriented controller in fig. 2 is applied.

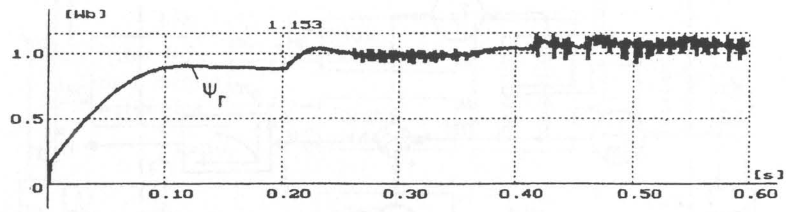

Fig. 3.

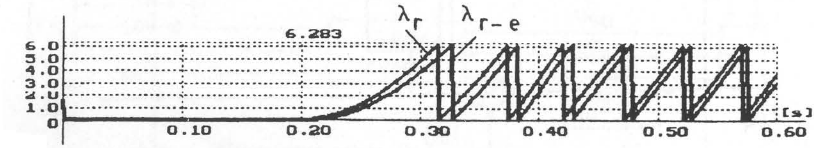

Fig. 4.

Fig. 5 and Fig. 6 display the same operating regime as in fig. 3 and 4. As can be seen in fig. 6, the application of the proposed decoupling controller enables very good matching between actual and estimated rotor flux space phasor angle values. Also, the induction motor drive is capable to obtain a decoupled vector control, the commanded rotor flux remain unchanged (fig. 5) during the modification of the speed command.

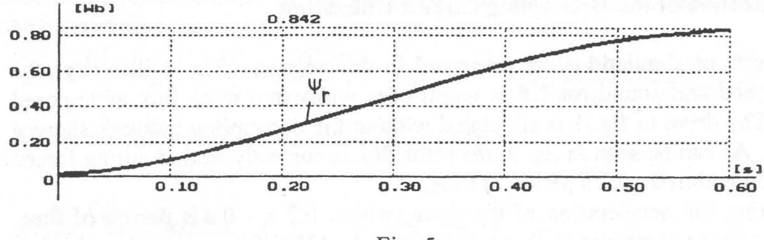

Fig. 5.

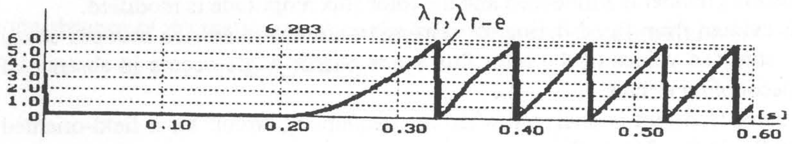

Fig. 6.

The simulation of the starting transient displayed in fig. 7 has been made under following circumstances: no load torque, considering the magnetic saturation, rotor resistance at 20° C, the control system in fig. 1 with the decoupling circuit in fig. 2.

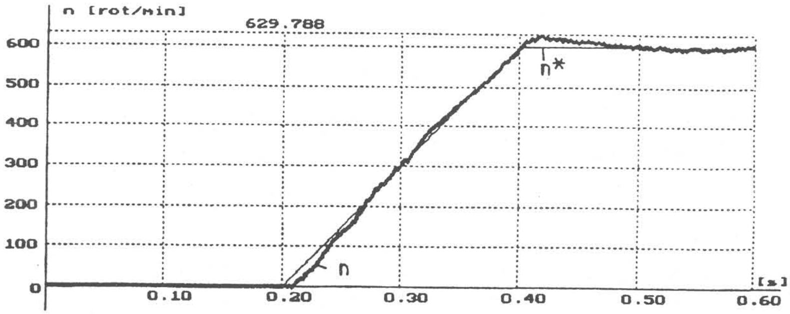

Fig. 7.

4. Conclusions

This article proposes a method to deduce the decoupling circuit structure for the two command channels of a rotor flux oriented control system of an induction motor drive.
The results of the simulations are presented for a dynamic regime with and without the decoupling deduced circuit.
The models of the induction motor and of the saturation adaptive estimator assure a correct simulation of the real system.
The use of the decoupling controller provides a very good vector control of the drive in spite of the parameters variation effects due to the magnetic saturation, or to the temperature increasing.

5. Further researches

In all the applications of vector control with asynchronous motors on the basis of field orientation principle for the position, speed and torque control, it appears the necessity of a control structure analysis, at the interior loops level, common to these applications, that can ground the optimisation of the accomplishment of a flux correct orientation.
In the further work will be analysed the working of the control structure with rotor flux orientation, in the possible case of the orientation errors due to the influence of the rotor resistance parameter deviations.

On this basis, will be identified the action manner of the perturbation signal on the command channels of the control system, which permits the improvement of the two command channels decoupling and the developing of a rotor resistance parameter adapting mechanism, used in the control structure blocks.

6. References

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7. Appendix

The motor data:

$P_N = 1100\,W$;	$p = 2$;	$f = 50\,Hz$;	$U_l = 380\,V$;	$n_N = 1500\,rpm$;
$R_s = 7.78\,\Omega$;	$R_r = 2.87\,\Omega$;	$i_{sN} = 2.89\,A$;	$\Psi_r^* = 0.86\,Wb$;	$m_{eN} = 5\,Nm$;
$L_{\sigma s} = 37\,mH$;	$L_{\sigma r} = 20\,mH$;	$L_m = 450\,mH$;	$L = 70\,mH$;	$J = 0.0106\,kgm^2$.