A&QT-R 2002 (THETA 13)
2002 IEEE-TTC International Conference on Automation, Quality and Testing, Robotics
*May 23-25, 2002, Cluj-Napoca, Roman*ia

GENERALIZED SOLUTION FOR VECTOR CONTROL OF THE LCI-FED AC-MOTOR DRIVES

Viorel Buta*, Stefan Gavat*, Constantin Iordache*, Constantin Mada*, Dumitru Stanciu**

**SC IPA SA Bucuresti, E-Mail: gavat@ipa.ro*
***Electronics and Telecommunications Faculty, "Politehnica" University of Bucharest*

Abstract

A generalized solution for vector control of the LCI-fed AC-motor drives is proposed. Technical and economical advantages of a common solution are mentioned. The availability of the proposed solution for high power including medium-voltage converter-motor systems is verified by experimental results with induction and large synchronous motors.

Key-words: vector control, load commutated inverter, induction motor, synchronous motor.

1. Introduction

For the high power medium voltage AC motor drive applications, the thyristor based LCCSI (load commutated current source inverter) has presented in the literature [1,2,3]. Capacitive filter (for induction motor) and DC-side forced commutation circuit allows for motor currents and voltages a small harmonic content.

In this paper a simple generalized vector control solution for both induction (IM) and synchronous (SM) LCI-fed motors is proposed. To avoid the adverse effects by the electrical or mechanical resonances in certain frequency domains, the assisted commutation is required.

A part of the control scheme is implemented by a specialized microcontroller.

2. Description of the proposed solution

Fig. 1 show the generalized vector control system. A main controlled converter supplies DC link current through a DC-link inductor. The load controlled converter distributes current to the motor and output capacitor (for induction motor). The DC-side commutation circuit allows motors to start up and to bring up to the critical frequency, wich will ensure load commutation. Assisted commutation avoids the large current interruptions by natural commutation and consequently the large drops in the torque and adverse effects by electrical and mechanical resonances.

Description of the control scheme for IM-application has been presented [4]. In this paper (actually, the second part of [4]) will be presented the SM-application and the common aspects. The control scheme is made up of the direct vector controller and an air gap flux estimator (using voltage model). The motors terminals voltage at a standstill and at low speeds is very small and the flux measurement is difficult [5]. To avoid such a problem an adequate starting algorithm is proposed: the output of estimator is supressed and the angle θ_{SA} (for IM) or the angle θ_{SS} (for SM) is utilised. When the estimated flux has established a certain level, the control algorithm is changed to flux vector control (θ_S).

In SM-application the calculation of $\theta_{SS} = \lambda + \delta$ needs the measurement of polar wheel position (λ) and load angle calculation (δ).

For SM-application, in control scheme (fig.1), the switches are in the upper position: the d component is imposed by desired PF ($\cos\varphi \approx 1$ by θ_{SS} and $\cos\varphi \approx 0.8$ cap. by θ_S) and the q component is imposed by speed error (motor or generator mode). Stator voltage controller for Ψ_m maintaning, through I_E, by load variation (Fig.2) is proposed.

A certain other similarity can be observed (Fig 2, 3, 4) between control solutions of both applications: the capacitive domain required for thyristors commutation is ensured by IM with $I_{Cd} > I_m$ ($\omega > \omega_{0g}$) and by SM with $I_{Ed} > I_m$. In both applications, a PWM function of the forced commutation circuit CS alows a motors currents harmonic content reduction. The active damping for electrical or mechanical oscillations is compatible with the proposed solution [6].

3. Experimental results

Experimental conditions and results for IM-application has been presented [4]. The rated values for SM-application by the motor: $P_n = 3$Mw, $U_{Sn} = 1000$ V, $f_{Sn} = 75$Hz, $N_n = 1500$ rpm., $J_M = 1300$ Kgm^2 with the load moment of inertia $J_L = 15000$ Kgm^2 (in the mechanical transmission an gear with two fixed steps is used).

Without the PWM function of DC-side forced commutation circuit, can be observed significant differences by stator currents and voltages harmonic content (Fig.5, 6) at 100 rpm (5Hz): for IM-application, with capacitive filter, phase currents have a reduced harmonic content but in the stator voltage appears superposed commutation oscillations (with transition frequency resonance $\omega_{0t} = (\sigma L_S C)^{-1/2}$). For SM-application the stator voltage has a reduced harmonic content, due to absence of commutation oscillations but, without capacitive filter, the harmonic content is the same for the motor phase currents and for the inverter phase currents.

Significant differences appears in waveforms of the phase currents (Fig.7a, 7b) by the natural commutation and by the forced commutation: duration of the motor phase currents interruption decrease to 1ms and the risk of the mechanical resonances is limitated due to diminuation of the repetitive drops in the torque.

The speed control algorithm including speed reference ramp, the starting algorithm, the drive monitorisation and fault diagnosis, the serial communication (RS 485) with the process computer are by an specialized microcontroller implemented. An optical encoder allows the speed and polar wheel position mesurement. The time of the speed response for an imposed step change of 300 – 320 rpm was 200 ms (1500 A current impulse amplitude, in no-load condition). The time of the speed response with inertia load is imposed by the speed reference ramp: 30 s response time for an 0 –50 rpm change was registered (1000 A current impulse amplitude).

4. Conclusions

The high power medium voltage AC motor drives required as an possible solution the load commutated current source inverter (LCCSI) and an adequate start-up algorithm to pass at the flux vector control. A generalized solution for both induction and synchronous motor is proposed. With the proposed drive system, the speed of a large AC motors can be adjusted with good dynamics in hard start-up conditions.

References

[1] Hyung-Soo Mok, Seung-Ki Sul, Min-Ho Park., (1994), "A load commutated inverter-fed induction motor drive system using a novel DC-side commutation circuit", *IEEE Transactions on Industry Applications*, vol. 30, no. 3, pp. 736-745.

[2] Obermeyer, P., Pouliquen, J-L., (1987), "Industrial application of cycloconverters", *Proc. of EPE Grenoble*, pp. 1165-1170.

[3] Wiart, A., Hamel, J., (1987), "Railway traction powered by synchronous motors supplied through natural commutation inverters", *Proc of EPE Grenoble* , vol.3, pp. 39-45.

[4] Stanciu, D., Gavat, St., Buta, V., (2000), "Vector control power converter for feeding multiresonant loads", *Proceedings of Q&A-R 2000*, vol III, pp. 85-90.

[5] Schröder, D., (1995), *Elektrische Antriebe 2 – Regelung von Antrieben*, Springer, vol.2

[6] Ma, J.D.,Wu, B., Zargari, N. R., Rizzo, S. C., (2001), "A space vector modulated CSI-based AC drive for multimotor applications", *IEEE Transactions on Power Electronics*, vol.16, no.4, pp.535-542.

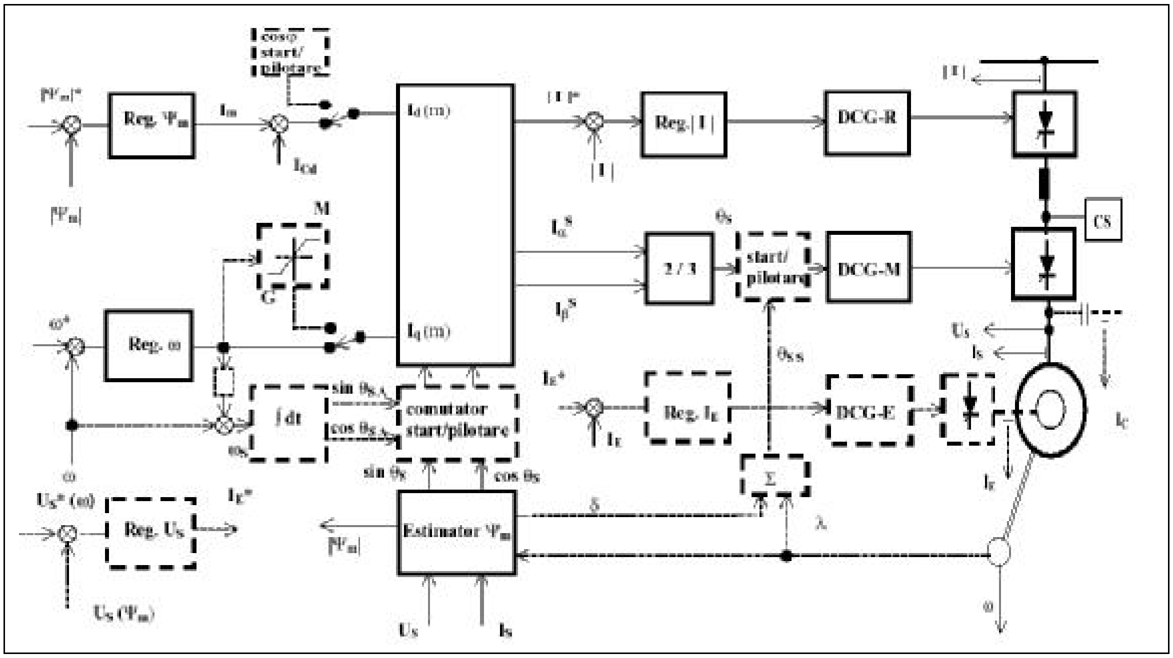

Fig.1 Generalized block diagram for the vector control of the LCI-fed AC motors.

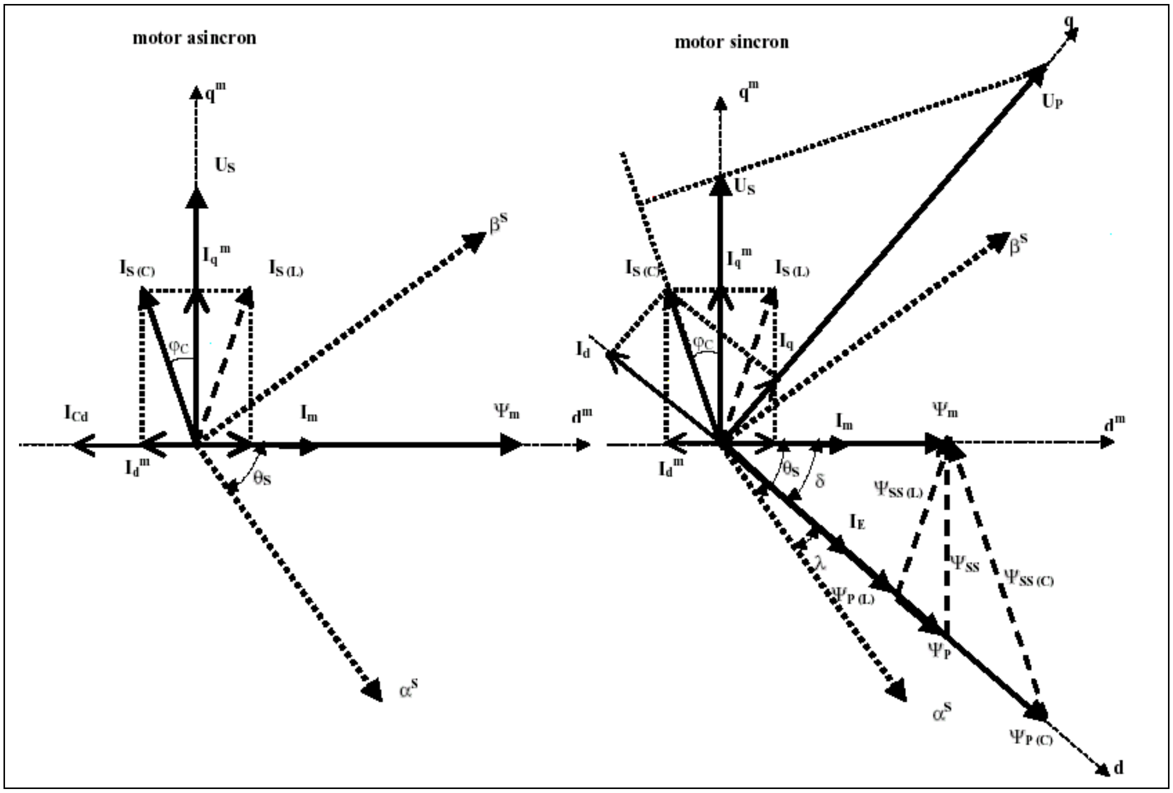

Fig.2 Current vector diagrams with respect to air gap flux's reference frame.

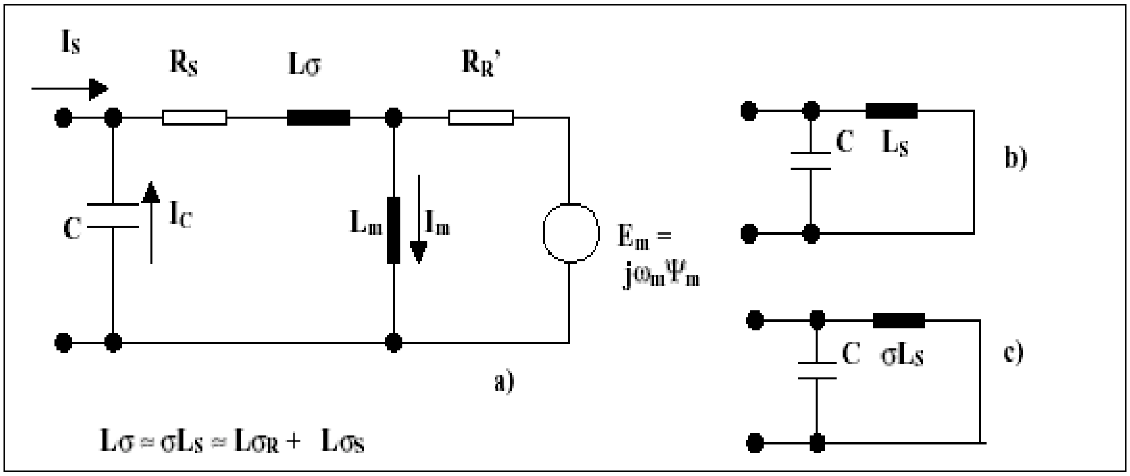

Fig.3 The equivalent circuit (T-I) of the induction motor with capacitive filter (a), the equivalent circuit of no-load reactances (b) and of transient state reactances (c). The resonance frequencys are: $\omega_{0g} = (L_S C)^{-1/2}$ for (b) and $\omega_{0t} = (\sigma L_S C)^{-1/2}$ for (c). The IM with capacitive filter can present in steady-state an capacitive ($\omega > \omega_0$, $I_{Cd} > I_m$) or an inductive ($\omega < \omega_0$, $I_{Cd} < I_m$) impedance.

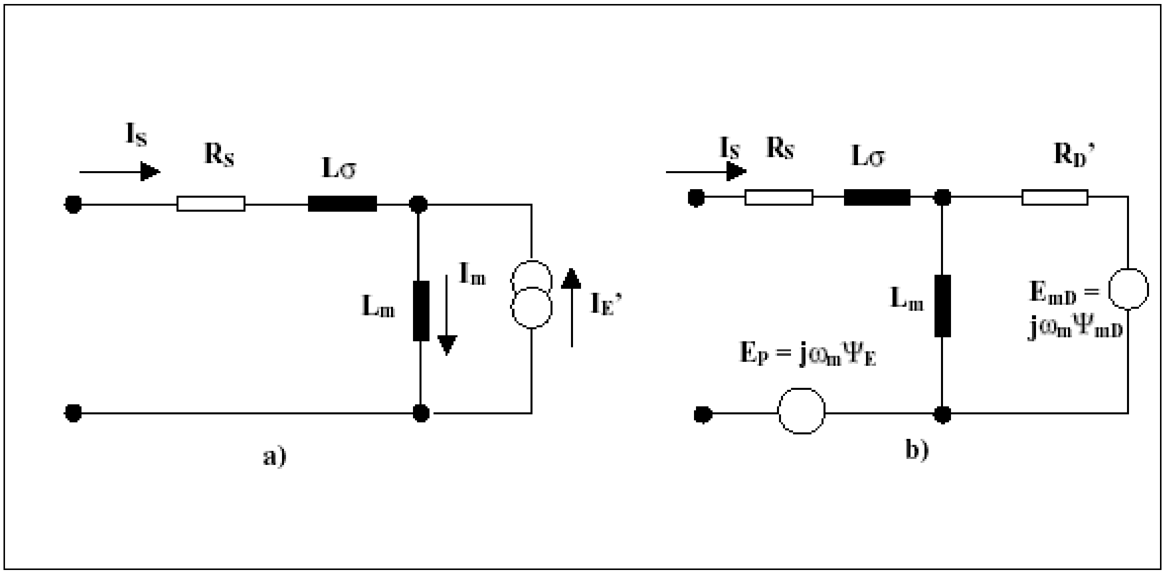

Fig.4 The simplified equivalent circuit (T-I) of the synchronous motor without (a) and with damper (b). The SM can present in steady-state an capacitive ($I_{Ed} > I_m$) or an inductive ($I_{Ed} < I_m$) impedance.

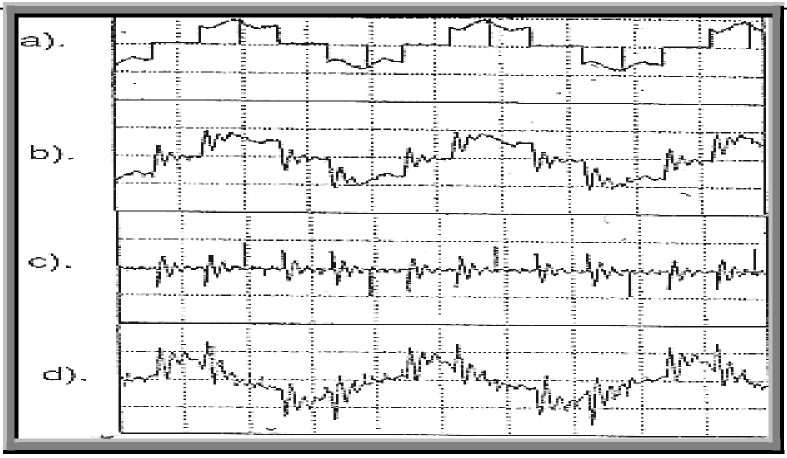

Fig.5 Experimental waweforms at 100 rpm (5Hz) for no-loaded IM, forced commutation (50ms/div): a) inverter phase current (10 A/div), b) motor phase current (10 A/div), c) capacitor phase current (10 A/div), d) motor phase voltage

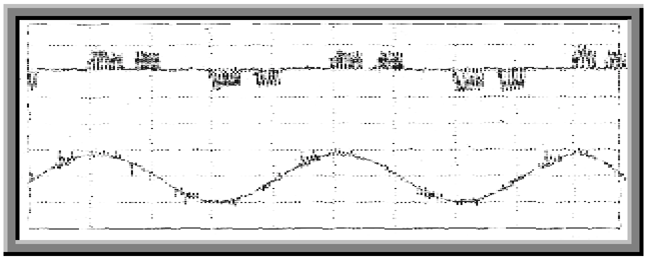

Fig.6 Experimental waweforms at 100 rpm (5 Hz) for no-loaded SM, natural commutation (50 ms/div): upper: motor (inverter) phase current (100 A/div), lower: motor voltage tension (125 V/div).

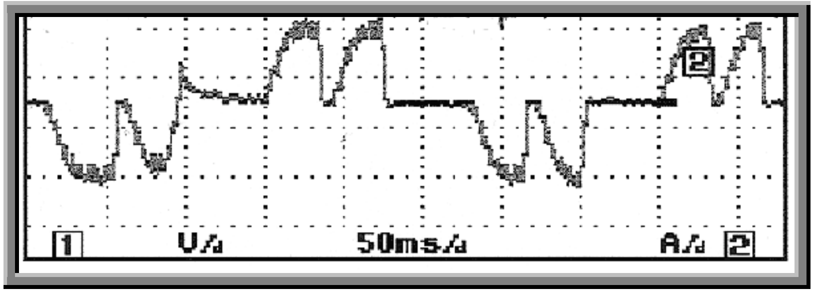

Fig. 7a. Experimental waweform for motor phase current (natural commutation, 400 A/div).

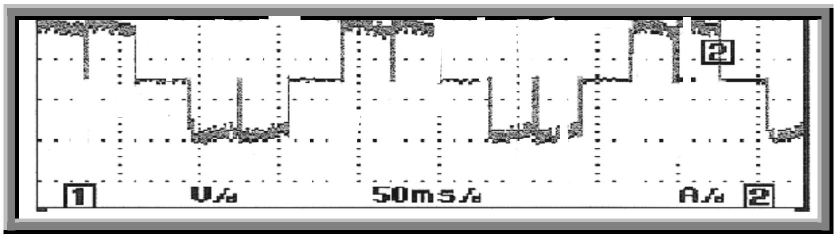

Fig. 7b: Experimental waweform for motor phase current (forced commutation, 400A/div).