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VECTOR CONTROLLED INDUCTION MOTOR DRIVE WITH A GAIN SCHEDULING ADAPTIVE SYSTEM

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1. INTRODUCTION

Nowadays, as a consequence of intense advances of power electronics and microelectronics, the vector controlled induction motor drive is considered to be one of the prime candidates to take the place of dc motor drives [2]. Generally, two types of field oriented control schemes are available, and both indirect [2] and direct [1] field orientation have been successfully established. In both control strategies, the stator current components responsible for the flux and torque production are decoupled.

The absence of field angle sensors and the ease of operation at low speeds compared to the direct vector control scheme has increased the popularity of the indirect vector control strategy. By comparaison, indirect field orientation has relatively simpler hardware and better overall performance.

However, in the indirect vector control. the slip frequency which is necessary for fast decoupling control, is calculated using the value of rotor circuit time constant. When this value changes due to temperature, the decoupling between the control variables is incorrect, and the control system operates in a detuned condition. Therefore, the variations of rotor resistance due to variations of operating temperature influence directly the accuracy of the speed and torque performance both in transient and steady states.

2. PROBLEM STATEMENT AND SOLUTION

To develop a controller that guarantee the performance and stability robustness, the assumption that the motor parameters are known and invariant are not valid. If the position of the rotor flux vector can't be known with accuracy, the transformation of the stator current component references, dependent on the desired values of rotor flux and torque, is not correct and this fact leads to poor dynamic properties. Therefore, much attention has to be given to rotor flux estimators and rotor circuit time constant identification schemes. To solve this problem, many contributions have been made in estimating the value of rotor circuit time constant.

Among the first publications to deal with the problem of parameter adaptation in vector control is the work [5]. The approach is based on the definition of an auxiliary function which appears as a modified expression of the reactive power. This function can be computed on the basis of voltage, current and speed. The comparison between the function computed from the motor and the model signals gives an indication about the deviation of the real rotor time constant. However, no proof of convergence is given and also the differenciation of the current signals is needed. The correct alignment of the rotor flux vector in the model with the actual flux in the machine can be detected by correlation as proposed by [4]. The correlation function is computed from the pseudo-random binary sequence added to the reference value of the d-axis current and the q-axis output of the control system. A nonzero value of the correlation function indicates that there exists a coupling fluxes and discrepancies between the parameters of the model and those of the rotor. The gradient method proposed by [6] is based on a real-time model of the machine and evaluation of the stator current errors. This method gives satisfactory results but can't be used on line since the computational time is about 60 s. A scheme using Kalman filter was proposed by [3] and used by many authors. But, this scheme require considerable computing time, or need a high background computational hardware and software. Some methods based on modern control theory such as model reference adaptation system [12,13,14] and flux observers [15,16] have been presented. These methods are also accomplished by complex hardware and sophisticated calculating algorithms. Furthermore, these methods cannot solve the problem of resistance thermal variations completely.

It is sometimes possible to find auxiliary process variables which correlate well with the changes in process dynamics. It is then possible to eliminate the influences of parameter variations by changing the parameters or the regulators as functions of the auxiliary variables. So, to solve the problem of performance degradation due to parameter variations in an indirect vector control of induction motor, a new approach for estimating induction motor parameters from measured rotor and stator temperatures is proposed. In essence, the approach uses a thermistor to detect temperature, which permits to determine the correct values of stator and rotor resistances. An experimental prototype system has been built for this purpose. In order to investigate the thermal behaviour of the induction motor, a 2.2 kW motor was used for experimental investigation. The machine is discretized by a large number of thermistors, which gives more information about the temperature distribution in the motor.
Applying the rotor resistance identified by the proposed method to the slip calculator and coordinate transformation, an adaptive (gain scheduling) vector control system can be set up.

3. SIMULATION RESULTS

The simulations were performed for an 2.2 kw induction motor. However, as additional simulations have shown, a generalisation of the conclusion to other motors should be possible and justified.
A comparison test has been made to compare the performance of conventional vector control and the gain scheduling adaptive vector control. In this test, the actual rotor resistance was changed. The decoupling control performance with a mismatch in rotor resistance parameter with $R_r^* = 1.5xR$ is demonstrated through computer simulations. In order to examine the effects of parameter variation, the rotor resistance adaptation was included in the first case and not in the other one.

4. CONCLUSION

The variation of rotor resistance with temperature has an important effect on the performance of indirect vector control system. The analysis has shown that the effects include destroying the decoupling of flux and torque, and deviation of the flux and stator current from the desired value.
To solve the above problem, a new approach to estimating rotor resistance via temperature is proposed. The appooach is simple, fast and may be easily implemented in real-time. The method is applicable for the design of gain scheduling ac drives to optimize their performance. The effectiveness is verified by computer simulation.

5. REFERENCES

[1] Blaschke F. *The principle of field orientation as applied to the new Transvector closed-loop control system for rotating field machines.* Siemens Rev., May 1972, vol.39, pp.217-220.

[2] Bose B.K. *Recent advances in power electronics.* IEEE Trans.Power Electr., Jan. 1992, vol.7, n°1, pp.2- 16..

[3] Zai L.C., Lipo T.A. *An extended Kalman filter approach to rotor time constant measurement in PWM induction motor drives.* IEEE Trans. Ind. Appl., Oct.1987, vol.1, pp.177-183.

[4] Gabriel R., Leonhard W., Norby C. *Field oriented control of a standard AC motor using microprocessors.* IEEE Trans. Ind. Appl., Mar./Apr.1980, vol.16, n°2, pp. 186-192.

[5] Garces L.J. *Parameter adaption for speed-controlled static AC drive with a squirell-cage induction motor.* IEEE Trans. Ind. Appl., Mar./Apr. 1980, vol.16, n°2, pp. 173-178.

[6] Holtz J., Thimm T. *Identification of the machine parameters in a vector-controlledinduction motor drive.* IEEE Trans. Ind. Electr., 1991, vol.27, n°6, pp.1111-1118.

[7] Nordin K.B.,Novotny D.W., Zinger D.S. *The influence of motor parameter deviations in feedforward field orientation drive systems.* in Conf. Rec. 1984 IEEE IAS Annu. Mtg., pp.525- 531.

[8] Marino R.,Peresada S., Tomei P. *Exponentially convergent totor resistance estimation for induction motor.* IEEE Trans. Ind. Electr., Oct. 1995, vol.42, n°5, pp.508-515.

[9] De Doncker R.W. *Parameter sensitivity of indirect Universal indirect field-oriented controllers.* IEEE Trans. Pow. Electr., July 1994, vol.9, n°4, pp.367-376.

[10] Tungpimolrut K., Peng F.Z., Fukao T. *Robust vector control of induction motor without using stator and rotor circuit time constants.* IEEE Trans. Ind. Appl., Sept./Oct.1994, vol.30, n°5, pp.1241-1246.

[11] Atkinson D.J., Finch J.W., Acarnley P.P. *Estimation of rotor resistance in induction motors.* IEE Proc. Electr. Power Appl., Jan. 1996, vol.143, n°1, pp.87-94.

[12] Krishnan R., Bharadwaj A.S. *A review of parameter sensitivity and adaptation in indirect vector controlled induction motor drive systems.* IEEE Trans. Pow. Electr., Oct. 1991, vol.6, n°4, pp.695-703.

[13] Ohtani T., Takada N., Tanaka K. *Vector control of induction motor without shaft encoder.* IEEE Trans. Ind. Appl., Jan./Feb. 1992, vol. 28, n°1, pp.157-164.

[14] Stephan J., Bodson M., Chiasson J. *Real-time estimation of the parameters and fluxes of induction motors.* IEEE Trans. Ind. Appl., May/June 1994, vol.30, n°3, pp.746-759.

[15] Wijesundera D.S., Jackson R.D., *Observers for field-oriented control of induction motors drives.* IEE Proc.-B, July 1992, vol.139, n°4, pp.381-386.

[16] Ho E., Sen P.C. *High-performance decoupling control techniques for various rotating field machines.* IEEE Trans. Ind. Electr., Feb.1995, vol.42, n°1, pp.40-49.