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Simulation Study of Enhanced Performance Three Phase Induction Motor Drive Using PI Controller

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Abstract

High dynamic performance, which is obtained from dc motors, became achievable from induction motors with the recent advances in power semiconductors, digital signal processors and development in control techniques. By using field oriented control, torque and flux of the induction motors can be controlled independently as in dc motors. The control performance of field oriented induction motor drive greatly depends on the correct stator flux estimation. In this thesis voltage model is used for the flux estimation. Stator winding resistance is used in the voltage model. Also leakage inductance, mutual inductance and referred rotor resistance values are used in vector control calculations.

1. Introduction

The electrical DC drive systems are still used in a wide range of industrial applications, although they are less reliable than the AC drives. Their advantage consists in simple and precise command and control structures. The AC drives, sometimes more expensive but far more reliable. The design of a control system is realized in two important steps:

1. The drive system has to be converted into a mathematical model, in order to accomplish the analysis and the evaluation of the system.
2. The imposed response of the drive system is obtained through an optimal regulator, when external perturbations are present.

The induction motors are relatively cheap and rugged machines because their construction is realized without slip rings or commentators. These advantages have determined an important development of the electrical drives, with induction machine as the execution element, for all related aspects: starting, braking, speed reversal, speed change, etc. The dynamic operation of the induction machine drive system has an important role on the overall performance of the system of which it is a part.

2. Classification of the control techniques

Another classification of the control techniques for the induction machine is made from the point of view of the controlled signal:

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2.1 Scalar control

2.1.1 Voltage/frequency (or v/f) control;
2.1.2Stator current control and slip frequency control. These techniques are mainly implemented through direct measurement of the machine parameters.

2.2 Vector control

2.2.1 Field orientation control (FOC)

2.2.1.1 Indirect method
2.2.1.2 Direct method

2.2.2 Direct torque and stator flux vector control.

3. Analogy of induction motor with DC drive

Initially the DC drives were used for variable speed control because they could easily achieve a good torque and speed response with high accuracy. Field orientation of the motor is achieved using a mechanical commutator with brushes [19]. In DC, torque is controlled using the armature current and field current. The main drawback of this technique is the reduced reliability of the DC motor – the fact that brushes and commutators wear down and need regular servicing; that DC motors can be costly to purchase; and that they require encoders for positional feedback.

With this technique, sometimes known as scalar control, the field orientation of the motor is not used. Instead, the frequency and the voltage are the main control variables and are applied to the stator windings. The status of the rotor is ignored, meaning

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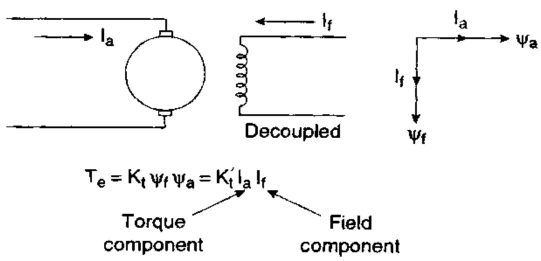
that no speed or position signal is fed back. The drive is therefore regarded as an open-loop drive. This type of drive is suitable for applications such as pumps and fans, which do not require high levels of accuracy or precision.



$$T_e = K_t \psi_f \psi_a = K_t' I_a I_f$$

Fig: 1. DC drive analogy of induction motor

We try to control induction motor drive in this way so that we can control speed and flux independently and can have enhanced performance drive.

4. Various type of controls available for induction motor drive

4.1 AC Drives, flux vector control using PWM

Here, field orientation is achieved by mathematical modelling using microprocessors and feedback of rotor speed and angular position relative to the stator field by means of an encoder. This results in a drive with greater stability and capable of fast torque response and accurate speed control. But the drawback is the need for the encoder, which reduces drive system reliability and adds cost[4]. The controlling variables in a DC drive for torque are armature current and field current, and armature voltage for torque. AC drives using the PWM principle; however, use voltage and frequency as the controlling variables and these are controlled by a device called a modulator. A modulator adds considerable delay in the responsiveness of a motor to changes in torque and speed. Furthermore, with flux vector AC drives, a tacho-generator or position encoder is invariably needed to obtain any real degree of accuracy. Such devices are costly and compromise the simplicity of the AC induction motor.

4.2 AC Drives, sensor less flux vector

The flux vector controlled drive with encoder feedback does offer very high levels of performance across a wide power range and should not be confused with sensor less vector - or open loop vector - drives, which offer performance only slightly superior to that of a standard inverter using scalar control.

5. Three phase to two phase conversion

To control induction motor drive independently, we need to have decoupled components of toque and speed affecting voltage and current [19].

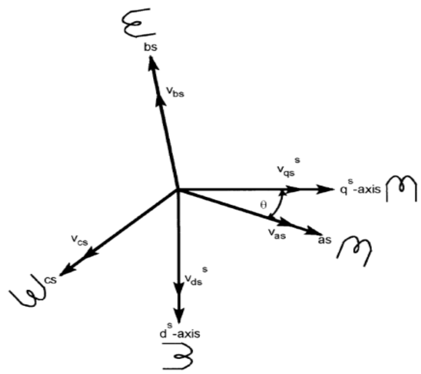


Fig: 2. Three phase to two phase transformation

We can achieve the above by using these equations

$$\begin{bmatrix} V_{as} \\ V_{bs} \\ V_{cs} \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta & 1 \\ \cos(\theta-120) & \sin(\theta-120) & 1 \\ \cos(\theta+120) & \sin(\theta+120) & 1 \end{bmatrix} \begin{bmatrix} V_{qs}^s \\ V_{ds}^s \\ V_{os}^s \end{bmatrix}$$

To find the inverse transformation, the equations are as follows

$$\begin{bmatrix} V_{qs}^s \\ V_{ds}^s \\ V_{os}^s \end{bmatrix} = \frac{2}{3} \begin{bmatrix} \cos\theta & \cos(\theta-120) & \cos(\theta+120) \\ \sin\theta & \sin(\theta-120) & \sin(\theta+120) \\ 0.5 & 0.5 & 0.5 \end{bmatrix} \begin{bmatrix} V_{as} \\ V_{bs} \\ V_{cs} \end{bmatrix}$$

6. Vector control of induction motor

The vector control analysis of an induction motor allows the decoupled analysis where the torque and the flux components can be independently controlled (just as in dc motor). This makes the analysis easier than the per phase equivalent circuit. The vector control is a type of control where decoupled control of speed and torque is carried out. By decoupled control we mean that variation of speed does not affect the torque and variation of torque does not affect the speed.

The high quality of the dynamic performance of the separately excited DC motor is a consequence of the fact that its armature circuit and the field circuit are magnetically decoupled. In a DC motor, the mmf produced by the field current and the mmf produced by the armature current are spatially in quadrature. Therefore there is no magnetic coupling between the field circuit and the armature circuit. Because of the repetitive switching action of the commutator on the rotor coils as the rotor rotates, this decoupling continues to exist irrespective of the angular position and speed of the rotor. This makes it possible to effect fast current changes in the armature circuit, without being hampered in this by the large inductance of the field circuit. Since the armature current can change rapidly, the machine can develop torque and accelerate or decelerate very quickly when speed changes are called for, attain the demanded speed in the fastest manner possible. As in the DC motors, in AC motors also, the torque production is the result of the interaction of a current and a flux. But in the AC induction motor, in which the power is fed on the stator side only, the current responsible for the torque and the current responsible for producing flux are not easily separable. The underlying principle of vector control is to separate out the component of the motor current responsible for producing the torque and the component responsible for producing the flux in such a way that they are magnetically decoupled, and then control each independently, in the same way as is done in a separately excited DC motor. Induction motors are the most widely used electrical motors due to their reliability, low cost and robustness. However, induction motors do not inherently have the capability of variable speed operation. Due to this reason, earlier dc motors were applied in most of the electrical drives. But the recent developments in speed control methods of the induction motor have led to their large scale use in almost all electrical drives. Out of the several methods of speed control of an induction such as pole changing, frequency variation, variable rotor resistance, variable stator voltage, constant V/f control, slip recovery method etc., the closed loop constant V/f speed control method is most widely used. In this method, the V/f ratio is kept constant which in turn maintains the magnetizing flux constant so that the maximum torque remains unchanged. Thus, the motor is completely utilized in this method [12]. During starting of an induction motor, the stator resistance and the motor inductance (both rotor and stator) must be kept low to reduce the steady state time and also to reduce the jerks during starting. On the other hand, higher value of rotor resistance leads to lesser jerks while having no effect on the steady state time.

7. Simulation study of vector control of three phase induction motor using PI controller

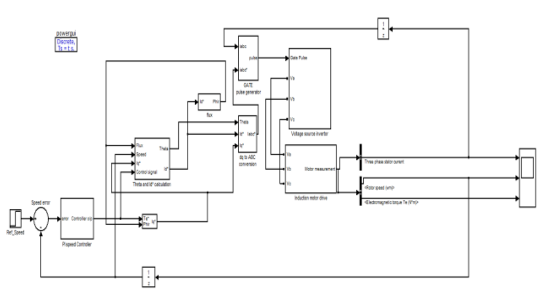


Fig: 3. Simulation block diagram

Simulation of vector control of induction motor is carried out and variation of speed with time, torque

7.1 Variation of torque with time

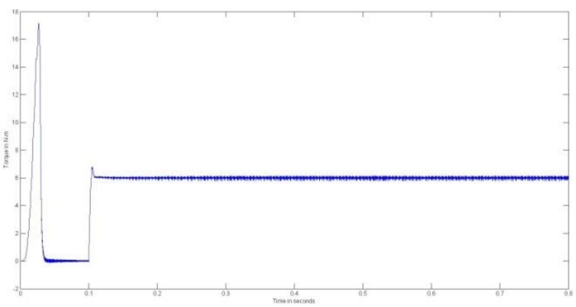


Fig: 4. Variation of torque with time

7.2 Variation of stator current with time

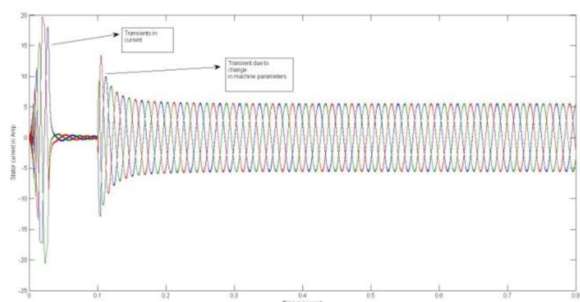


Fig: 5. Variation of stator current with time

7.3 Actual and reference speed

The diagram depicts the variation of actual speed of rotor and command speed.
Reference speed=100rpm

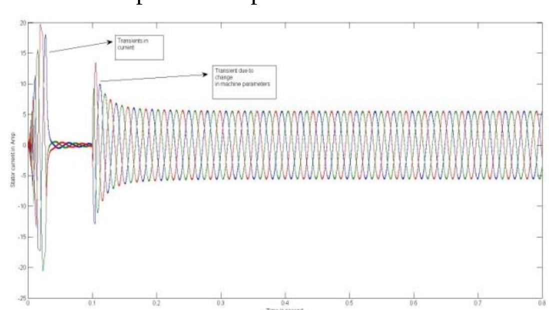


Fig: 6. Variation of stator current with time

References

[1] Novotny, D. W., A comparative study of variable frequency drives for energy conservation applications, University of Wisconsin Report #/ECE-81-4, 1981.

[2] Davis, R. M., Inverter-fed induction machines, Proc. of Drives/Motors/Controls '82, Leeds, England, pp. 66-75, 1982

[3] Lipo, T. A., and F. G. Turnbull, "Analysis and comparison of two types of square wave inverter drives, 2, 137-147, 1975

[4] IEEE Trans, on Industry Applications, IA-11Houldsworth, J. A., and W. B. Rosink, Introduction to PWM speed control system for 3-phase AC motors, Electronics Components and Applications, 2(2), 1980

[5] Bowes, S. R., New sinusoidal pulse width-modulated inverter, Proc. IEE, 122, 1279-1285, 1975

[6] Lorenz, R. D., Microprocessor control of motor drives and power converters, Microprocessor Motion Control of AC and DC Drives, IEEE Tutorial Course Note Book from 1991, '92 & '93 IEEE, IAS Annual Meetings, IEEE Publishing Services #THO587-6.

[7] Lorenz, R. D., K. Van Patten, High resolution velocity estimation," IEEE Trans. In. Appl., Vol. 27, no. 4, pp. 701-708, 1991

[8] Schmidt, P. B., and R. D. Lorenz, Design principles and implementation of acceleration feedback to improve performance of DC drives, IEEE Trans. Ind. Appl., 594-599, 1992

[9] Moatemri, M. H., P. B. Schmidt, R. D. Lorenz, Implementation of a DSP-based, acceleration feedback robot controller: Practical issues and design limits, IEEE-IAS Conf. Rec., 1425-1430, 1991

[10] Hasse, K., Zur dynamik drehzahlgeregelter antriebe mil stromrichter-gespeisten asynchron-kurzschlublaufermaschinen, Ph.D. dissertation, Tech. Hochschule Darmstadt, 1969

[11] Blaschke, F., The principle of field orientation as applied to the new transvec-tor closed loop control for rotating machines, Siemens Review, 39(5), 217-220, 1972.

[12] de Doncker, R., D. W. Novotny, The universal field oriented controller, IEEE-IAS Annual Meeting Conf. Rec., 450-456, 1988

[13] Xu, X., D. W. Novotny, Selection of the flux reference for induction machines in the field weakening region, IEEE Trans. Ind. Appl., 28(6), 1353-1358, 1992

[14] Nordin, K. B., D. W. Novotny, D. S. Zinger, The influence of motor parameter deviations in feed forward field orientation drive systems, IEEE-IAS Trans., IA-21, 4, 1009-1015, 1985

[15] Lorenz, R. D., D. W. Novotny, Optimal utilization of induction machines in field oriented drives, J. Electrical and Electronic Engin., Australia, 10(2), 95-100, 1990

[16] Wallace, I. T., D. W. Novotny, R. D. Lorenz, D. M. Divan, Increasing the dynamic torque per ampere capability of induction machines," IEEE-IAS Con/.Rec., 14-20, 1991

[17] Brod, D. M, D. W. Novotny, Current control of VSI-PWM inverters, IEEE Trans, fnd. Appl., IA-21, 4, 562-570, 1985

[18] Brod, D. M., Current control of VSI-PWM inverters," M.S.E.E, Thesis University of Wisconsin, 1984

[19] Bimal K. Bose, Modern power electrics and AC Drives, 2011

[20] Salama, S., S. Lennon, Overshoot and limit cycle free current control method for PWM inverters," European Power Electronics Conference Florence, 3-247-3-251, 1991.

[21] Schauder, C. D., R. Caddy, Current control of voltage-source inverters for fast four-quandrant drive performance, IEEE Trans. Ind. Appl., IA-18(2), 163-171, 1982

[22] Rowan, T., R. Kerkman, A new synchronous current regulator and an analysis of current-regulated PWM inverters, IEEE Trans. Ind. Appl., IA-22, 4, 678-690, 1986

[23] Holtz, J., S. Stated, A predictive controller for the stator current vector of AC machines fed from a switched voltage source, Int. Power Electronics Conf., Tokyo, 1665-1675, 27-31, 1983

[24] Nabae, A., S. Ogasawara, H. Akagi, A novel control scheme for current-controlled PWM inverters, IEEE Trans. Ind. Appl., IA-22, 4, 697-701, 1986

[25] Habetler, T. G., D. M. Divan, Performance characterization of a new, discrete pulse modulated current regulator, IEEE-IAS Annual Meeting Conf. Rec., 395-403, 1988

[26] Bocker, J., J. Janning, Discrete-time flux observer for PWM fed induction motors, Proc. EPE, Florence, 171-176, 1991

[27] Bottura, C. P., J. L. Silvino, P. Resende, A flux observer for induction machines based on a time-variant discrete model, Proc. APEC, 1991

[28] Franceschini, G., C. Tassoni, A. Vagati, Flux estimation for induction servo motors, Proc. IPEC-Tokyo, 1227-1234, 1990