Direct Torque Control for Three Phase Induction Motor without AC Phase Current Sensors

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Abstract

The paper present A novel low-cost and simple phase-current reconstruction algorithm for three-phase induction motor (IM) under direct torque control (DTC) using the information obtained from only one shunt resistor (in series with low side switches in a conventional three-phase inverter). The aim is to develop a low-cost high-performance IM drive. The proposed algorithm is robust and very simple. It uses the dc current to reconstruct the stator currents needed to estimate the motor flux and the electromagnetic torque. A theoretical concept is developed, the modified look-up table is presented, and current-access tables are designed and used in the phase-current reconstruction. The limitations are also studied and presented. Simulation results are given to prove the ability of the proposed scheme of reproducing the performances of a traditional DTC IM drive.

Keywords- *three-phase induction motor; Direct torque control; pwm control; speed control; current control; MATLAB Simulink.*

I. INTRODUCTION

A Direct torque control (DTC) of induction motors has gained popularity in industrial applications mainly due to its simple control structure from its first introduction in 1986. An electric motor drive controlled with the DTC technique exhibits performance similar to a field-oriented drive despite a simpler structure. In fact, a DTC scheme achieves the closed-loop control of the motor stator flux and the electromagnetic torque without using any current loop or shaft sensor. Many researchers are interested in this control technique because of its wide area applications used with various ac machine types as induction motor, PMSM, PM Brushless and reluctance motor.

II. PROPOSED SYSTEM

The proposes some interesting approaches based on the estimation of the motor phase currents using prediction-correction algorithms, thus introducing additional computational burden to the drive system. Only a few papers deal with the DTC technique for induction motor and PMSM. The algorithm used in these works operates in two stages. First, it predicts the stator currents from a model of the motor and then adjusts the prediction on the basis of the sensed dc-link current. This algorithm requires an additional computation burden and the knowledge of the stator transient inductance. In this paper, we propose a low-cost single shunt current sensor induction motor (IM) DTC. The stator flux vector and the electromagnetic torque are directly calculated from the voltage and the current derived from a single dc-link voltage sensor (simple voltage divider) and a single dc-link current sensor (simple shunt resistor). The phase currents are estimated by two dc-link current measurement processes. This algorithm does not require additional computation burden or other motor parameter knowledge.

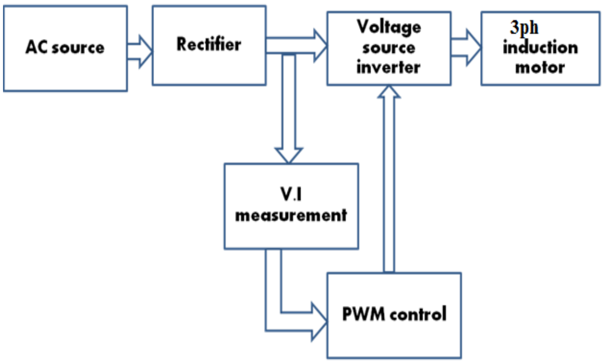

Fig.1, Block Diagram of the Proposed System

The error and change in error are given as inputs to the controller. The output of the controller is denoted as duty cycle. The input and output gain of the controller can be estimated by simulation. The ANN controller can reduce the error to zero by changing the duty cycle of the switching signal [4, 5 & 6].

III. MATHEMATICAL MODELING OF INDUCTION MOTOR

A. PMDC Motor

There are made several assumptions to simplify thinking over the three-phase induction motor: the three-phase motor is symmetrical, only a basic harmonics is taking in to account, the spatially distributed stator and rotor windings are replaced by a concentrated coil, an anisotropy effects, magnetic saturation, iron loses and eddy currents are not taking into considerations, the coil resistance's and reactance's are taking to be constant, in many cases, especially when considering steady states, the currents and voltages are taking to be sinusoidal.

There can be written a set of equations for such idealized motor model as follows:

$$U_A = I_A R_S + \frac{d\psi_A}{dt} \tag{3.5}$$

$$U_B = I_B R_S + \frac{d\psi_B}{dt} \tag{3.6}$$

$$U_C = I_C R_S + \frac{d\psi_c}{dt} \tag{3.7}$$

A further simplification of the mathematical considerations the motor model equations can be written in terms of space vectors, what give the equations of the motor as follows:

$$U_S = R_S I_S + T_N \frac{d\psi_s}{dt} \tag{3.8}$$

$$U_r = R_r I_r + T_N \frac{d\psi_r}{dt} \tag{3.9}$$

$$\psi_s I_s + M e^{j\gamma_m} I_r \tag{3.10}$$

$$\psi_r = L_r I_r + M e^{-j\gamma_m} I_s \tag{3.11}$$

Where the state space vector is defined as:

$$k_s = \frac{2}{3}[1.k_A(t) + a.k_B(t) + a^2.k_c(t)] \tag{3.12}$$

Where $1, a, a^2$ -complex vectors, $k_A(t), k_B(t), k_c(t)$ -temporary effective value of phase currents, voltages or fluxes, 2/3 - normalization constant.

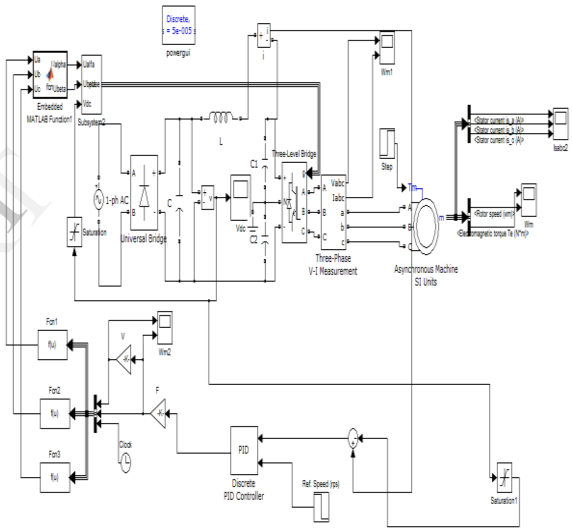

Fig. 2, Simulink model for the induction motor

B. AC induction motor

AC Induction motors are the most widely used motors in industrial motion control systems, as well as in home appliances thanks to their reliability, robustness and simplicity of control. Until a few years ago the AC motor could either be plugged directly into the mains supply or controlled by means of the well-known scalar V/f method. When power is supplied to an induction motor at the recommended specifications, it runs at its rated speed.

The method, even simple speed variation is impossible and its system integration is highly dependent on the motor design. However many applications need variable speed operation. The scalar V/f method is able to provide speed variation but does not handle transient condition control and is valid only during a steady state. This method is most suitable for applications without position control requirements or the need for high accuracy of speed control and leads to over-currents and over-heating, which necessitate a drive which is then oversized and no longer cost effective.

The last few years the field of electrical drives has increased rapidly due mainly to the advantages of semiconductors in both power and signal electronics and culminating in powerful microcontrollers and DSPs. These technological improvements have allowed the development of very effective AC drive control with lower power dissipation hardware and increasingly accurate control structures. The electrical drive controls become more accurate with the use of three-phase currents and voltage sensing. This application note describes the most efficient scheme of vector control: the Indirect Field Oriented Control (IFOC).

IV. PWM Control

A Pulse-width modulation (PWM), or pulse-duration modulation (PDM), is a commonly used technique for controlling power to inertial electrical devices, made practical by modern electronic power switches. The average value of voltage (and current) fed to the load is controlled by turning the switch between supply and load on and off at a fast pace. The longer the switch is on compared to the off periods, the higher the power supplied to the load. The PWM switching frequency has to be much faster than what would affect the load, which is to say the device that uses the power.

The switching have to be done several times a minute in an electric stove, 120 Hz in a lamp dimmer, from few kilohertz (kHz) to tens of kHz for a motor drive and well into the tens or hundreds of kHz in audio amplifiers and computer power supplies. The term duty cycle describes the proportion of 'on' time to the regular interval or 'period' of time; a low duty cycle corresponds to low power, because the power is off for most of the time. Duty cycle is expressed in percent, 100% being fully on.

The main advantage of PWM is that power loss in the switching devices is very low. When a switch is off there is practically no current, and when it is on, there is almost no voltage drop across the switch. Power loss, being the product of voltage and current, is thus in both cases close to zero. PWM also works well with digital controls, which, because of their on/off nature, can easily set the needed duty cycle. PWM has also been used in certain communication systems where its duty cycle has been used to convey information over a communications channel.

V. RESULTS AND DISCUSSION

Using MATLAB Simulink toolbox, the designed Neuron controller was tested. The simulation results were compared with PI controller. The simulated graph of speed variation of the motor for a set speed changes are shown in the following figure.

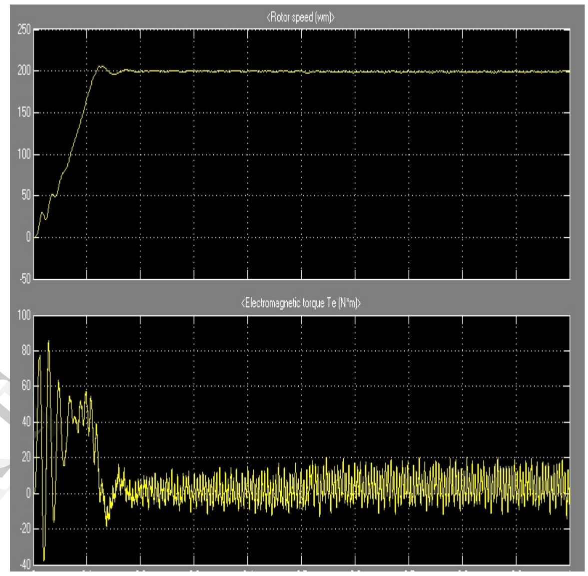

Fig.3, Simulation output for Rotor Speed, Vs Torque

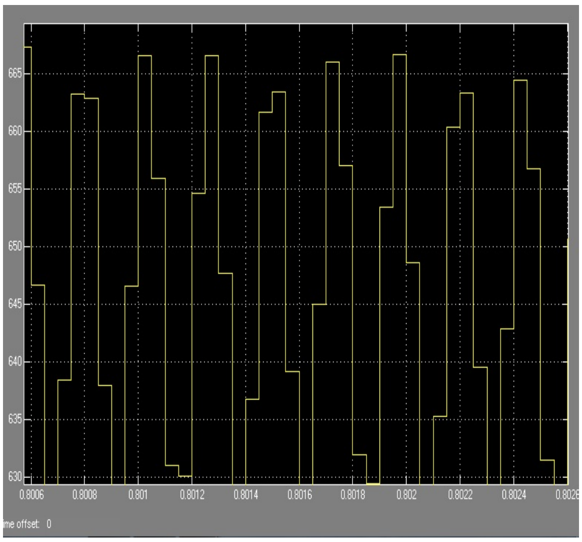

Fig. 4, Simulation Input DC Voltage

VI. CONCLUSION

A project low-cost DTC scheme for IM drives has been presented using a single shunt inductor inserted in the dc-line path. The effectiveness of the proposed DTC algorithm using a single shunt inductor was verified by computer simulations and experimentally on a three-phase induction motor, rated at 1.1 kW. The results presented have demonstrated that beyond the small reduction of the motor speed range, very close to the measured phase currents, with an excellent performance of the drive system, nearly identical to that achieved with the traditional DTC scheme.

VII. REFERENCES

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