Design, Simulation and Implementation of Speed Control of CSI Fed Single Phase Induction Motor with Constant Slip

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Abstract: The objective of this paper is to control the torque of the SPIM by controlling the currents of both stator windings aiming to improve the efficiency. This proposed strategy assures constant slip for varying loads. If slip increases, rotational speed decreases. It causes losses. Thereby efficiency is reduced. But here since slip is limited, it assures efficient operation on SPIM and to prevent excessive stator line currents caused by large slip variations. The phase difference angle between two reference currents has to be maintained constant at 90°. V/f control with constant slip speed operation is used for control purpose. Simulation had been carried out using MATLAB 7.2 software. The hardware model is fabricated to validate the simulation results.

Key words: Single Phase Induction Motor % Vector Control Technique % DSP processor

INTRODUCTION

The single-phase induction motor (SPIM) can be considered one of most widely used types of machine in the world. It is usual to find it operating several appliances in houses, offices, shoppings, farms and industries. With the advent of low-cost power semiconductor devices, the use of variable speed drives has become interesting in many applications of SPIM's, such as blowers, fans, compressors and pumps [1].

The SPIM is basically constituted by a squirrel-cage rotor and two stator windings displaced 90° in space, known as main and auxiliary windings. Usually, these windings have different impedances. If the main winding is fed by a single-phase source, the produced magnetic field is pulsating and stationary and a starting torque is not developed. To start a SPIM, a second phase must be simulated using the auxiliary winding, which is often open by a centrifugal switch when the rotor reaches 60% to 80% of rated speed. In general, a series capacitor is connected with the auxiliary winding to improve the starting [2]. In many applications, the auxiliary winding and a series capacitor are maintained at running operation to provide higher torque and to overcome any drawbacks related to pulsating torque, such as excessive power loss [3-4].

An easy way to regulate the speed of SPIM is to vary the effective voltages applied to stator windings. However, the speed range obtained by this method is very restricted. A more effective manner to control the SPIM speed is by adjusting of the stator frequency. In this case, one needs to establish a convenient control law to provide a constant level of magnetization. In general, the magnetizing currents on SPIMs are fixed using the scalar control law "Volts per Hertz" (V/f). The drawback of this method is that V/f control does not assure a constant slip for varying loads. Another method, the adjustment of the phase-difference angle (PDA) between stator voltages is rarely used to control the speed of SPIM drives [4]. Although efficient, it presents a nonlinear behavior.

In this paper, a new control strategy is proposed for adjustable speed drive for SPIMs. The torque is controlled by adjusting the currents of both stator windings, aiming to improve the machine efficiency. The proposed control law provides an adequate level of magnetization, assuring a constant slip for varying loads. Simulation results are used to verify the performance of the proposed control strategy. A hardware model is fabricated to validate the simulation results [5-7].
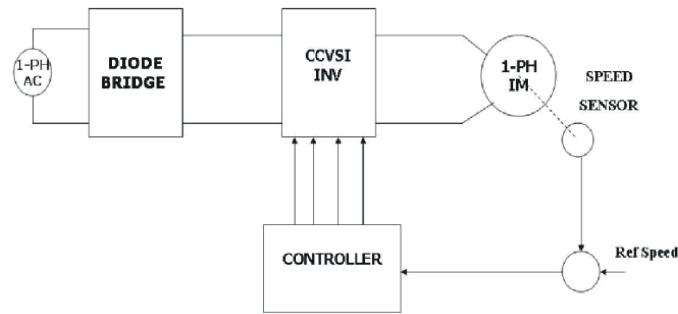
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Fig. 1: Block diagram

Block Diagram: The block diagram of the circuit shown in Fig. 1 consists of diode bridge rectifier, current controlled voltage source inverter (CCVSI), single phase induction motor, speed sensor, controller block. Single phase ac supply is given to the diode bridge rectifier. It converts ac into dc. The output of the diode bridge is given to the CCVSI. It can also be called as current source inverter. The output of this is then given to the single phase induction motor. Speed of this motor is measured using speed sensor and then compared with the reference speed. Thus the speed error is generated. This is given to the vector controller block [8]. PI controller is used in this block. Actual currents of the motor is measured and that is also given as a feedback to the controller block. It generates control signals which are used to control the switches of the inverter. Thus torque of the single phase induction motor is controlled.

Simulation Diagram: As per the block diagram, in Fig. 2 motor is fed from the universal bridge. Capacitors act as filters as well as voltage doublers.

Fig. 3 shows the control circuit diagram. This vector controller consists of the following blocks.

Ϲ   Desired I_d calculation
Ϲ   Desired I_q calculation
Ϲ   Desired calculation
Ϲ   DQ to AB transformation
Ϲ   Current regulator block

Scalar control such as the constant V/Hz method when applied to an AC IM is relatively simple to implement. However, it gives sluggish response because of the inherent coupling effect due to torque and flux beings functions of current and frequency. Vector control decouples the vectors of field current and armature flux so that they can be controlled independently to provide fast transient response.

Actual speed of the motor is measured and then compared with reference speed, thus error signal is generated. It is given to the PI controller which generates reference torque command. In PI controller torque command can be set. Depending on the torque command, reference torque value is generated [9-10].

$$w_e - w_r = (r_r / l_r) * (i_{qs} / i_{ds})$$

From the above relation, for a constant load torque, q axis current and d axis currents are constant and also motor parameters r_r and l_r are constant. Thereby slip can be maintained constant.

Since slip magnitude is limited, it assures a efficient operation on SPIM and to prevent excessive stator line currents caused by large slip variations.

Desired I_d Calculation: Flux is kept constant. I_d, d axis current is calculated using the below relation from mutual inductance of the motor, L_m

$$I_d = M_r / L_m$$

Desired I_q Calculation: Desired q axis current I_q is calculated from flux and reference torque value using the formula,

Desired Calculation: Angular speed is the rate of change of field angle. So, by integrating the angular speed we get the field angle. Electrical angle, = (wm + wr).

DQ to AB Transformation: Reference currents are generated from q axis current, flux and actual motor speed.

Current Regulator Block: Reference currents are compared with the actual currents and the pulses for the switches of the inverter are generated. Here 0.1 is set as hysterisis bandwidth in hysterisis current regulator.
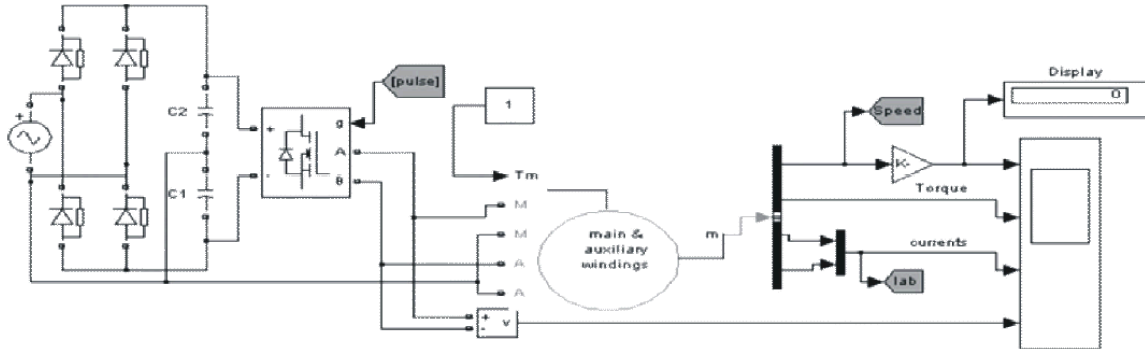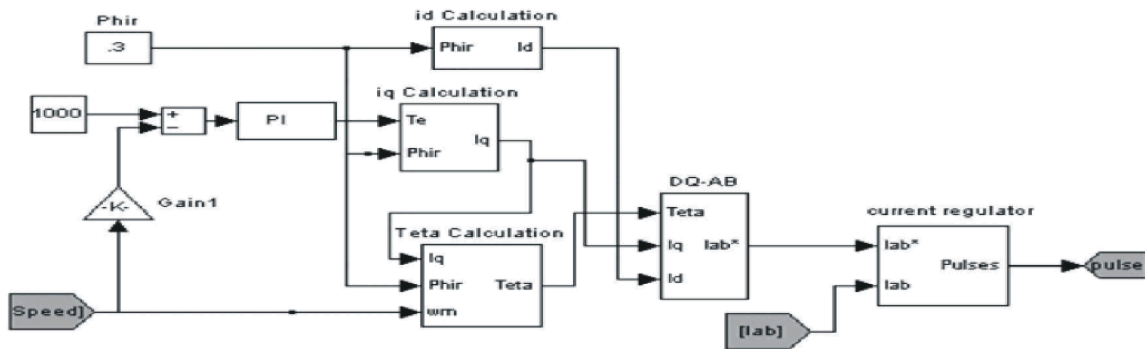
Fig. 2: Power circuit diagram
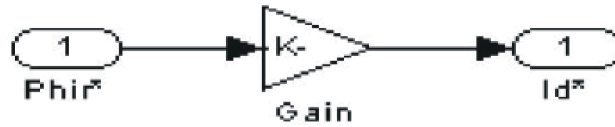

Fig. 3: Control circuit diagram

Fig. 4: Desired I_d calculation

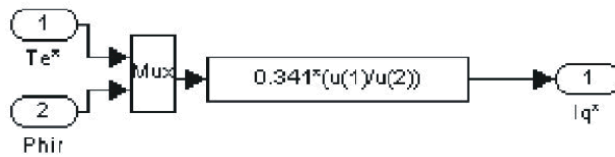$$I_q = 0.341 * T_e / \Phi_r$$

Fig. 5: Desired I_q calculation

$$\omega_r = \frac{L_m * I_q}{T_r * \Phi_r}$$
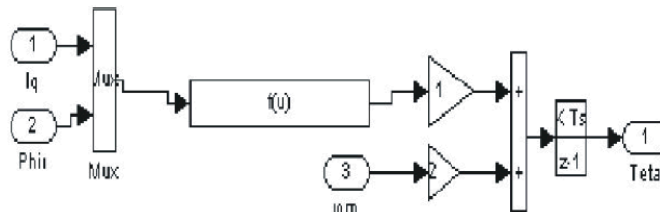
$$T_r = L_r / R_r$$
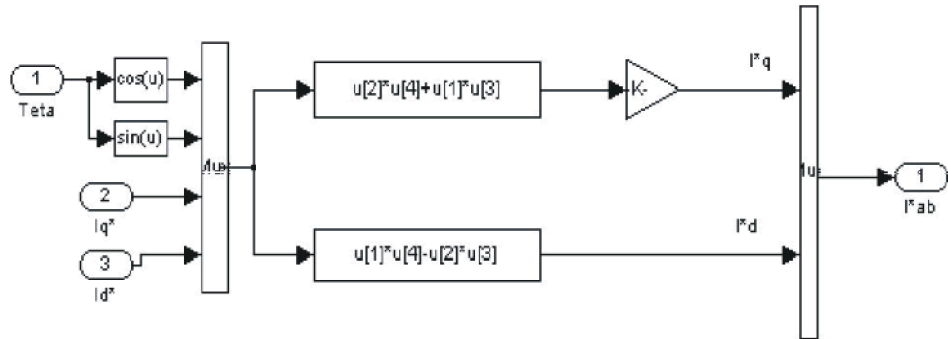

Fig. 6: Desired calculation
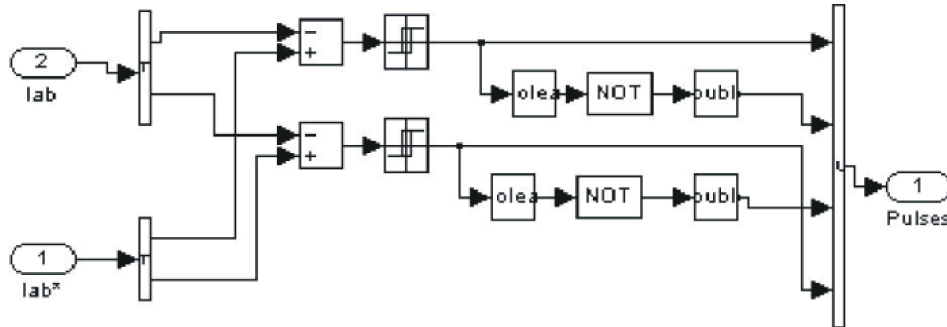
Fig. 7: DQ to AB transformation
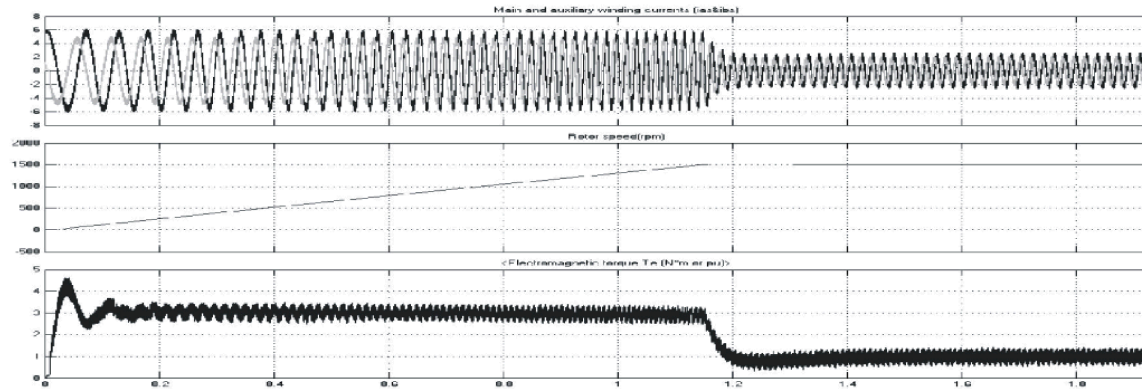

Fig. 8: Current regulator block

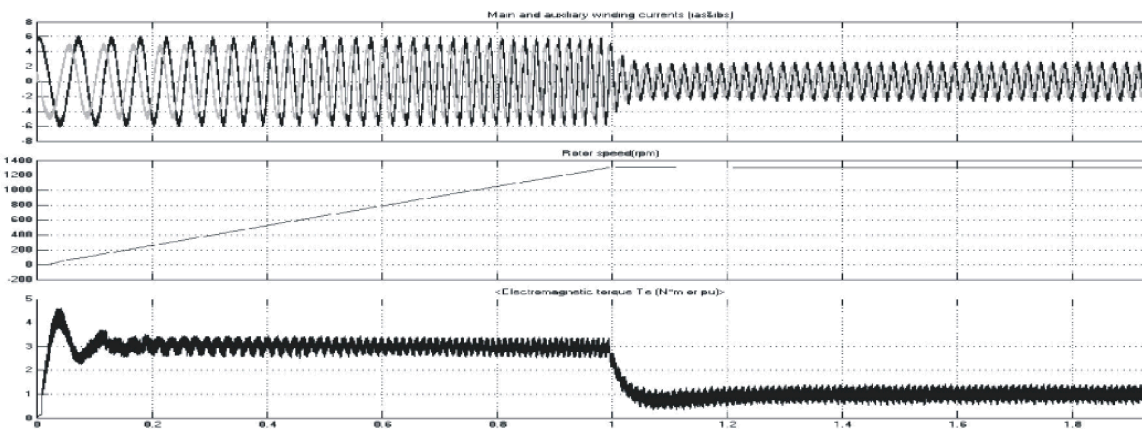Fig. 9: For ref. speed = 1500 rpm
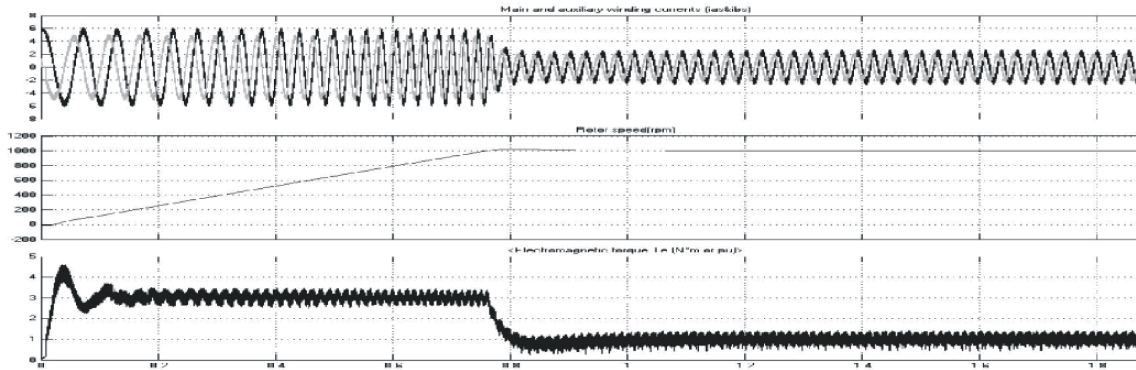

Fig. 10: For ref. speed = 1300 rpm

Fig. 11: For ref. speed = 1000 rpm

Simulation Result: For ref. Speed 1500rpm, main and auxillary winding currents flowing through the motor, speed and torque of the motor are shown in Fig. 9.

For ref. Speed 1300rpm, main and auxillary winding currents flowing through the motor, speed and torque of the motor are shown in Fig. 10.

For ref. Speed 1000rpm, main and auxillary winding currents flowing through the motor, speed and torque of the motor are shown in Fig. 11.

Hardware Implementation: In this proposed control strategy, vector control part is written in mneumonics and can be implemented on a laboratory experimental IM drive using a 16-bit fixed point digital signal processor, TMS320C240. Using optical sensor MOC7811, the actual speed of the motor is measured and the output of this sensor is given to frequency to voltage converter KA331. From this we can get voltage equivalent to speed [9-13].
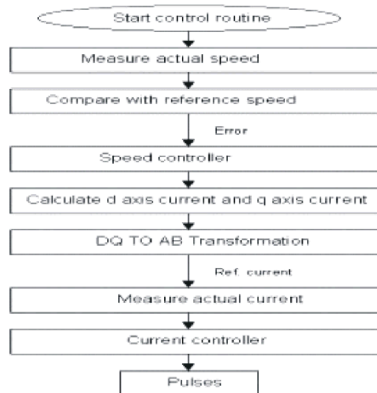
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