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# Induction Motor Drive Variable Speed and Torque Control Using DC Link

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**Abstract:** ***This paper presents a new control strategy for three-phase induction motor which overcome the limitation (i.e. sluggish/ slow response) of volts per hertz controlled industrial drives and provide independent speed & torque control loops and the current regulation. Induction motors are the most frequently used machines in different electrical drives. About 80% of all industrial loads utilize induction motors for various applications which require speed control for its implementation. Speed control of an induction motor requires position feedback information from an encoder, or a hall sensor to a controller unit. These feedback signals, which often pickup noise due to electromagnetic interference, can change the performance of the motor control system. In this project the feedback signals like current and speed are not taken directly from the motor side, instead it is estimated from the current and voltage measured from the dc link. The phase voltages and line currents are reconstructed from the measured dc link current and voltage. An algorithm is used to reconstruct the voltage and current.The inputs to this algorithm are the reconstructed waveforms of stator currents and voltages obtained from the dc link and not measured directly on stator side which avoid the noise . It also reduces the use of mechanical sensor as the rotor speed is not measured directly. The proposed drive thus requires only one sensor in the dc link to implement the close-loop speed and torque control of a three-phase induction motor which is simulated using MATLAB/ Simulink software.***

**Keywords:** Speed control, estimation, dc link, reconstruction, three-phase induction motor.

## 1. Introduction

A three-phase motor is not the best example of speed control application but using modern speed control technique it is use as good speed control drives. There are many technique of speed control of induction motor from stator as well as from rotor side by varying frequency or voltage or by varying frequency and voltage both .we know that The three-phase motor can give good torque performance at all operating speed . Selection of induction motor is depends on the what type of performance is required for work purpose. If we required high starting torque then we use sleep ring motor and if we required good running characteristics then we go for squirrel cage induction motor . If we required low torque then we go for single phase induction motor. Depending on the motor, there may be significant torque pulsations when a single-phase induction motor is run at low speeds. But the traditional way of speed control are produce very slow response .Three-phase voltage source inverters with closedloop current regulator are widely used in various applications. Isolated current sensors are used in two or three of the inverter lines to provide the current feedback signals. By using close loop control of voltage and current from output of induction motor for controlling the speed and torque of induction motor. The measurements of these currents in the presence of high di/dt and dv/dt switching transients are difficult. It is very difficult to to get thyristors having same gain on different frequency, voltage and current. With more than one current sensor, the related signal conditioning circuits increases the complexity, cost and size of the motor drive. An alternative to direct measurement of the two phase currents is the reconstruction of phase currents by using the measured dc link current and the switching vector information of the inverter. In dc link speed and torque control only one current sensor is use , basically all the three phase currents are measured with the same gain and no dc-offset occurs due to the transducer. Current sensor is generally use in ckt for over current protection . Variable speed control of an IM is simple by varying frequency as well as voltage magnitude.The line current and phase voltages are derived using the switching vectors of inverter. The stationery d-q values of stator current and stator flux are found using FOC technique. For estimate the reference value of rotor speed the electromagnetic torque and it is estimated using the stator flux. To estimate the speed, the synchronous speed and slip speed of motor is required. From the flux angle the synchronous speed is calculated. The slip speed is calculated using the electromagnetic torque and constant slip value. Rotor speed is estimated by subtracting the slip speed from the synchronous speed. The line current is taken as reference and the inverter switching signals are generated, and the speed of motor is controlled.

## 2. Proposed Scheme

Proposed scheme of the paper is given in the Figure 1 shows the block diagram. It consists of speed loop, estimation block and current regulator. The DC current and voltage are measured from the dc link. Three phase current and voltage is measured using reconstruction algorithm is used to estimate three phase current and voltages. The dc link voltage and current is given as input to the algorithm. Estimator is used to calculate speed from the reconstructed 3-phase voltage and current. The calculated speed is compared with the reference speed. Speed controller and current regulator were used and pulse is generated and given to the inverter. With that inverter pulse the speed of the induction motor is controlled.

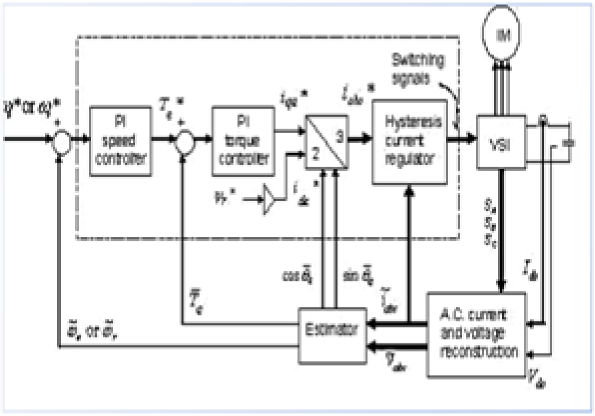


**Figure 1:** Block Diagram of Speed Control Technique

## 3. Stator voltages and Current Reconstruction from DC link

Speed can be derived from the stator voltages and currents expressed in d-q reference frame with the help of torque estimated. Generally, IGBTs are used because feedback diodes are used as switch in inverters. Due to the reverse recovery effect of diode, when a switch is being turned-on and the conducting diode at the same leg is being blocked off by this turn-on. This leg is in fact shorted and at this moment such that a positive current spike will appear at the dc link side.

### 3.1 Switching states

In the normal state, there are eight switching states of inverter which can be expressed as space voltage vector (SA,SB,SC) such as (0,0,0), (0,0,1), (0,1,0), (0,1,1), (1,0,1), (1,0,0), (1,1,0) and (1,1,1). SA =1 means upper switch of leg A is on while the lower one is off, and vice versa. The same switching logic is applicable to SB and SC also. Among the above eight voltage vectors, (0, 0, 0) and (1, 1, 1) are termed as zero vectors while the other six as active vectors. The switching vectors describe the inverter output voltages.

### 3.2. Phase voltage & line current reconstruction

For different voltage vectors, the phase voltage that will appear across stator winding can be determined by circuit observation.

$$\tilde{v}_a = \frac{V_{dc}}{3}(2S_A - S_B - S_C)$$
$$\tilde{v}_b = \frac{V_{dc}}{3}(2S_A - S_B - S_C)$$
$$\tilde{v}_c = \frac{V_{dc}}{3}(2S_A - S_B - S_C)$$

The stator voltages are expressed in stationary d-q frame as;

$$\tilde{v}_{qs} = \tilde{v}_a = \frac{V_{dc}}{3}(2S_A - S_B - S_C)$$
$$\tilde{v}_{ds} = \frac{1}{\sqrt{3}}(v_b - v_c) = \frac{V_{dc}}{3}(S_B - S_C)$$

:

The relationship between the applied active vectors and the phase currents measured from the dc link. It is clear that at-most, one phase current can be related to the dc.-link current at every instant. A reconstructed current calculated from the dc link current gives a reasonable approximation of the actual current. In terms of switching vectors and Idc, the three ac line currents can be derived as follows:

$$\tilde{\imath}_a = I_{dc}(S_A - \frac{S_B}{2} - \frac{S_C}{2})$$
$$\tilde{\imath}_b = I_{dc}(-\frac{S_A}{2} + S_B - \frac{S_C}{2})$$
$$\tilde{\imath}_c = I_{dc}(-\frac{S_A}{2} - \frac{S_B}{2} + S_C)$$

Stator current are expressed as:

$$i_{qs}{}^{s} = i_a;\ i_{ds}{}^{s} = \frac{1}{\sqrt{3}}(2i_b + i_a)$$
$$i_{qs}{}^{s} = i_a;\ i_{ds}{}^{s} = \frac{-1}{\sqrt{3}}(2i_c + i_a)$$
$$\tilde{\imath}_{qs}{}^{s} = -(i_b - i_c);\ i_{ds}{}^{s} = \frac{1}{\sqrt{3}}(i_b + i_c)$$

## 4. Simulation Results

The simulation model of speed and torque control of 3phase induction motor is shown below.

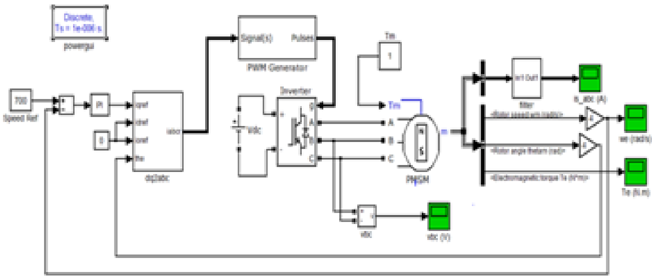


**Figure 2:** Simulation block of overall system

In conventional current-regulated induction motor drive, the phase currents are actually measured by using current sensors which are connected on the stator side. To reduce the number of sensors, the reconstruction of phase currents from dc link current measurements have been implemented. The methods proposed in the recent past years may be classified in two major categories depending upon the way information from dc link was processed to reconstruct the phase currents. The first category includes algorithm using PWM modification approach. The second category deals in estimation of phase currents by employing the machine model based state observer.

An alternative to direct measurement of the two phase currents is measuring the dc link current and based on this signal and pulse-width modulation (PWM) information, the phase currents can be reconstructed. To reconstruct the three phase currents from the dc link, information regarding the inverter switching states is required. In this paper a new speed sensor less control strategy for Induction motor is proposed that includes the speed control, torque control and current regulation. Unlike conventional close loop estimators, it involves less computation and is less dependent on machine parameters. These have drawbacks like higher switching loss and increased sensitivity to parameter variations. In indirect vector sensor less speed control, field angle θe is acquired using estimation of stator currents and voltages reconstructed from DC link measurements. It presents independent speed & torque control loops and current regulation. For close-loop control, the feedback signals including the rotor speed, flux and torque are not measured directly but are estimated. The inputs to estimator the reconstructed waveforms of stator currents and voltages obtained from the dc link and not measured directly on stator side.

In order to predict the behavior of the drive during steady-state and transient conditions, detailed simulation studies of the are carried out on a Induction motor by using Simulink software. The simulation was carried out for different operating conditions using Simulink software.

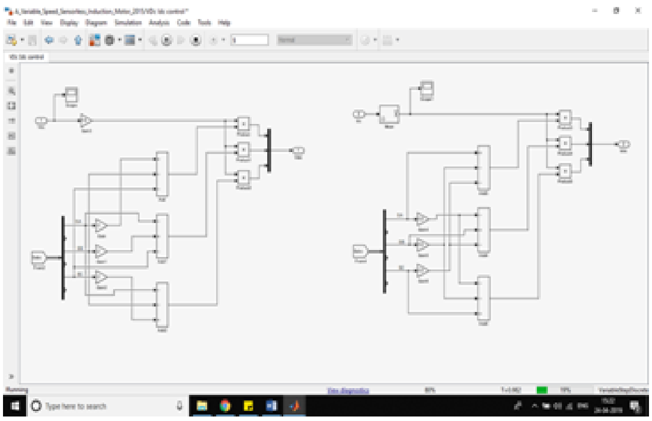

**Figure 3:** DC link voltage and current control

Above figure 3 shows the simulation block of voltage and current of DC link for controlling speed and torque of 3phase IM.

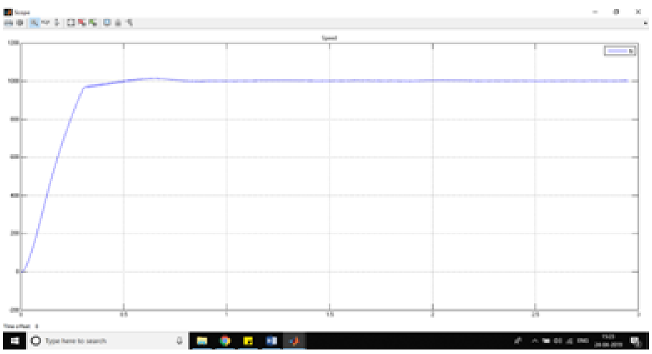

**Figure 4:** Speed waveform of dc link fed 3phase IM

Torque wave form of DC link fed induction motoris given in Figure 5.

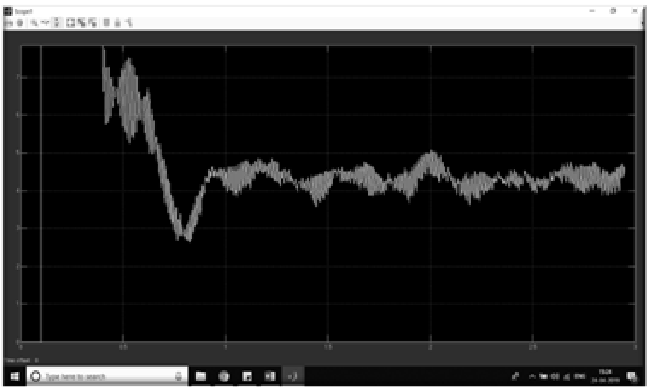

**Figure 5:** Torque waveform of DC link fed 3 phase IM

## 5. Conclusion

A new control strategy for induction motor drive is proposed. The drive is operated under torque control with an phase voltages, line currents, flux, torque and rotor speed. If the dc link voltage is assumed as constant, only one current sensor in the dc link is sufficient to give the estimates of all required feedback variables. Moreover, the same current sensor that is already available in the dc link of an open-loop v/f drive for protection purpose can be used. Thus the open loop control strategy in an existing v/f drive can be replaced by the proposed close-loop control strategy without requiring any additional power components or the physical sensors. The proposed strategy appears to be a good compromise between the high-cost, high-performance field-oriented drives and the low-cost, low-performance v/f drives.

The proposed technique uses only dc link voltage and dc link current measurements to generate the estimates of line currents, phase voltages, flux and rotor speed. If the dc link voltage is assumed as constant, one current sensor in the dc link is sufficient to give the estimates of all required feedback variables. It reduces the use of sensors in the stator sideand also it does not require any mechanical sensors for measuring the motor speed. Simulation and Hardware results confirm the effectiveness of the proposed scheme.

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