Hysteresis Vector Controller for Three Phase Induction Motor

Rahul Modanwal, S.K.Singh, Pushpender singh, Raj Kumar Sagar, Sanjay Singh

Abstract—The magnitude and orientation of the stator flux must be known in order to directly control the stator flux by selecting appropriate voltage vector. The stator flux plane is divided into six sectors. Each sector has a different set of voltage vectors to increase (voltage vector highlighted in gray) or decrease (voltage vector highlighted in black) the stator flux . The stator flux is forced to follow the reference value within a hysteresis band by using a 2-level hysteresis comparator. If the stator flux lies in sector k, then the voltage vector $\overline{V_{s,k+1}}$ selected to increase the stator flux, and $\overline{V_{s,k+2}}$ selected to decrease the stator flux. In This Paper, we are controlling torque or speed of three phase induction motor with concept hysteresis vector controller and we have designed hysteresis vector controller on Matlab Simulink tool which is the advancement in classical DTC model for induction motor.

Index Terms— Induction motor, Classical DTC, Matlab, Braking chopper, Inverter, Hysteresis vector controller, Stator sector.

1 INTRODUCTION

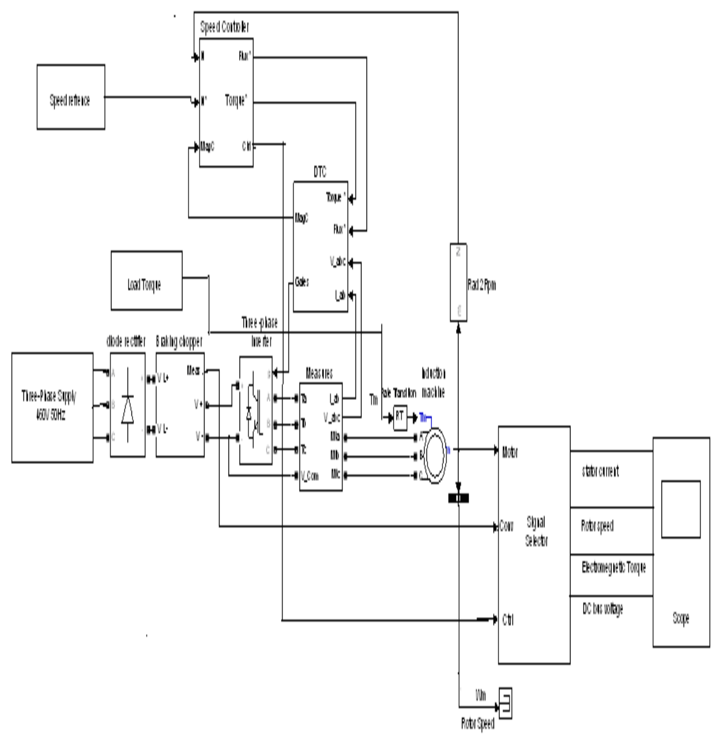
The direct torque method performs very well even without speed sensors. However, the flux estimation is usually based on the integration of the motor phase voltages. Due to the inevitable errors in the voltage measurement and stator resistance estimate the integrals tend to become erroneous at low speed. Thus it is not possible to control the motor if the output frequency of the variable frequency drive is zero. However, by careful design of the control system it is possible to have the minimum frequency in the range 0.5 Hz to 1 Hz that is enough to make possible to start an induction motor with full torque from a standstill situation. A reversal of the rotation direction is possible too if the speed is passing through the zero range rapidly enough to prevent excessive flux estimate deviation. A dynamic model of the machine is considered to design and simulate the direct torque control technique. The machine model in stator reference frame is used simulation. The stator flux linkage vector is given as in above equation,

$$\overline{\psi_s} = \int(\overline{v_s} - R_s\overline{i_s}).dt \quad ....1$$

Neglecting the voltage drop in stator resistance, the flux change over a small period of time can be written as

$$\Delta\overline{\psi_s} = \overline{v_s} \bullet \Delta t \quad .... 2$$

$\overline{v_s}$ is the voltage vector, which may occupy any of the eight space positions as shown in figure.



Block diagram speed control of induction motor

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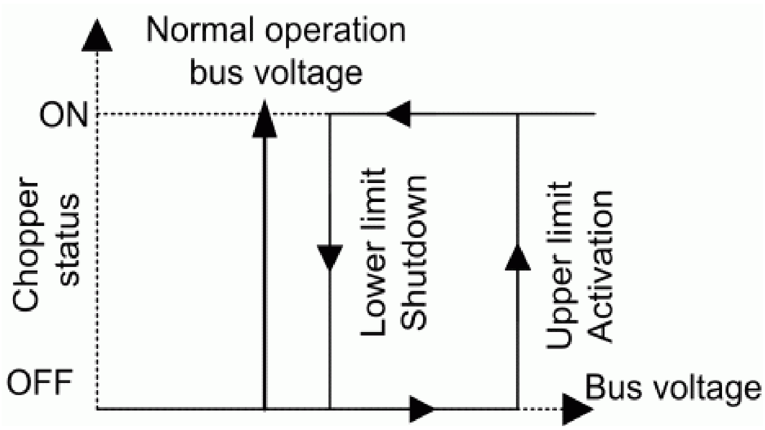
2 Procedure For Paper Submission

2.1 Braking Chopper

The braking chopper block contains DC bus capacitor and the dynamic braking chopper (consist of braking resistance series with chopper), which is used to absorb the energy produce by motor deceleration. Baking resistance is used to avoid bus over-voltage during motor deceleration or when the load torque tends to accelerate the motor.

Braking chopper activation and shutdown voltage;-



Hysteresis diagram

The dynamic baking is activated when the bus voltage reaches the upper limit of hysteresis band. Figure will illustrates the baking chopper hysteresis logic. The dynamic baking is shutdown when the bus voltage reaches the lower limit of hysteresis band. Figure will illustrates the baking chopper hysteresis logic. The output of baking chopper is applied to three-phase inverter.

2.2 THREE-PHASE INVERTER

It converts DC signal to AC signal and applied to three-phase induction motor. Here we are using Voltage Source Inverter which is used to regulate the speed of three-phase squirrel cage motors by changing the frequency and voltage and consist of input rectifier, DC link, output converter . They are available for low voltage range and medium voltage range.

2.3 SPEED CONTROLLER

The speed controller is based on PI regulator. PI controller is an algorithm that can be implemented without resorting to any heavy control theory. The aim of such an algorithm is to determine the plant input (in our case the stator volt-age frequency) that will make the measured output (in our case the speed of the rotor) reach the reference (the speed the user wishes to have). PI stands for Proportional and Integral, two terms which describe two distinct elements of the controller.

2.4 INDUCTION MOTOR

The three-phase squirrel-cage induction motor is used which may operate in either generator or motor mode. The mode of operation is dictated by the sign of the mechanical torque:
If Tm is positive, the machine acts as a motor.
If Tm is negative, the machine acts as a generator.
The electrical part of the machine is represented by a fourth-order state-space model and the mechanical part by a second-order system. All electrical variables and parameters are referred to the stator.

2.5 DIRECT FLUX CONTROL

A dynamic model of the machine is considered to design and simulate the direct torque control technique. The machine model in stator reference frame is used simulation. The stator flux linkage vector is given as in above equation,

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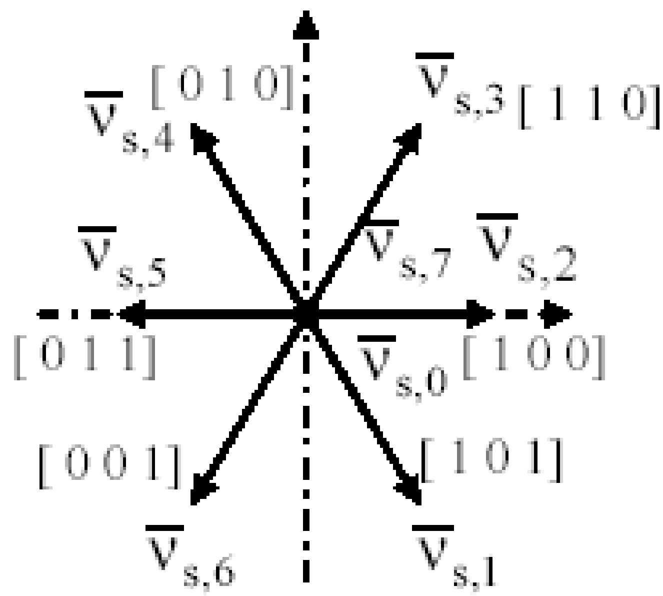
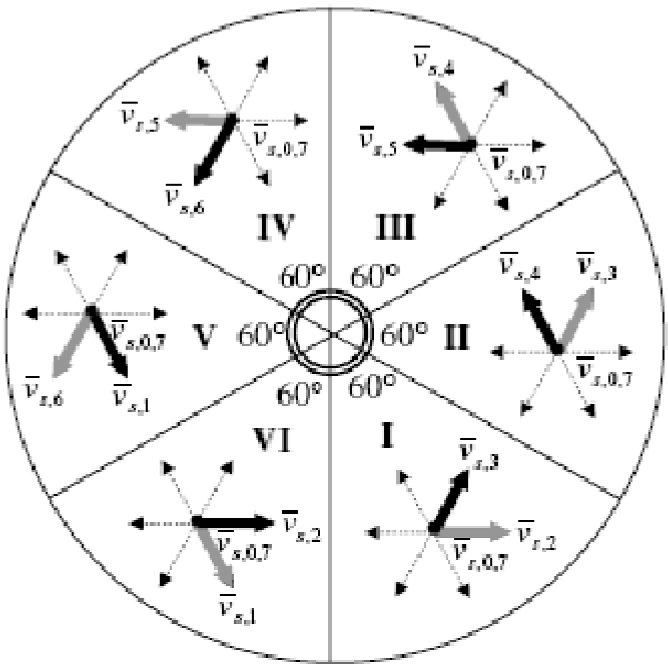


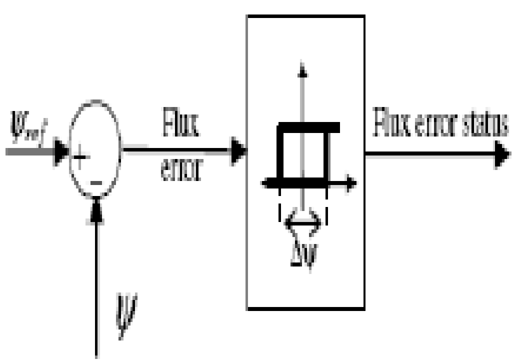
Voltage space vectors

The magnitude and orientation of the stator flux must be known in order to directly control the stator flux by selecting appropriate voltage vector. The stator flux plane is divided into six sectors as shown in Figure. Each sector has a different set of voltage vectors to increase (voltage vector highlighted in gray) or decrease (voltage vector highlighted in black) the stator flux as illustrated in Figure. The stator flux is forced to follow the reference value within a hysteresis band by using a 2-level hysteresis comparator. If the stator flux lies in sector k, then the voltage vector $\overline{V_{s,k+1}}$ selected to increase the stator flux, and $\overline{V_{s,k+2}}$ selected to decrease the stator flux.

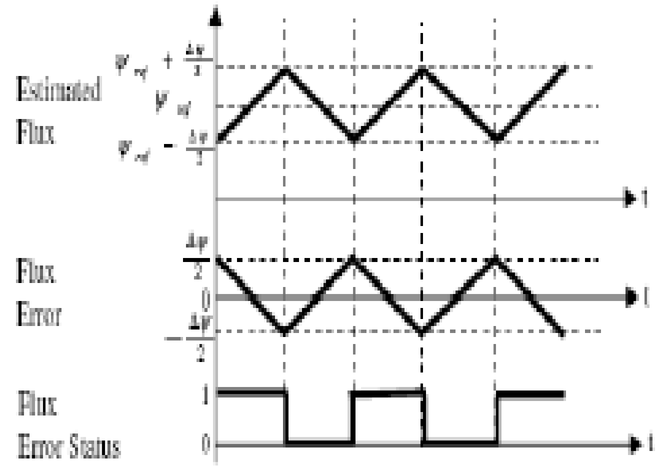


Control of voltage space vectors in six sectors of flux plane

The radial voltage vectors $\overline{V}_{s,k}$ and $\overline{V}_{s,k+3}$ which can be used to quickly affect the flux are generally avoided. The estimated stator flux error is fed to the hysteresis comparator shown in Figure, which produces the flux error status, dψ can be either 1 or 0. Typical waveforms of stator flux, stator flux error and stator flux error status are shown in Figure.



Block diagram of the stator flux hysteresis comparator



Waveforms of stator flux, flux error and flux error status

If stator flux is to be increased dψ = 1,and if stator flux is to be decreased dψ = 0.

$$d\psi = 1 \text{ if } \left|\overline{\psi_s}\right| \le \left|\overline{\psi_{s,ref}}\right| - \left|\Delta\overline{\psi_s}\right| \quad \text{...............3}$$

$$d\psi = 0 \text{ if } \left|\overline{\psi_s}\right| \le \left|\overline{\psi_{s,ref}}\right| + \left|\Delta\overline{\psi_s}\right| \quad \text{...............4}$$

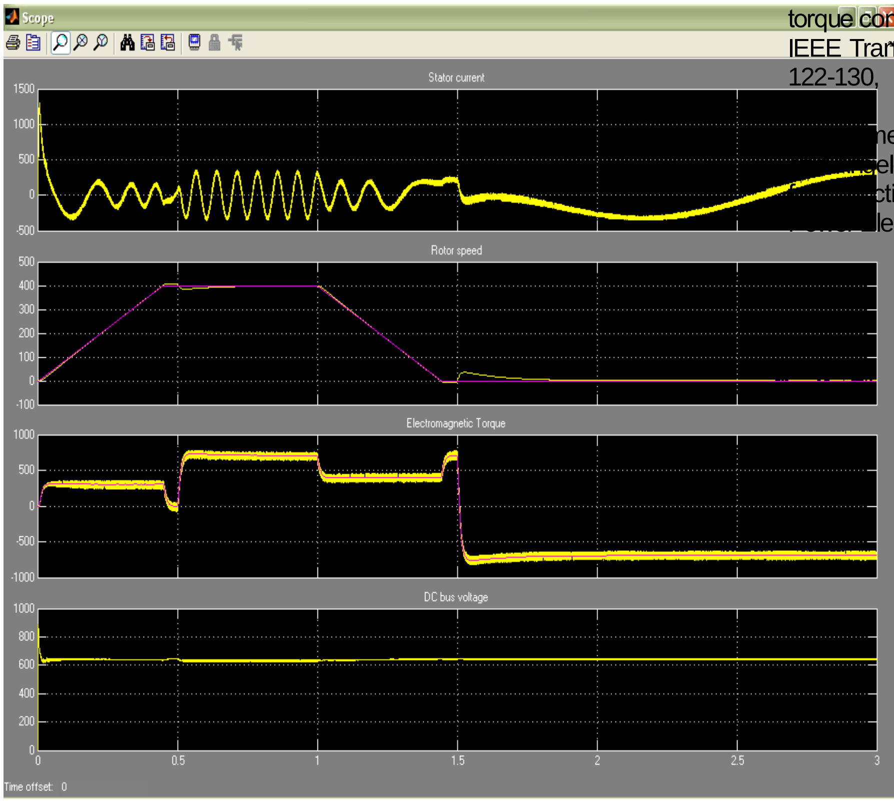
The performance of the control system is directly dependent on the estimation of stator flux and torque. Stator flux is estimated using the voltage model, as in Eq.(3).

3 SIMULATION RESULTS AND DISCUSSIONS

The induction motor is fed by a voltage source inverter which is built using a Universal Bridge Block. The speed control loop uses a proportional-integral controller to produce the flux and torque references for the DTC block. The DTC block computes the motor torque and flux estimates and compares them to their respective reference. The comparators outputs are then used by an optimal switching table which generates the inverter switching pulses. The result of simulation of the speed control with different reference speed and load torque is shown below:-

Simulation Test Run

Speed, at time(s): [0 1], amplitude is [300 0]
Torque, at time(s): [0 0.5 1], amplitude [0 692 -692]
Start the simulation. You can observe the motor stator current, the rotor speed, the electromagnetic torque and the DC bus voltage on the scope. The speed set point and the torque set point are also shown.
At time t = 0 s, the speed set point is 300 rpm. Observe that the speed follows precisely the acceleration ramp.



Result of space vector Hysteresis Controller of three Phase inductor Motor

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