

Nine Switch Inverter based Direct Torque Control for Dual Induction Motor

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Abstract - Induction motors are the starting point to design an electrical drive system which is widely used in many industrial applications. In modern control theory, different mathematical models describe induction motor according to the employed control methods. Vector control strategy can be applied to this electrical motor type in symmetrical three phase version or in unsymmetrical two phase version. The operation of the induction motor can be analyzed similar to a DC motor through this control method. With the joint progress of the power electronics and numerical electronics it is possible today to deal with the axis control with variable speed in low power applications. With these technological projections, various command approaches have been developed by the scientific community to master in real time, the flux and the torque of the electrical machines, the direct torque control (DTC) scheme being one of the most recent steps in this direction. This scheme provides excellent properties of regulation without rotational speed feedback. In this control scheme the electromagnetic torque and stator flux magnitude are estimated with only stator voltages and currents and this estimation does not depend on motor parameters except for the stator resistance. The proposed Nine switch inverter control based DTC for a 200 HP Dual induction motor is simulated on SIMULINK/ MATLAB platform and the simulation waveforms are discussed.

Key Words: Direct Torque Control, Nine Switch Inverter, Speed Control, Pulse width modulation Technique.

1. INTRODUCTION

The electric drives used in industry are Adjustable Speed Drives and in most of these drives AC motors are applied. Induction motors are the standard in these drives. Induction motors are today the most widely used AC machines due to the advantageous mix of low cost, reliability and performance. So effective control of IM parameters e.g. speed, torque and flux is of utmost importance.

Classification of control techniques for IM from the view point of the controlled signal [1] [2]:

Scalar control: based on relationships valid in steady state, only magnitude and frequency of voltage, current and flux linkage space vectors are controlled.

Vector control: based on relations valid in dynamics state, not only magnitude and frequency but also instantaneous position of voltage, current and flux linkage space vector are controlled. The most popular vector control methods are the Field oriented control (FOC) and DTC.

From the investigation of the control methods it is known that torque control of IM can be achieved according to different techniques ranging from inexpensive Volts/Hz ratio strategy to sophisticated sensor less vector control scheme. But every method has its disadvantages such as losses, need of separate current control loop, coordinate transformation (thus increasing the complexity of the controller), torque and current ripple etc. So it is very much necessary to design a controller to obtain an ideal electric vehicle motor drive system that would have high efficiency, low torque ripple and minimum current distortion.

1.1 Direct Torque Control

DTC was first introduced by Takahashi in 1984 in Japan and by Dopenbrock in 1985 in Germany and today this control scheme is considered as the world's most advanced AC Drives control technology. This is a simple control technique which does not require coordinate transformation, PI regulators, and Pulse width modulator and position encoders. This technique results in direct and independent control of motor torque and flux by selecting optimum inverter switching modes. The electromagnetic torque and stator flux are calculated from the primary motor inputs e.g. stator voltages and currents [7]. The optimum voltage vector selection for the inverter is made so as to restrict the torque and flux errors within the hysteresis bands. The advantages of this control technique are quick torque response in transient operation and improvement in the steady state efficiency.

The proposed idea for the decoupling direct torque control is to apply in alternative way the high and low active vectors. In this case, the nine switches inverter operates in the both modes. This logic ensures the independence in the supply of the both motors and therefore the independence in their control.

1.2 Nine Switch Inverter Control

Nine switches Inverter (NSI) is a power compact converter dedicated to supply two three-phase loads. It consists of nine power switches (MOSFET) (Fig.1).

In order to achieve an independent control of two induction motors, the adopted control strategy consists to operate as two conventional three phase inverters (Inv1 and Inv2) as shown in Fig.1. Middle Row Switches (2,5,8) will be common to both inverters. Inv1 contains switches upper row(1,4,7) and middle row switches(2,5,8) while Inv2 contains switches (2,5,8) and (3,6,9).

Each switch has two states (open OFF or closed ON) and since each leg of the converter is constituted by three switches consequently there are eight possible states. To avoid DC bus short-circuit; all three switches should not be closed simultaneously. In other hand to avoid floating the connected loads, at least two switches should be closed. So only three ON-OFF states are possible. Table 1 shows these states referred to (1, 0 and -1). In this table, J refers to leg A, B or C. The letters U, M and L refer to upper, mid and lower switches [6]. The state of the mid switch SJM is synthesized by a XOR between SJU and SJL [2].

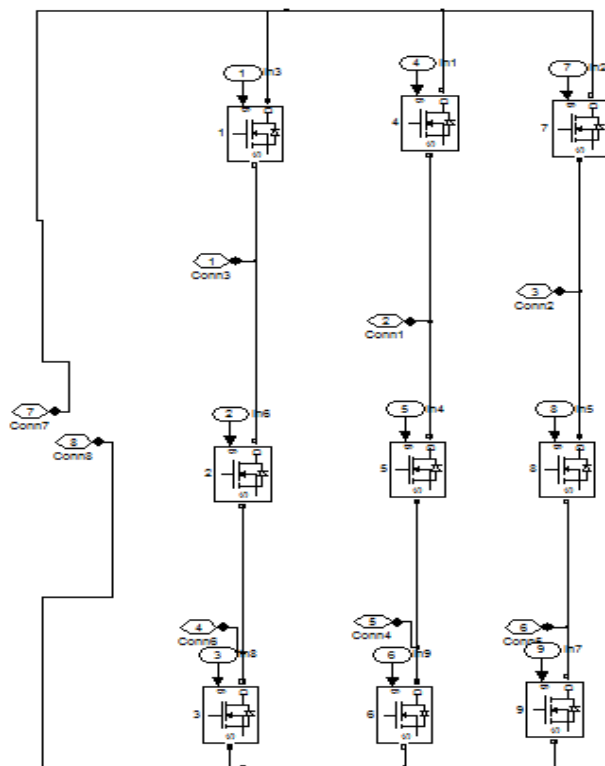


Fig -1: Proposed Nine Switch Inverter Model

Table -1: Switching Configuration

| Switching Table | | | |
|-----------------|-----|-----|-----|
| Switches | 1 | 0 | -1 |
| SJU | ON | OFF | ON |
| SJM | OFF | ON | ON |
| SJL | ON | ON | OFF |

2. Results and Discussion

The circuit models direct torque control (DTC) induction motor drive with a braking chopper for a 200HP AC motor. The induction motor is fed by a PWM voltage source nine switch inverter as shown in Fig.1. The speed control loop uses a proportional-integral controller to produce the flux and torque references for the DTC block as shown in Fig. 2. The DTC block computes the motor torque and flux estimates and compares them to their respective reference as in Fig. 3. The comparators outputs are then used by an optimal switching table which generates the inverter switching pulses.

The control scheme of the induction motors associated to the nine switches inverter is presented in Fig.3. It is based on a specified Direct Torque Control (DTC) applied to nine switches inverter.

Where the flux components in the (α, β) frame are given by:

$$\begin{cases} \psi_{s\alpha} = \int_0^t (v_{s\alpha} - r_s i_{s\alpha}) dt \\ \psi_{s\beta} = \int_0^t (v_{s\beta} - r_s i_{s\beta}) dt \end{cases} \quad (1)$$

The electromagnetic torque can be calculated by the following equation:

$$\Gamma = p(\psi_{s\alpha} i_{s\beta} - \psi_{s\beta} i_{s\alpha}) \quad (2)$$

The switching table is based on: flux and torque error (dψ, dr) and the sector number of the flux vector (Si).

Electromagnetic torque, stator flux estimations and their positions in the complex plane are estimated in the same way as for a single motor. Fig.3 shows the direct torque control structure of two asynchronous motors supplied by the nine switches inverter. The synchronization module ensures the operation in mode 1 and mode2 in alternative way.

Motor current, speed, and torque signals are available at the output as shown in Fig.4 and Fig.5.

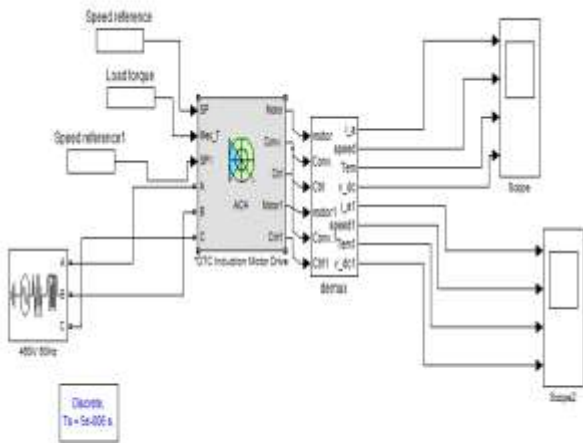


Fig -2: DTC Control

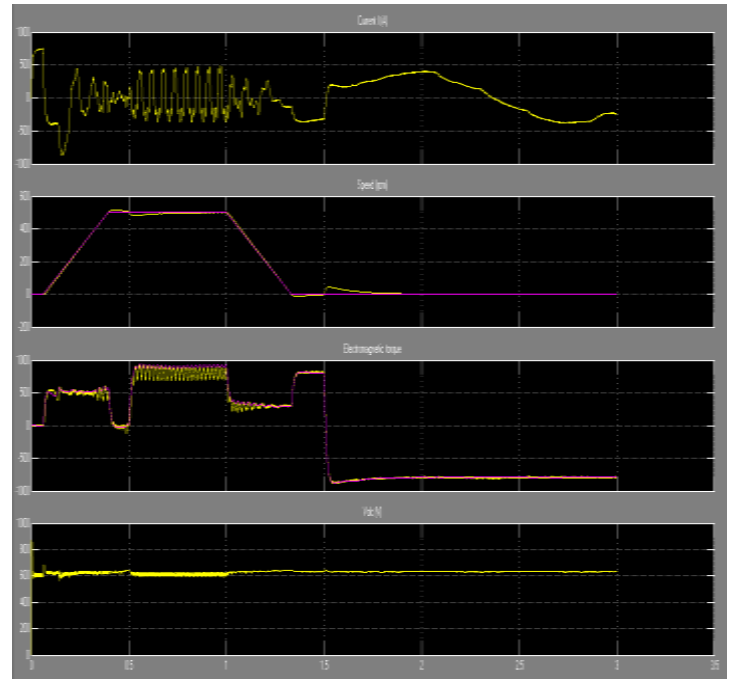


Fig -4: Current, Speed, Electromagnetic Torque and DC Voltage waveforms of Induction motor 1

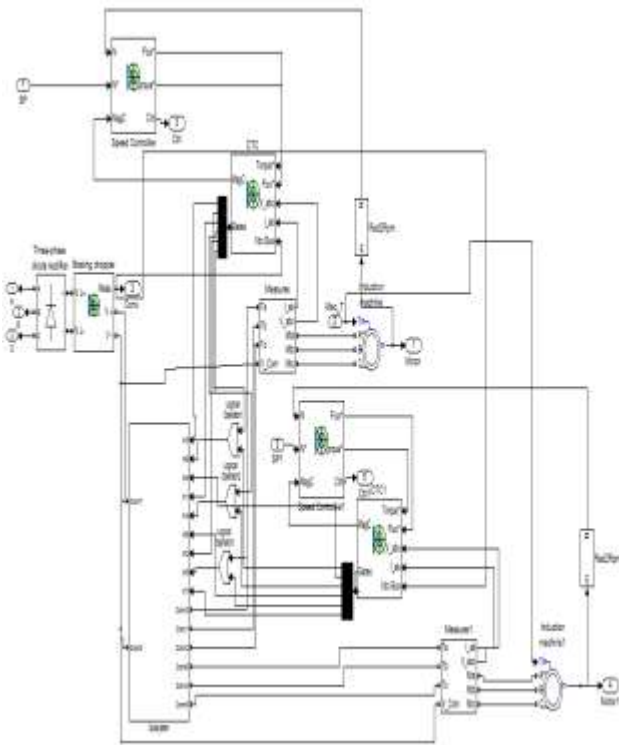


Fig -3: Nine Switch Inverter based DTC control for Dual Inductor Motor

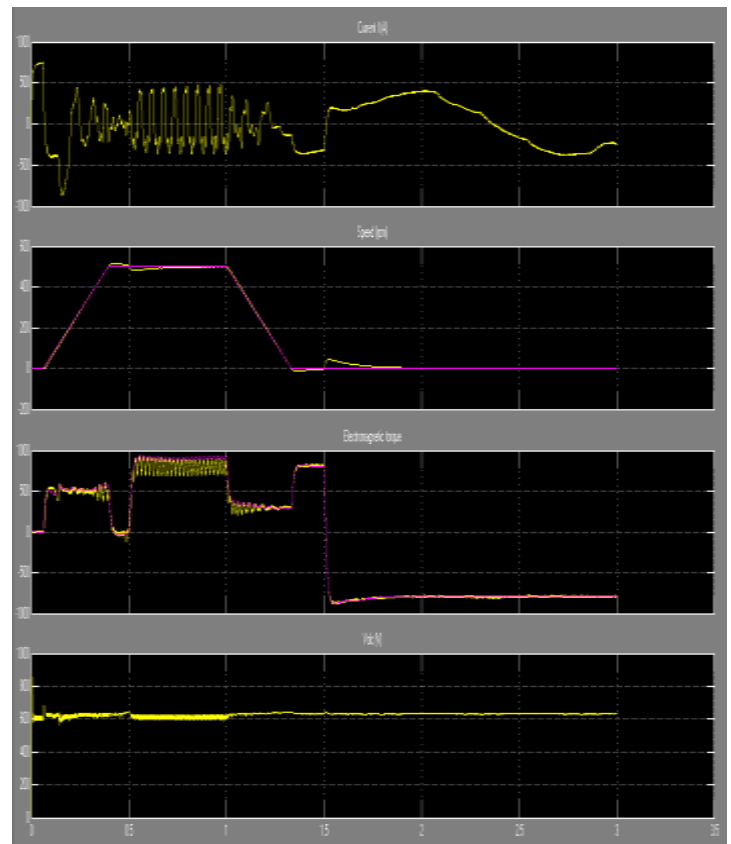


Fig -5: Current, Speed, Electromagnetic Torque and DC Voltage waveforms of Induction motor 2

3. CONCLUSION

This paper presents an independent control of nine switch inverter fed dual induction motor. The proposed technique mainly uses the direct torque control in order to benefit the advantages of this technique such as robustness with the parameter variations. It also provides great dynamic performance with a simple structure and without mechanical sensors. Simulations on induction motor drive are carried-out to show robustness of the developed independent control in terms of speed and torque responses.

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