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# Direct Control Strategies for Electrical Drives using multilevel inverter

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***Abstract*—Direct torque control (DTC) for medium- and high-power applications frequently uses multilevel inverters (MLI). To determine the ideal inverter switching states for the DTC control systems, the extra voltage vectors produced by MLI can be adjusted. Direct Torque Control (DTC) Control of the induction motor drive is presented using a novel multilayer inverter construction. It is demonstrated that the multilevel architecture offers enough degrees of freedom to regulate the stator flux and electromagnetic torque with very little ripple and a fast dynamic reaction on the opposite side. The simulation results from a five-level and a seven-level inverter are shown and contrasted. This investigation demonstrates how using multiple inverters to supply electrical drives may significantly boost drive performance.**

***Index Terms*— Induction Motor, DTC, 15-Level MLI, Two-Level Inverter, Switching Table**

## I. INTRODUCTION

In order to regulate the torque and flux performance by applying the suitable voltage vector, Takahashi and Noguchi's direct torque control (DTC) method first used a two-level or voltage source inverter (VSI) circuit.Because it can deliver superior torque control performance with a more straightforward control structure, direct torque control (DTC) has grown to be the most preferred motor control technology. The DTC does not need a reference frame transformer, current regulator, speed sensor, or any knowledge of the machine's characteristics, in contrast to the vector control technique known as Field Oriented Control (FOC).

The usage of the new High Current-High Voltage in the inverters used in traction drives was made fairly intriguing by technology. They were once only used as the drives for trams or regional trains, but today high-speed traction locomotives are starting to find them appealing.Although they have many more possible vectors, multilayer inverters should be employed for these applications in order to limit the maximum voltage stress and switching frequency across the switches.

Instantaneous space vector theory is the theoretical foundation of the DTC technique. DTC effectively controls the electromagnetic torque and the stator flux on the basis of the errors between their references and estimated values by selecting the space voltage vectors optimally during each sample cycle. By using a switching table, it is feasible to directly regulate the inverter states and lower the torque and flux errors while maintaining the appropriate band limits. The current work is based on a study of the application of DTC to the 15-Level & VSI and the benefits that may be realized when employing this topology in comparison to the Five-Level Inverter.

This essay presented the idea of induction motor direct torque control (DTC). This research compares and contrasts the topologies of the 15-level and 2-level inverters. The next section presents the suggested method's simulation findings. In the final part, findings are presented.

## II. MODELING AND IDEA OF DIRECT TORQUE CONTROL

With the aid of the DTC, the induction motor is able to respond to torque commands with extreme speed and accuracy. When the best inverter is chosen, the computed instantaneous values of flux and torque (voltages and currents) are directly regulated. The direct torque control technique is founded on the regulation of torque and flux to desired magnitude by selection of the suitable Voltage vector in accordance with the pre-defined vector table.Stator measurements are the only input for this control technique.

The inputs of the switching table are the outputs of flux and torque controllers, and the flux position sector S. The outputs of table are the inverter switching states (Sxa, Sxb, and Sxc)

## III.CASCADED H-BRIDGE MULTILEVEL INVERTER

A single-phase configuration of *n*-level H-bridge cascaded inverter is depicted in Fig.1. Each separate DC source is connected to a single-phase full-bridge/or H-bridge, inverter. Each inverter can generate three different voltage level outputs, $+V_{dc}$, 0, and $–V_{dc}$by connecting the DC source to the AC output by different combinations of the four switches, $S_1$, $S_2$, $S_3$, and $S_4$. To obtain voltage level $+V_{dc}$, switches $S_1$and $S_4$turned on, whereas for voltage level $–V_{dc}$switches $S_2$and $S_3$turned on. Zero level voltage can obtain by turning on switches $S_1$and $S_2$or $S_3$, and $S_4$. AC outputs of each synthesized different full-bridge inverter levels are connected in series for summing up to generate the multilevel voltage waveform. The number of output phase voltage *n*-levels in a cascade inverter defined by $n = 2l+1$, where $l$ is the number of separate DC sources. As example phase voltage waveform for *n*-level cascaded H-bridge inverter with (*n*-1) /2 separate DC sources and (*n*- 1)/2 full bridges.

The output phase voltage generalized use as

$$v = v_{a1} + v_{a2} + v_{a3} + v_{a4} + v_{a5} \dots\dots\dots + v_{an} \qquad [1]$$

The Fourier transform of the corresponding stepped waveform follows [9, 5]:

$$V(\omega t) = \frac{4V_{dc}}{\pi}\sum[\cos(n\theta_1) + \cos(n\theta_2) + \cdots + \cos(n\theta_l)]\frac{\sin(n\omega t)}{n} \qquad [2]$$

where n = 1,3,5,7.

By choosing conducting angles, $\theta_1$, $\theta_2$,…….,$\theta_l$, such that the total harmonic distortion (THD) is minimized. Predominately, these conduction angles for suppressing lower frequency harmonics of 5th, 7th, 11th, and 13th,… orders are eliminated in output [10]. The main benefits and drawbacks of cascaded H-bridge multilevel converters are briefly summarized as follows [23]:

Benefits:

- The number of possible output voltage levels is more than twice the number of DC sources ($n = 2l+1$).
- The series of H-bridges makes for modularized layout and packaging. Enable the manufacturing process to be done faster and cheaper.

Drawbacks:

- Separate DC sources required for each of the H-bridges and could generate oscillating DC source power.Units

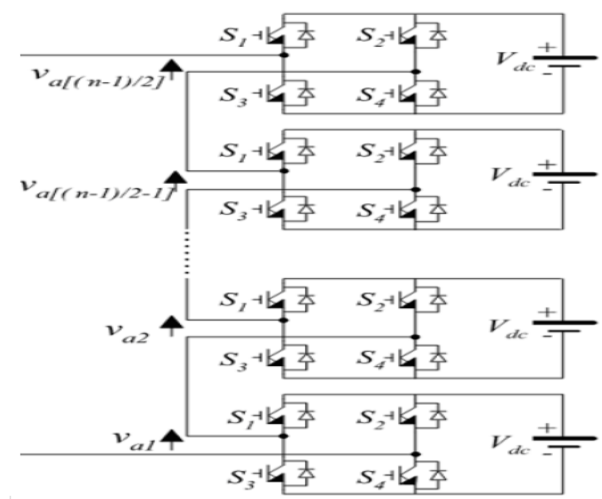

Fig. 1: Single leg of *n*-level cascaded H-bridge multilevel converter structure.

## IV.SWITCHING LOSSES

The losses in the semiconductors can be divided into two parts, namely switching losses (arising when the devices are switched on or off) and conduction losses (due to the ohmic resistance). These losses depend on the applied voltage, the commutated current and the semiconductor characteristics. Observing that in a VSI inverter, the voltage seen by each semiconductor is always half the total DC-link voltage leads to the Ideal switch turn-on (energy) loss

$$E_{on} = e_{on}\frac{1}{2}V_{dc}i_{ph} \qquad [15]$$

Where $e_{on}$ is a coefficient and $i_{ph}$ is the phase current. For the Ideal switch, turn-off losses, a corresponding equation results with the coefficient $e_{off}$. Typically, $e_{off}$ is an order of magnitude larger than eon. For a diode, the switch-on losses are effectively zero. The turn-off losses, however, which are reverse recovery losses, are linear in the voltage, but nonlinear in the commutated phase current.Similar to the switching losses, the conduction losses also depend on the applied voltage and the phase current. The DC link voltage is constant despite the neutral point fluctuations. The phase current is the sum of the current ripple and the fundamental component, which in turn depends only on the operating point given by the torque and the speed, but not on the switching pattern. Since the ripple is small compared to the fundamental current (typically in the range of 10% for a 3-level inverter), the conduction losses can be considered to be independent of the switching pattern.

## V.VOLTAGE SOURCE INVERTER

In this work, a two-level voltage source inverter is also applied to PTC and PCC methods. The topology of the inverterand its feasible voltage vectors are presented in Fig. 2. Theswitching state Scan be expressed by the following vector:

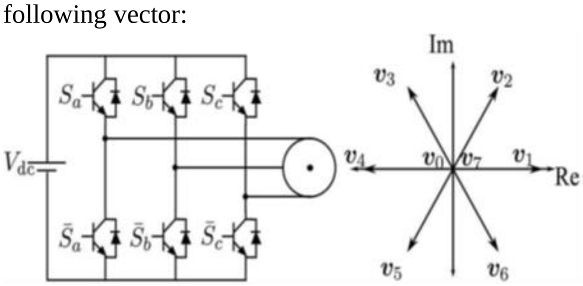


Fig. 2. *Left*: two-level voltage source inverter; *right*: voltage vectors

The stator voltage space vector representing the eight voltage vectors can be shown by using the switching states and the DC-link voltage,$V_{dc}$as:

$$V_s(S_a, S_b, S_c) = \left(\frac{2}{3}\right) V_{dc} \left(V_a + V_b e^{j\left(\frac{2}{3}\right)} + V_c e^{j\left(\frac{4}{3}\right)}\right) \quad [3]$$

Where$V_{dc}$, is the DC-link voltage and the coefficient of 2/3 is the coefficient comes from the Park's Transformation. The equation can be derived by using the line-to-line voltages of the AC motor which can be expressed as:

$$V_{ab} = V_{dc}(S_a - S_b) \quad [17]$$

$$, V_{bc} = V_{dc}(S_b - S_c) \quad [18]$$

$$V_{ca} = V_{dc}(S_c - S_a) \quad [19]$$

## VI. RESULTS

*A.DTC with PMSM and IM using15-level inverter:*

4-pole induction machine have simulated with 15-level multilevel inverter and compared with 2-level voltage source inverter. The rating of induction motor is 5HP, 440V, 50Hz, 1440 RPM star connected induction motor.For all simulations, the motor characteristics will be utilized as below:

| | |
|---|---|
| Stator Resistance (ohm) | = 1.403 |
| Rotor Resistance (ohm) | = 1.395 |
| Stator Self Inductance (H) | = 0.005839 |
| Rotor Self Inductance (H) | = 0.005839 |
| Mutual Inductance (H) | = 0.2037 |
| No. of poles | = 4 |
| Moment of Inertia (kg.m^2) | = 0.0005 |
| Sampling time, | = 1 Sec |

Table. 1: Induction motor parameters

PCC and PTC for a 4-pole PMSM have simulated with 15-level multilevel inverter and compared with 2-level voltage source inverter. For all simulations, the motor characteristics will be utilized as below: The parameters of PMSM motor are given in Table II. For all simulations, the motor characteristics will be utilized as below:

| | |
|---|---|
| Stator phase resistance Rs (ohm) | = 4.3 |
| Armature Inductance (H) | = 0.0001 |
| Flux linkage established by magnets (V.s) | = 0.05 |
| Voltage Constant (V_peak L-L / krpm) | =18.138 |
| Torque Constant (N.m / A_peak) | =0.15 |
| Inertia, friction factor, pole pairs [J (kg.m^2)] | =0.000183 |
| Friction factor F (N.m.s) | = 0.001 |
| Pole pairs p( ) | =2 |
| Initial conditions[ wm(rad/s) thetam(deg) ia,ib(A) ]= | [0,0, 0,0] |
| Sampling Time (Sec) | =1 |

Table. 2: PMSM parameters

The Matlab,Simulink model of DTC methods with PMSM using 15-level inverter shown in fig.5 and Fig.6. To achieve a comparison between the two methods, the external PI speedcontrollers are configured with the same parameters.

Fig.5: DTC with 15- MLI PMSM Result

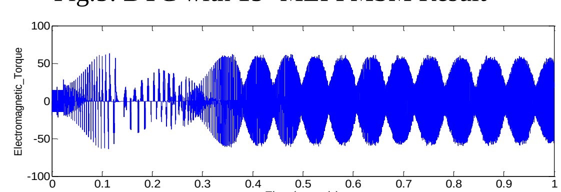


Fig.5.(a) Electromagnetic torque in DTC

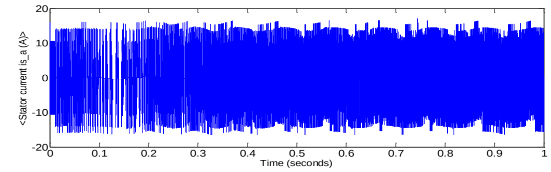


Fig.5.(b) Stator current in DTC

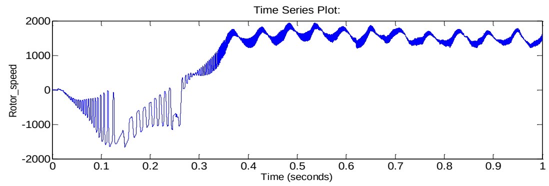


Fig.5.(c) Rotor speed in DTC

Fig.6: DTC with 15-MLI PMSM result

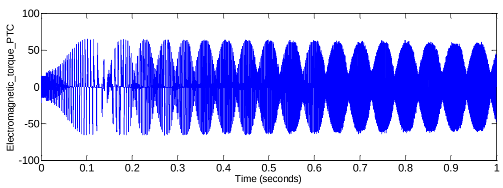


Fig.6.(a) Electromagnetic torque in DTC

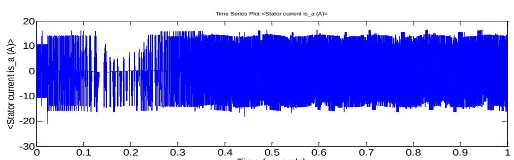


Fig.6.(b) Stator current in DTC

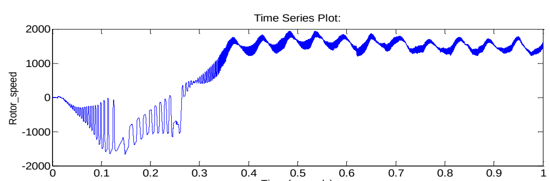


Fig.6.(c) Rotor speed in DTC

THD for fifteen-level inverter is 7.85% and it is 17.85% for Two-level inverter. From this it is concluded that stator line voltage distortions are decreased considerably for fifteen-level inverter compared to Two-level inverter. As can be seen in Fig. 5,6 the system Dynamic behavior is good, even in extreme conditions like the reverse speed operations. From the simulation results presented in Fig. 5,6 it is apparent that the flux ripple for the seven level DTC is considerably reduced to approximately 1 web

## *VIII.CONCLUSION*

A novel switching table for the DTC of the seven-level inverter-fed induction motor is presented in this research following a thorough case study on the DTC characteristics and output vector of the seven-level inverter. The system can obtain the necessary voltage levels via the proposed control technique. The benefits of employing a multilayer inverter and DTC have been demonstrated by simulation results. When comparing the seven level inverter fed DTC induction motor drive to the five level inverter fed induction motor drive, advantages including flux and torque quality improvements were discovered.

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