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Analysis of Direct Torque Control Induction Motor Drive Combine With the SVPWM

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Abstract:

In this paper, analysis of cascaded H-bridge multilevel inverter in DTC-SVM (Direct Torque Control-Space Vector Modulation) based induction motor drive is presented. Cascaded H-bridge multilevel inverter uses multiple series units of H-bridge power cells to achieve medium-voltage operation and low harmonic distortion. The drive control strategy is based on DTC-SVM technique. In this scheme, first, stator voltage vector is calculated and then realized by SVM method.

Contribution of multilevel inverter to the DTC-SVM scheme is led to achieve high performance motor drive. Simulations are carried out in Matlab-Simulink. Five-level and nine-level inverters are applied in induction motor drive for analysis the multilevel inverter. Each H-bridge is implemented using one source and diode bridge rectifier. Good dynamic control and low ripple in the torque and the flux as well as distortion decrease in voltage and current profiles, demonstrate the great performance of multilevel inverter in DTC-SVM induction motor drive.

Key words:

DTC-SVM, H-bridge multilevel inverter, harmonic distortion.

I.INTRODUCTION:

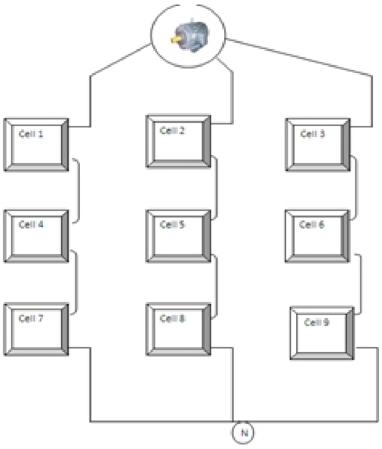
MULTILEVEL voltage-source inverters are intensively studied for high-power applications and standard drives for medium-voltage industrial applications have become available. Solutions with a higher number of output voltage levels have the capability to synthesize waveforms with a better harmonic spectrum and to limit the motor winding insulation stress. However, their increasing number of devices tends to reduce the power converter overall reliability and efficiency. On the other hand, solutions with a low number of levels either need a rather large and expensive LC output filter to limit the motor winding insulation stress, or can only be used with motors that do withstand such stress. The various voltage stages have been chosen after considering the real-power contribution of the highest voltage stage. The maximum power supplied by highest voltage stage is maintained below the load power.

Many studies have been conducted toward improving multilevelinverter. Some studies dealt with innovative topologies,such as cascaded multilevel inverter, to optimize the componentsutilization and the asymmetrical multilevel inverter to improvethe output voltage resolution [5]. Other studies focused on developingadvanced control strategies or upgrading the voltage-sourceinverter strategies for implementation in multilevel inverter[6], [7].

In symmetrical multilevel inverter, all H-bridge cells are fedby equal voltages, and hence all the arm cells produce similaroutput voltage steps. However, if all the cells are not fed byequal voltages, the inverter becomes an asymmetrical one. Inthis inverter, the arm cells have different effect on the outputvoltage. Other topologies are possible, such as the neutral point-clamped fed by unequal capacitors.

Asymmetrical multilevel inverter has been recently investigated[8], [9]. In all these studies, H-bridge topology has beenconsidered and a variety of selection of cascaded cell numbersand dc-sources ratios have been adopted [8]. The suggestedpulsewidth-modulation strategy that maintains the high-voltagestage to operate at low frequency limits the source-voltageselection.

One of the methods that have been used by a major multilevelinverter manufacturer is direct torque control (DTC),which is recognized today as a high-performance control strategyfor ac drives [10]–[13]. Several authors have addressed theproblem of improving the behavior of DTC ac motors, especiallyby reducing the torque ripple. Different approaches havebeen proposed [14]. Although these approaches are well suitablefor the classical two-levels inverter, their extension to agreater number of levels is not easy. Throughout this paper, atheoretical background is used to design a strategy compatiblewith hybrid cascaded H-bridge multilevel inverter; symmetricaland asymmetrical configuration are implemented and compared[15]. Experimental results obtained for an asymmetricalinverter-fed induction motor confirm the high dynamic performanceof the used method, presenting good performances andvery low torque ripples.



II. DIRECT TORQUE AND FLUX CONTROL:

The scheme of conventional direct torque controlled induction motor drive is shown in Fig. 1. It consists of a pair of hysteresis comparator, torque and flux estimators, voltage vector selector and a voltage source inverter.

The schematic diagram of 3-phase voltage source inverter is shown in Fig. 2. It has eight possible voltage space vectors, as shown in Fig. 3, according to the combination of the switching modes: k = [SaSbSc] where each of Sa, Sb, Sc takes the value 1 or 0 independent of others. There are six active voltage vectors: νs,1 to νs,6 and two zero voltagevectors: νs,0 , νs,7 corresponding to [0 0 0] and [1 1 1], respectively. It can be shown that the voltage vector is given by

$$\overline{v}_{s,k} = \frac{2}{3} V_{dc} \left[S_a + S_b e^{j2\pi/3} + S_c e^{j4\pi/3}\right]$$

DTC performs separate control of the stator flux and torque, which is also known as decoupled control. Direct flux control and direct torque control are discussed in the following sections.

A. 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 [1], is used for simulation. The stator flux linkage vector is given as

$$\overline{\psi}_s = \int(\overline{v}_s - R_s \overline{i}_s) \cdot dt$$

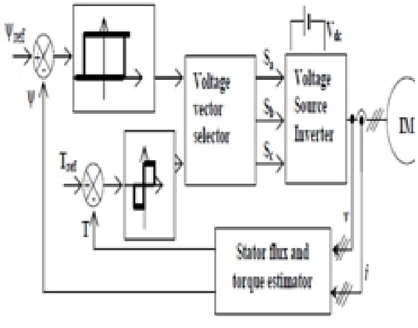


Figure 1. Schematic diagram of direct torque controlled induction motor drive

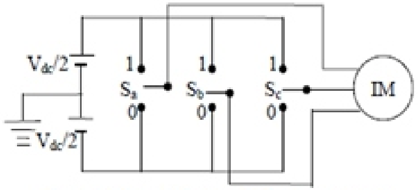


Figure 2. Schematic diagram of voltage source inverter

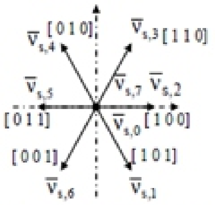


Figure 3. Voltage space vectors

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 Fig. 4. 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 Fig. 4.

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 vs,k1is selected to increase the stator flux, and vs,2 selected to decrease the stator flux.

III. CASCADED H-BRIDGES STRUCTURE AND OPERATION:

The cascaded H-bridge inverter consists of power conversioncells, each supplied by an isolated dc source on the dc side, whichcan be obtained from batteries, fuel cells, or ultracapacitors[15]–[17], and series-connected on the ac side.

The advantageof this topology is that the modulation, control, and protectionrequirements of each bridge are modular. It should be pointed outthat, unlike the diode-clamped and flying-capacitor topologies,isolated dc sources are required for each cell in each phase.Fig. 1 shows a three-phase topology of a cascade inverter withisolated dc-voltage sources. An output phase-voltage waveformis obtained by summing the bridges output voltages.

$$v_o(t) = v_{o,1}(t) + v_{o,2}(t) + \cdots + v_{o,N}(t) \qquad (1)$$

whereN is the number of cascaded bridges.
The inverter output voltage vo(t) may be determined from the individual cells switching states.

$$v_o(t) = \sum_{j=1}^{N} (\mu_j - 1) V_{\mathrm{dc},j}, \qquad \mu_j = 0, 1, \ \ldots. \qquad (2)$$

If all dc-voltage sources in Fig. 1 are equal to Vdc, the inverter is then known as a symmetric multilevel one. The effective number of output voltage levels n in symmetric multilevel inverter is related to the cells number by

$$n = 1 + 2N \qquad (3)$$

For example, Fig. 2 illustrated typical waveforms of Fig. 1 multilevel inverter with two dc sources (five-levels output). The maximum output voltage Vo,Max is then

$$V_{\mathrm{o,MAX}} = NV_{\mathrm{dc}}. \qquad (4)$$

To provide a large number of output levels without increasing the number of inverters, asymmetric multilevel inverters can be used.

In [18] and [19], it is proposed to chose the dc-voltages sources according to a geometric progression with a factor of 2 or 3. For N of such cascade inverters, one can achieve the following distinct voltage levels.

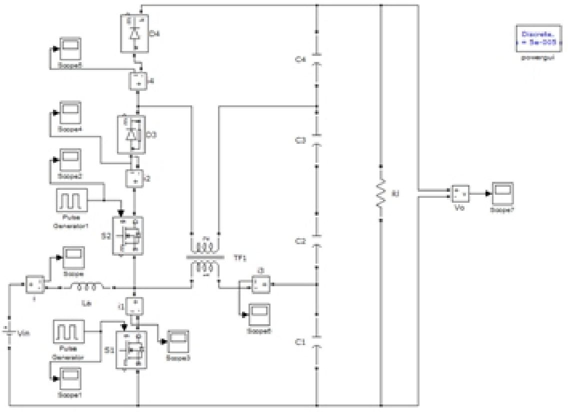
$$\begin{cases} n = 2^{N+1} - 1, & \text{if } V_{\mathrm{dc},j} = 2^{j-1} V_{\mathrm{dc}}, \quad j = 1, 2, \ldots, N \\ n = 3^N, & \text{if } V_{\mathrm{dc},j} = 3^{j-1} V_{\mathrm{dc}}, \quad j = 1, 2, \ldots, N. \end{cases} \qquad (5)$$

TABLE I: COMPARISON OF MULTILEVEL INVERTERS:

	Symmetrical inverter	Asymmetrical inverter	
		Binary	Ternary
N	$2N+1$	$2^{N+1}-1$	3^N
DC sources number	N	N	N
Switches number	$4N$	$4N$	$4N$
$V_{o,MAX}$ [pu]	N	2^N-1	$(3^N-1)/2$

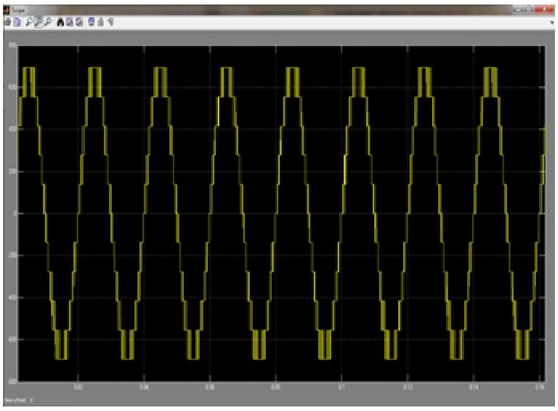
Fig. 5.First Stage.

V.MATLAB MODELING AND SIMULATION RESULTS:

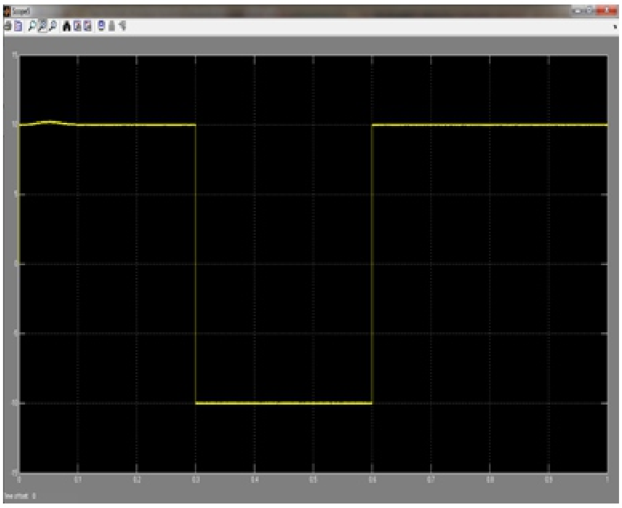


Matlab/Simulink crcuit of proposed system.

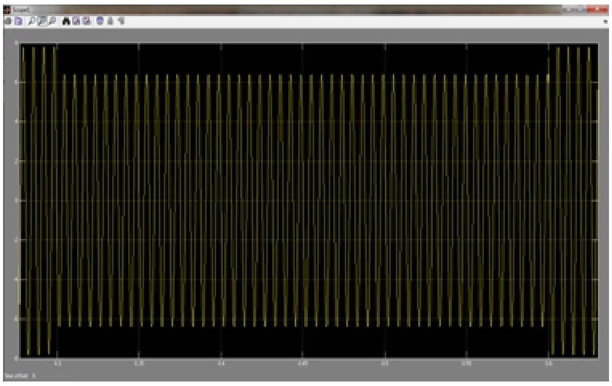
Vabc:-



Torque:



Current:



VI. CONCLUSION:

A boost converter with high voltage gain was presented, and its equations, operation principle, and main theoretical waveforms were all detailed. The topology presents, as main feature, a large voltage step-up with reduced voltage stress across the main switches, important when employed in grid connected systems based on battery storage, like renewable energies systems.

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