Direct Torque Control Method for Induction Motor Drive with Novel Topology

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Abstract— Induction motors are currently used in many industrial applications. Thus, their control techniques have received a lot of interest. An efficient method of induction motor control is the direct torque control (DTC). Three phase induction motor has been used in order to run and evaluate the developed model. The aim of this research work is to evaluate and compare the performances of the 5 level cascaded h-bridge multilevel inverter and Novel Topology of Multilevel inverter with reduce switch both applied to a three phase induction motor drive. The comparison has been made based on the torque and current ripples, settling time, and response times during speed and load disturbances and Total Harmonic distortion (THD). The algorithms are simulated using MATLAB/Simulink and the results are presented. Simulation results have shown the validity and high accuracy of the proposed model.

Key words: Direct Torque Control (DTC), Induction Motor Drive, Novel Topology

I. INTRODUCTION

A three-phase induction motor is basically a constant speed motor. Induction motors are used in a very large scale in industries because of its robust construction, higher efficiency, easy for maintenance, low price and easy availability [1]

The speed control of induction motor is done at the cost of decrease in efficiency. Speed control means change the drive speed as desired by the process to maintain different process parameter at different load. There are basically three types of speed control methods. Such voltage control, frequency control and a voltage to frequency control. In V/f method among these DTC has the advantage of fast torque response along with computational simplicity requiring no coordinate transformations [1]

In the industries, the application like mills, laminators, conveyors, fans and pumps etc require high power and medium voltage. Such a high-power application the multilevel inverter (MLI) [2-3] topology is extending the usage because of its own advantages. The conventional square wave inverter produces more harmonics[4-6].Multilevel inverter the output voltage wave shape is nearly sinusoidal with number of level are introduced in to the market such as diode clamped type, flying capacitor type and cascade multilevel type inverter.

The cascaded multilevel control method is very easy when compare to other multilevel inverter because it doesn't require any clamping diode and flying capacitor. So, most commonly used topology is the cascade H-Bridge invert topology. The number of level can be increased by increasing the number of H-Bridge by using the formula number of levels=2n+1, where n is the number of H-Bridges. In CHB also there are two configurations like Symmetrical [7] and asymmetrical [8]

II. DIRECT TORQUE CONTROL

Direct Torque Control (DTC) has become an alternative to field oriented control or vector control of induction machine. It was introduced in Japan by Takahashi (1984) and Depenbrock (1985). DTC of induction machine has increasingly become the best alternative to Field-Oriented Control methods [9,10].

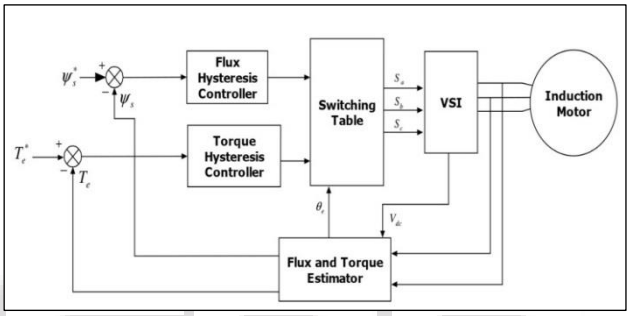

Fig. 1: Induction motor direct torque control block diagram (Basic DTC)

A block diagram of a DTC system for an induction motor is shown in Figure 1 [9]. The DTC scheme is very simple; in its basic configuration it consists of hysteresis controller, torque and flux estimator and switching table. The configuration is much simple that the vector control systems due to the absence of coordinate transformation between stationary frame and synchronous frame and PI regulator. It also does not need a pulse with modulator and a position encoder, which introduce delays and requires mechanical transducer respectively.

DTC base drive is controlled in the manner of a closed loop system without using the current regulation loop. In addition, this controller is very insensitive to parameter detuning in comparison with vector control.

DTC scheme use a stationary d-q frame reference frame (fixe to the stator) having its d-axis aligned with the stator q-axis. Torque and flux are controlled the stator voltage space vector defined in this reference frame.

III. CASCADED H-BRIDGE MULTILEVEL INVERTER

The 5-level cascaded H-Bridge inverter with symmetrical configuration is shown in fig.1. Here, the DC voltage is divided in to two voltage sources as Vdc/2 each and applied as an input for each bridge. In this symmetrical configuration we can get maximum of five levels (Vdc, Vdc/2, 0, -Vdc/2,-Vdc) with two bridges. As each bridge requires four switches, the total switches for the configuration is 8.

Symmetrical Cascaded H-Bridge 5-Level Inverter,

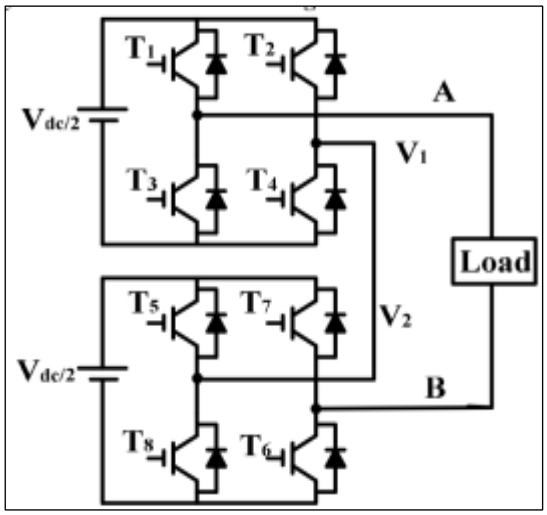

Fig. 2: Symmetrical 5 level CHB inverter

Output Voltage	Switching Sequence							
	T1	T2	T3	T4	T5	T6	T7	T8
0	ON	ON	OFF	OFF	ON	ON	OFF	OFF
VDC/2	ON	OFF	OFF	ON	OFF	OFF	OFF	OFF
VDC	ON	OFF	OFF	ON	ON	OFF	OFF	ON
VDC/2	OFF	ON	ON	OFF	OFF	OFF	OFF	OFF
-VDC	OFF	ON	ON	OFF	OFF	ON	ON	OFF

Table 1: Switching sequence for symmetrical 5 levels CHB inverter

The switching operation for symmetrical 5 level CHB inverter is shown in table I. To get the zero-voltage level, either top or bottom switches must be in ON position. For Vdc/2 and –Vdc/2 level, only one H-Bridge operation is enough.

IV. PROPOSED MULTILEVEL INVERTER

As the number of levels is increasing, the number of switches required increases in case of cascaded H-Bridge multilevel inverter. This drawback can be overcome by using a new multilevel inverter proposed in this work. The new multilevel inverter is configured in both symmetrical configurations. In these configurations the number of switches required is only six.

Proposed Symmetrical 5 Levels Multilevel Inverter:

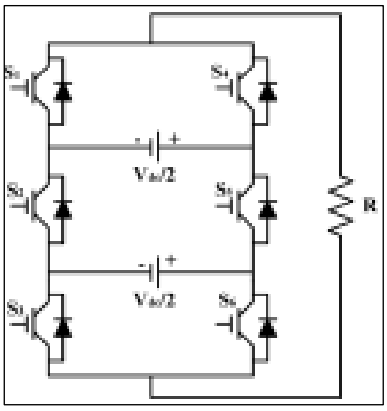

Fig. 3: proposed symmetrical 5 level multilevel inverter

Fig. 3 represents the new symmetrical multilevel inverter topology for five levels. In this topology, two voltage sources of Vdc/2 is used along with six switches.

S.no	Output Voltage levels	Switching sequence					
		S1	S2	S3	S4	S5	S6
1	Vdc/2	0	1	1	1	0	0
2	Vdc	0	1	0	1	0	1
3	0	1	0	0	1	0	0
5	-Vdc/2	1	0	0	0	1	1
6	-Vdc	1	0	1	0	1	0

Table 2: Switching sequence for proposed symmetrical 5level multilevel inverter

The switching sequence for symmetrical five level multilevel inverter is given in Table III. If we switch on the S2,S3 and S4 switches, the voltage appeared across the load is Vdc/2. For Vdc voltage level the switches S2, S4 and S6 must be in ON position. In this manner, we can get five different levels with six switches.

V. COMPARISON OF CASCADED H-BRIDGE AND PROPOSED MLI

The comparison of number of switches used in conventional H-bridge and novel topology for different levels is shown in Table 6.2. From the comparison, it can be seen that for three phase 5-level (24-18=) 6 switches can be saved. For producing m level in output voltage waveform, (m-3) per phase switches can be reduced as compared to conventional multilevel inverter.

No. of voltage levels	Cascaded H-bridge MLI		Novel Topology	
	3-phase No. of switches 6*(m-1)	No. of switches in conduction	3-phase No. of switches 3*(m+1)	No. of switches in conduction
5	24	12	18	9
7	36	18	24	12
9	48	24	30	15

Table 2: Comparison of cascaded h-bridge and proposed MLI for number of switches used for 5, 7 and 9 voltage level

VI. MULTILEVEL INVERTER FED INDUCTION MOTOR DRIVE

The proposed multilevel inverter output is applied to an induction motor drive and the performance characteristics are analyzed.

Proposed 5 Level Inverter Fed Induction Motor Drive,

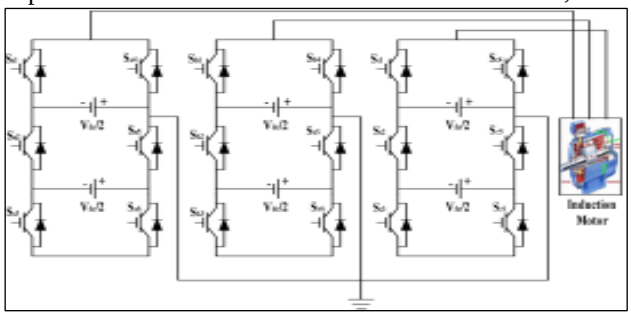

Fig. 4: Proposed 5 level inverter fed induction motor drive

The circuit configuration for 5 level (proposed symmetrical) inverter fed induction motor drive is shown in fig. 4. Each phase consists of six switches with two voltage sources of Vdc/2 each.

VII. MATLAB/SIMULATION RESULTS

Case A : Symmetrical 5 Level CHB Inverter,

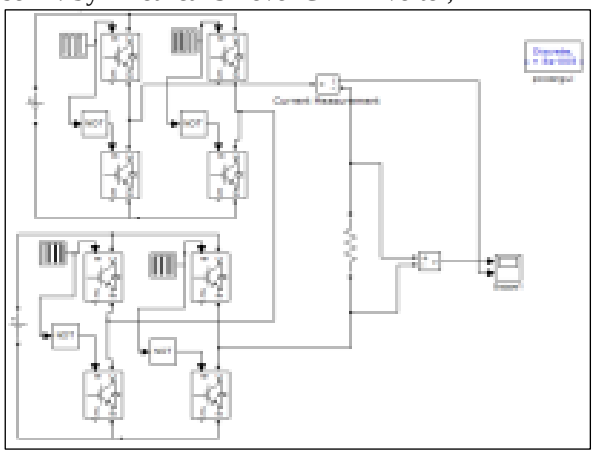

Fig. 5: Simulink model of Symmetrical 5 Level CHB Inverter

The Simulink model of 5 level CHB inverter is shown in fig.7. Here, two DC voltage sources of same rating has been connected to each bridge circuit.

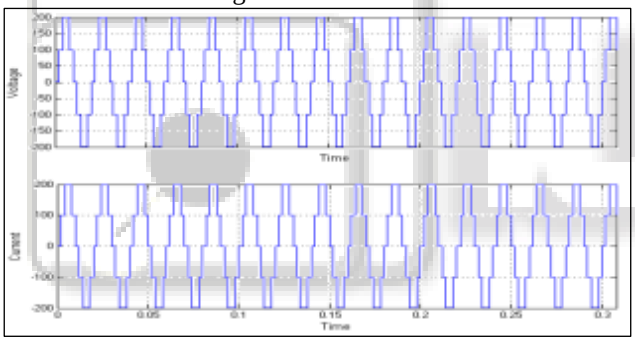

Fig. 6: Output Voltage and Current Waveforms

The output voltage and current wave forms of 5 level CHB Inverter are shown in Fig.6

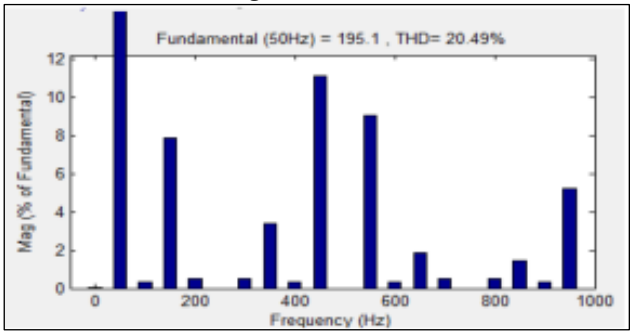

Fig. 7: THD Analysis of 5 Level Output Voltage

The FFT analysis for 5 level voltage wave form is shown in fig.7 and the value of total harmonic distortion is 20.49%.

Case B: Proposed 5 Level Inverter

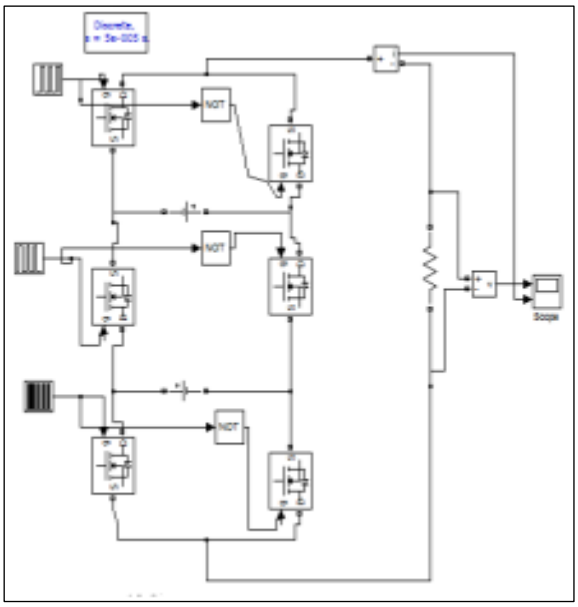

Fig. 8: Simulink Model of Proposed 5 Level Inverter

The Simulink model of proposed six switch inverter for 5 Level is shown in fig.8.

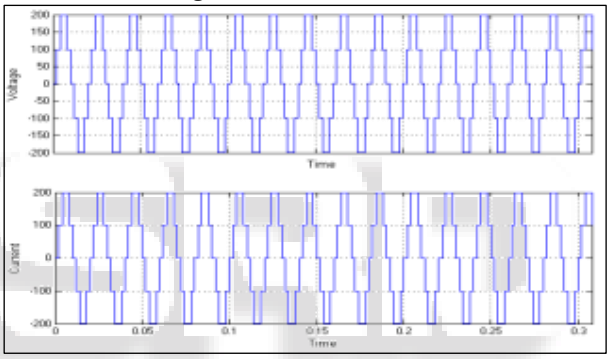

Fig. 9: Output Voltage and Current Waveforms

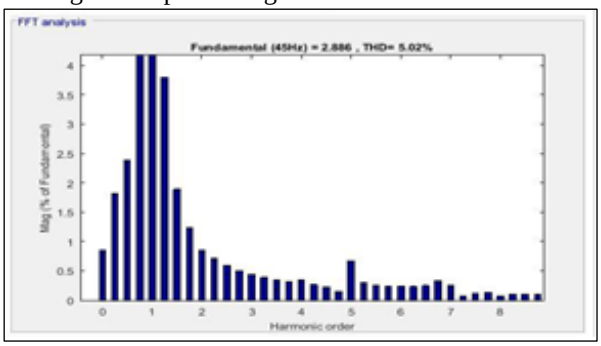

Fig. 10: THD Analysis of 5 Level Output Voltage

Case C: Proposed 5 Level Inverter Fed Induction Motor Drive

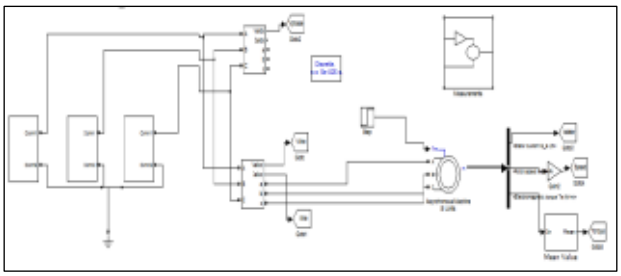

Fig. 11: Simulink Model of Proposed 5 Level Inverter Fed Induction Motor

The proposed 5 level inverter is fed to induction motor and the Simulink model is shown in Fig.11.

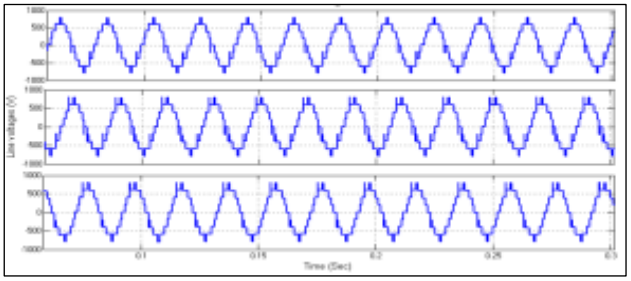

Fig. 12: Line Voltage

The wave form of line voltage supplied to the induction motor is shown in fig.12.

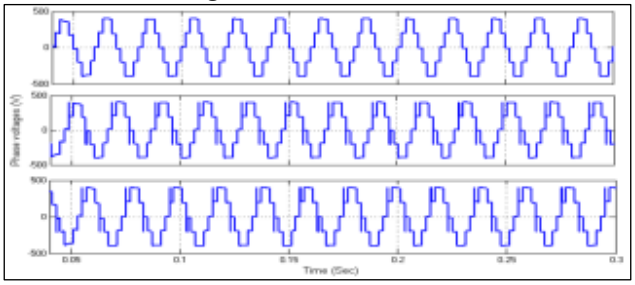

Fig. 13: Phase voltage

Fig.13 Shows the Phase voltage wave form of induction motor.

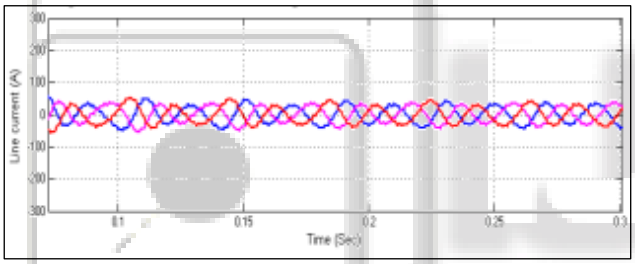

Fig. 14: Line Current

The wave form of line voltage supplied to the induction motor is shown in fig.14.

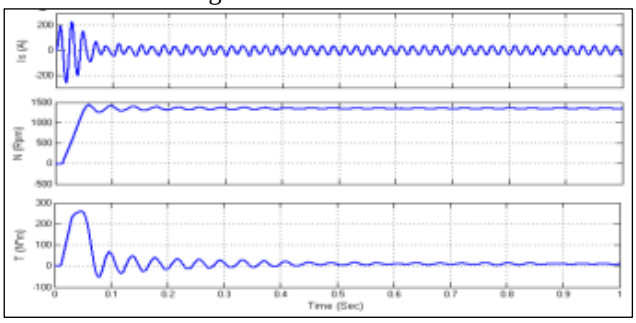

Fig. 15: Stator Current, Speed and Torque of an Induction Motor

The performance characteristics of induction motor like torque, speed and stator current are shown in fig.15.

VIII. Conclusion

A new multilevel inverter with minimum number of switches is proposed for five levels. And, it is strongly proved from the comparison that the proposed topology requires six switches and cascaded H-Bridge inverter requires eight switches for symmetrical configurations. Therefore, we could able to decrease the circuit complexity, size, cost and number of gate driver circuits. Also, the conversion efficiency of the converter increases because of less number of switches. The circuits are modeled and results are displayed. The operation and performance of the proposed multilevel inverter is proved by connecting an induction motor as a load. The stator current, speed and torque characteristics of induction motor are analyzed for proposed five and seven level inverter topologies. The total harmonic distortion is also compared for CHB and proposed topology.

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