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A Comparative Study of Two Level and Cascaded Multilevel Inverter Fed Induction Motor Drive

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Abstract: ***Frequency converters are used in wind turbines because they make it possible to apply the variable-speed concept. They also make it possible for wind farm to become active element in the power system. The traditional frequency converter is back-to-back connected two level converters, in which the output voltage has two possible values. However, the output voltage is smoother with a three-level converter, where output voltage has three possible values. This results in smaller harmonics, but on the other hand it has more components and is more complex to control. Multilevel inverter machinery has emerged recently as a very important alternative in the area of high power medium-voltage control and also for improving the total harmonic distortion by reducing the harmonics. Generally, the poor quality of voltage and current of a conventional inverter fed induction machine is obtained due to the presence of harmonics and hence there is a significant level of energy losses. The objective of this paper is to obtain a 3-level output, which is acquire by a three phase three level cascaded multilevel inverter (MLI) fed induction motor drive. This paper compares three phase two level inverter and three level cascaded inverter fed induction motor Drive.***
Keywords: Two level inverter, PWM Techniques, Total Harmonic Distortion, Cascaded three level Inverter, Induction motor.

I. INTRODUCTION

In the most of industries like oil sector, gas sectors, production plants and process industries Induction motor drive is used. Induction motors is a self starting constant speed AC motors and the speed of motor is depend upon the frequency of the supply and the no of windings. To control the speed of induction motor uses multilevel inverter drives. Because of its low cost and increased reliability Induction motor is the most widely used? The difficulty in using ac drives lies with the selection of suitable power electronic converter hence Pulse Width Modulation (PWM) is used for the control of the power electronic converter. Multilevel inverter could be a great choice for replacing the conventional voltage source inverters or current source inverters, it provides many advantages like reduced voltage stress, increased quality of output voltage and increased power rating [1]

Majority of industrial drives use ac induction motor drive because these motors are rugged, reliable, and relatively and expensive. Induction motors are mainly used for constant speed applications because of unavailability of the variable frequency supply voltage, but many applications need variable speed operations Industrial applications have begun to require higher power apparatus in topical years. Some medium voltage motor drives and utility applications require medium voltage [2]. For a medium voltage grid, it is difficult to connect only one power semiconductor switch directly. As a outcome, a multilevel power converter structure has been introduced as an alternative in high power and medium voltage situations. The perception of multilevel converters has been introduced since 1975. The main advantages of multilevel inverters include the increase of power, the diminution of voltage stress on the power switching devices, and the generation of high quality production voltages[3][4-8]. Multilevel converters are mainly utilized to synthesis a desired single or three-phase voltage waveform. The desired multi-staircase .The importance of multilevel inverters has been increased since last few decades. These new types of inverters are suitable for high voltage and high power application due to their ability to synthesize waveforms with better harmonic spectrum and with less THD. Plentiful techniques have been introduced and widely studied for utility of non conventional sources and also for drive applications. e output voltage is obtained by combining several dc voltage sources[10].

An inverter convert DC power into AC power through waves called either sine waves or modified sine waves. A multilevel(MLI) uses a sequence of semiconductor power converters(usually two or three) thus generating higher voltage, while an inverter would have to flip several switches. An inverter is a device which receives dc supply for its input and produces ac output. A multilevel inverter is a power electronic device that is widely used in industries for high voltage and high power applications, with output harmonic content is reduced by using multilevel inverter (MLI). One important application of multilevel converters is focused on medium and high-power conversion. Nowadays, there exist three commercial topologies of multilevel voltage source inverters:

neutral point diode clamped (NPC), cascaded H-bridge (CHB), and flying capacitors (FCs)[3]. Among these inverter topologies, cascaded multilevel inverter (MLI) reaches the higher output voltage and power levels and the higher reliability due to its modular topology[9][11-12]. Cascaded inverter is the most commonly used multilevel topology, in which the diode is used as the clamping device to clamp the dc bus voltage so as to achieve steps in the output voltage.

The converters which produce an output voltage or a current with levels either 0 or +- Vdc are known as two level converter. In high power and high voltage application, these two level inverters have some limitations in operating at high frequency mainly due to switching losses and constraints of device rating. The three level converter produces output voltage or a current with three levels. The unique structure of three level voltage source converters allows them to reach high voltages with low harmonics without the use of transformer. This results in smaller harmonics. As compare to two level converters, three level converters have smaller output voltage. In addition, the output waveform provides an effective switching frequency twice that of actual switching frequency. In two levels converter total harmonic distortion is poor while in three levels it is better. Power losses in two level converter is more than that of three level converter. Efficiency of three level converters at full load is better than two level converter which is dominate by rectifier losses. Cost of three level converter. The cost of the converter is 40% higher than two level converter. The cost of the converter is mainly dependent on the IGBT and other component used in circuit. Pulse Width Modulation (PWM) technique here used to obtain variable output voltage by varying the gain of the inverter if the dc input voltage is fixed and it is not controllable. The inverter gain may be the ratio of ac output voltage to dc input voltage. This paper presents the most important topologies like diode- clamped inverter (neutral- point clamped), capacitor-clamped (flying capacitor), and cascaded multilevel with separate dc sources. Multilevel inverter is based on the fact that sine wave can be approximated to a stepped waveform having large number of steps. The steps being supplied from different DC levels supported by series connected batteries or capacitors.

II. TWO LEVEL INVERTER

The converters which produce an output voltage or current with level either zero or +Vdc /-Vdc are known as two level converters. In high power and high voltage applications this two level inverter however have some limitations in operating at high frequency mainly due to switching losses and constraints of device rating. In 2-level inverter output voltage waveform is produced by using PWM with two voltage levels, this causes the output voltage and current to be distorted and the THD of the voltage is poor. Figure 1 shows the schematic circuit diagram of two level inverter.

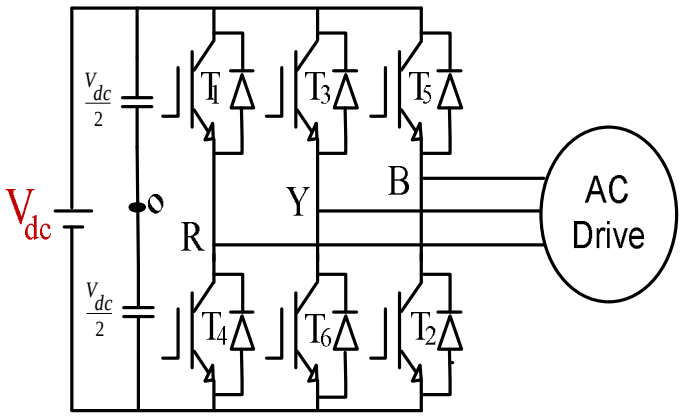

Figure1. Three Phase Voltage Source inverter schematic diagram

TABLE 1: Pole Voltage of two level Inverter

Switches turn on Inverter	pole voltage of Inverter
T1	V_{dc}
T2	0

III. TYPES OF THREE LEVEL INVERTER

The basic three types of multilevel topologies used are:

Diode clamped multilevel inverters

Flying capacitors multilevel inverter or capacitor clamped multilevel inverter.

Cascaded inverter with separate DC sources.

A. Diode Clamped Inverter

The diode clamped multilevel inverter uses capacitors in series to divide the dc bus voltage into a set of voltage levels. To produce n levels of the phase voltage, an n level diode clamp inverter needs (n-1) capacitors on the dc bus.Diode clamped multilevel inverters topology is shown in figure 2

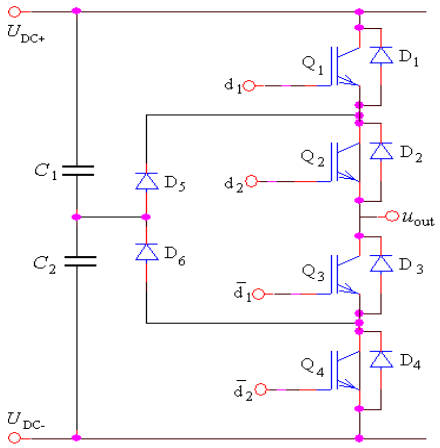

Figure2. Diode Clamped Inverter

B. Flying Capacitor Multilevel Inverter

It uses ladder structures of dc side capacitors where the voltage on each capacitor differs from that of the next capacitor. To generate n- level staircase output voltage, (n-1) capacitors in the dc bus are needed. The size of the voltage increment between two capacitors determines the size of the voltage levels in the output wave. flying capacitor multilevel inverters topology is shown in fig 3.

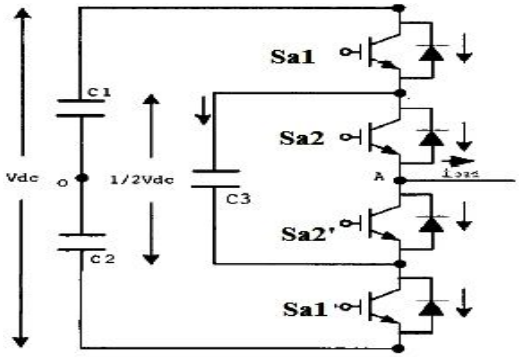

Figure3. Flying Capacitor Multilevel Inverter

C. Cascaded Inverter with Separate DC Source

This inverter is nothing but the series connection of single connection of single phase inverters with separate dc source. This inverter can be avoiding the extra clamping diodes or voltage balancing capacitors. In this paper, cascaded multilevel inverters topology is used and is shown in fig 4

TABLE 2: Comparison of different Multilevel Inverter Topologies

S.No	Topology	Diode Clamped	Flying Capacitor	Cascaded
1	Power Semi conductor switches	2(n-1)	2(n-1)	2(n-1)
2	Clamping diodes per phase	(n-1) (n-2)	0	0
3	DC capacitors	0	(n-1) (n-2)/2	0
4	Balancing capacitors per phase	0	(n-1) (n-1)/2	0
5	Voltage unbalancing	Average	High	Very small

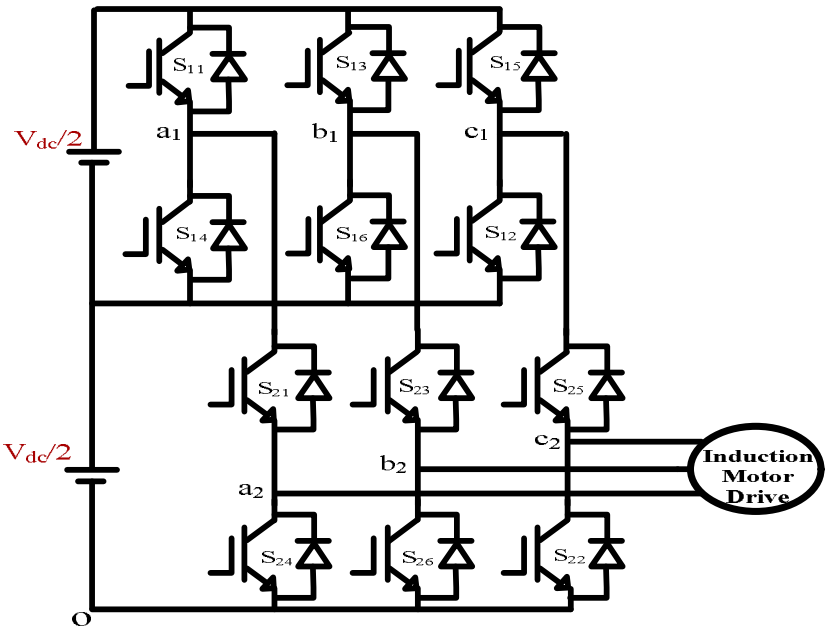

Figure4.Cascaded three level Inverter

IV. THREE LEVEL CASCADED INVERTER

The concept of multilevel converters has been introduced since 1975. The term multilevel began with the three-level converter. Subsequently, several multilevel converter topologies have been developed. However, the elementary concept of a multilevel converter to achieve higher power is to use a series of power semiconductor switches with several lower voltage dc sources to perform the power conversion by synthesizing a staircase voltage waveform. Capacitors, batteries, and renewable energy voltage sources can be used as the multiple dc voltage sources.

The functions of using multilevel power converters are twofold. Firstly [14], the series connection of power converter modules reduces the voltage stress of each converter module (or increases the voltage capability of the overall converter structure), making the multilevel converters suitable for high-voltage applications. Secondly, the resolution of the ac voltage waveforms (i.e., the quality of the generated voltage) increases with the number of voltage levels available in the multilevel converters. As a result of the improved resolution in the voltage harmonic content, filtering efforts can be reduced if the multilevel converters are used in FACTS applications.

The unique structure of three level voltage source converters allows them to reach high voltages with low harmonics without the use of transformers or series-co. The harmonic content of the output voltage waveform decreases significantly. As compared to two level inverters, three level inverters have smaller output voltage. In addition, the output waveform provides an effective switching frequency twice that of the actual switching frequency.

TABLE 3: Comparison of conventional two level inverters and multilevel inverters

S.No	Conventional Inverter	Multilevel Inverter
1	Higher THD in output voltage	Low THD in output voltage
2	More switching stresses on devices	Reduced switching stresses on Devices
3	Not applicable for high voltage applications	Applicable for high voltage Applications
4	Higher voltage levels are not produced	Higher voltage levels are Produced
5	Since dv/dt is high, the EMI from system is high	Since dv/dt is low, the EMI from system is low
6	Higher switching frequency is used hence switching losses is high	Lower switching frequency can be used and hence reduction inswitching losses
7	Power bus structure, control schemes are simple	control scheme becomes complex as number of levels increases

TABLE 4: Pole Voltage of Inverter-2

Switches turn on Inverter-I	Switches turn on Inverter-2	pole voltage of Inverter-2
S14 or S16 or S12	S21 or S23 or S25	V_{dc}
S14 or S16 or S12	S21 or S23 or S25	$V_{dc}/2$
S11 or S13 or S15	S22 or S24 or S26	0
S11 or S13 or S15	S22 or S24 or S26	0

V. MODULATION ALGORITHM

Multilevel converters are mainly controlled with Space Vector PWM extended to multiple carrier arrangements of two types: Level Shifted (LS-PWM), which includes Phase Disposition (PD-PWM), Phase Opposition Disposition (POD-PWM) and Alternative Phase Opposition Disposition (APOD-PWM) or they can be Phase Shifted (PS-PWM). In propose topology POD is used as shown in Figure 5

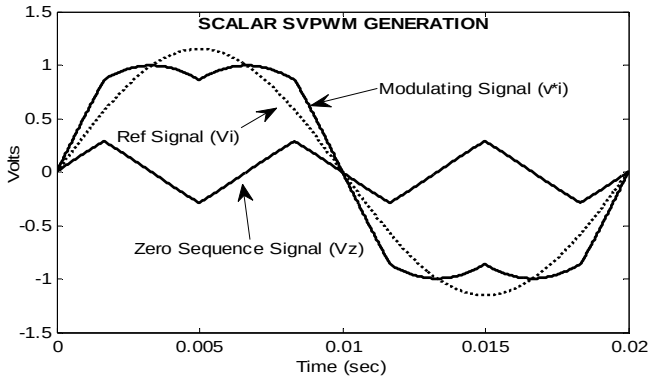

Figure 5.Modulating signals and zero sequence signals

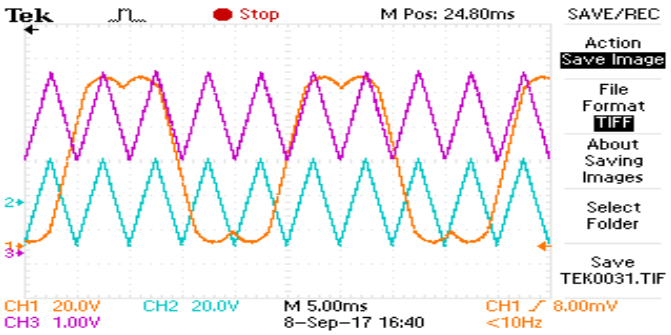

Figure6.Modulating signals with carrier signal arrangements.

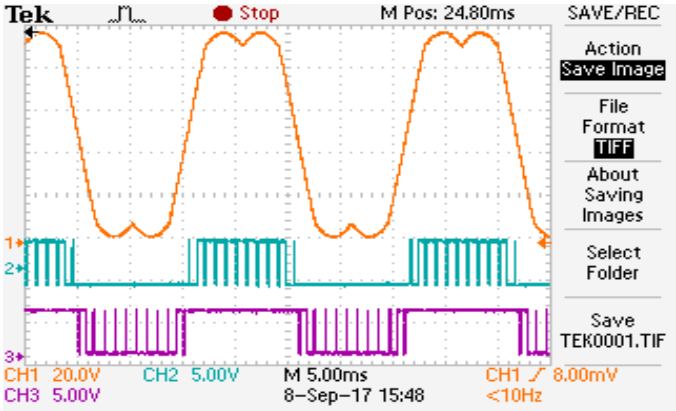

Figure7.Modulating signals with carrier signal arrangements.

VI. RESULTS AND DISCUSSION

To validate the proposed work, simulation studies has been carried by using MATLAB/SIMULINK. The switching frequency considered for simulation is 3 kHz and the ratings of the induction motor considered as 3-pahse 50 Hz, 4-pole, 1470rpm, 4 kW with the following parameters.

Rs= 1.57Ω, Rr = 1.21Ω, Ls = 0.17H, L r = 0.17H,

Lm = 0.165 H and J = 0.089 Kg.m^2.

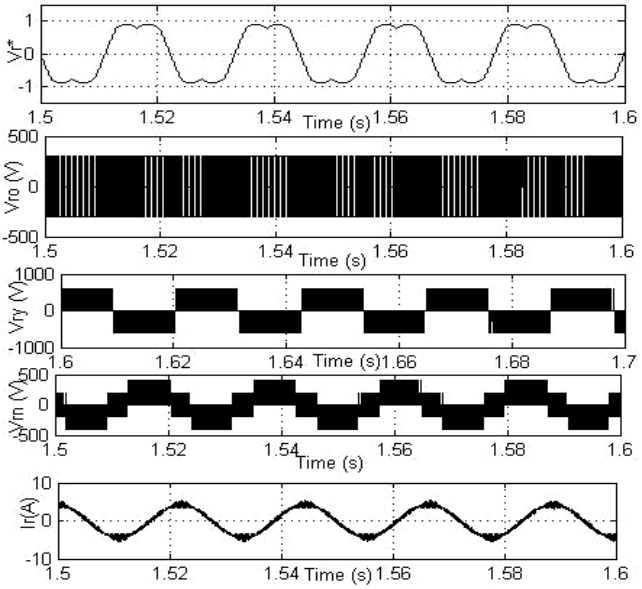

Fig. 8 Two Level Inverter: Modulating Signal, Pole Voltage, Line Voltage, Phase Voltage and stator current.

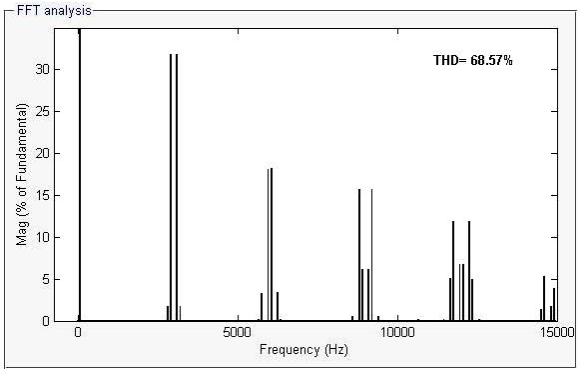

Fig. 9 Two Level Inverter: Harmonic distortion of line voltage along with THD

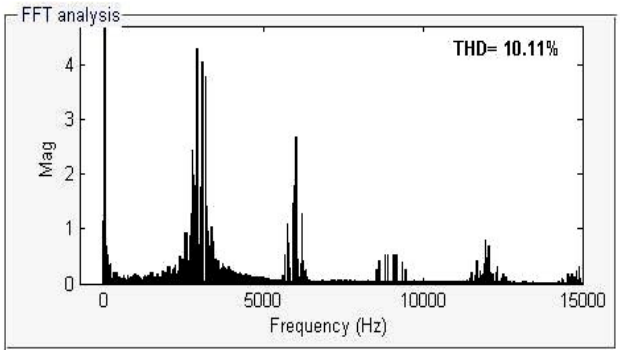

Fig. 10 Two Level Inverter: Harmonic distortion of line current along with THD

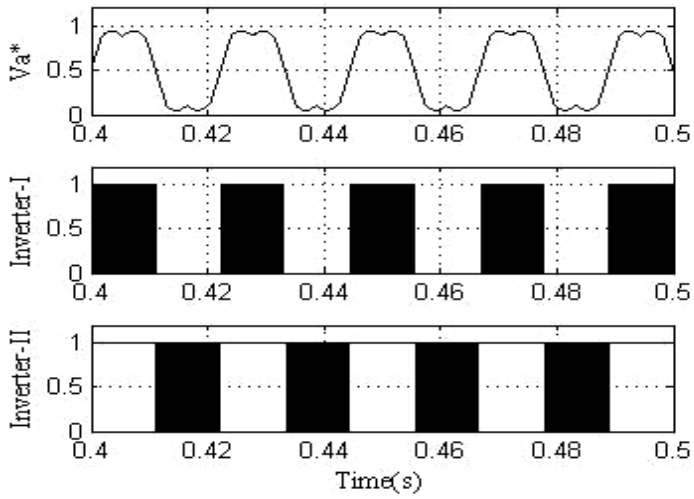

Fig 10. Three Level Inverter: Modulating Signal, Pulses for Inverter-I & II

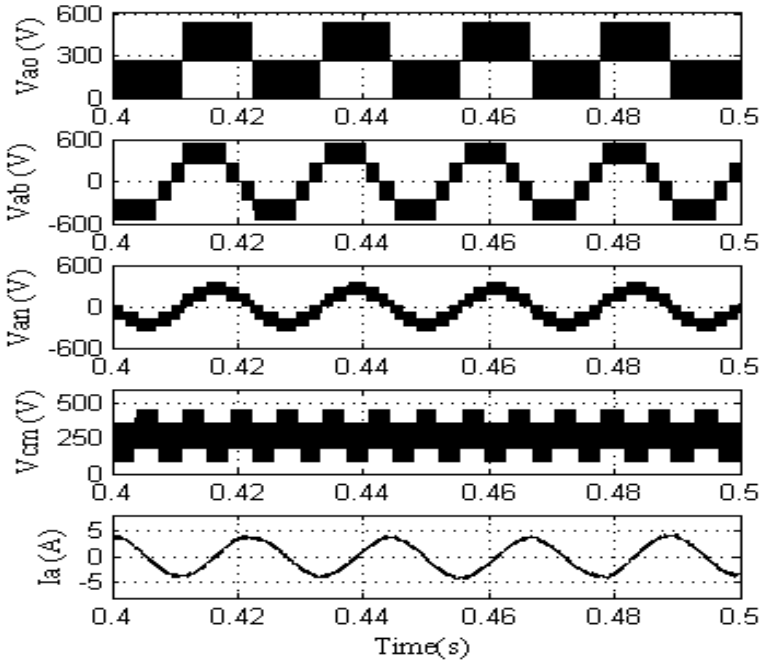

Fig. 11 Three Level Inverter: Pole Voltage, Line Voltage, Phase Voltage, Common mode voltage and Stator Current

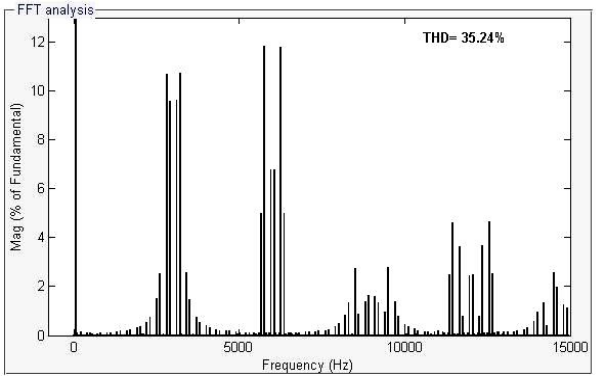

Fig. 12 Three Level Inverter: Harmonic distortion of line voltage along with THD

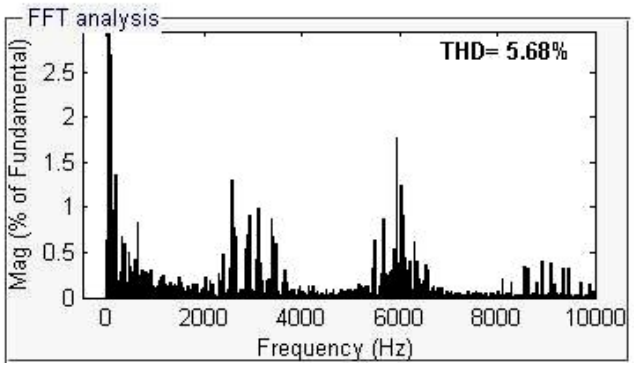

Fig 13. Three Level Inverter: Harmonic distortion of line current along with THD

TABLE 5: Comparison of Line Current THD & Common Mode Voltage

S.No.	Inverter Configuration	THD	
		Line voltage	Stator Current
1	Two Level Inverter	68.57%	10.11%
2	Three Level Inverter	35.25%	5.68%

VII. CONCLUSIONS

In this paper scalar SVPWM techniques for two level and cascaded three level inverter fed v/f controlled induction motor drive is presented. In this paper simulation results of three phase three level cascaded multilevel inverter fed Induction Motor drivewith modulating strategy are obtained through MATLAB/SIMULINK. The cascaded inverter provides multiple voltage levels through cascade connection of two 2 level inverters. The harmonic characteristics of stator current of induction motor are obtained and is observed that using three level configuration there is a considerable reduction in total harmonic distortion of stator current as compare to two level inverter.

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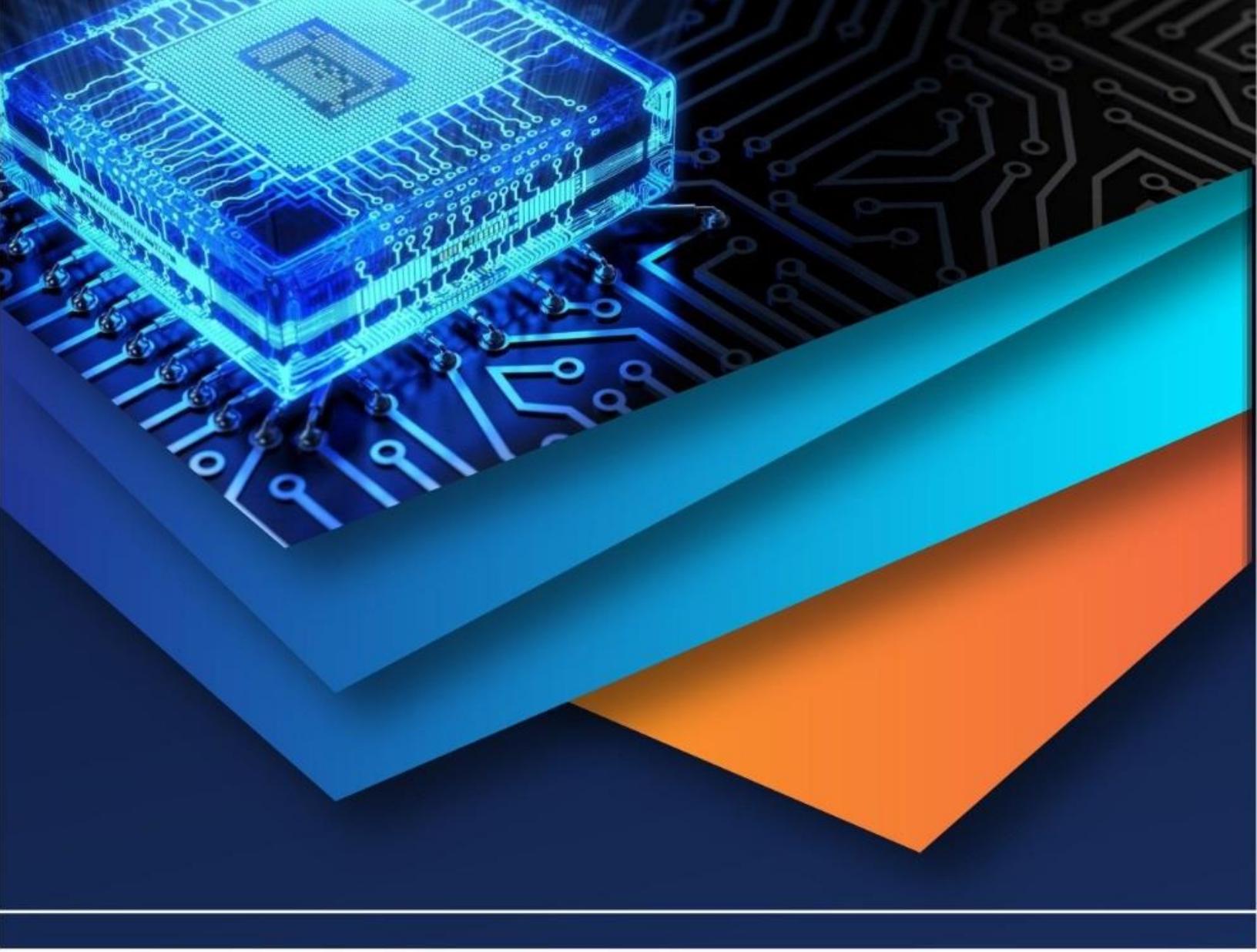

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