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Performance Evaluation of Induction Motor with Reduced Components Count Multilevel Inverter

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***Abstract*— This research paper includes the simulation model of 3 phase Induction Motor with half bridge Multi level Inverter built in MATLAB Simulink. This involves constructing the block diagram of the system, including the inverter, the motor, and the control system. The output parameters of the motor are analyzed like Rotor Current, Rotor Voltage, Stator Current, Stator Voltage, THD, as well as the number of levels and the switching frequency of the inverter. Extensive research is carried out to study various performance parameters of the induction motor, such as the FFT analysis and the load torque, the stator current where the motor speed, the rotor current, etc. were investigated. The results are verified by the MATLAB/ SIMULINK environment.**

***Index Terms*— Induction Motor, Multilevel Inverter, Harmonics, THD..**

I. INTRODUCTION

ELECTRIC motors are an essential component of modern industrial and household applications. They are highly efficient, reliable, and durable, making them a popular choice for various purposes such as driving pumps, compressors, fans, and conveyor systems. However, despite their numerous advantages, electric motors do have certain limitations associated with their usage [1]. These limitations include limited speed control, low efficiency, poor power factor, and difficulty in starting. Fortunately, inverters can be used to address these issues by providing variable frequency and voltage control to the motor. This enables the motor to operate at different speeds and loads, which can significantly improve its efficiency, reduce energy consumption, and increase its lifespan. Additionally, inverters can improve the power factor of the motor, making it operate more efficiently and reducing power losses. Inverters can also enable soft starting, which reduces voltage dips [2] and other problems during the starting phase, improving the reliability and longevity of the motor.

Overall, inverters are a highly effective tool for addressing the limitations of electric motors, providing greater control and flexibility over the motor's operation while improving its overall efficiency and reliability. Over the past few decades, multilevel inverters (MLIs) have become incredibly popular [3]. To lower overall harmonic distortion and boost power quality and output waveform, researchers are attempting to explore for an increasing number of levels. Although the less distorted waveform is quite close to a perfect sinusoidal wave, there will always be some distinguishing features. The number of components and switching losses rise as the number of voltage levels and switching devices increases [4].

This paper is structured as follows. Section II deals with the MATLAB simulation of induction motor with reduced components five level multilevel inverter along with working principle and proposed DC switched MLI. In section III Results of Output voltage and its total harmonic distortion is discussed. In section IV, Induction Motor performance of proposed work is compared with conventional Inverter. In section V, conclusion is discussed.

II. PROPOSED H MULTILEVEL INVERTER

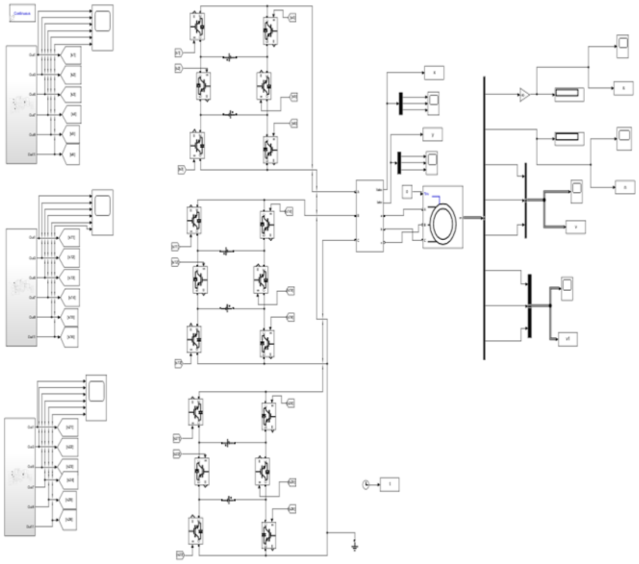

Fig: 1 Model of Induction Motor with proposed DC switched MLI

The proposed Multilevel Inverter (MLI) is designed to achieve a greater number of voltage levels with fewer switches, while enabling the parallel operation of multiple DC voltage sources [5]. Figure 1 depicts a MATLAB/SIMULINK model of the proposed induction motor integrated with the DC Switched Multilevel Inverter.

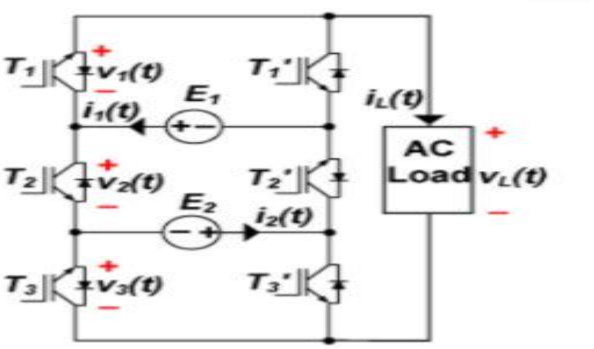

Figure 2: Proposed DC Switched MLI

In Figure 2 DC switched source scheme DC sources are alternately connected in opposite polarities with one another through power switches.

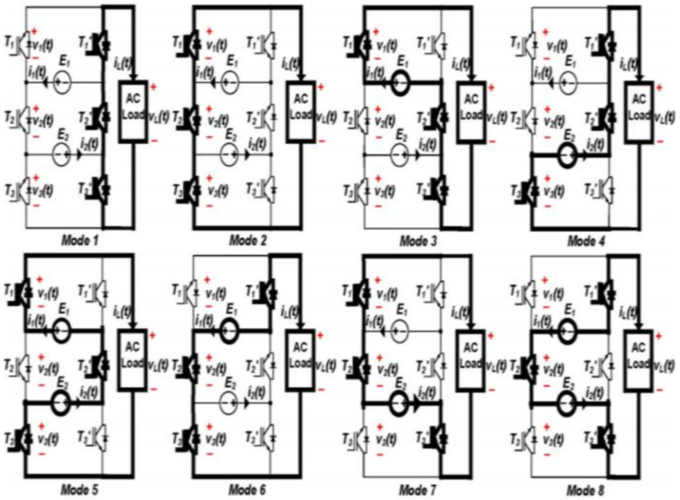

Figure 3: Operation modes of DC Switched MLI

In the phase opposite disposition PWM control scheme, the four carrier signals are generated using a switching algorithm that ensures that each signal is 120 degrees out of phase with the others. The switching algorithm is designed to ensure that the output waveform has a low total harmonic distortion (THD) and a high power factor [6].

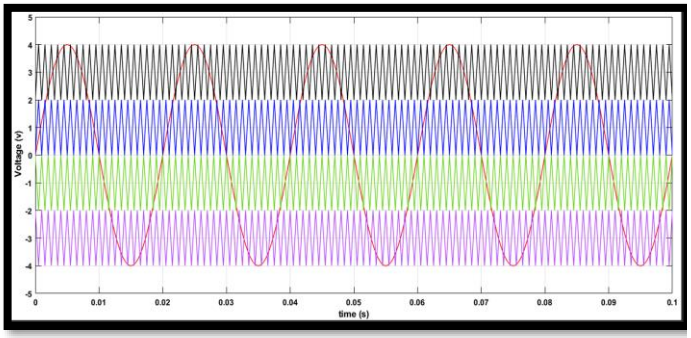

Fig: 5 POD Sinusoidal PWM control scheme for Phase voltage

The switching algorithm works by dividing each half-cycle of the reference sine wave into six equal parts. Each carrier signal is then turned on for two of these parts and turned off for the other four, resulting in a series of pulses with a width proportional to the amplitude of the reference sine wave. The resulting PWM signals are then combined to produce the three-level output waveform. To generate the positive half of the waveform, the two upper carrier signals are combined, while to generate the negative half, the two lower carrier signals are combined. The middle level is simply the absence of any carrier signal. The three-level output waveform can be used to regulate the voltage and current of a load, such as a motor or a power supply. The PWM technique allows for precise control of the output waveform, which can be used to achieve high efficiency, low THD, and high power factor.

Mode	Switch states(1=ON: 0=OFF)			Nodal voltages			Source Currents		Output Voltage $V_L(t)$
	T_1	T_2	T_3	$V_1(t)$	$V_2(t)$	$V_3(t)$	$i_1(t)$	$i_2(t)$	
1	0	0	0	-E1	E1+E2	-E2	0	0	0
2	1	1	1	0	0	0	0	0	0
3	1	0	0	0	E1+E2	-E2	$i_L(t)$	0	E1
4	0	0	1	-E1	E1+E2	0	0	$i_L(t)$	E2
5	1	0	1	0	E1+E2	0	$i_L(t)$	$i_L(t)$	E1+E2
6	0	1	1	-E1	0	0	$-i_L(t)$	0	-E1
7	1	1	0	0	0	-E2	0	$-i_L(t)$	-E2
8	0	1	0	-E1	0	-E2	$-i_L(t)$	$-i_L(t)$	-(E1+E2)

Fig: 4 Switching Scheme of Control signals

In the first mode T1, T2 and T3 are not turned on which means no any source is acting on the load therefore output voltage is Zero. In second mode output is again zero. Third mode generates E1 voltage at the output. Mode 4 generates E2. Output of mode 5 is combination of E1 and E2. For rest of the modes negative voltages appeared at the output.

III. RESULTS AND DISCUSSION

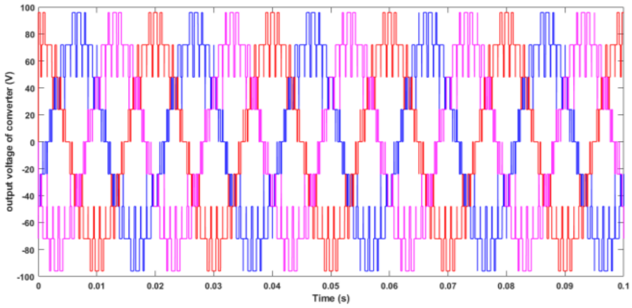

Fig: 5 Stator Line Output Voltage Waveform

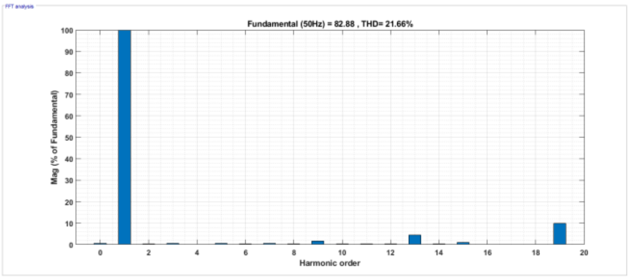

Figure 6 THD of Stator line output voltage

According to Fig. 5, the output voltage's overall harmonic distortion is 21.66 percent. A 50Hz fundamental frequency is used to create the harmonics, which are then sampled at a Nyquist frequency. The harmonic order is indicated at the x-axis, while the harmonic magnitude is indicated at the y-axis.

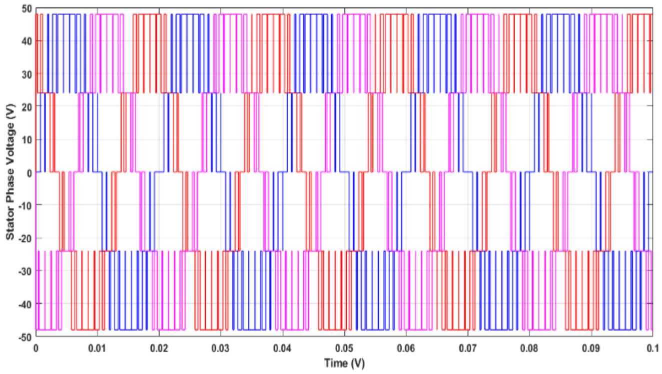

Figure:7 Stator Phase Output Voltage

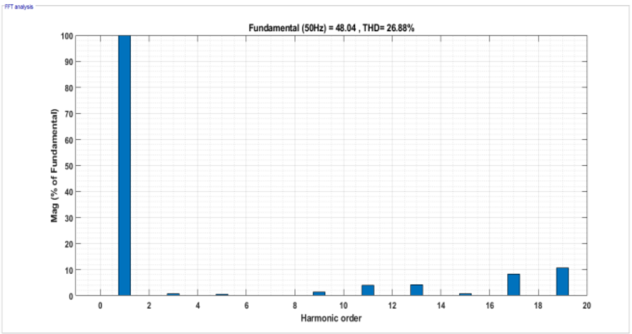

Figure:8 THD of Stator Phase output voltage

According to Fig, 8 the output voltage's overall harmonic distortion is 14.15 percent. A 50Hz fundamental frequency is used to create the harmonics, which are then sampled at a Nyquist frequency. The harmonic order is indicated at the x-axis, while the harmonic magnitude is indicated at the y-axis

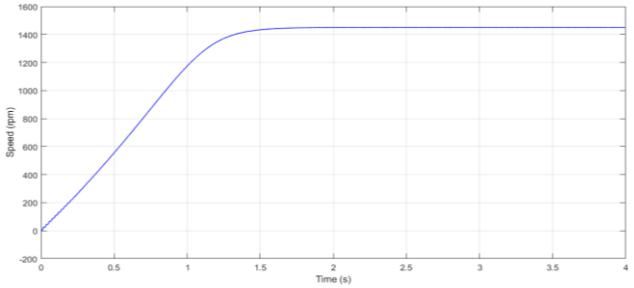

Figure:9 Motor Speed with rpm

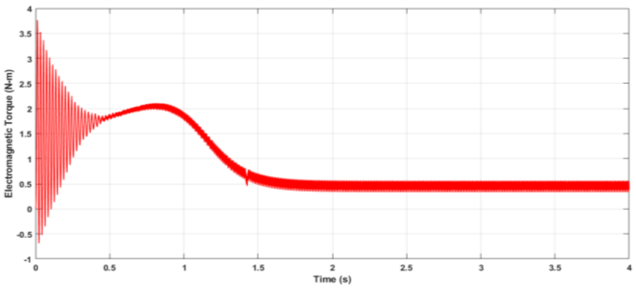

Figure:10 Torque produced by motor

The above graph shows the electromagnetic torque developed by the machine. Because the stator is fed by a PWM inverter, a noisy torque is observed. However, this noise is not visible in the speed because it is filtered out by the machine's inertia, but it can be seen in the stator and rotor currents.

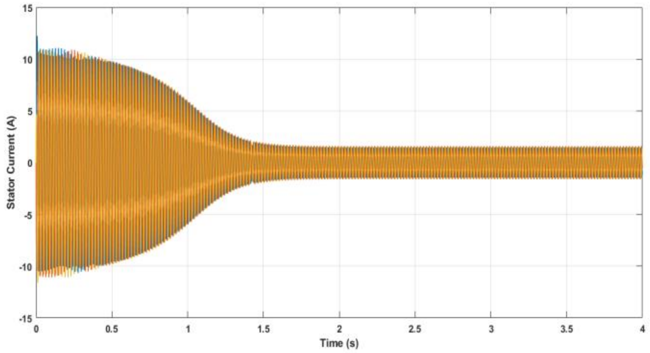

Figure:11 Stator current of IM with dc switched MLI

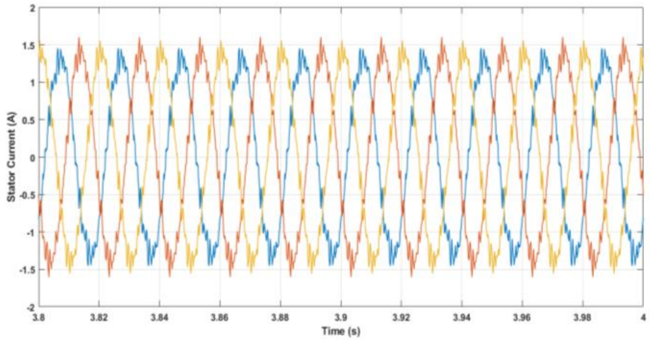

Figure:12 Zoom view of Stator current Output

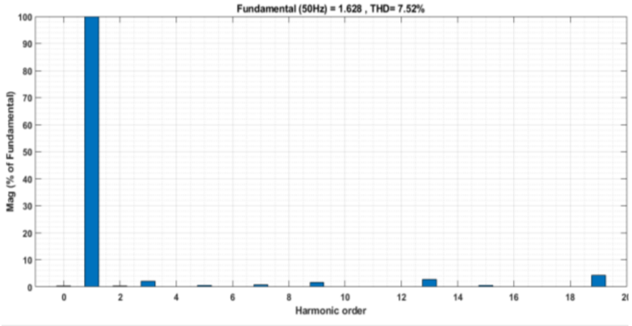

Figure:13 THD spectrum of Stator Current

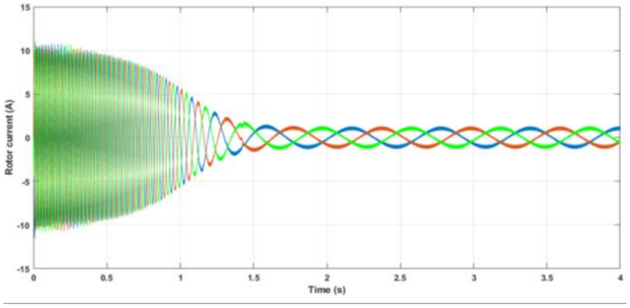

Figure:14 Rotor Current with DC Switched MLI

IV. PERFORMANCE COMPARISON WITH CONVENTIONAL INVERTER

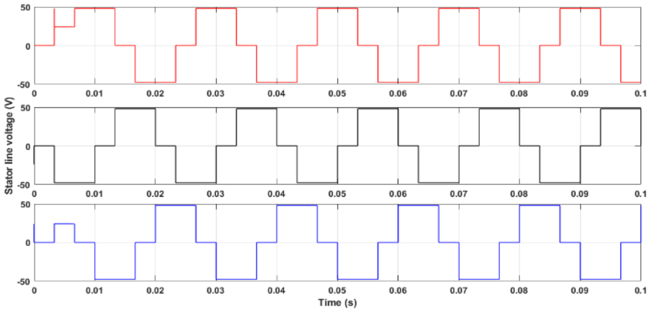

Figure:15 Stator Line voltage with 2 level Inverter

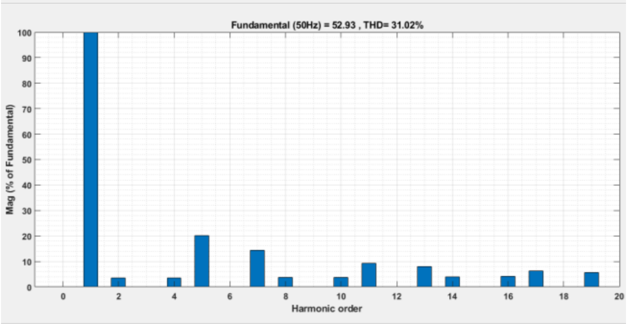

Figure:16 Harmonic Spectrum with two level Inverter

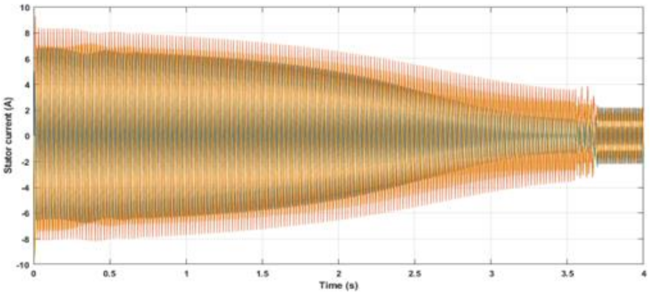

Figure: 17 Stator Current With Two level Inverter

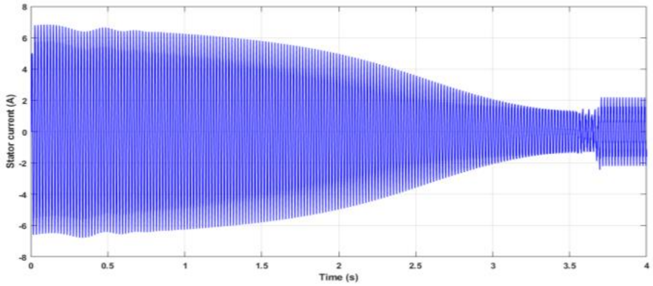

Figure:18 Rotor Current with two level inverter

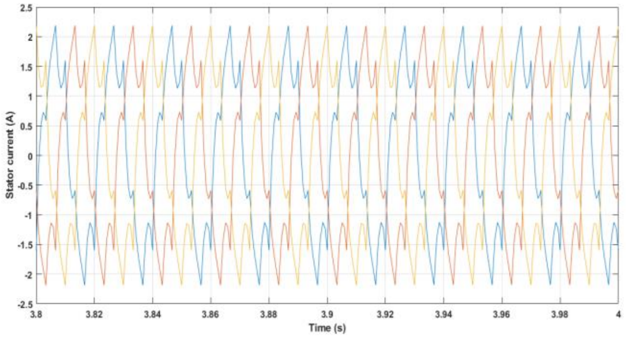

Figure:19 Enlarge view of Stator Current with two level inverter

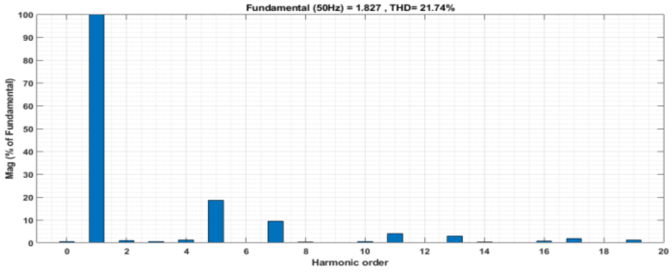

Figure:20 Harmonic spectrum of Stator current with two level inverter

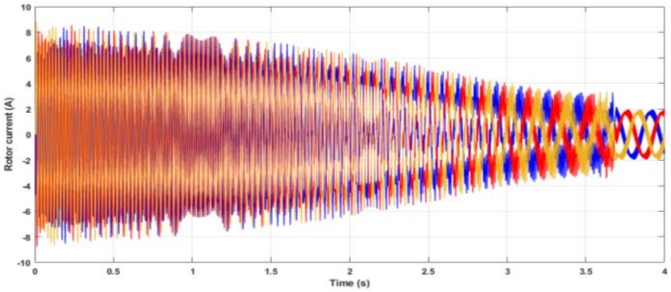

Figure:21 Rotor current with two level inverter

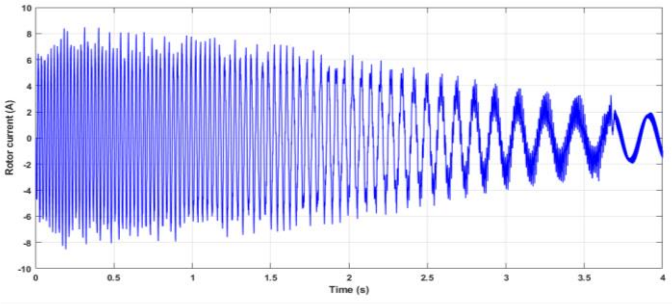

Figure: 22 Rotor current with two level inverter.

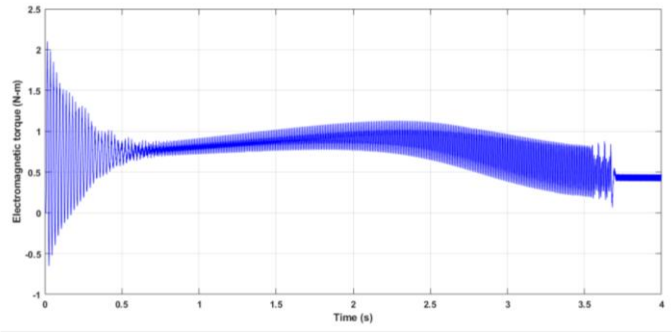

Figure:23 Electromagnetic Torque of IM with two level inverter.

Table : 1 Comparison of proposed and two level inverter

Topology	**$F_{fundamental}$**	**$F_{switching}$**	**No: of Switches**	**Number of Output levels**	**%THD in Stator Current**
Two Level Inverter	50	1 KHz	6	2	21.74
Proposed Work	50	1 KHz	6	5	7.52

In this table. The two proposed works are contrasted with earlier research on Induction Motor performances with MLI and conventional inverter. The designed model is being examined using traditional topology in relation to the quantity of devices, output voltage ranges, and THD. The data clearly shows that the proposed topology generates five levels at the output when the same number of components are used, which lowers THD levels as well.

The THD value of the suggested work is clearly lower than that of earlier work, as can be shown in table 1.

V. CONCLUSION

The results show that the THD of the stator current with the reduced component count MLI is significantly lower than that with the conventional two-level inverter. Specifically, the THD of the stator line voltage with the reduced component count MLI is 26.88%, while that with the two-level inverter is 31.02%. Furthermore, the THD of the stator current with the reduced component count MLI is 7.52%, while that with the two-level inverter is 21.74%. These findings demonstrate the potential of the reduced component count MLI as a more efficient and effective alternative to the conventional two-level inverter for induction motor control. This can lead to reduced losses as well as improved thermal management and reduced electromagnetic interference. This can be particularly important in critical applications where downtime can be costly or dangerous.

Overall, the use of a multi-level inverter can significantly improve the performance, efficiency, and reliability of an induction motor. With their ability to produce high-quality output waveforms, operate at high frequencies, and offer improved fault tolerance, multi-level inverters are a promising development in the field of power electronics that can benefit a wide range of industrial and transportation applications.

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