International Journal of Innovative Research in Advanced Engineering (IJIRAE) ISSN: 2349-2163
Volume 1 Issue 12 (December 2014) www.ijirae.com

Speed Control of 3 phase of Induction Motor by Using Multilevel Inverter

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Abstract: Induction motors are widely used in industries, because they are rugged, reliable and economical. Induction motor drive requires suitable converters to get the required speed and torque without or negligible ripples. Multilevel inverter technology 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 simulation results of proposed topology three phase five-level and seven-level multilevel inverter fed induction motor drive are verified using MATLAB. The THD between five-level and seven-level inverter is compared it can be observed that in the higher levels THD is reduced.
Key words: Induction Motor, Multi Level Inverter, Total Harmonic Distortion, PWM Technique

I. INTRODUCTION

Most of the industrial drives use ac induction motor because these motors are rugged, reliable, and relatively inexpensive. 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. Historically, mechanical gear systems were used to obtain variable speed. Recently, power electronics and control systems have matured to allow these components to be used for motor control in place of mechanical gears. Present day drive types are the Induction motor drives with voltage source inverters. Also the voltage waveforms of traditional two level inverter fed Induction motor shows that the voltage across the motor contains not only the required "fundamental" sinusoidal components, but also pulses of voltage i.e. "ripple "voltage. The recent advancement in power electronics has initiated to improve the level of inverter instead increasing the size of filter. The total harmonic distortion of the classical inverter is very high. The performance of the multilevel inverter is better than classical inverter. In other words the total harmonic distortion for multilevel inverter is low. The total harmonic distortion is analyzed between multilevel inverter and other classical inverter. To get the speed control of induction motor, we need vary both voltage and current. This technique is called as constant V/F [1] method. By choosing the suitable inverter we can vary both voltage and frequency of the induction motor to get the required speed control. Normally the conventional H-bridge inverter produces a square output, which contains infinite number of odd harmonics and dv/dt stress is also high. Normal PWM inverter[2] can reduces the THD , but Switching losses are high and also this inverter is restricted to low power applications. The importance of multilevel inverters [MLI] has been increased since last few decades [3], [4]. 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. Generally MLIs are classified into three types: they are 1.Diode Clamped MLIs 2. Flying capacitor MLIs 3. Cascaded H-bridge MLIs. Diode clamped MLIs require large number of clamping diodes [5] as the level increases. In flying capacitor MLIs, Switching utilization and efficiency [6, 7] are poor and also it requires large number of capacitors as the level increases and cost is also high. Cascaded H-bridge MLIs are mostly preferred [8] for high power applications as the regulation of the DC bus is simple. But it requires separate dc sources and also the complexity of the structure is increases as the level predominantly increase. In order to address the above concerns, this paper proposes a new type of multilevel inverter which requires less number of DC sources and switches compared to Cascaded H-bridge MLIs.

II. BASIC STRUCTURE OF INDUCTION MOTOR DRIVE SYSTEM

Its structure configured in five sections such as supply system, communication system, control system, sensor system, drive system.

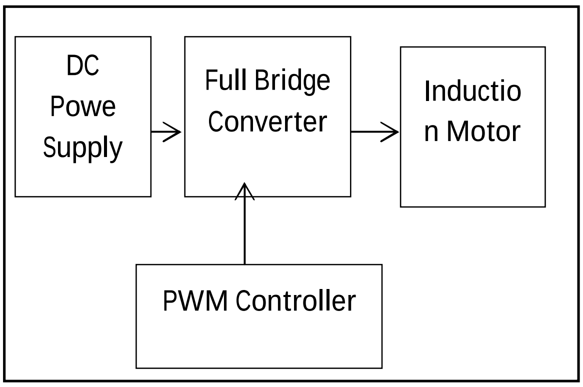

Fig1: Block dia. Of Multilevel Fed Induction Motor Drive

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III. CLASSIFICATION OF MULTILEVEL INVERTER

1. Neutral point clamped inverter (NPC): The neutral point clamped topology is also known as diode clamped topology. The main advantage of the NPC topology is that it requires only one DC source similar to two- level inverter, and gives better performance. With the increase in level 'n', not only the number of clamping diodes increases but also the problem of ensuring the DC-link balance becomes more severe.

2. Cascaded H-bridge Topology (CHB)

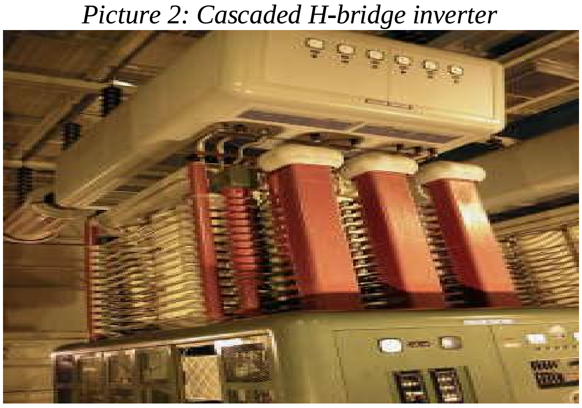
In this topology the H-bridges are cascaded in every phase. With the increase in H- bridges in a phase, the output voltage waveform tends to be more sinusoidal. In n-level topology, (n-1)/2 identical H- Bridges are used in every phase. There must be a separate DC source for the DC bus of every individual H-bridge.

3. Flying Capacitor Topology (FC)

It is also known as capacitor clamped topology. For this topology 'n' can take any integer value similar to NPC topology. The voltage clamping is done by using capacitors floating with respect to the earth potential.

Picture 1: Three level neutral clamped inverter

Picture 2: Cascaded H-bridge inverter



Picture 3: Flying Capacitor Topology

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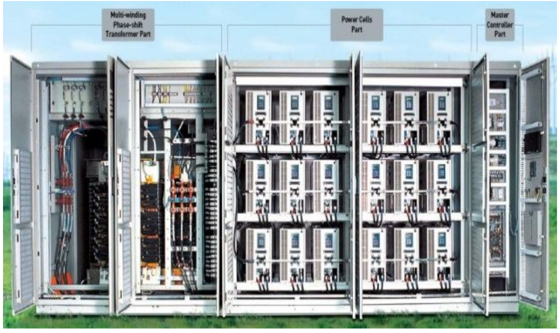

Fig.4: Multilevel Inverter

IV. Operation of Multilevel Inverter :

1) Five level Inverter:

Operation can be explained with the help of fig.2 and Table.1. By proper switching combinations of the switches S1 to S4 the positive half cycle can be generated. Switches SH1 and SH2 are complementary in full bridge converter, similarly SH2 and SH3 are also complementary. When SH1 and SH2 are switched on together positive half cycle can be obtained to the load. When SH3 and SH8 switched on together positive half cycle to be converted in to negative half cycle to the load. This

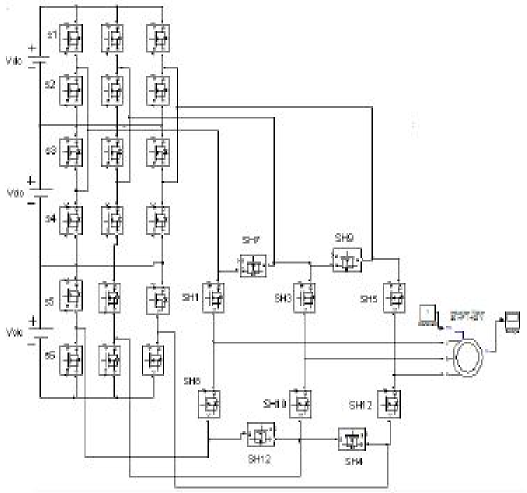

Fig.3 Simulink diagram of Seven-level multilevel inverter for Induction motor drive

topology requires half of the fundamental output whereas output for negative half cycle is automatically generated by switching of full bridge converter.

Table 1
Switching states for five level inverter

Output Voltage	S1	S2	S3	S4
0	0	1	1	0
V_{dc}	0	1	0	1
$2V_{dc}$	1	0	0	1

2) Seven level Inverter:

The operation of seven level inverter is shown in Fig.3.The proper switching combination of switches S1 to S6 as shown in Table.2 the positive half cycle can be generated. This positive half cycle can be converted in to negative half cycle by means of full bridge converter circuit. In seven level inverter modified full bridge converter circuit is used to reduce the switching devices requirement. Generally in fig.2 full bridge converter need 12 switches to generate positive or negative half cycle. In seven level inverter circuit of fig.3 modified full bridge converter need only 10 switches to generate positive and negative half cycle to the load. When compared to other available topologies of multilevel inverters as shown in Table.3 this new topology require less device count.

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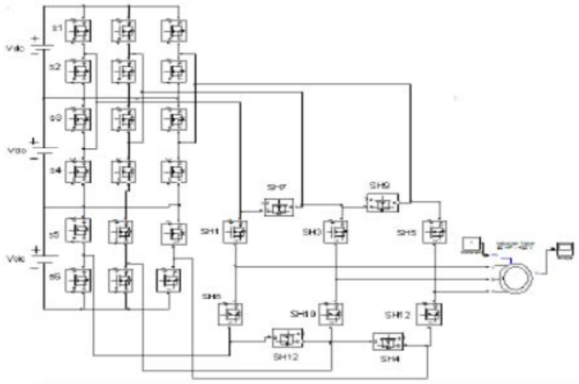

Fig.3 Simulink diagram of Seven-level multilevel inverter for Induction motor drive

Table 2

Switching states for 7 level inverter

Output Voltage	S1	S2	S3	S4	S5	S6
0	0	1	1	0	0	0
V_{dc}	0	1	0	1	0	0
$2V_{dc}$	1	0	0	0	1	0
$3V_{dc}$	1	0	0	0	0	1

Number of components for three phase inverter

Table 3

Inverter Type	NPC	Flying Capacitor	Cascaded H-Bridge
Main Switches	6(N-1)	6(N-1)	6(N-1)
Main Diodes	6(N-1)	6(N-1)	6(N-1)
Clamping Diodes	3(N-1)(N-2)	0	0
DC bus Capacitors	3(N-1)	3(N-1)	3(N-1)/2
Flying Capacitors	0	3(N-1)(N-2)	0
Total Numbers	$3(N^2+2N-3)$	3/2((N-1)(N+8))	27/2(N-1)

V. Performance of 3 phase induction motor using 5 level inverter:

The performance of three phase induction motor five- level inverter is shown in fig.5. The Line current is shown in fig.5 (a). The five-level Phase voltage is shown in fig.5 (b). The fig.5(c), (d), (e) are the Induction motor RYB currents in Amperes, speed in R.P.M and Electromagnetic Torque in Newton meter respectively. Similarly the performance of three phase induction motor seven level inverter is shown in fig.6 The Line current is shown in fig.6 (a)The five-level Phase voltage is shown in fig.6 (b). The fig.6(c), (d), (e) are the Induction motor RYB currents in Amperes, speed in R.P.M and Electromagnetic Torque in Newton meter respectively

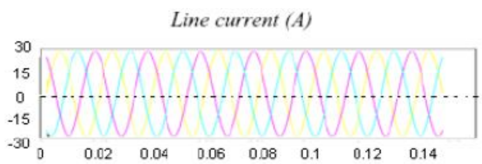

Fig.5 (a)

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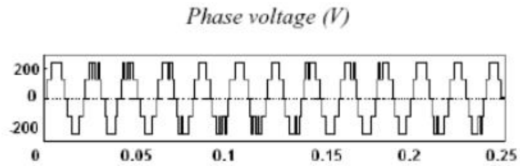

Fig.5 (b)

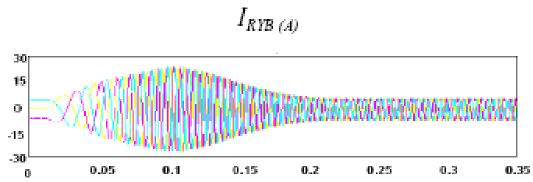

Fig.5 (c)

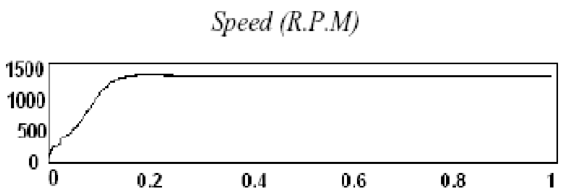

Fig.5 (d)

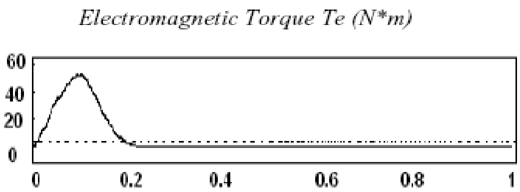

Fig.5 (e)

Fig.5: Simulation results for 5 level inverter fed Induction motor drive.

Line current (A)

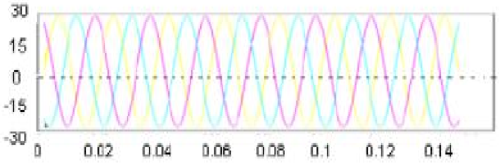

Fig.6 (a)

Phase voltage (V)

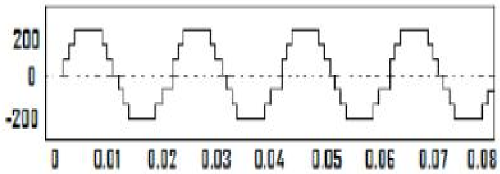

Fig.6 (b)

I_{RYB} (A

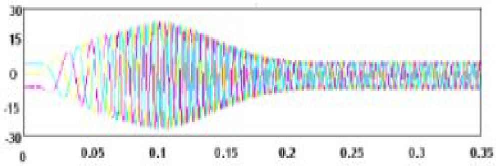

Fig.6 (c)

Speed (R.P.M)

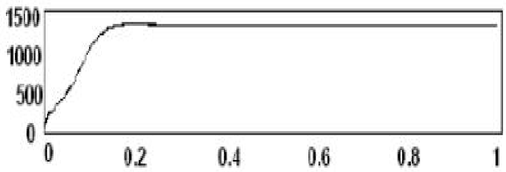

Fig.6 (d)

*Electromagnetic Torque Te (N*m)*

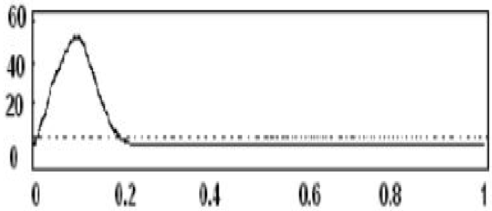

Fig.6 (e)

Fig.6 Simulation Results for Three-phase 7- level inverter induction motor load

VI. Total Harmonic Distortion Comparison:

The comparison of THD between the 5 level inverter and 7 level inverter based on their Modulation Index is shown in the following table:

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Modulation Index	THD of 5 level	THD of 7 level
0.2	37.84	27.92
0.3	36.21	26.42
0.4	34.37	25.36
0.5	20.10	16.47
0.6	18.72	17.24
0.7	26.28	19.49
0.8	24.41	22.26
0.9	17.32	16.84
1.0	12.48	8.94

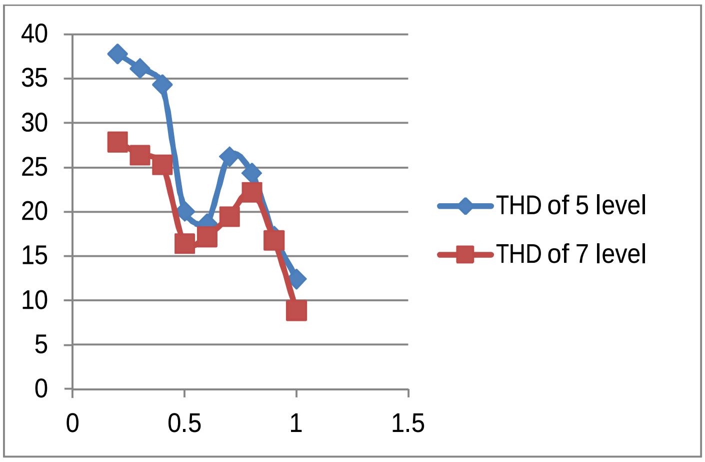

Fig.7: Modulation Vs THD of 5 level & 7 level Inverter

According to chart it is observer that with increase in the level of inverter the THD of the inverter gets reduced.

OBJECTIVES FOR FUTURE WORK

Since multilevel inverter fed motor drives have gained special attention in the industry andacademia as the preferred choice of electronic power conversion for high power applications, there are still quite a few important aspects to be solved. First, as the present work has been carried out for a small machine. It can be extended for typical rated values of drives in the industry, up 12MW. It means that an H-bridge cascaded multilevel inverter with four (4) and (6) cells per phase in order to generate the desired voltage of 4,16kV and 6kV respectively are needed. Both control methods have been evaluated with an H-bridge cascaded multilevel inverter. By the use of the other two typical configuration of multilevel inverters: diode-clamped (or neutral-point-clamped) and flyingcapacitor the control methods should be developed. The conventional PWM modulation technique was implemented for both control methods. A comparison with base on space vector modulation technique should be analyzed in order to see the advantages and/or drawbacks in the control performance. Finally and because of the wide use of DTC and FOC in drives, more efficient inner loop controllers should be explored in order to replace the implemented PI controllers. Model predictive control allows to control a plant within their bounds while optimize a variable of interest. This basic idea can be used to control flux and torque while reduce one of the main concerns in multilevel inverters such as the switching frequency and/or the switching losses and harmonics.

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VIII. CONCLUSION

The modelling of multilevel inverter fed induction motor drive was done and simulated using Simulink. The total harmonic distortion is very low compared to that of classical inverter. The simulation result shows that the harmonics have been reduced considerably. The multilevel inverter fed induction motor system has been successfully simulated and the results of voltage waveforms, current waveforms, motor speed, electromagnetic torque and frequency spectrum for the output were obtained. The inverter system can be used for industries where the adjustable speed
drives are required.

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