Analysis and Simulation of Two Different Topologies of Three Phase cascaded Inverter Fed Induction Motor Drive

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Abstract— The main objective of this paper is to control the speed of an induction motor by using five level Cascaded H-Bridge multilevel inverter to obtain high quality sinusoidal output voltage with reducedharmonics.An open loop speed control can be achieved by changing switching frequency. Two topologies of cascaded multilevel inverter have been proposed. 1st topology requires separate DC sources and the 2nd topology requires only a single DC power source, capacitors. The inverters with a large number of stepscan generate high quality voltage waveforms. The higher levels can follow a voltage reference with accuracy and with the advantage that the generated voltage can be modulated in amplitude instead of pulse-width modulation. The simulation results shows that the proposed topologies effectively controls the motor speed through reduction in total harmonic distortion(THD).The simulation of three phase five level inverter fed induction motor model is done using Matlab/Simulink. The performance of MLI is also compared with conventional inverter in terms of THD. The FFT spectrums for the outputs are analyzed to study the reduction in the harmonics.

Key words: Induction motor, Matlab/simulink, Multilevel inverters, H bridge, Total Harmonic distortion.

I. Introduction

Adjustable Speed Drives (ASDs) are the essential and endless demand of the industries and researchers. They are widely used in the industries to control the speed of conveyor systems, machine tool speeds. DC motors were the work horses for the Adjustable Speed Drives (ASDs) in many industrial applications due to their excellent speed and torque response. But, they have the certain disadvantages of commutator and mechanical brushes, which undergo wear and tear with the passage of time. In most cases, AC motors are preferred to DC motors, in particular, an induction motor due to its more advantages. The advent of controlled switches the speed and torque control of induction machines have become relatively easier. A voltage source inverter can run the induction by applying three phase square wave voltages to the motor stator winding. A variable frequency square wave voltage can be applied to the motor by controlling the switching frequency of the power semiconductor switches. The square wave voltage will induce low frequency harmonic torque pulsation in the machine. Also variable voltage control with variable frequencies of operation is not possible with square wave inverters. Power electronic devices contribute with an important part of harmonics, such as power rectifiers, thyristor converters and static var compensators. Even updated pulse-width modulation (PWM) techniques used to control modern static converters such as machine drives, do not produce perfect waveforms. Voltage or current converters, as they generate discrete output waveforms, force the use of machines with special isolation, and in some applications large inductances connected in series with the respective load. Also, it is well known that distorted voltages and currents waveforms produce harmonic contamination, additional power losses, and high frequency noise that can affect not only the power load but also the associated controllers. All these unwanted operating characteristics associated with PWM converters could be overcome with multilevel converters, in addition to the fact that higher voltage levels can be achieved. The poor quality of output current and voltage of an induction motor fed by a classical two-level inverter is due to the presence of harmonics. The presence of significant amount of harmonics makes the motor to suffer from severe torque pulsations, especially at low speed, which manifest themselves in cogging of the shaft. It will also causes undesired motor heating and Electromagnetic interference. The reduction in harmonics calls for large sized filters, resulting in increased size and the cost of the system. Nowadays multilevel inverters are the promising alternative and cost effective solution for high voltage and high power applications including power quality and motor drive problems. Multilevel structure allows raising the power handling capability of the system in a powerful and systematic way. The advancements in the field of power electronics and microelectronics made it possible to reduce the magnitude of harmonics with multilevel inverters. The term multilevel began with the three-level converter. Subsequently, several multilevel converter topologies have been developed.

II. Conventional Method

The conventional voltage source inverter produces an output voltage with levels either zero or + Vdc. It is known as two level inverter. The poor quality of voltage and current of a conventional inverter fed induction machine is due to the presence of harmonics. The dc link voltage of a two-level inverter is limited by voltage ratings of switching devices[13].

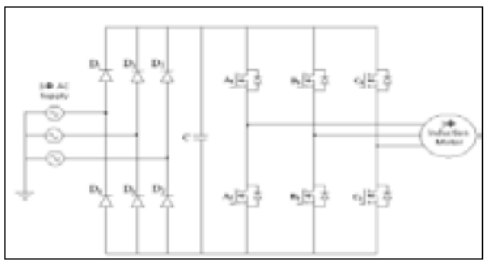

Fig. 1: Two level inverter

From the aspect of harmonic reduction and high dc-link voltage level, five level approaches seem to be the most promising alternative. The harmonic content of a five level inverter is less than that of a two level inverter at the same switching frequency [13]. A five level inverter will

generate lower common mode voltages compared to normal inverter. So, the five-level inverter topology is generally used in realizing the high performance medium voltage drive systems.

III. DRIVE SYSTEM DESCRIPTION

The poor quality of voltage and current of a conventional inverter fed induction machine is due to the presence of harmonics in which normal PWM method is used. In order to overcome those disadvantages three phase cascaded h-bridge multilevel inverter[6] are used. The voltage and current qualities are better and the switching losses are reduced when compared to the conventionaltechnique. Also the THD is found to be better.

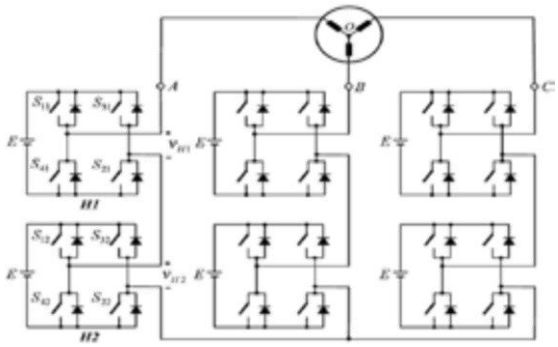

Fig. 2: Multilevel inverter based drive circuit

The three phases five level cascaded h-bridge voltage source inverter is shown in fig.2.Each H bridge has its own dc source. Using various combinations of the four switches each H bridgecan generate three different voltage outputs, +Vdc, 0, and –Vdc. The ac outputs of the different full bridge inverter levels are connected in series such that the synthesized voltage waveforms the sum of the inverter output.

IV. FIVE LEVEL INVERTER CIRCUITS USING SEPARATE DC SOURCES

There are several types of multilevel inverters but the one considered in this paper is the cascaded multilevel inverter (CMI). The structure of the CMI is not only simple and modular but also requires the least number of components compared to other types of multilevel inverters. This in turn, provides the flexibility in extending the CMI to higher number of levels without increase in circuit complexity as well as facilitates packaging.

A. Three phase structure of a five level Cascaded Multilevel inverter using separate DC source

The Three Phase Structure of Cascaded Multilevel inverter is illustrated in Fig.3. Each H bridge has its own dc source. Using various combinations of the four switches each H bridge can generate three different voltage outputs, +Vdc, 0, and –Vdc.. The ac outputs of the different full bridge inverter levels are connected in series such that the synthesized voltage waveform is the sum of the inverter outputs[2].

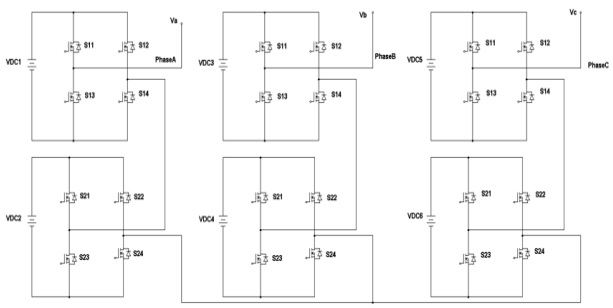

Fig. 3: Three Phase Structure of Cascaded Multilevel inverter

1) Advantages:

(1) The number of possible output voltage levels is more than twice the number of dc sources (m =2s+ 1).

(2) The series of H-bridges makes for modularized layout and packaging.

2) Disadvantage:

Separate dc sources are required for each of the H-bridges. So that cost of overall devices llbe less.

B. Three phase structure of a five level Cascaded Multilevel inverter using single DC source and capacitor

To operate a cascade multilevel inverter using a single DC source, it is proposed to use capacitors as the DC sources for all but the first source. Consider a five level cascade multilevel inverter with two H-bridges as shown in Fig. 4.

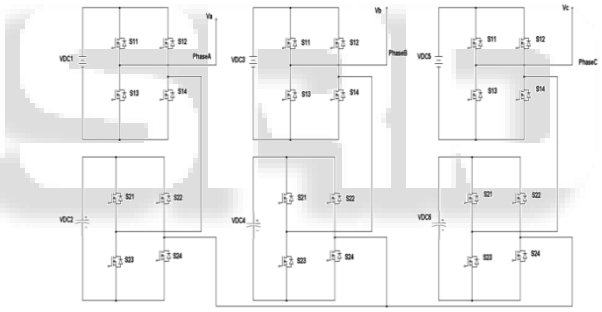

Fig. 4: Three-phase structure of a multilevel cascaded H-bridges inverter

The DC source for the first H-bridge (H1) is a DC power source with an output voltage of Vdc, while the DC source for the second H-bridge (H2) is a capacitor voltage. Each inverter level can generate three different voltage outputs, +Vdc, 0, and –Vdc using various combinations of the four switches. The ac outputs of the different full bridge inverter levels are connected in series such that the synthesized voltage waveform is the sum of the inverter outputs [5].

V. SIMULATION MODEL AND RESULTS

Multilevel inverter fed induction motor drive inverter is implemented in MATLAB SIMULINK which is shown in Fig.5.The MATLAB SIMULINK model of Single leg of five level Cascaded Multilevel inverter using two H-bridge configuration is shown in Fig.6.

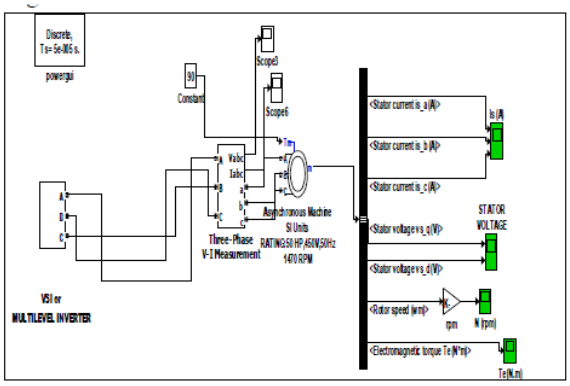

Fig. 5: Matlab/Simulinkmodelof multilevel inverter Induction motor drive

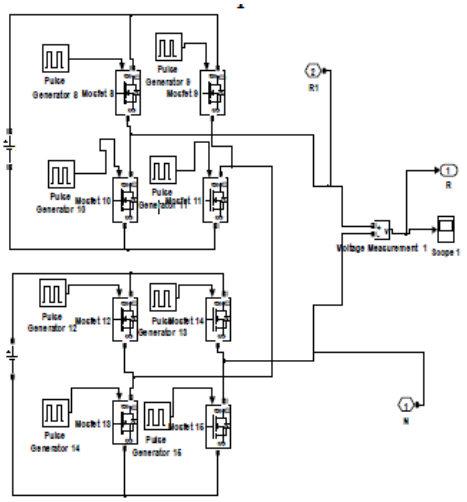

Fig. 6: Matlab/Simulink model of single leg of three phase Five level Multilevel Inverter

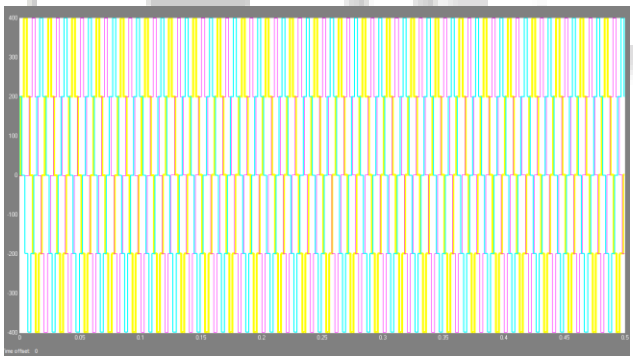

Fig. 7: Three phase five level inverter output of Proposed Topology-I

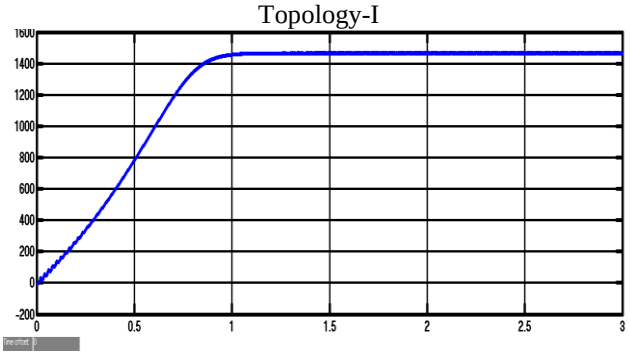

Fig. 8: Variation in speed of Proposed Topology-I

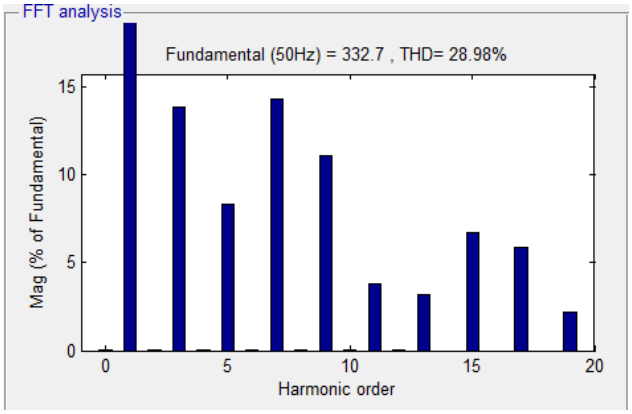

Fig. 9: FFT analysis of Voltage of Proposed Topology-I

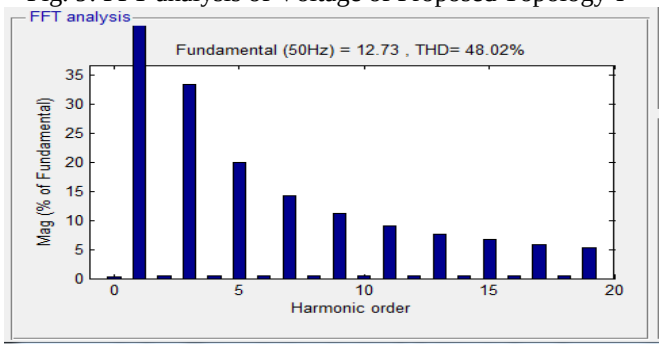

Fig. 10: Harmonic spectrum for conventional inverter

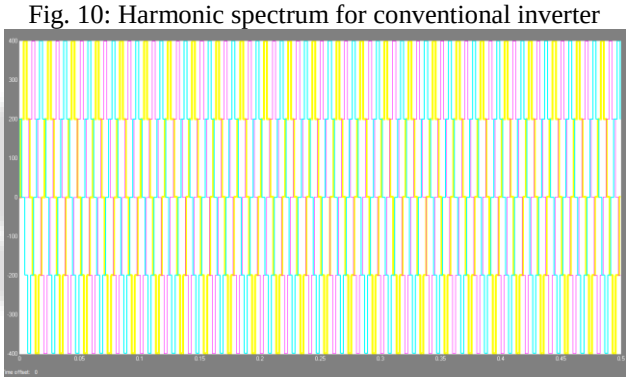

Fig. 11: Three phase five level inverter output of Proposed Topology-II

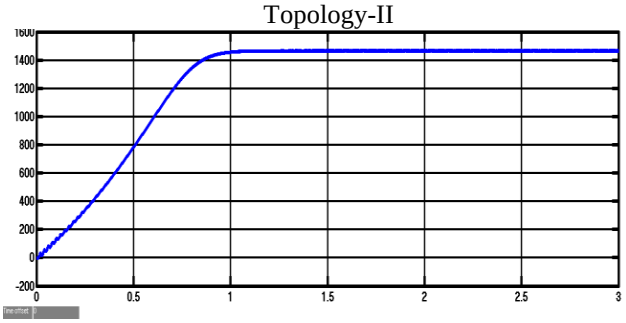

Fig. 12: Variation in speed of Proposed Topology-II

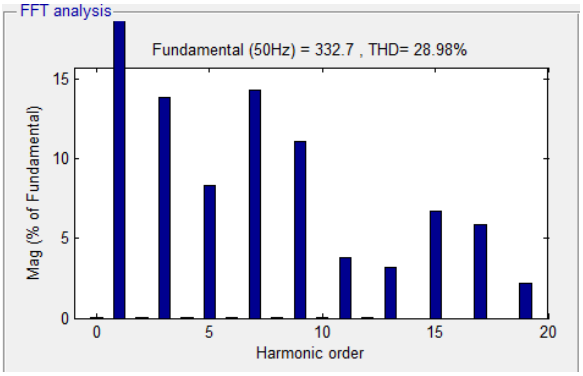

Fig. 13: FFT analysis of Voltage of Proposed Topology-II

VI. CONCLUSION

In this paper two topologies of Cascaded H-bridge inverters for five-levelwith an induction motor are simulated. 1st topology requires separate DC sources and the 2nd topology requires only a single DC power source, capacitor. The open loop speed control was achieved by changing the switching frequency. The total harmonic distortion is very low compared to that of classical inverter. The simulation result shows that the harmonics have been reduced considerably-bridge MLI With single DC source are best if we consider Cost. The simulation results show that the proposed system effectively controls the motor speed through reduction in total harmonic distortion (THD). This drive system can be used for variable speed applications like conveyors, rolling mills, printing machines etc.

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