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Simulation and Analysis of 11-Level Multilevel Inverter with Reduced No of Switches Fed to Induction Motor drive

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ABSTRACT: This project presents the simulation of three phase 11- level inverter fed induction motor drive. The poor quality of voltage and current of a conventional inverter fed induction machine is due to the presence of harmonics and hence there is significant level of energy losses. The 11 level inverter is used to reduce the harmonics. The inverters with a large number of steps can generate high quality voltage waveforms. The 11 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. An active harmonic elimination method is applied to eliminate any number of specific higher order harmonics of multilevel converters with unequal dc voltages. The simulation of three phase 11 level inverter fed induction motor model is done using Simulink

KEYWORDS: Multilevel Inverter, Induction Motor, Harmonics.

I. INTRODUCTION

Power Electronics is playing an important role in the torque and speed control of motor drive. Variable speed AC induction motor drives are replacing the conventional DC Drives in industrial drive environment. DC motors have excellent speed and torque response, they have inherent disadvantage of commutator and mechanical brushes, which undergo wear and tear with time. AC induction machines are single excited, mechanically rugged and robust, but speed and torque control of these machines are more complex and involved, compared to DC machines. Induction motors have low starting torque and the motors carry large amplitude of starting currents, star delta starting or pole changing methods were followed.

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. 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.

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, power factor compensators, do not produce perfect waveforms, which strongly depend on the semiconductors switching frequency. 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 present work was not reported.



II. RELATED WORK

The Inverter is an electrical device which converts direct current (DC) to alternate current (AC). The inverter is used for emergency backup power in a home. The inverter is used in some aircraft systems to convert a portion of the aircraft DC power to AC. The AC power is used mainly for electrical devices like lights, radar, radio, motor, and other devices. Now a day's many industrial applications have begun to require high power. Some appliances in the industries however require medium or low power for their operation. Using a high power source for all industrial loads may prove beneficial to some motors requiring high power, while it may damage the other loads. Some medium voltage motor drives and utility applications require medium voltage. The multi level inverter has been introduced since 1975 as alternative in high power and medium voltage situations. The Multi level inverter is like an inverter and it is used for industrial applications as alternative in high power and medium voltage situations.

3 TYPES OF MULTI LEVEL INVERTERS:

Multilevel inverters are three types.

- Diode clamped multilevel inverter
- Flying capacitors multilevel inverter
- Cascaded H- bridge multilevel inverter

2B.3.1 Diode Clamped Multilevel Inverter:

The main concept of this inverter is to use diodes and provides the multiple voltage levels through the different phases to the capacitor banks which are in series. A diode transfers a limited amount of voltage, thereby reducing the stress on other electrical devices. The maximum output voltage is half of the input DC voltage. It is the main drawback of the diode clamped multilevel inverter. This problem can be solved by increasing the switches, diodes, capacitors. Due to the capacitor balancing issues, these are limited to the three levels. This type of inverters provides the high efficiency because the fundamental frequency used for all the switching devices and it is a simple method of the back to back power transfer systems.

Ex: 5- Level diode clamped multilevel inverter, 9- level diode clamped multilevel inverter.

- The 5- level diode clamped multilevel inverter uses switches, diodes; a single capacitor is used, so output voltage is half of the input DC.
- The 9- level diode clamped multilevel inverter uses switches, diodes; capacitors are two times more than the 5- level diode clamped inverters. So the output is more than the input.

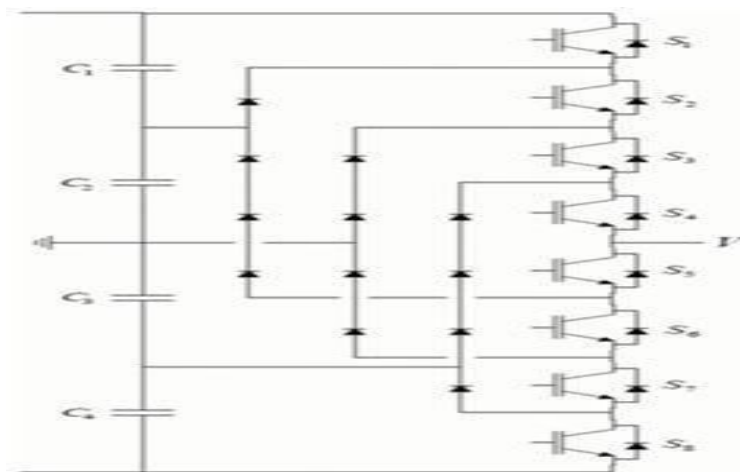


Fig:2.2 DIODE CLAMPED MULTILEVEL INVERTER

Applications of Diode Clamped Multilevel Inverter:

- Static var compensation
- Variable speed motor drives

- High voltage system interconnections
- High voltage DC and AC transmission lines

2.B.3.2 Flying Capacitors Multilevel Inverter:

The main concept of this inverter is to use capacitors. It is of series connection of capacitor clamped switching cells. The capacitors transfer the limited amount of voltage to electrical devices. In this inverter switching states are like in the diode clamped inverter. Clamping diodes are not required in this type of multilevel inverters. The output is half of the input DC voltage. It is drawback of the flying capacitors multi level inverter. It also has the switching redundancy within phase to balance the flying capacitors. It can control both the active and reactive power flow. But due to the high frequency switching, switching losses will takes place.

EX: 5-level flying capacitors multilevel inverter, 9-level flying capacitors multilevel inverter.

- This inverter is same like that diode clamped multi inverter
- In this inverter only switches and capacitors are used.

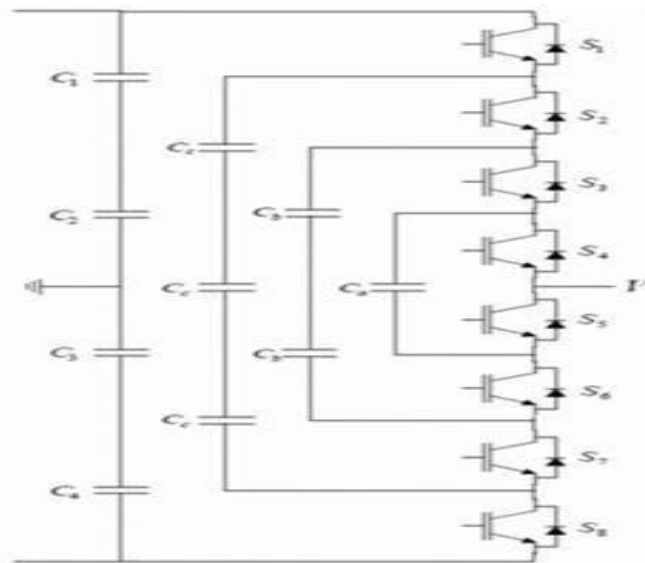


Fig:2.3 FLYING CAPACITOR MULTILEVEL INVERTER

Applications of Flying Capacitors Multilevel Inverter

- Induction motor control using DTC (Direct Torque Control) circuit
- Static var generation
- Both AC-DC and DC-AC conversion applications
- Converters with Harmonic distortion capability
- Sinusoidal current rectifiers

III. METHODOLOGY

An induction or asynchronous motor is an AC electric motor in which the electric current in the rotor needed to produce torque is obtained by electromagnetic induction from the magnetic field of the stator winding. An induction motor therefore does not require mechanical commutation, separate-excitation or self-excitation for all or part of the energy transferred from stator to rotor, as in universal, DC and large synchronous motors. An induction motor's rotor can be either wound type or squirrel-cage type. Three-phasesquirrel-cage induction motors are widely used in industrial drives because they are rugged, reliable and economical. Single-phase induction motors are used extensively for smaller loads, such as household appliances like fans. Although traditionally used in fixed-speed service, induction motors are increasingly being used with variable-frequency drives (VFDs) in variable-speed service. VFDs offer especially important energy savings opportunities for existing and prospective induction motors in variable-torque centrifugal fan, pump and compressor load applications. Squirrel cage induction motors are very widely used in both fixed-speed and VFD applications.



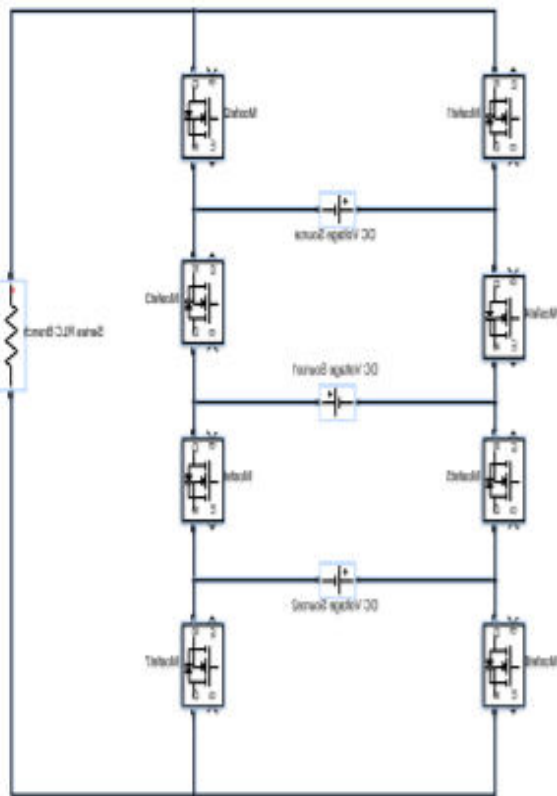
Three-phase totally enclosed fan-cooled (TEFC) induction motor with end cover on the left, and without end cover to show cooling fan. In TEFC motors, interior losses are dissipated indirectly through enclosure fins mostly by forced air convection. Cutaway view through stator of TEFC induction motor. Note rotor air circulation vanes.

Total harmonic distortion is a complex and often confusing concept to grasp. However, when broken down into the basic definitions of harmonics and distortion, it becomes much easier to understand. Imagine a power system with an AC source and an electrical load (Figure 1)

CONFIGURATION AND ITS SWITCHING

The proposed circuit consists of eight switches and three DC voltage sources per phase as shown in Fig 2. Four switches in left hand side are used to produce positive half cycle output waveform and the other four are used to produce the output waveform of negative half cycle. The three DC voltages are as V_{dc} , $2V_{dc}$, $2V_{dc}$ and they are connected in series to generate a 11 level output voltage.

As per the switching point of view we have to turn on four switches at a time to produce one output level. For example if we want to generate $+5V_{dc}$ voltage level then we need to turn on switches $S1 S3 S1' S4'$. For $+4V_{dc}$ we need to turn on $S3 S1' S2' S4'$. In the same way all the different DC output voltages are generated. Table 2 Shows a Table which gives the switching details of all the eight switches.



Output voltage	S1	S2	S3	S4	S1'	S2'	S3'	S4'
+5V _{dc}	1	0	1	0	0	1	0	1
+4V _{dc}	0	0	1	0	1	1	0	1
+3V _{dc}	1	0	1	1	0	1	0	0
+2V _{dc}	1	1	1	0	0	0	0	1
+V _{dc}	1	0	0	0	0	1	1	1
0	0	0	0	0	1	1	1	1
-V _{dc}	0	1	1	1	1	0	0	0
-2V _{dc}	0	0	0	1	1	1	1	0
-3V _{dc}	0	1	0	0	1	0	1	1
-4V _{dc}	1	1	0	1	0	0	1	0
-5V _{dc}	0	1	0	1	1	0	1	0
0	1	1	1	1	0	0	0	0

Different PWM techniques are used to produce the switching pulses for the single phase inverter. PWM techniques are used to control the frequency and to reduce the harmonics. A simple method to generate the PWM pulse is to compare reference wave which is usually a sine wave with a carrier signal which is a saw tooth or triangular signal

The advantage of PWM is that there is very low power loss in the switching device. When a switch is off there is no current in it and when it is on and power is transferred to the load there is negligible voltage drop. Here the modulation indices are same for all the methods. The amplitude modulation index is 0.9 and the frequency modulation index is 200. The Pulse width modulation methods used in this paper are In-phase disposition level shift PWM method, Antiphase disposition level shift PWM method, Carrier overlap PWM method, Variable frequency PWM method

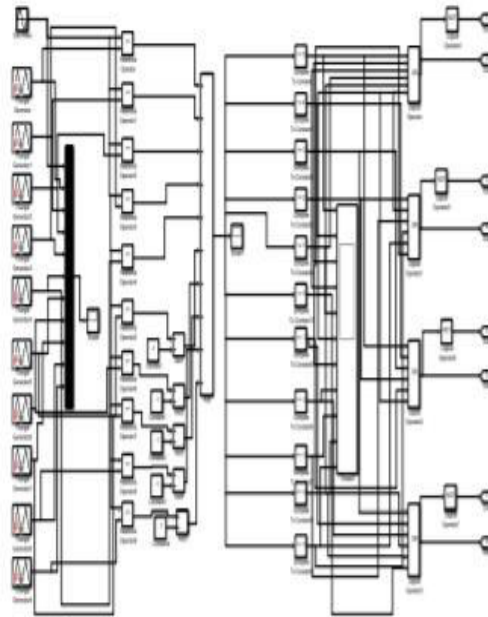


IN-PHASE DISPOSITION LEVEL SHIFT PWM (IPD-LSPWM) METHOD

In this method the carrier signals are level shifted. Also here as carrier signals are in phase across all the bands, the harmonic energy is concentrated at the carrier frequency. The amplitude of the carrier signal is 1V and frequency is 10 kHz. And it is compared to a reference sine wave.

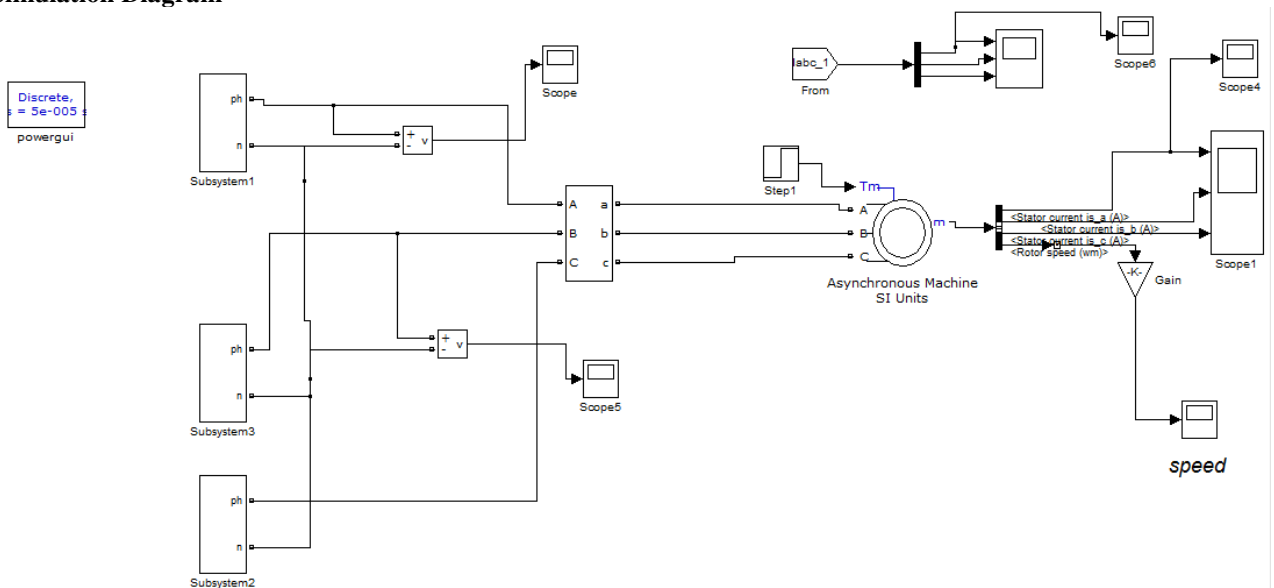
3.2 ANTI-PHASE DISPOSITION LEVEL SHIT PWM (APD-LSPWM) METHOD In this method the carrier signals are out of phase with each other by 1800 . The amplitude and frequency is same.

IV. SIMULATION CIRCUITS

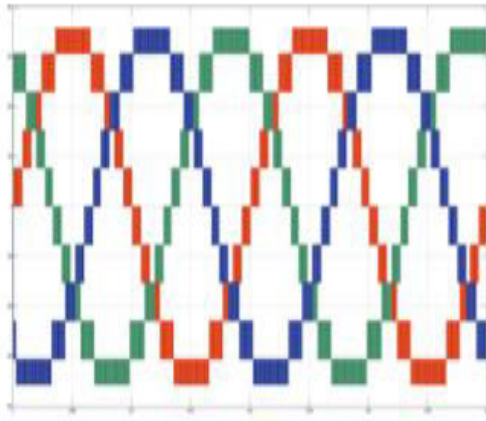


4.1 Simulation circuit to generate the switching pulse

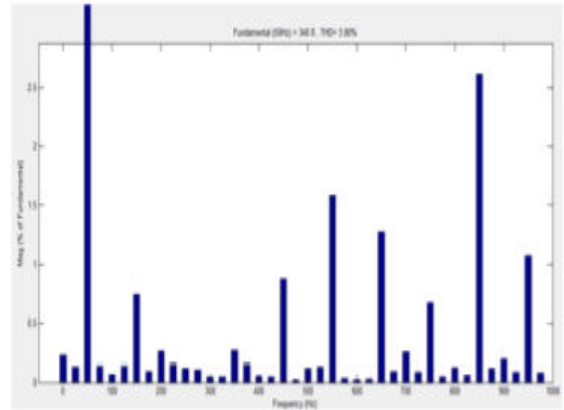
Simulation Diagram



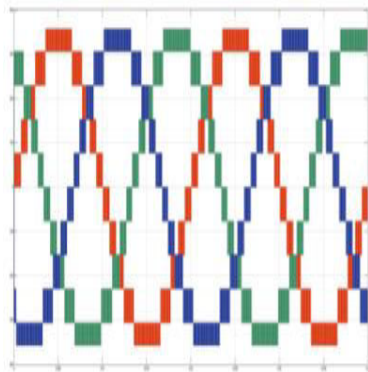
4.2 3 phase inverter simulation circuit to produce 11 level output waveform



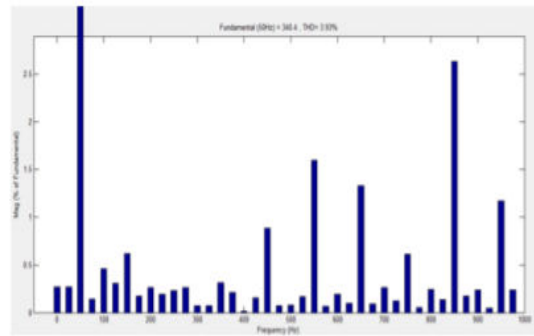
4.3 Output voltage waveform for 3Ph 11 level inverter



4.4 FFT analysis of harmonics



4.5 Output voltage waveform APD-LSPWM



4.6 FFT analysis of harmonics for APD-LSPWM

V. CONCLUSION

Three Phase 11 level inverter topology with less number of switches is proposed for three phase induction motor which is and simulated. Various PWM methods are analysed and compared. From simulation results and THD analysis it is found that In-phase level shift PWM method provides minimum 3.80% in the output voltage. Therefore this will be the best PWM technique for inverter switching.

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