DESIGN OF FIVE LEVEL INVERTER FED INDUCTION MOTOR USING PHASE SHIFTED CARRIER PWM TECHNIQUE

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Abstract - Multilevel inverter is an effective and practical solution for increasing power demand and reducing harmonics of ac waveforms. Such inverters synthesize a desired output voltage from several levels of dc voltages as inputs. This paper analyses the performance of five level inverter using phase shifted carrier PWM technique. It has been found that this technique reduces the switching losses and total harmonic distortion. The performance being analyzed by the SimPowerSystems in Matlab-Simulink and hardware being prepared using IGBT as a switching device and a microcontroller for Gate pulses.

Keywords - Multilevel inverter, carrier phase shifted PWM Technique, IGBT, Induction motor, Simulink.

I. INTRODUCTION

Over the past two decades, multilevel inverters have attracted wide interest both in the scientific community and in the industry. The reason for the increased interest is that the multilevel inverters are a viable technology to implement.The use of a multilevel inverter to control the frequency, voltage output (including phase angle), and real and reactive power flow at a dc/ac interface provides significant opportunities in the control of distributed power systems.

II. MULTILEVEL PWM INVERTER

The multilevel PWM inverters include an array of power semiconductors and capacitor voltage sources, the output of which generate voltages in stepped waveform. The commutation of the switches allows the addition of the capacitor voltages which reaches the high voltage level at the output, while the power semiconductors withstand only with reduced voltage.

TYPES OF PWM TECHNIQUES:

Multi level inverter is simulated for various multicarriers based pulse width modulation (PWM) techniques for a resistive load.
The PWM techniques include:-

1. Phase Opposition Disposition (POD) PW
2. Alternative Phase Opposition Disposition (APOD) PWM
3. Phase Shift PWM (PSPWM)
4. Phase Disposition (PD) PWM
5. Carrier Overlapping PWM (COPWM)
6. Variable Frequency PWM (VFPWM)

The power PWM inverter generates an output voltage with five values (levels) with respect to the negative terminal of the capacitor.

The concept of multilevel inverter control has opened a new possibility that induction motors can be controlled to achieve dynamic performance equally that of dc motors. The performance of the multilevel inverter is better than a classical inverter.

1. Phase Opposition Disposition (POD) PWM:-The carriers above the zero reference are in phase but shifted by 180° from those carriers below the zero reference.
2. Alternative Phase Opposition Disposition (APOD) PWM:- Each carrier band is shifted by 180° from the adjacent bands.
3. Phase Disposition (PD) PWM: - All the carriers are in phase.
4. Phase Shift PWM (PSPWM):- All carrier signals have the same amplitude and frequency but they are phase shifted by 90 degrees to each other.
5. Carrier Overlapping PWM (COPWM):- All carriers with the same frequency and same peak to peak amplitude are disposed such that the bands they occupy overlap each other.
6. Variable Frequency PWM (VFPWM):- Carriers have the variable frequency and same amplitude each other

III. CASCADED MULTILEVEL INVERTER

A cascaded multilevel inverter made up of from serious connected single full bridge inverter each with their own isolated dc bus. This multilevel inverter can generate almost sinusoidal waveform voltage from several separate dc sources, which may be obtained from solar cells, fuel cells, batteries, ultra capacitors, etc.This type of converter does not need any transformer or clamping diodes or flying capacitors. Each level can generate five different voltage outputs $+2V_{dc}$, Vdc, 0, $-2V_{dc}$ and $+V_{dc}$ by connecting the dc sources to the ac output side by different combinations of four switches. The output

voltage of an M-level inverter is the sum of all the individual inverter outputs.

IV. ADVANTAGE OF MULTILEVEL INVERTER OVERCONVENTIONAL TWO LEVEL INVERTER

A multilevel inverter has four main advantages over the conventional bipolar inverter. First, the voltage stress on each switch is decreased due to series connection of the switches. Therefore, the rated voltage and consequently the total power of the inverter could be safely increased.
Second, the rate of change of voltage (dv/dt) is decreased due to the lower voltage swing of each switching cycle. Third, harmonic distortion is reduced due to more output levels. Fourth lower acoustic nois and electromagnetic interference (EMI) is obtained.

CARRIER PHASE SHIFT PWM TECHNIQUE

In case of phase shift PWM technique, the carriers are horizontally displaced. This introduces a new parameter θ (phase shift angle) for controlling the output voltage. The output voltage is found to be greatly dependent on the phase shift angle.
The carriers have the same frequency f_{cr} and the same peak to peak amplitude V_{cr}.
For five level triangular carriers required (m-1) = 4 where m= voltage level.
There is a phase shift between any two adjacent carrier waves, given by

$$Ø_{cr} = 360°/ (m–1)$$

Here $Ø_{cr} = 360°/ 4$

$$Ø_{cr} = 90°$$

The principle of the phase shifted modulation for a five-level CHB inverter, where four triangular carriers are required with a 90° phase displacement between any two adjacent carriers.

BLOCK DIAGRAM

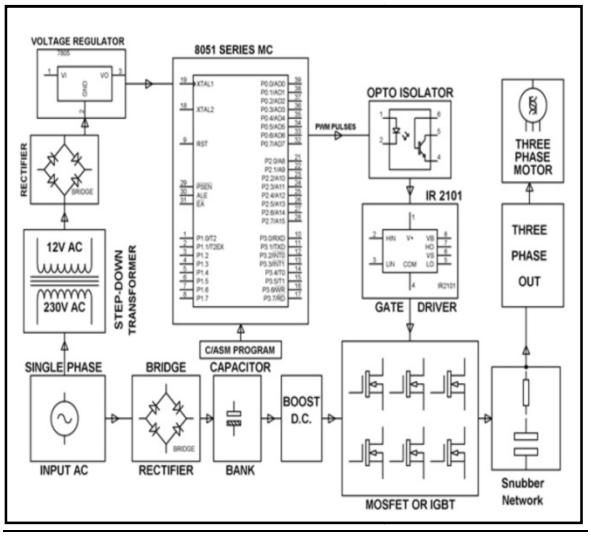

Fig 1. Block Diagram of the proposed scheme

V. COMPONENTS USED

1. IGBT
2. DIODE RECTIFIER
3. CAPACITIVE FILTER
4. MICRO-CONTROLLER
5. GATE PULSE GENERATOR
6. OPTO COUPLER
7. INDUCTION MOTOR
8. GATE DRIVER
9. STEP DOWN TRANFORMER

MAIN COMPONENTS

IGBT

IGBT stands for Insulated Gate Bipolar Transistor. It is a three terminal power semiconductor device with four alternating layer (P-N-P-N) and primarily, it used as an electronic switch. It switches electric power in many modern appliances. It is designed to turn on and turn off rapidly.

The IGBT combines the simple gate-drives characteristics of MOSFET with high current and low saturation voltage capability of bipolar transistor.

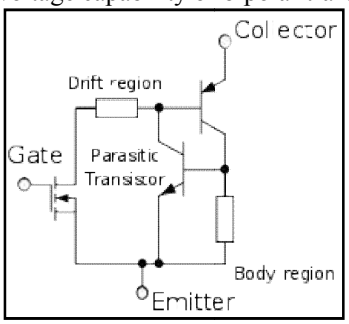

Fig 2. Equivalent circuit of IGBT

ADVANTAGES OF IGBT OVER MOSFETS

While designing this circuit, a choice had to be made between the two main types of switches used in power electronics. One is the power MOSFET, which is much like a standard MOSFET, but designed to handle relatively large voltages and currents. The other is the insulated gate bipolar transistor, or IGBT.
IGBTs tend to be used in very high voltage applications, nearly always above 200V, and generally above 600V. IGBT have less conduction and power loss as compare to MOSFETs. Switching of IGBT is better than MOSFETs.
But IGBT do not have the high frequency switching capability of MOSFETs.

PULSE GENERATOR

Pulse generator is either electronic circuit or a piece of electronic test equipment used to generate rectangular pulses.
Pulse generator usually allows control of the pulse repetition rate (frequency), pulse width; delay with respect to an internal or external trigger and the high and low voltage level of the pulses. Pulse generator

are available for generating output pulses having a width (duration) ranging from minutes down to under 1 picosecond.

MICRO-CONTROLLER

A micro-controller is a small computer on a single integrated circuit containing of processor core, memory, and programmable input/output peripherals.
Micro-controllers are designed for embedded applications, in contrast to the microprocessors used in personal computer or other general purpose applications.
Micro-controllers are used in inverter for controlling switching of IGBT and other programs.
Micro-controllers are used in automatically controlled product and devices, such as automobile engine control systems, remote controls, power tools.

DIODE RECTIFIER

Diode rectifier is used to convert AC into DC these are used as half wave rectifier or full wave rectifier.
Points to remember

- Maximum forward current capacity
- Maximum reverse voltage capacity
- Maximum forward voltage capacity

The diode of some capacities can be used in place of one another.
Diode of more capacity can be use in place of diode of low capacity.
Diode of low capacity cannot be used in place of high capacity.

OPTO COUPLER

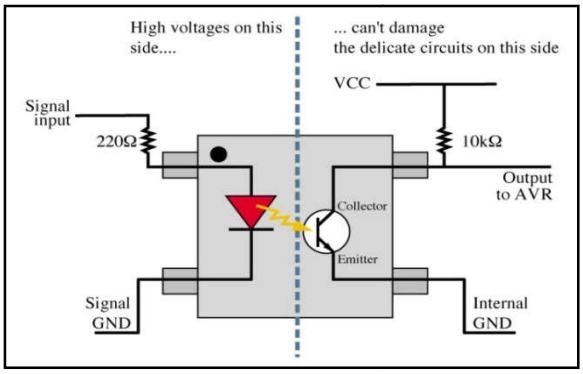

Fig 3. Opto-Coupler

It is the component that use for protection purpose, from high voltage circuit to low voltage circuit. Opto-coupler prevents high voltage from affecting the system receiving the signal.
Commercially available isolator withstands input to output voltage up to 10 KV. It is also called as opto-isolator.

VI. RESEARCH OBJECTIVE

Multilevel inverters have drawn tremendous interest in the power industry. They present a new set of features that are well suited for use in reactive power compensation.
Multilevel inverters will significantly reduce the magnitude of harmonics and increases the output voltage and power without the use of step-up transformer. The general function of this multilevel inverter is to synthesize a desired voltage from several DC sources.

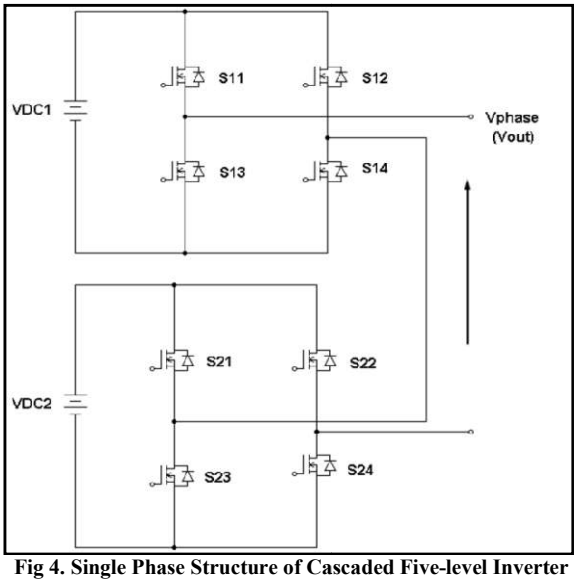

Fig 4. Single Phase Structure of Cascaded Five-level Inverter

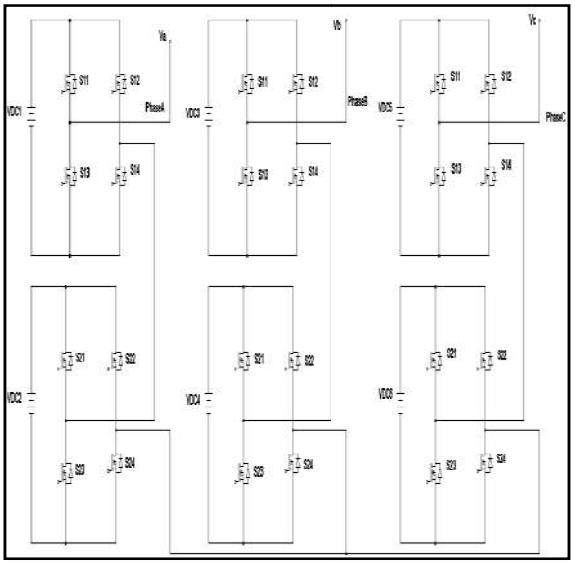

Fig 5. Three Phase Structure Of Cascaded Five- Level Inverter

DESCRIPTION:

In this research, a three phase five level Cascaded H-Bridge inverter fed induction motor drive will be designed and implemented.
Five levels will be realized by cascading two H-bridges with equal dc sources value. The proposed inverter can reduce the harmonic contents by using phase shifted carrier PWM technique. V/f is an efficient method for speed control in open loop.
In this scheme, the speed of induction machine is controlled by the adjustable magnitude of stator

voltages and its frequency in such a way that the air gap flux is always maintained at the desired value at the steady state.

Here the speed of an induction motor is precisely controlled by using five levels cascaded H-bridge Five level inverter.

Table 1: SWITCHING TABLE

S_{11}	S_{22}	S_{12}	S_{21}	V_{N1}	V_{N2}	V_a
1	0	1	0	V_{dc}	V_{dc}	2 V_{dc}
1	0	1	1	V_{dc}	0	V_{dc}
1	0	0	0	V_{dc}	0	V_{dc}
1	1	1	0	0	V_{dc}	V_{dc}
0	0	1	0	0	V_{dc}	V_{dc}
0	0	0	0	0	0	0
0	0	1	1	0	0	0
1	1	0	0	0	0	0
1	1	1	1	0	0	0
1	0	0	1	V_{dc}	$-V_{dc}$	0
0	1	1	0	$-V_{dc}$	V_{dc}	0
0	1	1	1	$-V_{dc}$	0	$-V_{dc}$
0	1	0	0	$-V_{dc}$	0	$-V_{dc}$
1	1	0	1	0	$-V_{dc}$	$-V_{dc}$
0	0	0	1	0	$-V_{dc}$	$-V_{dc}$
0	1	0	1	$-V_{dc}$	$-V_{dc}$	$-2V_{dc}$

DESCRIPTION

The three phase five level cascaded h-bridge voltage source inverter is shown circuit diagram 3 .In the conventional technique normal PWM method is used. So that the voltage and current is of poor qualities and the switching frequency causes more amount of switching losses.

Those drawbacks are rectified using three phase cascaded h-bridge multilevel inverter.

The voltage and current qualities are better and the switching losses are reduced when compared to the conventional technique. Also the THD is found to be better.

FEATURES OF PWM TECHNIQUE:-

- Carriers are horizontally displaced.
- Main use is to allow the control of power supplied to the electrical device.
- Used to encode information for transmission.
- The drawback associated with this technique is that the switching actions in this case are not balanced.

FIVE LEVEL VOLTAGE OUTPUT WAVEFORM:

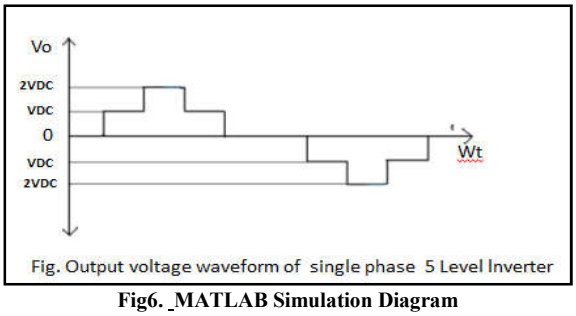

Fig6. _MATLAB Simulation Diagram

(For 1 -phase CHB Inverter):

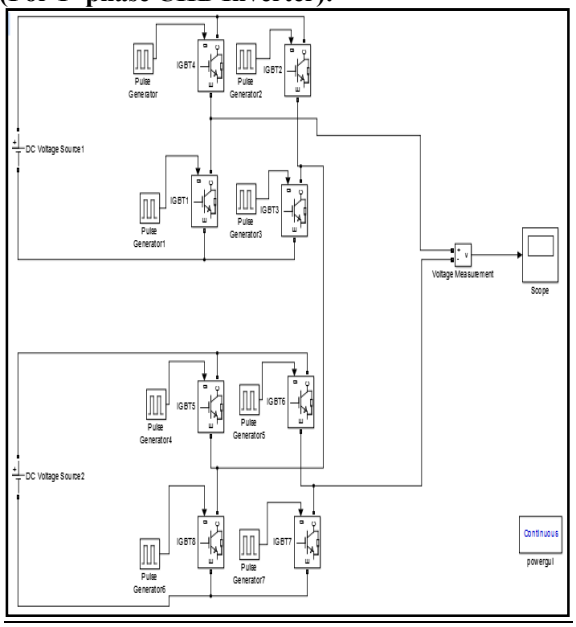

Fig 7. MATLAB Simulation Diagram for 1-phase CHB Inverter

Hardware Setup for 5-level Inverter

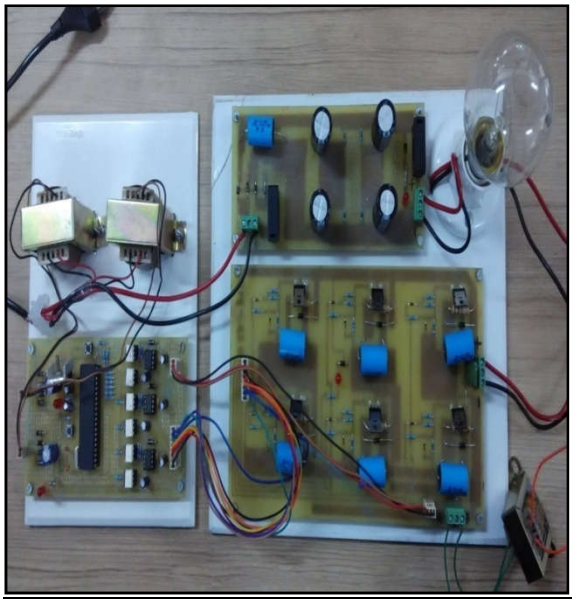

Fig 8. Level Output Line-voltage of a Five-Level Inverter as seen on CRO

CONCLUSION

Experimentally, the multilevel cascaded inverter using the 24 switches and single sources with phase shifted pulse width modulation is prepared. The five level cascade inverter has been built using POWER MOSFET for the bridge inverter as shown above. The gating signals are generated using phase shifted carrier pulse width modulation. The hardware implementation of proposed method of multilevel cascade inverter is shown in fig.

The waveform of the inverter output voltage (line) after stepping down through a transformer and as seen in power scope is shown below. The line voltage is seven levels for a five level inverter. And the phase voltage, if seen, is obtained as five levels.

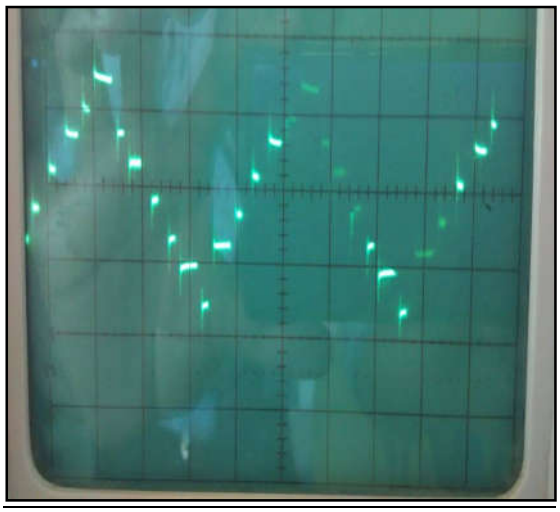

Fig 9. Output Voltage (Line Voltage) waveform as seen on PowerScope

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