Implementation of three level H-bridge cascaded multilevel inverter by using AVR microcontroller for SPWM technique

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Abstract

The multilevel inverters are basically classified as diode clamped, flying capacitor inverter and cascaded multi-level inverter. The cascaded multilevel control method is comparatively easy to other multilevel inverter because cascaded multilevel inverter do not require any clamping diode and flying capacitor. The simulation had been carried for three level cascaded H-bridge multilevel inverter (MLI) by using DC power source with advance control pulses. The main objective of this paper was to analyze three level H-bridges MLI for gate pulses generated by AVR microcontroller which reduces total harmonic distortion and enhances output voltage without adding any complexity to the power circuit and control circuit. Gating signals for these insulated-gate bipolar transistors (IGBTs) have been generated by using AVR microcontroller. In order to maintain the different voltage levels at appropriate intervals, the conduction time intervals of IGBTs have been maintained by controlling the pulse width of gating pulses.

Keywords

MLI, SPWM, μC , H-bridge.

1.Introduction

Inverters are the circuits which convert the DC power into AC power at essential output voltage and frequency with the use of power electronic devices. In case of normal inverters output contains only two level +Vdc & -Vdc, the output of this inverter is not pure sine wave its output contains more harmonics. For these harmonic minimization requires additional filter circuit therefore the system makes more costly and bulky. Demerits of inverter are less efficiency, high THD, and high switching losses. To overcome these demerits, we are going to use multilevel inverter (MLI). The term Multilevel starts from three-level converter. In 1975 the concept of multilevel converters were introduced. The first proposal for cascaded multilevel inverter was in 1975 [1]. MLI are used for high power and high voltage applications from past few years. Staircase output waveform is achieved in the output voltage of MLI, this output waveform is nearer to sinusoidal waveform. It was observed that conventional two level inverter output voltages were having more number of harmonics when compared to MLI output voltage.

The reduction in harmonics with use of MLI is achieved by increasing the number of levels, generally the number of levels of output is denoted by symbol 'N'. There are various control strategies to implement MLI but most widely used strategies in which its classified is Diode clamped, Flying capacitor inverter and cascaded multilevel inverter. In comparison with these techniques cascaded H-bridge MLI are easy to implement as compared to others, as it doesn't require any clamping diodes & flying capacitors [2].

The Sinusoidal Pulse Width Modulation (SPWM) methods are mainly used in multilevel inverter control strategy. This method is most effective method for reduction of harmonics. The generation of SPWM pulses using analog technique is complicated & tedious, whereas generation of SPWM pulses using microcontroller is simpler, easy to implement and most of the task is completed in software part which reduces the hardware cost of the MLI system. For the generation of SPWM pulses AVR microcontroller (μC) ATmega 32A has been used.

2.H-bridge cascaded multilevel inverter

The cascaded multilevel inverter has multiple units of single phase full bridge inverters connected in cascade. As we increase the number of units

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connected in cascade the number of levels of output also increases. The advantage of using multiple units in cascade is that we can synthesize desired single output from various dc sources such as batteries, fuel cells, solar PV panels etc. The ac output of each single unit is connected in series. Due to simple cascaded connections of multiple units the cascaded inverter is free from voltage clamping diodes or voltage balancing capacitors.

A cascaded MLI, as shown in *Figure 1* is basically a series connection of several H-bridge inverters as per the required level of output voltages. The output appearing across the load is combined output of all the bridges which are cascaded. Each single unit of full bridge inverter has its own DC source, originating from conventional or unconventional DC sources. The power circuit of Single Phase Unipolar inverter consists of four bidirectional IGBT arranged in bridge form. The circuit diagram of the power circuit is shown in *Figure 1*. The circuit diagram consists of four distinct IGBTs such that they are connected as the bridge circuit. The input to the circuit is the DC supply.

Figure 1 Cascaded H-bridge 3 level MLI

The IGBTs are triggered accordingly such that the AC output voltage is obtained at the output. The operation of the circuit is as follows

Table 1 Switching strategy for three level inverter

Switches	+VDC	0	-VDC
S1	ON	OFF	OFF
S4	ON	ON	OFF
S2	OFF	ON	ON
S3	OFF	OFF	ON

3.SPWM generation using AVR microcontroller

The gate pulses are generated by utilizing the simplicity of multi carrier sine PWM. For this procedure sine wave is the reference wave of amplitude A_{ref} and frequency F_{ref} which is

continuously compared with triangular carrier wave of amplitude A_c and frequency f_c . If sine wave is greater than triangular wave, the IGBTs are turned on otherwise off. For N level N-1 carrier wave with same frequency f_c and same amplitude A_c are disposed such that the bands they occupy are contiguous. The reference waveform has peak-to-peak amplitude A_r , the frequency f_r and it is zero centered in the middle of the carrier set. The reference is continuously compared with each of the carrier signals. If the reference is greater than a carrier signal, then the device corresponding to that carrier is switched on otherwise off [3].

The ratio of reference amplitude (A_r) to carrier amplitude (A_c) is called as the amplitude modulation index, for implementation of pulses in MLI.

$$Ma = A_r / (N - 1)A_c \quad (1)$$

For generation of SPWM pulses with switching sequence mentioned in *Table 1* AVR ATmega 32 μC has been used [4]. This μC has many features like inbuilt ADC, timer/Counter, and etc. Among all the feature, its timer/counter contains 4 PWM channels which we can utilize for generation of SPWM pulses [5-12]. The timer contains three modes which are as follows:

1. Timer 0
2. Timer 1
3. Timer 2

Among these three timer we are going to use timer 1 for generation of gate pulses. AVR has three PWM modes [13]

1. Fast PWM mode.
2. Phase correct PWM mode.
3. Phase and Frequency correct PWM mode.

In fast PWM mode the triangular wave generated is of sawtooth type while in phase correct PWM mode and phase and frequency correct PWM mode the triangular wave is of symmetrical type[8][9][11].

Algorithm for generation of SPWM pulses

Step 1: initialize variable i, duty and duty1.

Step 2: initialize array of data in sin table.

Step 3: set port D as output.

Step 4: Load TCCR1A with 0xA0 for non-inverting mode operation of compare match

Step 5: Load TCCR1B with 0x12 for Phase & Frequency Correct PWM mode and sets the prescale to 8.

Step 6: Set the top value in ICR1 reg.

Step 7: Load OCR1A with the count from sin table whenever TCNT1 reaches zero.

The *Figure 2* below shows the SPWM pulses generated using AVR by above algorithm.

Figure 2 SPWM pulses using AVR microcontroller

Where, CH1-Shows SPWM pulses (Amplitude =5V).

4. Simulation and hardware results

The simulation model for three level H-bridge Cascaded MLI was developed in MATLAB as per circuit diagram shown in *Figure 3*. The simulation parameter used are given below in *Table 2* [10][12].

Table 2 Simulation parameter

Dc Bus Voltage	100 V
Carrier frequency	1 kHz
Fundamental frequency	50Hz
Load	R=10Ω

Simulation model is shown in *Figure 3* below:

Figure 3 Simulation model for 3 level cascaded H-bridge MLI

Figure 4 Gate pulses for three level H-bridges MLI

Figure 5 Phase voltage and current for H-bridge MLI

The *Figure 4* and *Figure 5* show the gate pulses given to MLI and the output voltage & current for three level H-bridges MLI. Based on simulation model the hardware was developed as shown in *Figure 6* block diagram given below:

Figure 6 Block diagram for hardware implementation of 3 level H-bridge MLI

Figure 7 PCB board of power circuit and control circuit for H-bridge MLI

Figure 8 Complete hardware setup for three level H-bridges MLI with DSO output

Figure 9 Output Voltage of 3 level H-bridge MLI

5. Conclusion and future work

Simulation of three levels Cascaded H-bridge MLI was carried out by using MATLAB/Simulink. The gate pulses have been generated by using SPWM techniques and SPWM pulses was generated by using AVR μ C. The implementation of hardware was done shown in *Figure 6*, *7* & *8* and three level output was achieved successfully. But there was some issue with driver circuit as shown in *Figure 9* which needs to be rectified to achieve SPWM in output voltage.

Acknowledgment

None.

Conflicts of interest

The authors have no conflicts of interest to declare.

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