



Design of Single Phase Five Level Inverter

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ABSTRACT

This paper focuses on the result of simulation by using MATLAB and initial phase of hardware implementation of single phase flying capacitor clamped multilevel inverter in which output of triggering has been completed. This inverter has wide application for low and medium voltage DC-DC converter for renewable energy application. It is not only achieve high power rating operation but also enable their use in non-conventional power generation. The elementary concept of a multilevel converter is to achieve higher power by using a series of power semiconductor switches with several lower voltage sources. The power conversion is performed by synthesizing a staircase voltage waveform. It has better performance of medium voltage and high power electric drive, the dV/dt and harmonic should be minimized by introduction of more level in the output voltage.

Keywords : Multilevel Inverter, Simulation Result, Triggering Waveform, Hardware

I. INTRODUCTION

The advancement in the field of power electronic has increased the usage of high power medium voltage drive applications in the industrial arena. In order to get better performance of medium voltage and high power electric drive, the dv/dt and the harmonic should be minimized by the introduction of more levels in the output voltage. This has initialized the theory of multilevel inverter for industrial drive to overcome the above disadvantages. In multilevel inverter the output voltage are generated at high frequency and low switching frequency with low distortions. In case of high power and medium voltage situation such as laminators, SVC, HVDC Pumps, blowers, compressors and so on. Multilevel inverter plays an important role in the area of electronic and it is widely used in industrial and renewable energy applications for converting dc to ac. It not only achieves high power rating but also enables the use of renewable energy source. There are several configurations available for forming the multilevel inverter.

1. Diode clamped multilevel inverter
2. Flying capacitor clamped multilevel inverter
3. Cascade H-bridge multilevel inverter.

Flying capacitor multilevel inverter usage of extra capacitor clamped to the power switches phase rail to provide the dc voltage level. The structure allow for the inverter to supply high capabilities especially during the power outages due to reducing the switching states providing by clamping capacitor.

II. FIVE LEVEL FLYING CAPACITOR 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 flaying capacitors. It can control both the active and reactive power flow. But dur to the high frequency switching, switching losses will takes place[5,6].

BASIC FEATURES

The topology consists of diodes, capacitors and switching devices. Although theoretically this topology has been designed to give infinite levels, but due to practical limitations this only gives up to six levels of voltage. Each leg consists of switching devices which are generally transistors. Capacitors nearer to the load have lower voltage. Capacitors nearer to the source voltage (V_{dc}) have higher voltage. The number of level depends upon the number of conducting switches in each limb.

CALCULATION

The formula to find number of devices needed for obtaining five level multilevel inverter is

An 'n' level inverter needs:

Number of voltage sources $N_{dc} = (n-1)$

Number of switching devices $N_{sd} = 2(n-1)$

Number of balancing capacitors $N_{bc} = (n-1)(n-2)/2$

Number of DC bus capacitors $N_c = (n-1)$

In a five level flying capacitor inverter:

$N = 5$

Therefore:

$N_{dc} = (5-1) = 4$

$N_{sd} = 2(5-1) = 8$

$N_{bc} = (5-1)(5-2)/2 = 6$

$N_c = (5-1) = 4$

The following one phase leg of a five level flying capacitor multilevel inverter to produce a staircase output voltage is shown below

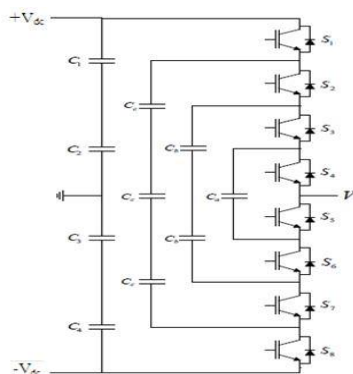


Figure 1. One Phase of a Five Level Flying Capacitor Multilevel Inverter

OPERATION

For an output voltage level $V_0 = V_{dc}$, turn on all upper half switches S1 through S4. For an output voltage level $V_0 = V_{dc}/2$, turn on three upper switches S1 through S3 and one lower switch S5. For an output voltage level $V_0 = 0$, turn on two upper switches S1 & S2 and two lower switch S5 & S6. For an output voltage level $V_0 = -V_{dc}/2$, turn on one upper switch S1 and three lower switches S5 through S7. For an output voltage level $V_0 = -V_{dc}$, turn on all lower half switches S5 through S8.

Table 1 shows the voltage levels and their corresponding switch states. State condition 1 means the switch is on, and state 0 means the switch is off.[1]

Table 1 : The Switching State of Flying Level Multilevel Inverter

V_0	S1	S2	S3	S4	S5	S5	S5	S8
V_{dc}	1	1	1	1	0	0	0	0
$V_{dc}/2$	1	1	1	0	1	1	1	0
0	1	1	0	0	1	1	1	0
-	1	0	0	0	1	1	1	0
$V_{dc}/2$								
$-V_{dc}$	1	0	0	0	1	1	1	1

III. SIMULATION

The whole research has been carried out to find out about the performance of single phase five level multilevel inverter using MATLAB/SIMULINK simulation software. Matlab/ Simulink is software for modelling, simulating, and analysing. It supports linear and nonlinear systems, modelled in continuous time, sampled time. The simulation process is performed on circuit having two different switches i.e IDEAL switch and IGBT switch. The working procedure is same in both the type of switches[3,10].

SIMULINK MODEL USING IDEAL SWITCH

The Ideal Switch block does not correspond to a particular physical device. When used with appropriate switching logic, it can be used to model simplified semiconductor devices such as a GTO or a MOSFET. The Ideal Switch block is fully controlled by the gate signal ($g > 0$ or $g = 0$). It has the characteristics like it blocks any forward or reverse applied voltage with zero

current flow when $g=0$, conducts any bidirectional current with quasi zero voltage drop when $g>0$, switches instantaneously between on and off state when triggered.

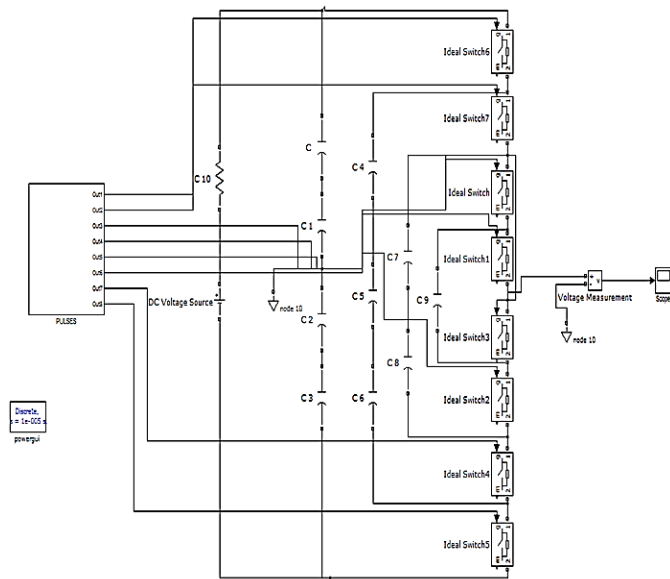


Figure 2. Simulink Model Using Ideal Switch

SIMULINK MODEL USING IGBT SWITCH

The simulation is then performed using IGBT switch. The main advantages of IGBT compared with various kinds of transistors are low ON resistance, high voltage -capacity, fast switching speed, ease of drive and joined with zero gate drive current creates a good option for sensible speed, and various high voltage applications like PWM, SMPS, variable speed control, AC to DC converter powered by solar and frequency converter applications which operates with a hundred's of KHz. The main disadvantages are: The speed of the Switching is lower to a Power MOSFET and higher to a BJT.[10]

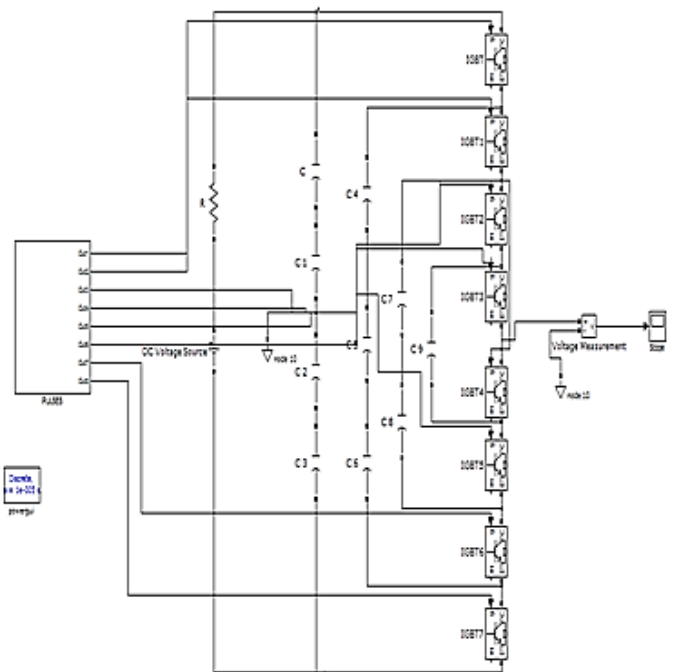


Figure 3. Simulink Model Using IGBT Switch

TRIGGERING OF SWITCHES

In the triggering circuit, basically for generating pulses OR GATE logic is used. In the triggering circuit there are total 8 OR gate are used in which 4 OR gates are used for positive half cycle and other 4 OR gates for negative half cycle.[7]

For generating 8,6,3 and 1 input signals we need to trigger 1st, 2nd,3rd and 4th OR gates respectively. In triggering circuit total 9 pulse generators are used. The phase angle delay for one half cycle is as follows:

For generating output voltage at $V=0$ instant pulse generator 1,2 and 3; phase delay of 0^0 , 180^0 and 360^0 is given respectively. For generating output voltage at $V=V_{d/2}$ instant pulse generator 1 and 2; phase delay of 45^0 and 135^0 is given respectively. For generating output voltage at $V=V_d$ instant pulse generator 1 the phase delay of 90^0 is given[2,4].

The triggering simulation block diagram is shown below

HARDWARE

1. Driver Circuit

A driver circuit is an electrical circuit used to control another circuit or to regulate current flowing through a circuit or to control other factors such as electronic components in the circuit. The need of a driver circuit is to switch a power semiconductor device from OFF state to the ON state and vice versa. In the ON state the driver circuit must supply adequate drive power (gate source voltage in case of MOSFET) to keep the power switch in the ON state. The driver circuit needs to provide reverse bias to the gate to minimize turn off times and to ensure that the device remains in the OFF state and is not triggered ON by stray transient signals generated by the switching of other power devices. Driver circuit interfaces between the control circuit and power circuit. It provides isolation between control circuit power circuit. Gate drive circuit also helps for protection to the power device from over current and short circuit.

Below figure(7) shows the circuit diagram of simple gate driver circuit with the help of optocoupler to drive gate of the MOSFET. A 5V dc supply is given to optocoupler through a resistance R1, resistance R1 is the current limiting resistance which is required to protect optocoupler because it requires only voltage from 1.2V to 1.5V. Optocoupler has two internal parts LED and Photo transistor there is isolation between them. Initially contact between LED and photo transistor. When 5V dc supply is ON then LED in the optocoupler will glow and the contact between photo transistor and LED closes and MOSFET gets the power circuit voltage i.e. 12V.

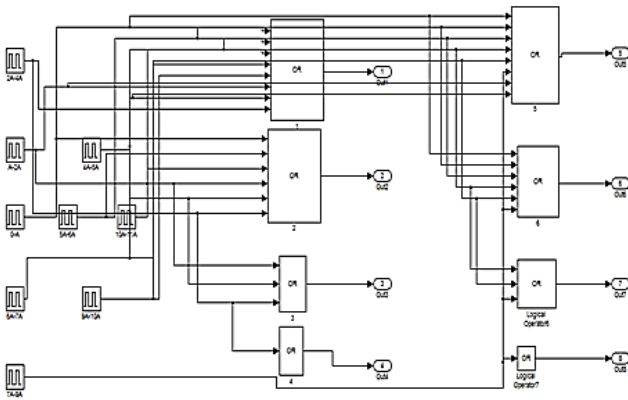


Figure 4. Simulink Model Of Triggering Circuit

SIMULATION RESULT

The analysis of timing diagram in figure (4) and from table (1), the switching time of IGBT shows relationship among the IGBT which reduces the voltage stress of the multilevel inverter by using the MATLAB Software[8,9]. The output waveform of output voltage of 460 V, 50Hz, 1ph from the input voltage 460V dc supply and also the waveform nearly equal to sine wave.

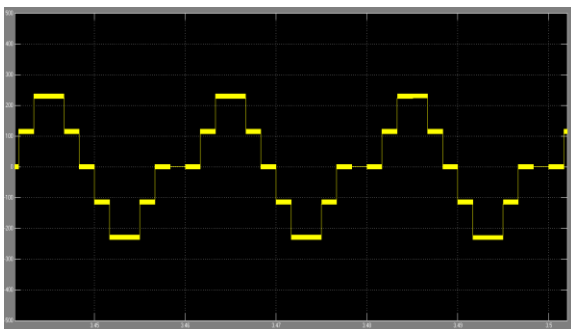


Figure 5. Waveform Obtained After Triggering of the IGBT Switches

The output waveform of simulation of multilevel inverter using IGBT switch is shown below.

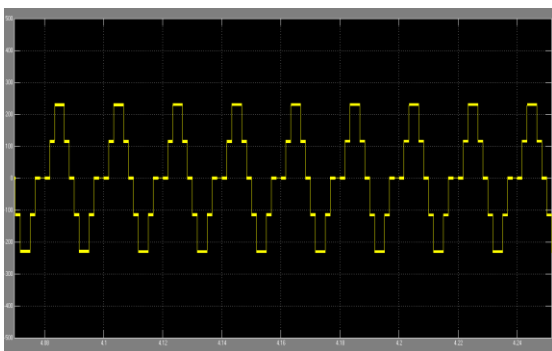


Figure 6. Waveform of Output Voltage Against Time(S)

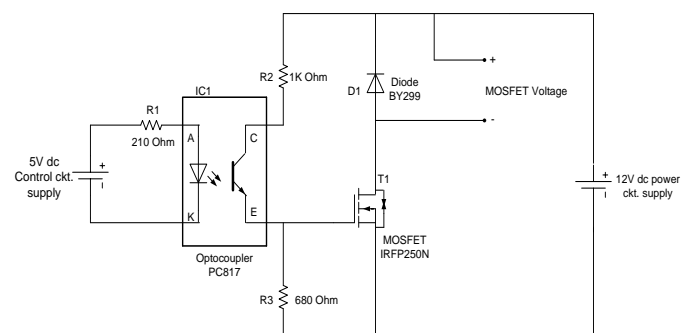


Figure 7. Circuit Diagram of Driver Circuit

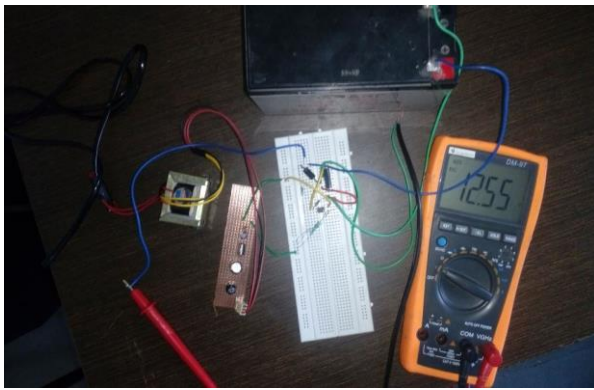


Figure 8. Experimental Arrangement of Driver Circuit

In above figure(8) multimeter shows the MOSFET voltage 12V when control circuit is in ON state and multimeter shows 0V when control circuit is in OFF state (if control circuit gives the signal to the optocoupler it closes the contact and MOSFET switch is get turn ON)

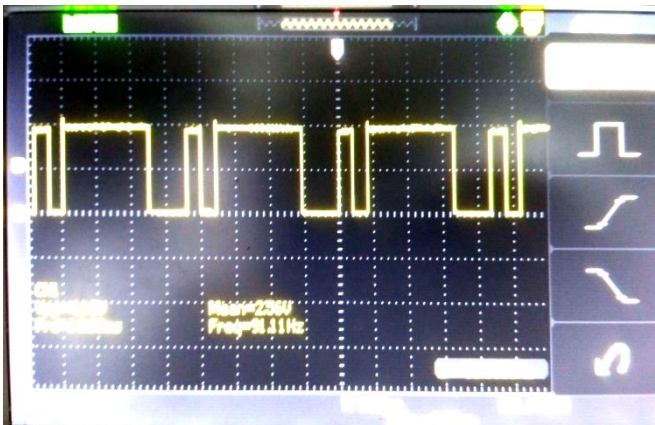


Figure 9. Output Waveform of Programmed Microcontroller IC of Pin 4

Above figure(9) shows the output waveform of ATMEGA16 microcontroller IC .The microcontroller IC is programmed by BASCOM software, it is the software used for programming of ATMELs microcontroller. ATMEGA16 microcontroller IC is an 8 bit high performance microcontroller having features of low power consumption. ATmega16 need voltage supply of 5V.The triggering signal from the microcontroller is given to MOSFETs of the multilevel inverter for proper switching to get an appropriate output. For the programming of microcontroller IC first we check switching timing in the pulse generator by connecting scope to the 8 terminal of the gate pulse generator in the MATLAB triggering model(2) , then done the

programming of microcontroller IC. Output waveform of microcontroller IC(10), having the magnitude of 5V and frequency near about 100Hz. This is because due to we done the programming for only positive half cycle and waveform (10) is showing for positive as well as negative half cycle. And the waveform of pin4 will matches the waveform of the first terminal of the gate pulse generator s first terminal in MATLAB triggering model(2).

IV. CONCLUSION

In this paper, analysis of five levels Inverter has been carried out. They are widely acceptable for power application ranges in medium and high power due to their advantages. With the help of Matlab/Simulink the simulation of five levels was carried out with the help of a simple control strategy. A simple approach was used to trigger the switches at appropriate firing angle with suitable delay. The output waveform obtained from an IDEAL switch and IGBT switch is almost similar. The design of five levels Inverter was successfully done with respect to the resistive load.

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