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Design and Implementation of Multilevel Inverter for Drive Applications with Minimum Number of Transistors

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ABSTRACT

A unique topology for single-phase 7- level Inverter is brought into being. A detailed description of the structural parts of the inverter is given. A powerful elucidation has been made with respect to the workable theories involved in this novel Inverter. Similarly, there is an exposition of its various functional topologies and the schedule of changeover. Simulations play a vital role in substantiating the authenticity of the Inverter. The outcome of simulation is first presented and then juxtaposed with ordinary H-Bridge Inverter. The recommended Inverter emanates an excellent degree of output voltage waveform. This in turn leads to a decrease in dv/dt stresses enforced on those devices meant for power-switching. It also curtails the harmonic components of output voltage and encumbers current suitably well. The circuit is simulated using MATLAB SIMULINK and is implemented using Embedded Controller. Both simulation and hardware results are verified.

KEY WORDS: H-Bridge, Multilevel Inverter, and Total Harmonic Distortion.

1. INTRODUCTION

In the application of numerous industrial drives, the popularity of power-electronic inverters is immense. Nowadays, inverters have become inevitable in many implementations namely motor controlling and power systems. Hence, there is an increase in the study on inverters. This has brought about a progressive breakthrough in the field of inverter technology. The principal aim of this scrutiny is to obtain an exalted grade of output energy. Thus, numerous configurations are tried out and new modes of changeover are perceived on these configurations. The prevalent H-bridge square-wave or pulse Width modulated (PWM) inverters were known for their simple switch configuration and they were easily controllable. For these reasons, conventional H- bridge inverters were applied in many industrial applications. However, these inverters have got their own demerits too. Well-proportioned elements of H-bridge inverters are, of course, large in number and so they cannot be used conveniently in sensitive applications. Besides, elevated conversion frequency of PWM inverters and the dv/dt stress existing in them culminate in low productivity and induce the requirement of high switch-frequency ingredients. In order to mitigate these complications, multilevel inverters have taken the place of the usual H-bridge square wave and PWM inverters. In this aspect, there is a tremendous increase in the use of multi-level inverter techniques in many industrial applications so as to lower the voltage stress thrust on the apparatus meant for transferring power as well as to turn out an excellent degree of output voltages.

It has been manifested that, when there is an increase in the number of levels of the generated output voltage, there is a certain decrease in the total harmonic distortion of the output current. Consequently, some innovative methods of approach have been explored to raise the quantity of levels, without affixing any intricacy to the power circuit. Therefore, quite a number of single and three-phase multi-level inverters have been displayed. Also, several switching techniques of multi-level inverters have been scrutinized and considered along with their specific traits. At the same switching frequency, the lesser genre harmonic components of output voltage wave form are much lesser than those of a two-level voltage wave form. There is no need for additional transformers or reactors to lessen the number of harmonic components. With regard to the progress in inverter technology, this article brings to the limelight an advanced topology for single-phase 7-level inverter. The output voltage is produced in the form of seven values: +Vd, +2Vd, +3Vd, zero, - Vd, -2Vd and -3Vd. This novel topology has got certain merits. It employs least number of switches. Moreover, it has the potential to bring down the amount of harmonic components to a great extent when compared to the existing H- bridge square-wave inverters and inverters belonging to similar group. This eventually turns out an output voltage wave of a high standard. It also minimizes dv/dt stresses exerted on power switching devices. Switching performances are upgraded to figure out the angles along which switching takes place. The reliability of the suggested inverter is confirmed through simulations. In this manner, output wave forms and harmonic components are ascertained. Simulation results are put forth and contrasted with the habitual H-bridge inverter.

Configuration of proposed 7- level inverter: Figure1 displays configuration of the proposed 7-level inverter. It consists of Level and H-Bridge Modules. Operational principles of the inverter will be elaborately elucidated. The most significant hallmark of the system is being accessible for expanding. In this work, this suggested system is designed for 7-level output voltage.

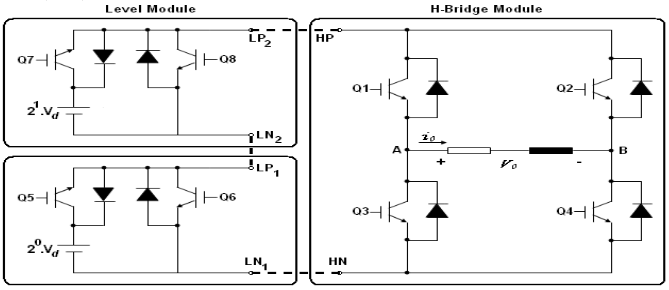

Fig.1.Configuration of seven level multi-level inverter

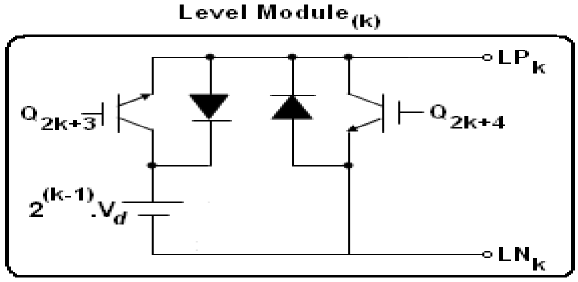

Fig.2.Configuration of level module

Level Module: Level Module comprises two switching devices and a battery. The battery voltage is expressed by k and Vd as,

2(k-1) Vd

k = 1, 2, 3,……………………m (1)

Here, Vd regulates the voltage of the first level module and m stands for the quantity of level modules. Usually, Vd is expressed as,

Vd= 2.Vmax/n-1 (2)

In this equation, Vmax refers to the utmost value of the necessary load voltage and n denotes the amount of output voltage level. The following figure portrays configuration of the Level Module.

H-Bridge Module: The H-Bridge Module of the recommended system uses the traditional H-Bridge inverter structure. H-Bridge Module can be defined as the stable part of the proposed system. An increase in the number of output voltage levels can be brought about by altering the number of Level Modules. Whatsoever, there is no modification made in the structure of the H-Bridge Module. Figure 3 exhibits configuration of the H-Bridge Module.

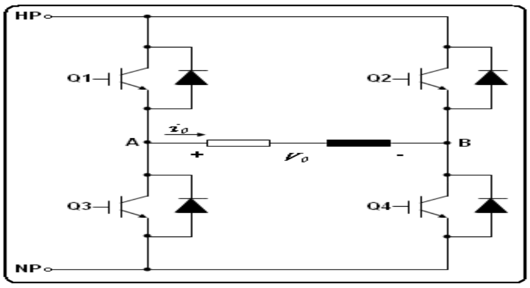

Fig.3.Configuration of H-bridge module

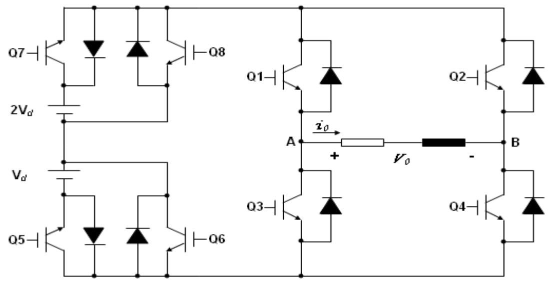

Fig.4.Configuration of single phase 7-level inverter

Proposed 7-level multilevel inverter: Figure 4 shows a configuration of the proposed single phase 7-level inverter. It encompasses an H-Bridge module and two level modules.

As far as Figure 5 is concerned, it generates 7-level shaped output voltage wave.

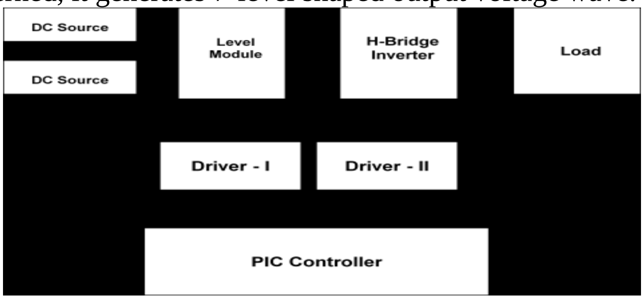

Fig.5.Block diagram

The primary concern of this project is DC source. This DC source provides the essential DC supply to the Inverter. The DC source can be Battery or fuel cell or rectified from AC source. Level Module is employed to enhance multilevel output voltage. This Module contains multi input source and switching devices. The selection of DC source and switches is done on the basis of output voltage level. H-Bridge Inverter is H in shape and hence it derives its name from its shape. This Inverter comprises four MOSFETs. H-Bridge Inverter has got its own advantages. It is used to generate ac output voltage. It is also made use of in operating single phase ac motor as well as any appliance required for ac voltage. In comparison with Analog circuits and Microprocessor, Microcontroller is more advantageous in nature. It is known for its quick response, low cost and small size. Besides, it is used at its best to generate triggering pulse for MOSFETs. It also plays an important role in the stabilization of the outputs. Driver is used in the amplification of the pulse output from Microcontroller. Due to this fact, it is also known as power amplifier. Moreover, it is also called upto coupler IC. It provides isolation between microcontroller and power circuits. Regulated Power Supply (RPS) generates 5V supply for Micro controller and 12V supply for Driver. It is converted from AC supply. AC supply is step down using step down transformer.

Operational Principles and Topologies: The operation of the suggested inverter can possibly be divided into 9 switching states. The proposed 7-level inverter is manipulated through calculated switching angles (θ1, θ2, θ3). In order to obtain voltage levels, proper switches in H- Bridge and Level Modules are activated at the correct angle values. Hence, 7- level output voltage levels (0, ±Vd, ±2Vd and ±3Vd) are attained by applying proper battery voltages (Vd, 2Vd, Vd+2Vd). The output voltage levels according to switch on/off conditions are explicitly shown in Table 1.

Table.1.Switching states of 7-level Inverter

Switch ON OFF Conditions and Output Voltages			
On Switches	Node A	Node B	Output
Q3,Q4	0	0	0
Q1,Q4, Q5	Vd	0	Vd
Q1,Q4, Q7	2Vd	0	2Vd
Q1,Q4, Q5 Q7	3Vd	0	3Vd
Q1,Q4, Q7	2Vd	0	2Vd
Q1,Q4, Q5	Vd	0	Vd
Q1,Q2	0	0	0
Q2,Q3, Q5	0	Vd	-Vd
Q2,Q3, Q7	0	2Vd	-2Vd
Q1,Q3, Q5	0	3Vd	-3Vd
Q2,Q3, Q7	0	2Vd	-2Vd
Q2,Q3, Q5	0	Vd	-Vd

Figure 6 (a)-(f) above highlights the operational topologies of the proposed inverter for ±Vd, ±2Vd and ±3Vd voltage levels respectively. Also, illustrates both freewheeling states and regenerative states.

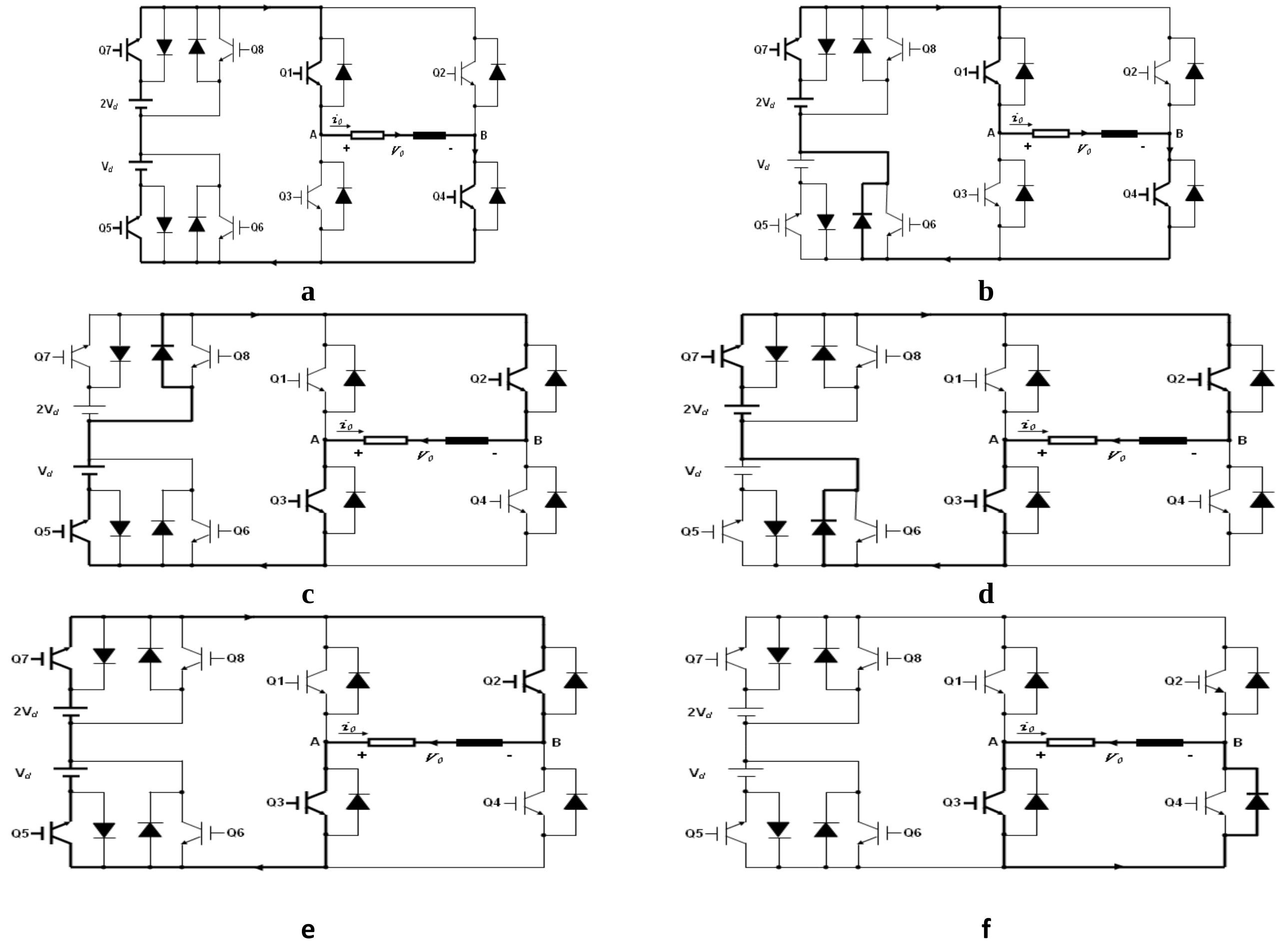

Fig.6.Operational topologies according to switching states

Performance estimation of proposed 7- level system: It goes without saying that the performance of the inverter gets highly affected by harmonic components in load current. Therefore, attempts are made to minimize harmonic components and consequently load current is brought in a quality sinusoidal form. For this purpose, simulations are worked out ahead to prove availability of the proposed single-phase 7-level inverter for different loads. The results of simulation are compared with conventional H-bridge inverter. Further, simulations for 15-level and 31-level inverters are also carried out in order to compare with the suggested inverter as well as to improve the proposed inverter for the future work.

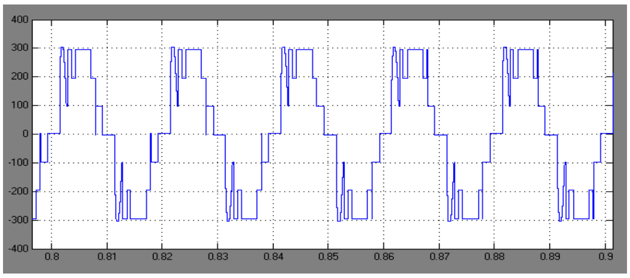

Fig.7.Simulation result of output voltage in7-level inverter

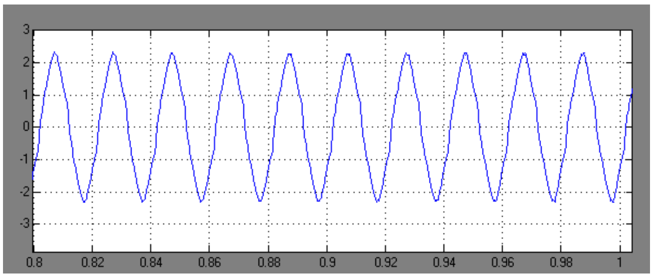

Fig.8.Simulation result of output current in 7-level Inverter

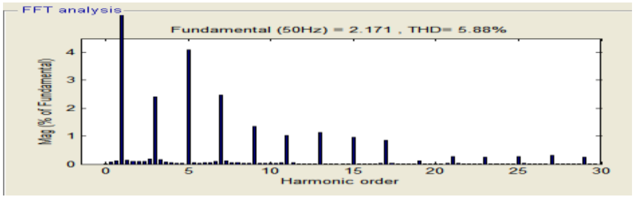

Fig.9.FFT Analysis of current

The Total Harmonic Distortion of the 2-level, 5- level and 7-level Multilevel Inverter has been calculated and hence tabulated as shown in Table 2.

Table.2.Comparison of THD values

INVERTER	% THD
2 Level	17.29
5 Level	11.77
7 Level	5.88

2. EXPERIMENTAL WORK

A prototype is designed and produced to verify the validity of the proposed inverter. The proposed single phase7-level inverter is controlled by using PIC16F84A microprocessor. IR2110 power MOSFET (500V, 20A) is probably preferred for switching devices.

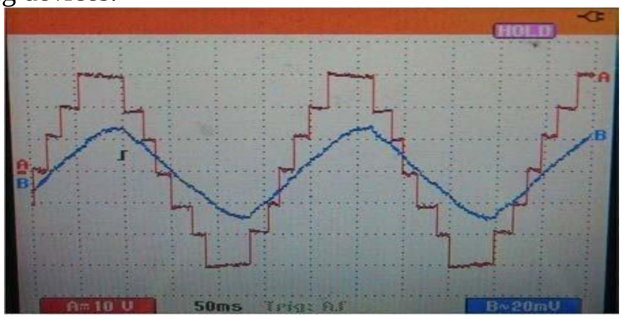

Fig.10.Experimental result of output voltage and load current in proposed 7-level multilevel Inverter

3. CONCLUSION

A novel single-phase 7-level inverter topology has been put forth in this paper. The primary characteristic feature of this system is its flexibility to expand and increase the number of output levels. The number of output levels can be raised even with a considerably less increase of switching devices. The method and formula applied in this new system for calculating switching angles are simple. Simulations and experiments are made use of in testing single- phase 7-level inverter topology. Through simulations and experiments, it is observed that proposed inverter topology generates a high- quality output voltage wave form. Moreover, this topology also minimizes *dv/dt* stresses imposed on power-switching devices as well as harmonic components of output voltage and current quite satisfactorily.

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