SINGLE PHASE QUASI-Z-SOURCE BASED MODIFIED CASCADED MULTILEVEL INVERTER WITH HALF-BRIDGE CELL

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Abstract: In this paper a new Quasi-Z-Source Modified Cascaded Multilevel Inverter with Half-Bridge Cell is presented and proved to be advantageous over conventional Cascaded Multilevel Inverter with voltage boost ability and reduced switches. The proposed topology is comprised of cascaded auxiliary units and a full H-bridge inverter, where the auxiliary unit includes half bridge cell with quasi Z Source network. With quasi Z Source network shoot-through state control, the output voltage amplitude can be boosted, which is not limited to DC source voltage summation similar to conventional cascaded Multilevel Inverter. The performance parameters of quasi Z Source Modified Cascaded Multilevel Inverter with various multicarrier PWM control methods are analyzed with simulation results and portrayed here.

Keywords—CHB, MLI, SPWM

1. INTRODUCTION

A circuit that converts dc power into ac power at desired output voltage and frequency is called an inverter. Some industrial applications of inverters are for adjustable speed ac drives, induction heating, stand by air-craft power supplies, UPS (uninterruptible power supplies) for computers, HVDC transmission lines etc. The dc power input to the inverter is obtained from an existing power supply network or from a rotating alternator through a rectifier or a battery, fuel cell, photovoltaic array or magneto hydrodynamic (MHD) generator. The configuration of ac to dc converter and dc to ac inverter is called a dc-link converter. The rectification is carried out by standard diodes or thyristor converter circuits. Inverters can be broadly classified into two types: voltage source inverters and current source inverters[1].

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.

The need of multilevel converter is to give a high output power from medium voltage source. Sources like batteries, super capacitors, solar panel are medium voltage sources.

The multi-level inverter is to synthesize a near sinusoidal voltage from several levels of dc voltages. As number of levels increases, the synthesized output waveform has more steps, which provides a staircase wave that approaches a desired waveform. Also, as steps are added to waveform, the harmonic distortion of the output wave decreases, approaching zero as the number of voltage levels increases. The Multi-level inverters can be classified into three types. 1. Diode – clamped Multi-level inverter 2. Flying – capacitor Multi-level inverter 3. Cascade Multi-level inverter.

2. CASCADED H-BRIDGE MULTI-LEVEL INVERTER

Cascaded H-Bridge (CHB) configuration has recently become very popular in high power AC supplies and adjustable-speed drive applications. A cascade multilevel inverter consists of a series of H-bridge (single-phase full bridge) inverter units in each of its three phases. Each H-bridge unit has its own dc source, which for an induction motor would be a battery unit, fuel cell or solar cell. Each SDC (separate D.C. source) is associated with a single phase full-bridge inverter. The ac terminal voltages of different level inverters are connected in series. Through different combinations of the four switches, S1-S4, each converter level can generate three different voltage outputs, +Vdc, -Vdc and zero. The AC outputs of different full bridge converters in the same phase are connected in series such that the synthesized voltage waveform is the sum of the individual converter outputs.

3. NEW DESIGN OF MULTI-LEVEL INVERTER

3.1 Introduction

In recent trends, the quasi-Z-source inverter has engrossed ever-increasing applications in renewable energy sources such as Photovoltaic (PV) and wind energy systems [2]. The modern research revealed that the quasi-Z-source concept has been applied to cascaded H-bridge multilevel inverter that provides the combined advantages of traditional Cascaded Half-Bridge Multilevel Inverter [3], [4] and quasi-Z-Source Inverter. Quasi-Z-source cascaded multilevel inverter offered numerous merits over traditional Cascaded Half-Bridge Multilevel Inverter in distributed generation applications [5]. The balanced dc-link voltage and voltage boost capability are the most fruitful advantages of the quasi-Z-Source Cascaded Half-Bridge Multilevel Inverter. The switching device count increases as the number of levels increases in the conventional Cascaded Half-Bridge Multilevel Inverter that leads to higher switching losses and increased cost for designing the module. Modified Cascaded H-Bridge Multilevel Inverter has fascinated extensive interests in recent researches as it leads to reduced number of switches and minimized manufacturing cost. Until now, there is no literature to provide the complete analysis of Quasi-Z-Source Based Modified Cascaded Multilevel

Inverter. The novelty of this paper is to propose the Quasi-Z-Source Modified Cascaded Multilevel Inverter with Half-Bridge Cell presenting gorgeous advantages over conventional cascaded Multilevel Inverter with voltage boost ability and reduced number of switches. The quasi-Z-Source Modified Cascaded Multilevel Inverter has the ability of single stage power conversion with improved reliability and wide voltage control through boost factor and modulation index. The Quasi-Z-Source Modified Cascaded Multilevel Inverter also provides reduced THD and reliability against short-circuits. A multilevel output voltage waveform of the Quasi-Z-Source Modified Cascaded Multilevel Inverter is synthesized by the combination of multicarrier pulse width modulation technique and simple boost control that launches shoot-through states into the traditional zero states to control the Quasi-Z-Source Modified Cascaded Multilevel Inverter module. The boost control methods uses maximum modulation index to provide output voltage with high voltage gain. In this paper, Phase Disposition Pulse Width Modulation control scheme in combination with simple boost control on the proposed topology are analysed.

The conventional quasi-Z-Source Cascaded Half-Bridge Multilevel Inverter is shown in Fig 1. It has quasi Z source network consisting of two inductors (L1, L2), capacitors (C1, C2) and one diode (D1). The quasi Z source network shares the common ground with inverter, and the current drawn by the dc source is continuous.

This topology is a simplified Cascaded Half-Bridge inverter symmetric topology. The main advantage of proposed topology is less number of switches compared with conventional multilevel inverter.

- Number of Level (m)= 2n+1
- Number of Main Switches (s switch) = 2n
- Number of low frequency switches(s switches)=4

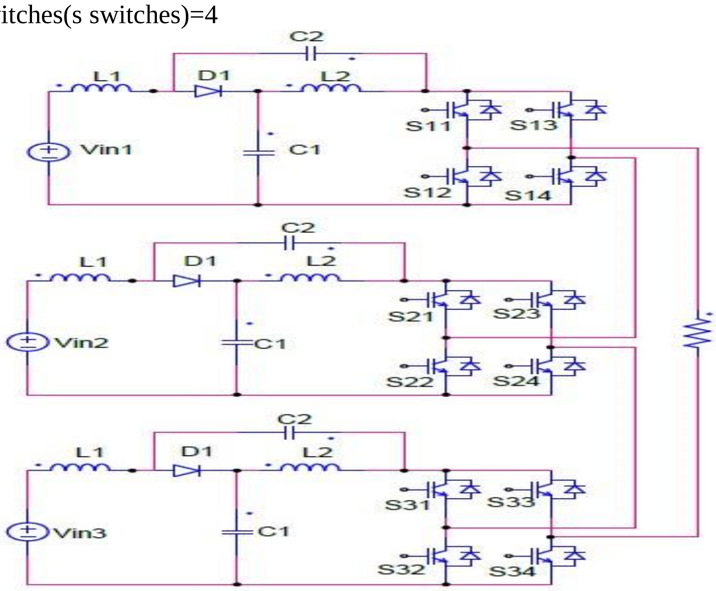

Fig.1 Conventional quasi-z-source cascaded h-bridge

Where 'm' is the number of output voltage level, 'n' number DC source switches. Figure.1shows the general circuit diagram of proposed multilevel inverter. If number levels increases add one switch for each level, simple control circuitry. The Unique modulation strategies are applicable for this topology. The numbers of switches are required for each level and switches can be calculated from the above equations. To get a Positive half, properly turn ON the switches and the current flow from the point A to B will generate a positive polarity, the flow from B to A will generate the negative polarity as shown in below figure. In general, in order to achieve an equal voltage steps, the equal and same dc source voltage to be use. The unequal Vdc generate the different voltage steps. There are several multilevel inverters are commercialized for high power applications such as Flexible AC Transmission Systems Controllers, Train Traction, Automotive applications, renewable energy power conversion and transmission etc. This project proposes a new PV system based on quasi Z Source Cascaded Half-Bridge multilevel inverter. Now-a-days, the Z-source inverter and the quasi-Z-source inverter have been widely applied for renewable energy power generation system due to some unique features. They can implement voltage boost and power conversion simultaneously in a single stage, and improve the reliability due to the shoot-through cases no longer destroying the inverter. PV systems purely depends on solar energy and it is consistently shows its great potential to serve as a clean and inexhaustible renewable energy source.

At shoot-through states each PV array and quasi Z Source capacitors charge the inductors and diode is cut-off due to negative voltage.

3.2 Proposed Quasi-Z-Source Modified Cascaded Multilevel Inverter

The proposed topology of the Quasi-Z-Source Modified Cascaded Multilevel Inverter with Half-Bridge Cell is depicted as in the Fig.2. The circuit of the Quasi-Z-Source Modified Cascaded Multilevel Inverter is developed such that it can produce multi-level outputs with reduced number of semiconductor switches.

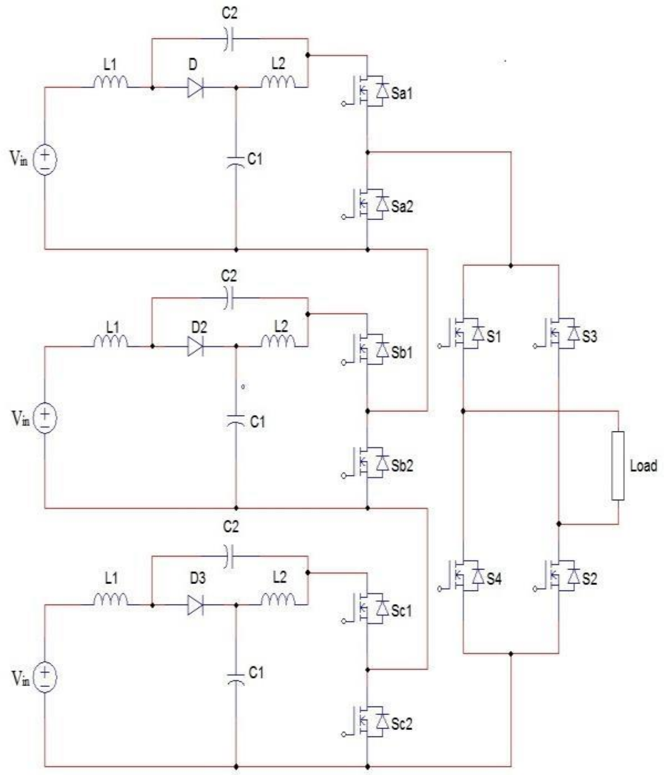

Fig.2 Reduced topology

This topology has cascaded auxiliary units and a full H-bridge inverter, where the auxiliary unit includes half bridge cell with quasi Z Source network. The quasi Z Source Modified Cascaded Multilevel Inverter module has a single stage voltage boost and inversion capability.

4.DESIGN PROCEDURE AND CIRCUIT OPERTION

4.1 New Design

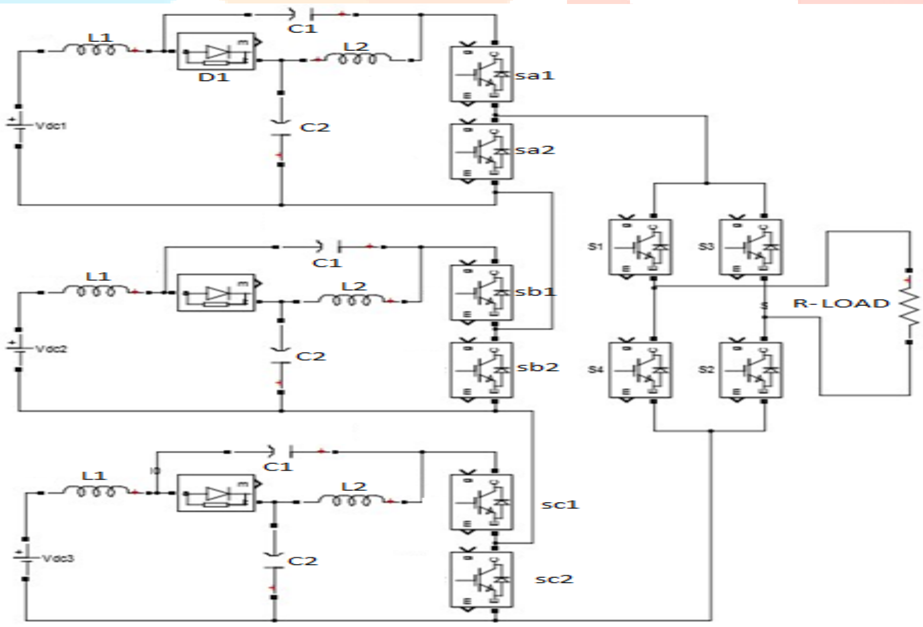

Fig.3 New design

Fig 3 shows a new 7-level inverter which consists of three main switches which are high frequency switches and also there four low frequency switches which are for polarity generation For Vdc the S2, S7, S3 switches are ON. The S1 is connected in positive terminal of the load and S3 is connected with negative terminal of the load through S7 for +2Vdc and+3Vdc, switches S2 and S7. This new design has three DC sources.

4.2 Operation

The number of levels to be generated is based on the mathematical formula which is given as **m=2n+1** where n=no of dc sources based on this the number of levels to be generated is calculated. The number of switches is also calculated using the mathematical formula i.e., **S=2n**

Hence for 7-level inverter three Dc sources are required and number of switches required is three. The number of low frequency switches is calculated by using mathematical formula

S=4

The frequency of low frequency switch is 50 HZ whereas the frequency of high frequency switch is 10 KHZ

4.3 Switching Sequence

The output voltage +1Vdc (first level) is produced across the load when switching on controlled switches Sa2, Sb2, Sc1, S1 and S2, and maintaining the remaining switches in off state. The output voltage +2Vdc (second level) is produced across the load by turning on the switches Sa2, Sb1, Sc1, and S2. Similarly, the output voltage +3Vdc is obtained by switching on Sa1, Sb1, Sc1, S1 and S2.

The following table shows the switching sequence of all the levels of proposed topology.

Sa1	Sb1	Sc1	Sa2	Sb2	Sc2	S1	S2	S3	S4	Voltage level
0	0	1	1	1	0	1	1	0	0	+ Vdc
0	1	1	1	0	0	1	1	0	0	+2 Vdc
1	1	1	0	0	0	1	1	0	0	+3 Vdc
1	1	1	1	1	1	1	1	1	1	0
1	1	0	0	0	1	0	0	1	1	-Vdc
1	0	0	0	1	1	0	0	1	1	-2 Vdc
0	0	0	1	1	1	0	0	1	1	-3 Vdc

This topology is operated in 2 modes

1. Shoot through state
2. Non-shoot through state

4.4 Shoot through State

The shoot-through zero state is provided by the LC and diode network. This network defends the circuit from damage during the shoot-though zero state by storing energy in L and C. The quasi Z Source network boosts the dc-link voltage with the help of stored energy in the network elements.

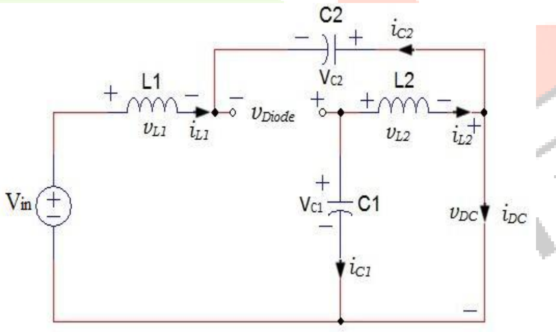

Fig.4 Equivalent circuit of quasi Z Source Modified Cascaded Multilevel Inverter in shoot-through state

4.5 Non-Shoot through State

But, in non-shoot through state the power is transmitted from dc side to ac side. There is no power transmission during shoot-through state since the dc-link voltage is zero.

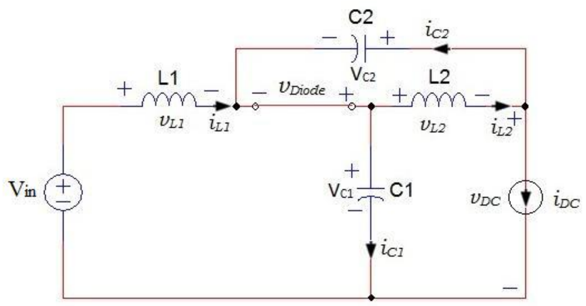

Fig.5 Equivalent circuit of quasi Z Source Modified Cascaded Multilevel Inverter in non-shoot-through state

4.6 Equations

The fundamental equations governing the operation of the quasi Z Source Modified Cascaded Multilevel Inverter are given below. The average value of the voltage across capacitor C1 is given

$$v_{c1} = \frac{1-D}{1-2D} v_{in}$$

The average value of the voltage across capacitor C2 is given

$$v_{c2} = \frac{D}{1-2D} v_{in}$$

The average value of the currents through the inductors L1 and L2 are given

$$I_{L1} = I_{L2} = \frac{1-D}{1-2D} V_{in}$$

The average value of DC link voltage is given

$$V_{DC} = \frac{1}{1-2D} V_{in} = BV_{in}$$

The average value of AC output voltage is given

$$V_{ac} = M * B * \frac{V_{in}}{2}$$

The boost factor B is given

$$B = \frac{1}{1-2D}$$

The voltage gain G is given

$$G = M * B$$

Where, M is the modulation index and Vin is the input dc voltage to the quasi-Z-Source network.

Each boosted voltage from the quasi-Z-Source network is connected in cascade with other boosted voltages through the half bridge cell comprising of one active switch and one diode that can generate multilevel positive output voltage. The full H-bridge unit is connected with the cascaded auxiliary units to acquire both positive and negative multilevel positive output voltage.

5. MODULATION TECHNIQUES

The following are the multilevel Modulation techniques.

Multiple Pulse Width Modulation Technique is used in three level or more than three levels. These are classified into two types: - Level Shift, Phase Shift. In this paper we used the level shifted modulation technique[6,7].

There are three different types of level shifted SPWM strategies with differing phase relationships:
Phase disposition(PD)- All carrier waveforms are in phase.
Phase opposition disposition
(POD) – All carrier waveforms above zero reference are in phase and are 180^0 out of phase with those below zero.
Alternate phase disposition
(APOD) – Every carrier waveform is in out of phase with its neighbor carrier by 180^0.
In this paper simulation results using POD method are shown

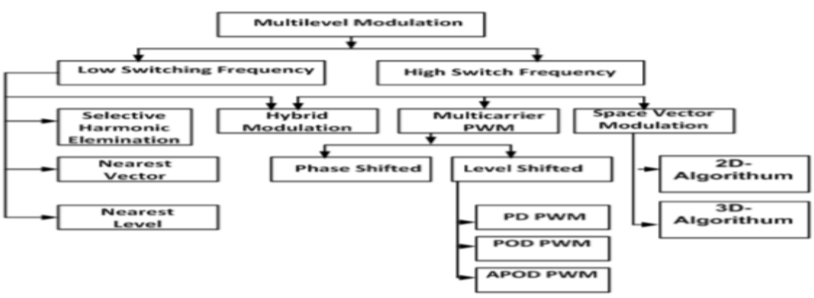

Fig 6 Multilevel modulation techniques

5.1 Phase Opposition Disposition (POD)

In phase opposition disposition (POD) modulation all carrier waveforms above zero reference are in phase and are 180 degrees out of phase with those below zero.

Carrier arrangements for PODPWM strategy The rules for the phase opposition disposition method, when the number of level N = 7 are The N –1 = 6 carrier waveforms are arranged so that all carrier waveforms above zero are in phase and are 180 degrees out of phase with those below zero. There are 3 carrier waveforms above the reference zero line and other 3 carrier waveforms with 180 degree shift are below the zero reference line. The converter switches to + Vdc when the reference is greater than 1st positive carrier waveform. The converter switches to +2Vdc when the reference is greater than the 2nd positive carrier waveform. The converter switches to +3Vdc when the reference is greater than the uppermost 3rd positive carrier waveform. The converter switches to 0 when the reference is lesser than all positive carrier waveforms as well as lesser than negative carrier waveforms.

The converter switches to - Vdc when the reference is lesser than 1st negative carrier waveform. The converter switches to - 2Vdc when the reference is lesser than 2nd negative carrier waveform. The converter switches to - 3Vdc when the reference is lesser than 3rd lowermost negative carrier waveform.

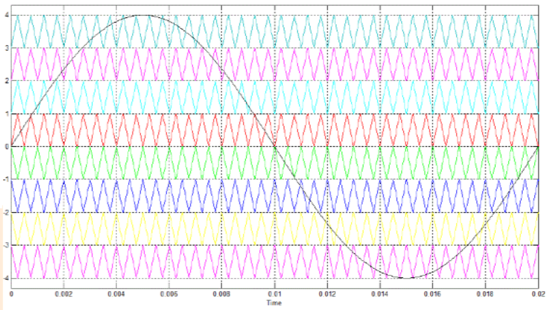

Fig.7 POD technique

For phase opposition disposition (POD) modulation all carrier waveforms above zero reference are in phase and are 180 degrees out of phase with those below zero[6,7].

6. SIMULATION DESIGN AND RESULTS

6.1 Matlab/Simulation Design of Proposed MLI

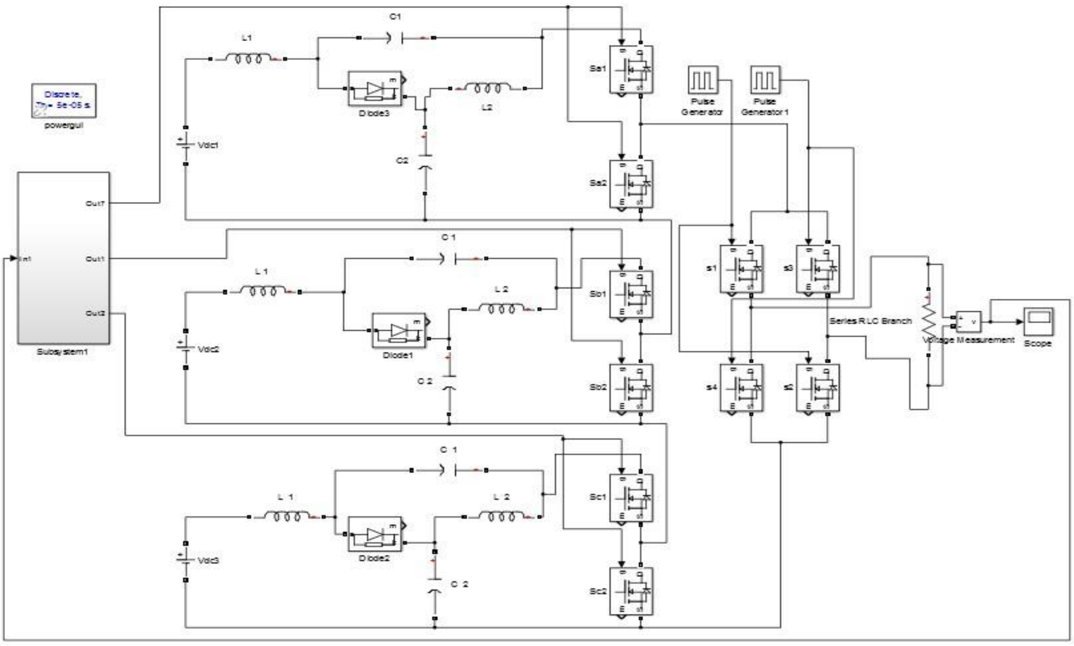

Fig.8 Proposed 7 level quasi Z Source Modified Cascaded Multilevel Inverter topology

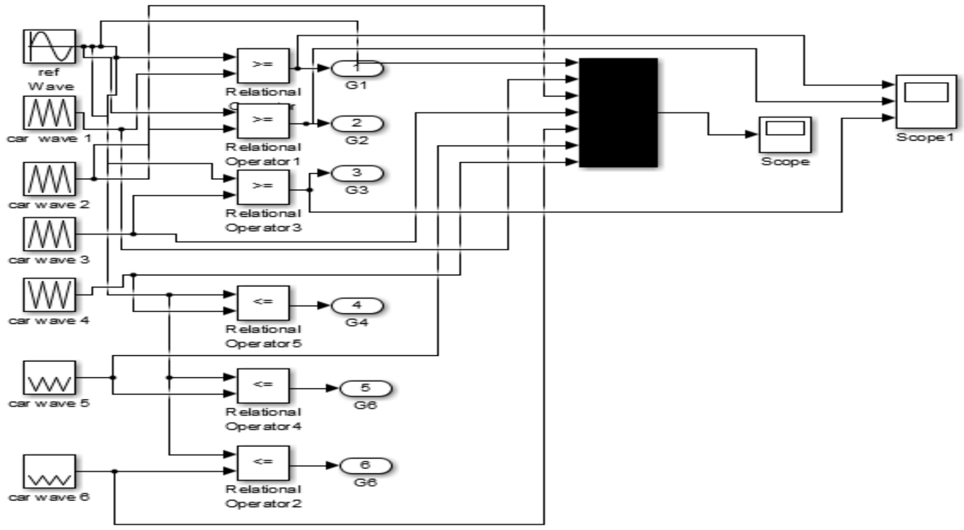

Fig.9 Sub-system of Simulink model of Sinusoidal Pulse with modulation.

6.2 Components used:

1) Number of dc sources = 3

2) Number of IGBT high frequency switches = 6

3) Number of IGBT high frequency switches = 4

4) Resistive load = 50 ohms

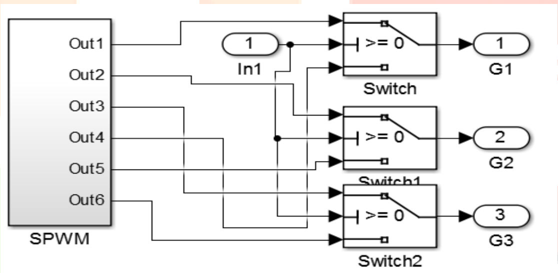

Fig.10 Sub-system of Proposed MLI using SPWM inverter topology.

It is the 7-level cascaded multilevel Inverter output.

6.3 Output of Phase Disposition

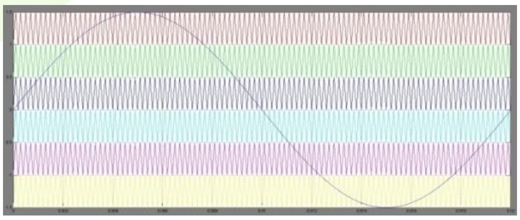

Fig.12 Phase Disposition

- **Phase disposition (PD)** – Here all carrier waveforms are in phase with each other.

6.4 Output of Impedances and Dc Link Voltages

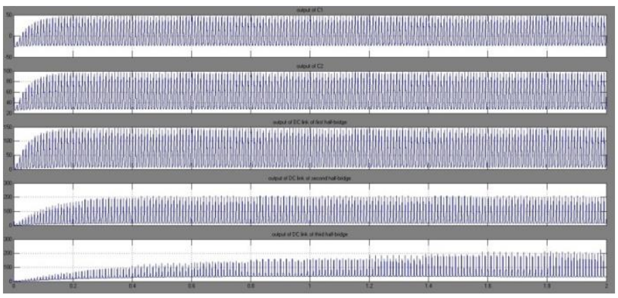

Fig.13 Impedances and DC link voltages

6.5 Output of Proposed Quasi Z Source Multilevel Inverter

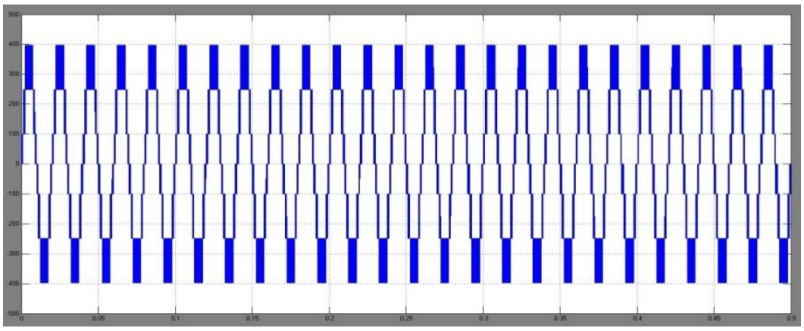

Fig.14 Cascaded half-bridge output with Z-source

In the fig 11 we observe that the output voltage is 150V which is equal to input magnitude but the output of quasi-Z-source multilevel inverter which is shown in fig 14 has boosted to 400V.

7. CONCLUSION

The proposed quasi Z Source Modified Cascaded Multilevel Inverter topology provides attractive advantages like reduced number of switches, voltage boost ability not limited to input voltage (DC source) summation, single stage conversion and reliability against short-circuits. Using Phase Disposition PWM control method, the quasi Z Source Modified Cascaded Multilevel Inverter performance parameters are analysed and presented. The Phase Disposition-PWM control method combined with simple boost control technique provides better results. This proposed quasi Z Source Modified Cascaded Multilevel Inverter topology is more suitable and can be effectively used for Photo Voltaic based applications.

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