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Multilevel Inverter from a New Basic Unit

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Abstract

This research makes a novel suggestion for a cascaded single-phase multilevel inverter. The suggested basic unit is connected in series with this inverter, which can only create positive levels at the output. So, the recommended inverter is expanded upon by an H-bridge. This inverter is referred to as a developed cascaded multilevel inverter, and it allows the output of the architecture to have both even and odd voltage levels. Having fewer driver circuits, DC voltage sources and power switches is a benefit of the single-phase cascaded multilevel inverter that is built. In turn, this lowers the inverter's cost as well as the size on installation. These features are acquired when comparing the proposed inverter with the conventional inverter.

Keywords: Multi-Level Inverter (MLI), High level, Reduced switches

1. Introduction

Today's industrial applications increasingly demand greater power. Nonetheless, certain industrial machinery only requires a small amount of power to operate. Although while some motors that require high power may benefit from it, using a high-power source could cause damage to all industrial loads. Medium voltage is required for the utility applications and the motor drives that operate at medium voltage. The Multi-Level Inverter (MLI) has been an alternative for high power and medium voltage applications since it was first introduced in 1975. The multilevel inverter, which works like an inverter and used in industrial applications where high power and medium voltage are required, is used in those situations.

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The industry's first preference for high power and voltage applications is multilevel inverters. Recent developments in the field of high-power medium- voltage energy regulation have made multilevel inverter technology an extremely significant alternative. Without the need of a filter circuit, the output waveform has low Total Harmonic Distortion (THD) thanks to the selective harmonic elimination technique and the multi-level structure [5]. These days, high power and medium voltage applications use multilevel inverters. Applications in a variety of fields include grid integration for renewable energy sources, and other electrical appliances.

Power semiconductor switches cannot be directly connected to a high voltage network due to the growing demand for inverters with high voltage and high power. As a result, MLI were introduced and are now being developed. In multilevel inverters, there are several types of arrays for various electrical and electronic devices [4]. The two advantages of MLI are THD and sinusoidal output waveform obtained by increasing the level of the output voltage. Apart from this, MLI also provides better efficiency, electromagnetic interference, low switching loss and voltage stress [3].

Multilevel inverters are widely used in v/f inverter drives of motors. Recently, the MLI topology with minimized number of components are being developed and various topologies are available but are still faces problems in the size and cost management. Hence, a modified configuration is proposed which uses less switches than the existing model to produce more level of voltages at the output [6].

2. Existing System

Cascaded H-Bridge Inverter

Cascaded H-Bridge Multilevel Inverter is shown in fig.1 below [1].

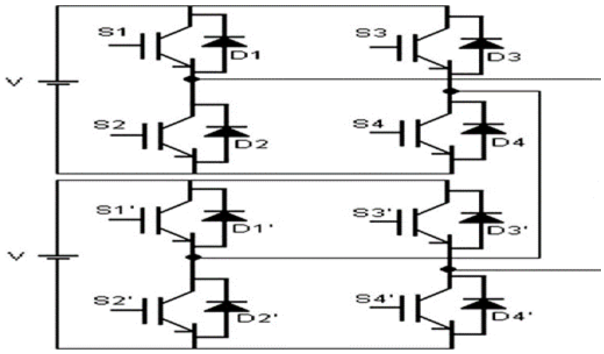

Figure 2.1. Cascaded H-Bridge inverter

The number of DC sources attached decides the number of levels in the output. The relation is given as m=2s+1.

Where,

m –No. of levels.

s – No. of DC sources.

All the outputs from H-Bridges should be quarter symmetric to generate a sine like wave. No evenharmonics are present in a series of H bridge inverter units with separate DC Sources form cascaded multilevel inverter. The output voltage is synthesized by the sum of inverter outputs. Each inverter in cascaded H bridge inverter can generate three level i.e., +Vdc, -Vdc, 0.

When switches S1 and S2 are turned ON, output is +VDC. When switches S3 and S4 are turned ON, output is -Vdc. Turning off all switches results in 0 output voltage. If N is the number of DC sources, then the output voltage level is L = N+1. Thus, a six-level cascaded inverter requires five distinct DC sources as well as five full bridge inverters.

In this topology, more voltage level at the output can be obtained by cascading or connecting more h-bridge units in series. The switching scheme that is implemented in this type of MLI plays the major role [3]. Commonly level shift PWM switching scheme is implemented.

Disadvantages of Cascaded H-bridge MLI:

It needs more switches than other configuration.

The size of the inverter in huge and because of more switches the control circuit will be more complex.

Flying Capacitor Multilevel Inverter

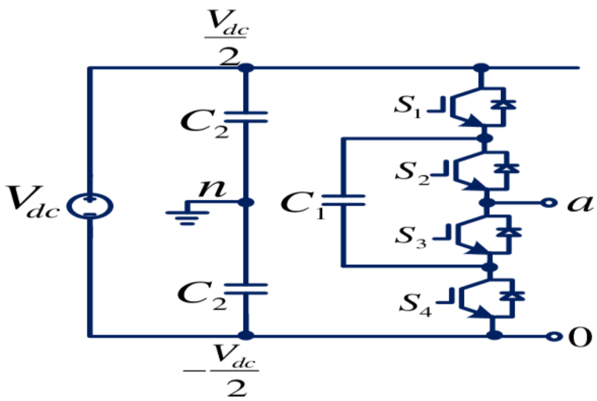

Figure 2.2. Flying Capacitor Multilevel Inverter

The utilisation of capacitors is the basic idea in inverter. The capacitor-clamped switching cells are connected in series in an inverter. The capacitors deliver the constrained voltage to electrical equipment. Switching states in this inverter are comparable to those in a diode clamped inverter. This particular style of MLI don't prefer clamping diodes. Half of the DC input voltage is output [5]. It is a flaw in the multilayer inverter with flying capacitors. The flying capacitors are balanced by the switching redundancy inside the phase that manages the reactive and the active power. High frequency switching usually results in switching losses.

The topology shown in Fig 2.2 is a Flying Capacitor MLI [2]. Each cell contains two power switches and one capacitor. An anti-parallel diode and a transistor are combined to form a power switch. Capacitors are used for clamping in this topology [4]. Every inverter consists N cells, N+1 voltage levels and 2N switches. It is understood that a MLI with N cell produces 2N+1 voltage-levels including negative voltage, and that negative voltage levels are possible. Lower voltage capacitors are located closer to the load. Higher voltage capacitors are located closer to the source voltage (Vdc).

3. Basic Unit of Multilevel Inverter

The basic unit of MLI consists of:

- Five IGBT with Diode.
- Three isolated DC source

With this basic unit, three levels of voltage can be achieved, they are:

- 0V
- V1+V3
- V1+V2+V3

Only the positive level outputs are generated from the basic unit. Hence in order to support the circuit in the generation of negative voltage cycles to sinusoidal voltages at the output, the H inverter is cascaded to the output of the basic unit.

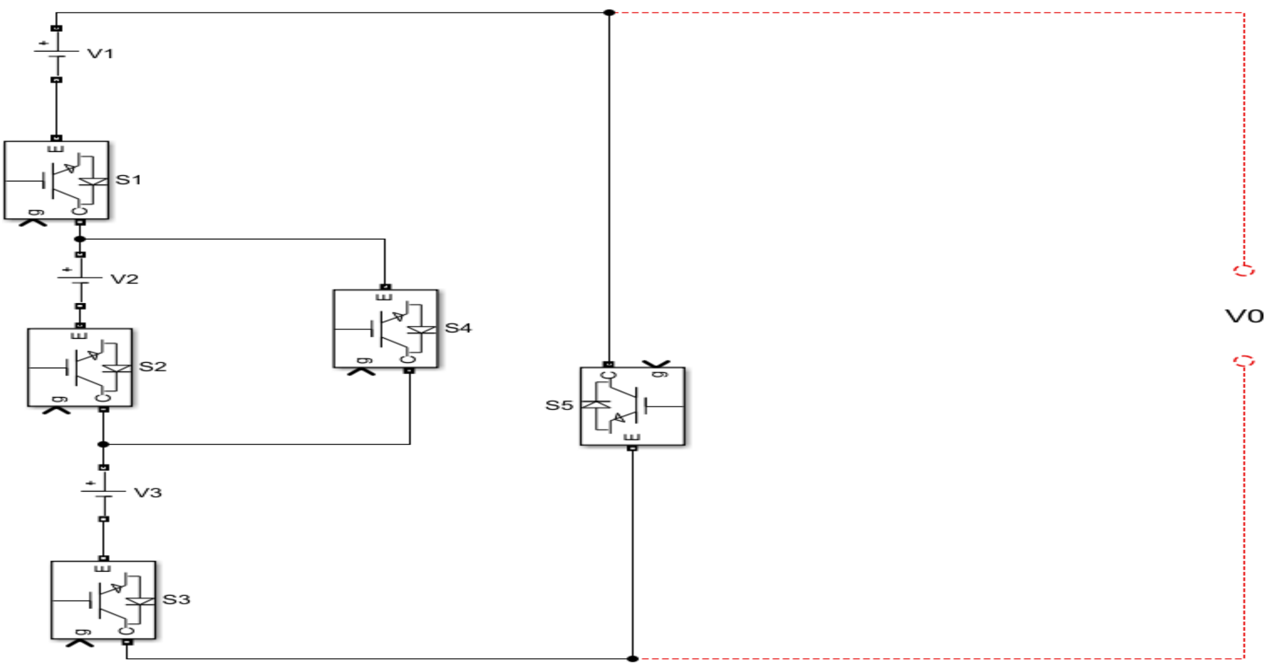

Figure 3.1 Basic unit of MLI

Working of Basic Unit of MLI:

1. At first, the switch S5 is turned on and the other switches are turned off. Now the voltage across the load will be 0V because the switch S5 acts as a short circuit across the load.

2. Then the switches S1, S3, S4 are turned on. Now the switch S4 acts as short circuit and the voltage sources V1 and V3 gets added in series and thus, the output voltage will be V1+V3.

3. After that the switches S1, S2, and S3 are on and adds the voltage sources V1,V2,and V3 in series.

Figure 3.2 Mode 1

Figure 3.3 Mode 2

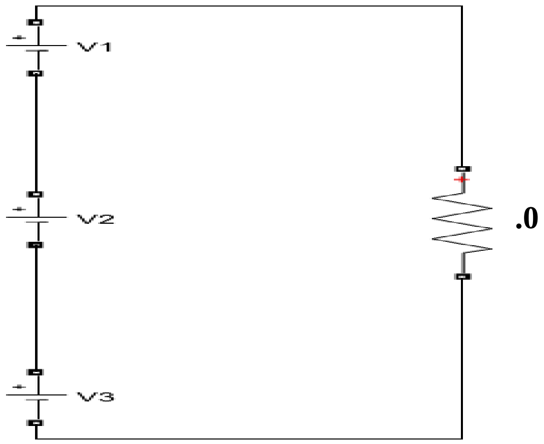

Figure 3.4 Mode 3

State	S1	S2	S3	S4	S5	V0
1	open	open	open	open	close	0
2	open	open	close	close	open	V1+V2
3	close	close	close	open	open	V1+V2+V3

Table I. Basic Unit Switching Sequence

Series Unit of MLI:

In basic unit, only three level of voltage can be achieved and the voltage level Vdc cannot be achieved. Hence a series unit consists of a single isolated DC source and two IGBTs with diode are added in series with the basic unit.

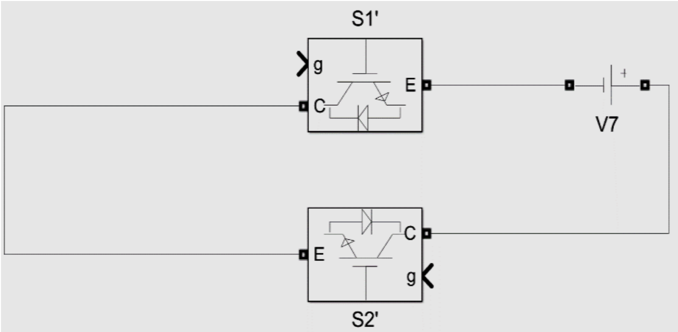

Figure 3.5 Series Unit

With this series unit, the voltage level Vdc (voltage of a single source) can also be obtained. The switch S and S' should not be turned on simultaneously.

Hence in symmetrical configuration = Vdc, (DC voltage) with both the basic and series unit, the following four level of voltages can be obtained:

0V, V_{dc}, $2V_{dc}$, $3V_{dc}$

The circuit shown in Fig.4.4 can be used as a five-level multilevel inverter while an inverter (H-bridge is added to it).

The unit shown in Fig 4.4 is implemented with only one basic unit, increasing the basic units in the array and establishing connection between the array and series unit helps in achieving the desired output voltage levels as shown in Fig.4.2. For voltage configuration that is symmetric, the output= 6n+3. Where, n is the serially connected basic units count.

Table II. Switching Sequence of BS Unit

State	S1'	S2'	S11	S21	S31	S41	S51	V_0
1	Off	On	Off	Off	Off	Off	On	0
2	On	Off	Off	Off	Off	Off	On	V_1
3	Off	On	On	Off	On	On	Off	$V_{11}+V_{31}$
4	Off	On	On	On	On	Off	Off	$V_{11}+V_{21}+V_{31}$

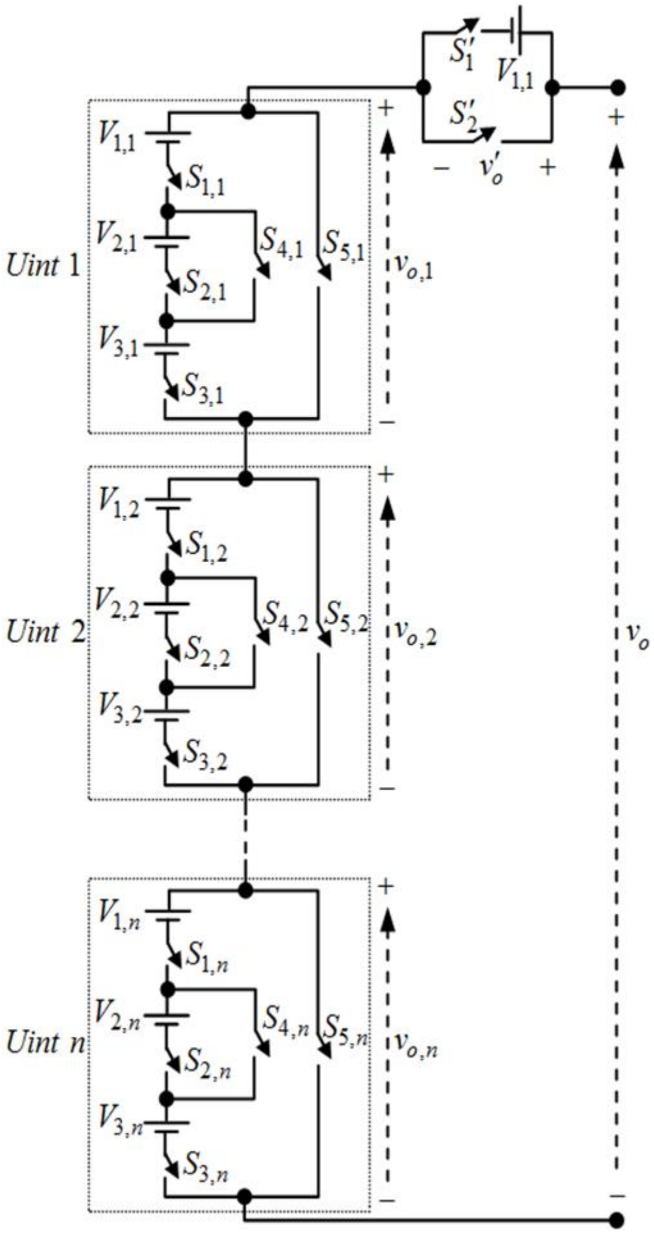

Figure 3.6 Circuit diagram of BS unit for n level

4. Switching Function of Basic Unit

Generally, the converter consists solely of switches, which have only two possible states. Such control can be affected only by changes in the switching pattern. The switching

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sequence will be different for different n number of units implemented; thus, the general configuration of the switching sequence is given in table.

The table shows only the switching pattern of the switches for different voltage levels but to implement this, firing instance or the time in which each switch should be turned on and turned off should be calculated.

In this research, both modified unit and the existing unit is simulated with only one basic unit (i.e., n=1). Hence the switching pattern is designed for the structure having only one basic unit.

At first, the firing instances are calculated for the desired frequency of the output.

Let, 50 Hz be the desired frequency at the output after the H-bridge inverter unit. The time period and electrical conduction angle for a full cycle of sine wave with 50 Hz frequency are 0.02 seconds and 3600 respectively.

Here the BS unit only produce the positive half cycle with the time period and the conduction angle as

0.01 seconds and 1800.

The number of levels obtained from BS unit for a half cycle is 6. Therefore,

Firing interval = 1800/6 = 300

For every 300, each switching state must be verified for change of state with reference to the switching sequence as shown in Table. To generate switching pulse in MATLAB, repeating sequence block is used. The repeating sequence based on the values in the parameters for the vector of time values and vector of output values, the interpolated block produces a periodic discrete-time sequence. The block determines the result using the procedure defined for the Lookup method argument in between data points. Yet, the value does not immediately alter. While a square pulse with the desired ON and OFF times is required for switching gate pulses, the output produced is a triangle pulse.

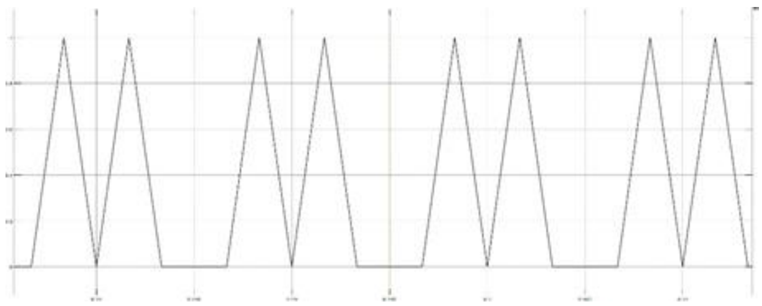

Figure 4.1 Output Pulse from Repeating Sequence

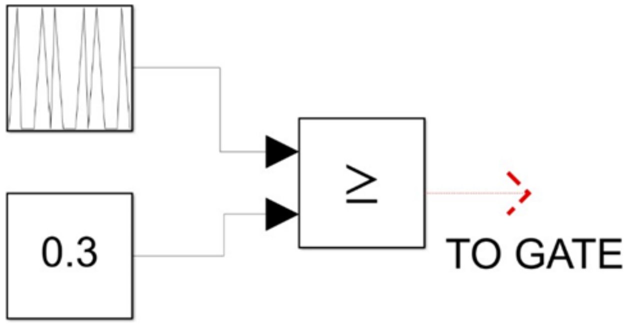

Figure 4.2. Switching Logic

The block shown in Fig.4.2 shows the switching logic for a single switch. The amplitude of output from repeating sequence varies from 0 to 1 and the constant value of 0.3 is compared to find the change of state.

Modified Structure from Basic Unit

In the modified structure shown in Fig.4.3, the collector terminal of S41 is connected between S11 and V2 and the emitter terminal S41 is connected between S21 and V3. The same switching scheme is followed

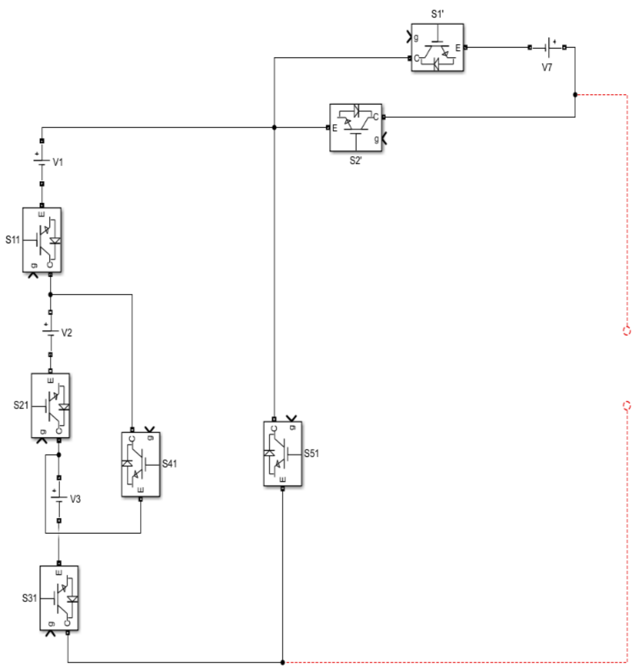

Figure 4.3 Modified Structure of a Basic Unit

The switching sequence and the switching circuit are implemented as like the BS unit. In this, the switch S41 is triggered after the completion mode as described in mode diagram and the V2 again gets added to the output. For the same configuration, an output of 11 level is obtained. Thus, an additional level is obtained and the source V2 delivers more power than the other sources. Since, the power delivered by the V2 is higher and the current flows through the switch S41 is higher hence in modified structure the switch S41 is used with higher rating than in BS unit.

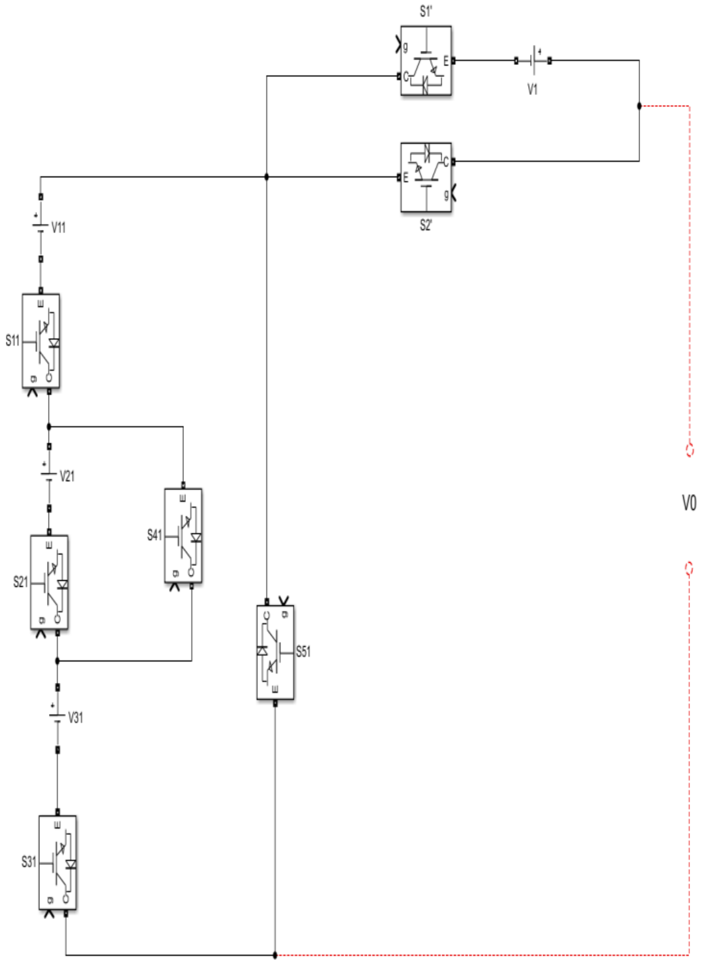

Figure 4.4 Basic Unit with Serie connection

5. Simulation and Result

The Simulation is done using MATLAB R- 2018b.For switches IGBT with Diode is used. The Discrete solver is used in PowerGui block and the Sample time of 1e-5 second is chosen. Here the simulation is carried out for the basic unit and the modified unit.

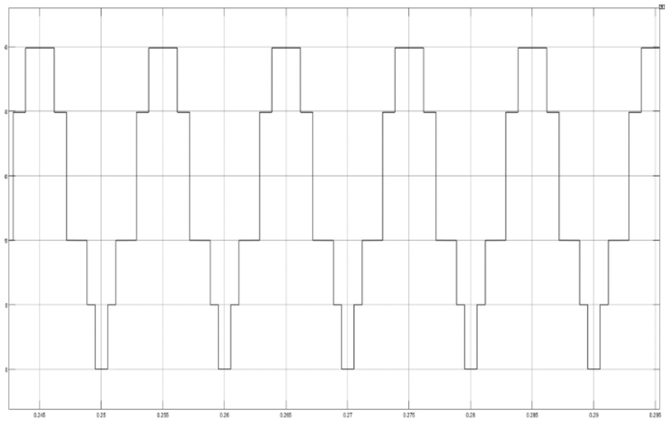

Figure 5.1 Positive Output Voltage (BS Unit)

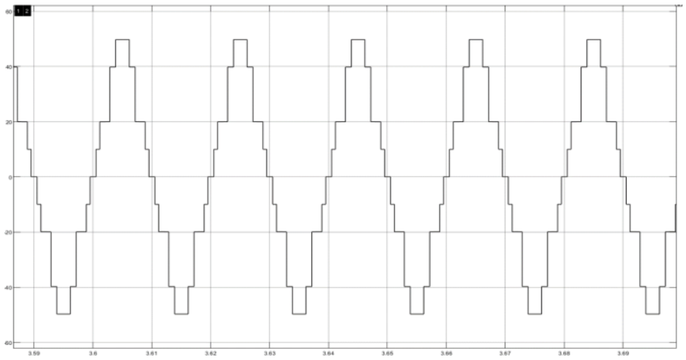

Figure 5.2 Sinusoidal Like Output Voltage (BS Unit)

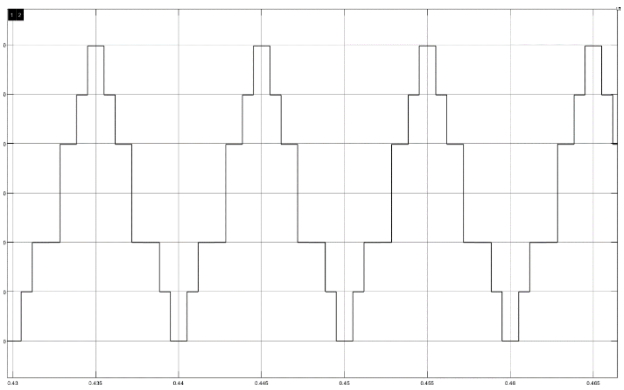

Figure 5.3 Positive Output Voltage (Modified Unit)

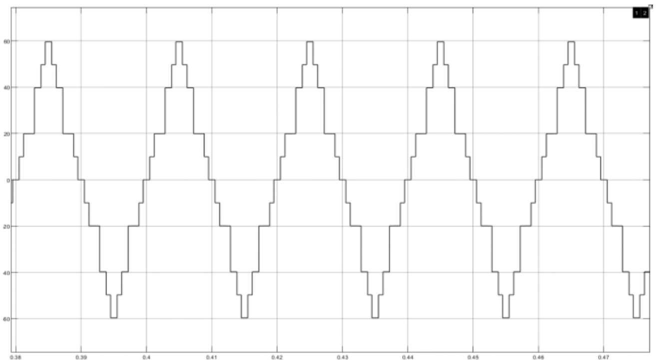

Figure 5.4 Sinusoidal Like Output Voltage (Modified Unit)

Fig. 4.3 shows the Simulink diagram of BS unit. Fig. 5.1 and Fig. 5.2 are the positive phase output voltage of basic unit and the output phase voltage of H-bridge inverter. Here the maximum peak of 50 V is obtained. Sinusoidal output voltage with 9 level of voltage is obtained.

Fig. 5.3 and Fig. 5.4 show the modified units' output. Here the maximum peak 60 V is obtained. Sinusoidal output voltage with 11 level of voltage is obtained.

6. Conclusion

Multilevel inverter from a new basic unit is simulated using MATLAB. A cascaded multilevel inverter is designed connecting one or more basic units with output of the basic unit cascaded with the H-inverter to produce the output voltage for both positive and negative cycles. From the basic unit, for 'n' number of basic unit (6n+3) level of output voltage can be obtained. In this modified design, (6n+5) level of output voltage is obtained. Thus, for same number of switches and same switching scheme, more level output voltage is obtained. These cascaded multilevel inverters are employed for applications with low as well as medium voltages.

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