

Modelling and Simulation of Novel 25 Level Inverter with Single DC Source

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ABSTRACT: The major problem faced in today's world is energy scarcity. Since the conventional energy sources are diminishing, more focus is towards alternate energy source. DC power is converted into AC power using inverters. Main issues that related to the conventional inverters are non-sinusoidal output, high total harmonic distortion (THD), high switching stress, loss and more number of switches. So multilevel inverter (MLI) have much importance over conventional inverters. The topology used is the cascaded H bridge 25 level inverter with single DC source using SPWM technique. 25 output levels using 10 switches with near sinusoidal voltage can be obtained with a single DC source. The advantages of this topology are Low THD, voltage stresses, small common mode voltage and operated with lower switching frequency

KEYWORDS: PWM-pulse width modulation, MLI-multi level inverter, THD-total harmonic distortion

I. INTRODUCTION

All nations over the world are engaged in solving the problem of energy crisis due to the depletion of fossil fuels. Combustion of non renewable energy sources like fossil fuels leads to pollution. This has ignited the spark of green energy concept with the use of renewable energy sources. Plenty of researches are being carried out to harvest the renewable energy. Compared to other types of renewable energy source solar energy has wide importance as it is pollution free and freely available. Solar energy is trapped by PV arrays and it is converted into electrical energy. The output obtained from the PV arrays is in DC form. The high gain DC-DC boost converter stepped up the DC output voltage and then connected to inverters for DC to AC conversion. A Power inverter is an electronic device or circuitry that changes DC (direct current) to AC (Alternating Current). Conventional two-level inverter creates two different output voltages V_{dc2} and $-V_{dc2}$ when fed with a DC voltage V_{dc} . To build an AC output voltage, these two voltages are usually obtained using PWM (Pulse Width Modulation).

Earlier 2- Level inverters were developed but these were not useful for high voltage and high power AC applications due to presence of harmonics and non sinusoidal output. As the technology got advanced multilevel inverters were developed which have fetched tremendous interests in renewable and power industry. The concept of multilevel inverter is not just creation of output waveform with two levels. Instead different voltage levels are added and higher levels are generated to get a stepped waveform. As the number of levels increases, more smoother will be the output waveform. It also has advantages like low harmonic distortion, low dv/dt and less EMI. But, in order to increase the number of levels, more number of components are required and same will make the circuit complex and congested. However the cost of production will also increase. There are several types of multilevel inverters: cascaded H-bridge, diode clamped converter, and flying capacitors. In particular, among these topologies, CHB inverters have been focused because of their modularity and simplicity. CHB inverters can also increase the number of output voltage levels easily by increasing the number of H-bridges. However, if the number of output voltage levels is increased, the number of switching devices is also increased, which makes a multilevel inverter more complicated. The disadvantage of conventional MLI is that if more number of output levels are required, then more number of components are needed and due to this complexity increases in gate driver circuits.

At present the most famous hardware implementable topologies are cascaded H-bridge and the diode clamped. Though this method is effective, yet it creates harmonic distortions on the output voltage, EMI (Electro Magnetic Interference) and high dv/dt . When it comes to multilevel inverter modulation there are basically two groups of methods: modulation with fundamental switching frequency or high switching frequency PWM. For both cases a stepped output waveform is achieved, but with the high switching frequency methods the steps are modulated with some sort of PWM. Independent of switching frequency choice there are also space vector methods to choose from. Multilevel PWM methods use high switching frequency carrier waves in comparison to the reference waves to generate a sinusoidal output wave, much like in the two-level PWM case.

To reduce harmonic distortions in the output signal phase-shifting techniques are used. There are several methods that change disposition of or shift multiple triangular carrier waves. The number of carrier waves used is dependent to the number of switches to be controlled in the inverter. The Phase Shifted Carrier PWM (PSCPWM), is a multi carrier modulation strategy that has all carrier waves phase shifted from each other. But In Phase Distortion PWM (PDPWM), all carrier waves are in phase. A great acknowledgement for this technique is that it is generally accepted as the method that creates the lowest harmonic distortion in line-to-line voltage. The proposed topology contains minimum number of switches for generating same output levels as compared to conventional MLI.

II. RELATED WORKS

Multilevel inverter technology has emerged recently as a very important alternative in the area of high power medium voltage energy control and grid connected applications. Three basic topologies are;

1. Diode clamped
2. Flying capacitor
3. Cascaded H- bridge Multilevel inverters

An attempt has been made in [8] to propose a new structure for the multilevel inverter with the reduced number of power electronic devices compared to the conventional type of cascade inverter. But this inverter requires large number of bidirectional switches and also its magnitude of blocked voltage is high. In [8] different structures of bidirectional switch combinations also explained.

In [10], another topology for cascade multilevel converter has been introduced. It reduces the number of bidirectional switches, power diodes, and dc voltage sources compared with [9]. But this topology requires large number of gate driver circuits and switches. It consists of several submultilevel converters and full-bridge converters.

R. Shalchi-Alishah et al. proposed topologies for symmetric, asymmetric, and cascade switched-diode multilevel inverters in [11]. It has more advantages in comparison with the topologies in the [8], [10]. When compared with the proposed topology, it requires more number of fast recovery diodes and separate dc sources. The modulation technique used is a fundamental switching strategy, a low switching frequency compared to other control techniques.

A. PROBLEM IDENTIFICATION

Multilevel inverter technology has emerged recently as a very important alternative in the area of high-power medium-voltage energy control and grid connected applications. Three basic topologies are; Diode clamped, Flying capacitor and Cascaded H-bridge Multilevel inverters. But these 3 topologies have several drawbacks.

The drawbacks of diode clamped multi level inverter are Real power flow is difficult for a single inverter; the number of clamping diodes required is quadratically related to the number of levels and Expensive The disadvantages of flying capacitors are Control is complicated to track the voltage levels for all of the capacitors. Pre charging all of the capacitors to the same voltage level and start up are complex. Switching utilization and efficiency are poor for real power transmission. The large numbers of capacitors are both more expensive and bulky than clamping diodes in multilevel diode-clamped converters. Packaging is also more difficult in inverters with a high number of levels

The demerits of cascaded H Bridge multilevel inverters are that Separate dc sources are required for each of the H-bridges and this makes it expensive. Thus the major draw-backs of a multilevel inverter is that Greater number of power semiconductor switches needed therefore Each switch requires a related gate drive circuit and this makes the Over-all system more expensive and complex and also More number of DC source required.

III. PROPOSED MLI

The proposed topology consists of two converter stages namely: the flyback converter and the cascaded H-bridge inverter.

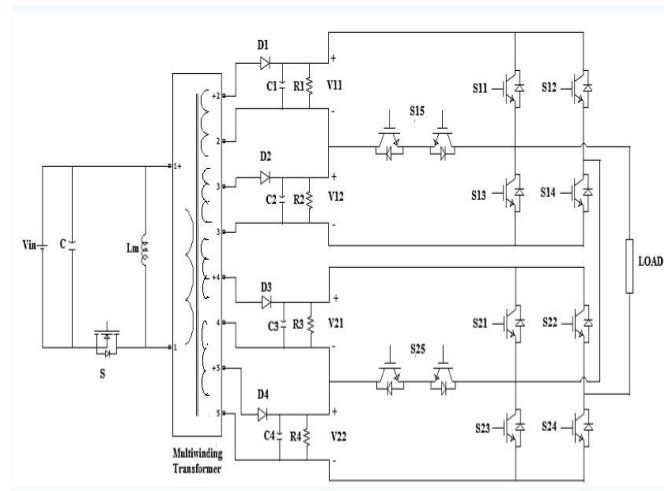


Fig 1. Circuit diagram of proposed MLI

The complete circuit diagram of the proposed MLI under the stand-alone mode is shown in Fig. 1. In conventional symmetric CHB MLI, the voltage levels of the isolated DC sources are equal. Meanwhile, in asymmetric inverters, the sources are not equally distributed. Although symmetric multilevel inverters have the advantage of a simple controller, asymmetric multilevel inverters can produce a higher number of voltage levels with the same number of H-bridge modules.

Fig.1 shows MLI where 25 output levels are obtained by using only 10 switches. This arrangement can be further augmented by cascading 'P' number of basic cells in series. As the number of output levels is increased the output approaches close to sinusoidal waveform. This topology contains two cascaded basic cells. Each cell consists of two equal voltage sources. The voltage sources of second basic cell are in ratio of 1:5 with respect to voltage sources of first basic cell. This topology helps to generate 25 output levels. This arrangement is defined as asymmetric MLI because of unequal voltage sources in two respective basic cells.

The 25-level inverter consists of two cascaded basic units. Each unit consists of two equal voltage input from the flyback converter. The voltage input to the first unit to the second is in the ratio of 1:5. This topology helps to generate 25 level output. The 1:5 ratio is maintained by the proper turns ratio (1:5) in the transformer winding of the flyback converter. Let $n_1 = n$, then $n_2 = n$, $n_3 = 5n$, $n_4 = 5n$. This arrangement leads to an unequal voltage input to the two respective basic units (asymmetrical MLI).

$$\begin{aligned} V_{11} &= V_{12} = V_{dc} \\ V_{21} &= V_{22} = 5V_{dc} \\ V_{m1} &= V_{m2} = 5^{(m-1)} \times V_{dc} \end{aligned}$$

The proposed structure requires a multi-output flyback converter and a 25-level inverter. The output of the flyback inverter is fed to the MLI. It requires 10 switches for the MLI and one switch for the flyback converter for its operation.

A. OPERATION OF PROPOSED STRUCTURE

The proposed MLI includes single input and four output flyback converter. Single dc source is supplied to the input of flyback converter. Four output from the flyback converter is connected across the two basic H bridge module. The operation of multi-output flyback converter is similar to the conventional single input single output flyback

converter. The transformer windings also depend on the load voltages. The operation of the proposed MLI is illustrated in the Table 1.

State	S11	S12	S13	S14	S15	S21	S22	S23	S24	S25	Output Voltage
1	1	1	0	0	0	1	1	0	0	0	0
2	0	0	0	1	1	0	0	1	1	0	V12
3	1	0	0	1	0	0	0	1	1	0	V11+V12
4	0	1	1	0	0	0	0	0	1	1	V22-V12-V11
5	0	1	0	0	1	0	0	0	1	1	V22-V11
6	0	0	1	1	0	0	0	0	1	1	V22
7	0	0	0	1	1	0	0	0	1	1	V22+V12
8	1	0	0	1	0	0	0	0	1	1	V22+V12+V11
9	0	1	1	0	0	1	0	0	1	0	V22+V21-V12-V11
10	0	1	0	0	1	1	0	0	1	0	V22+V21-V11
11	0	0	1	1	0	1	0	0	1	0	V22+V21
12	0	0	0	1	1	1	0	0	1	0	V22+V21+V12
13	1	0	0	1	0	1	0	0	1	0	V22+V21+V12+V11
14	0	1	0	0	1	0	0	1	1	0	-V11
15	0	1	1	0	0	0	0	1	1	0	-V12-V11
16	1	0	0	1	0	0	1	0	0	1	V12+V11-V21
17	0	0	0	1	1	0	1	0	0	1	V12-V21
18	0	0	1	1	0	0	1	0	0	1	-V21
19	0	1	0	0	1	0	1	0	0	1	-V11-V21
20	0	1	1	0	0	0	1	0	0	1	-V12-V11-V21
21	1	0	0	1	0	0	1	1	0	0	V12+V11-V22-V21
22	0	0	0	1	1	0	1	1	0	0	V12-V22-V21
23	0	0	1	1	0	0	1	1	0	0	-V22-V21
24	0	1	0	0	1	0	1	1	0	0	-V11-V22-V21
25	0	1	1	0	0	0	1	1	0	0	-V12-V11-V22-V21

Table1 Switching states

The switches S_{15} and S_{25} are the selection switches to add the number of output levels. The basic units are connected in series to form cascade structure. The output of each basic unit is added together to achieve the final output voltage.

B. MODULATION TECHNIQUES

The multilevel converters can be controlled by using different modulation schemes. For this topology a multicarrier PWM technique is adopted. The carrier based PWM technique is used to generate the switching pulses for the MLI. In this technique the sinusoidal reference signal is compared with the triangular carrier waveform. In this topology phase opposition disposition sinusoidal PWM (POD SPWM) is adopted for its simplicity and all the carrier waveforms are in phase with each other as shown in Fig. 2. The pulses obtained are used for switching the MLI corresponding to the respective voltage levels.

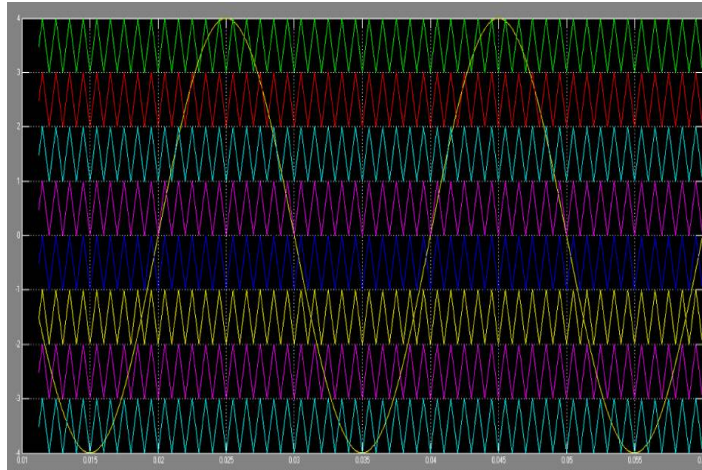


Fig. 2 POD SPWM technique

IV. SIMULATION RESULTS

The Simulink model of the proposed 25 level inverter using a single source is shown in Fig. 4. The simulations are performed using MATLAB. The Simulink model mainly consists of the multilevel inverter circuit, subsystem for the pulses generation and subsystem for the multi-output flyback converter. In this system R-L load is used as load.

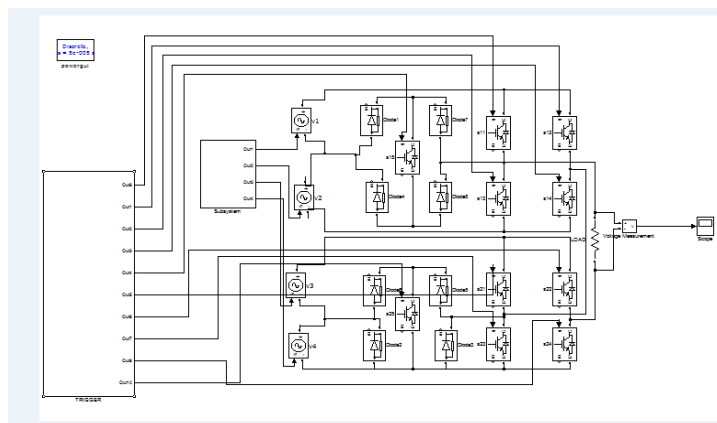


Fig. 3 Simulink model of proposed structure

The subsystem of POD SPWM is shown in Fig. 4 respectively. Fig. 4 shows the POD SPWM simulation. In this modulation technique sinusoidal waveform is compared with all the 25 carrier waveforms. For all the carrier waveforms above the time-axis, the results of comparison with the reference sine wave are '1' or '0'. For all the carrier waves below the time-axis, the results of comparison with the reference sine wave are '0' or '-1'. The aggregated signal has same number of output levels as desired in the output waveform. The switching signals are derived from this 'As' by comparing the signal with the desired level using the lookup table and the output is fed to the switches of MLI. The lookup table is generated by using the switching states of the 25-level inverter.

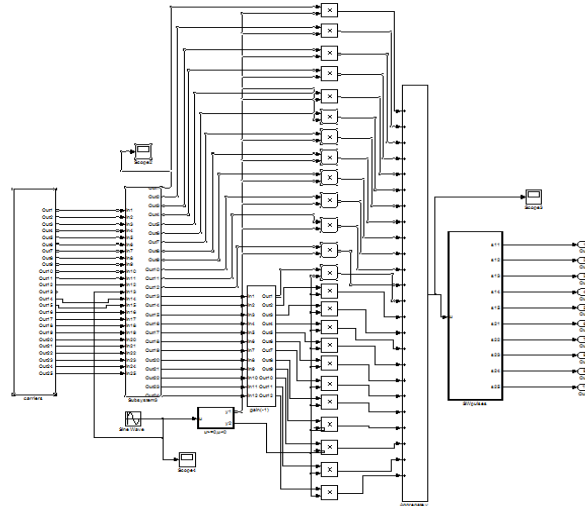


Fig 4. Subsystem of POD SPWM

The output voltage obtained is shown in Fig.5. The maximum output voltage obtained in this structure is the sum of the load voltages of the multi-output flyback converter. The output voltages of flyback converter is given by figure 6.

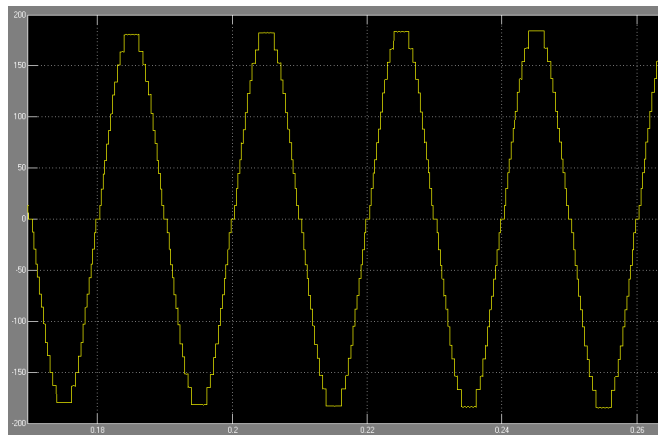


Fig 5. Output of proposed structure

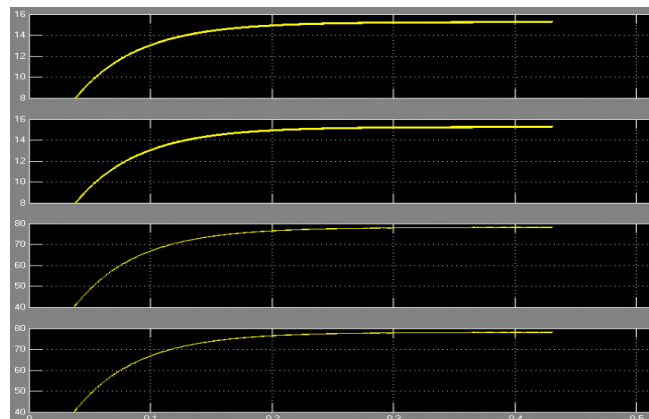


Fig 6. output of flyback converter

The gate pulse to the switches in the MLI is shown in Fig.7. The multilevel inverter requires 10 switches for twenty five level output. The pulses generated are by using the POD-SPWM technique. The corresponding pulses are given to switches S11, S12, S13, S14, S15, S21, S22, S23, S24 and S25 respectively in the Fig.7.

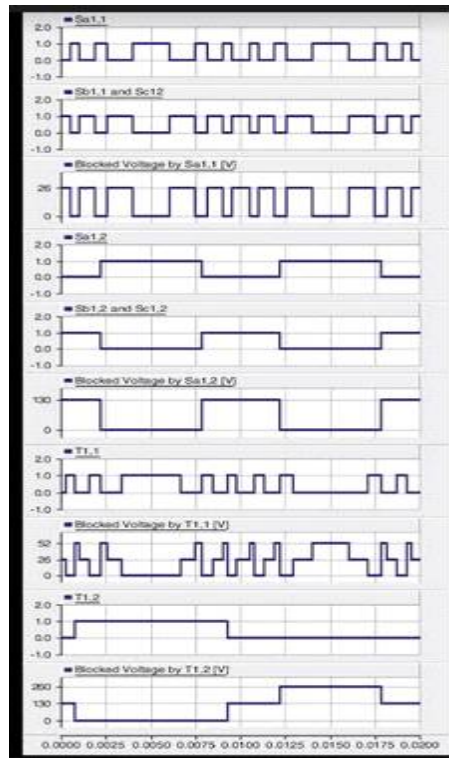


Fig 7. switching pulses of proposed modulation scheme

The resulting total harmonic distortion of the proposed structure is shown in Fig. 8. The THD of this structure is 4.76%. The total harmonic distortion is very less compared to conventional type cascade inverters.

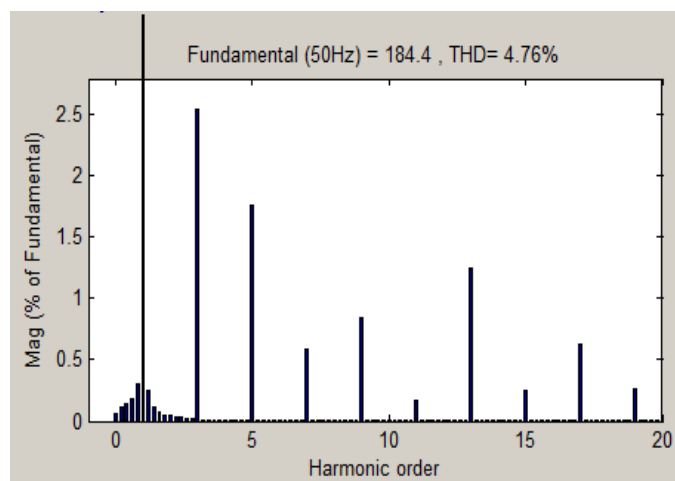


Fig 8. THD of 25 level inverter

V. CONCLUSION

In this paper, a cascaded multilevel inverter is proposed which requires minimum number of switches with increased output levels where, output waveform is near-sinusoidal. Compared with conventional multilevel inverters, it requires less number of components to achieve same number of output levels. Overall THD is very low and thus the quality of output waveform is improved. Due to the use of fewer switches, optimized circuit layout and packaging is possible. Thus less Cost is required to implement the proposed inverter. When sinusoidal pulse width modulation (SPWM) technique is installed THD value will reduce even further. This topology can be successfully installed for solar based ac applications. The operations of the cascaded MLI using the flyback converter have been verified by MATLAB software.

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