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A Single DC Source Seven-Level Switched-Diode Multilevel Inverter

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ABSTRACT: Multilevel inverters are among the members of the family of power converter topologies with high power levels and better waveform qualities. So the use of multilevel inverters has become more popular in medium and high power applications. In this paper, a new structure of multilevel inverter (MLI) is proposed which contains minimum number of switches and a single dc source compared to conventional multilevel inverters. The proposed structure consists of multi-output fly back converter and a seven level inverter. It requires reduced number of power switches and gate driver circuits compared to conventional MLI. This topology requires a single dc source which can be from renewable energy sources such as photovoltaic panels or fuel cells, or with energy storage devices such as capacitors or batteries. Modelling and simulation is carried out using MATLAB/Simulink software.

KEYWORDS: Fly back converter, Multilevel inverter, Total harmonic distortion (THD).

I. INTRODUCTION

The multilevel power inverter has been receiving increasing attention in the past few years for medium and high power applications. The term multilevel began with the three-level inverter. Later, several multilevel inverter topologies have been developed. However, the fundamental concept of a multilevel inverter is to achieve higher power using a series of power semiconductor switches with several lower voltage dc sources to synthesize a staircase voltage waveform [1]. The quality of multilevel inverter is enhanced by its increased number of output voltage levels with minimum number of power switches. The conventional inverters can produce maximum number of voltage levels at output, but it inadvertently leads to large number of power semiconductor devices. This increases the number of power switches that leads to large number of gate circuitry and system complexity. Therefore, the practical system necessitate in the reduction of power switches.

Many kinds of multilevel converter topologies have been proposed by the researchers. The three basic types of multilevel converters are neutral point clamped (NPC) or diode clamped [2], flying capacitor (FC) or capacitor clamped [3] and the cascaded H-bridge (CHB) [4]. The main drawback of NPC converter is the unequal voltage sharing among series connected capacitors. In addition, for higher levels this structure requires a large number of clamping diodes. The FC converter requires large number of capacitors as the number of level increases and also the capacitors voltage balancing is difficult. The CHB converter consists of the number of H-bridge converter units connected in series with separate dc sources for each unit. The CHB converter can be symmetrical (equal dc voltages for each unit) or asymmetrical (unequal dc voltages for each unit). However, the symmetric and asymmetric CHB converters require a large number of sources and power switches.

The researchers are focusing on the reduction of device count in the area of multilevel inverter topologies [5]-[7]. Many methods have been developed in this field through various approaches. Various control and modulation methods are developed for the family of multilevel inverter. It includes sinusoidal pulse width modulation (PWM) [8], fundamental frequency switching [9], selective harmonic elimination [10] and space vector modulation [11]. In this paper, the fundamental frequency switching method is adopted due to its low switching frequency strategy compared to other

control methods. This paper proposes a seven-level inverter which is fed by a multi-output flyback converter. The single input dc supply is given to the multi-output flyback converter. The seven-level inverter requires six switches and a single switch for the multi-output flyback converter.

II. LITERATURE SURVEY

A paper related to hybrid multilevel power conversion system was presented in [12]. It emphasises on the use of multilevel inverters. Various topologies and modulation schemes have been discussed for utility and drive applications. The trends in power semiconductor technology have been investigated in the selection of power devices in the terms of switching frequency and voltage-sustaining capability.

In paper [13] L.M. Tolbert et al. introduces the multilevel converters as a utility interface for renewable energy system such as photovoltaics or fuel cells. It also presents the advantages of multilevel inverters such as its improved power quality, modular and simple structure, low switching stress and the suitability for medium to high power applications. An attempt has been made in [6] to propose a new structure for multilevel inverter with minimum number of power electronic devices compared with the conventional converter. This paper introduces different types of bidirectional switch combinations. But the suggested inverter requires large number of bidirectional switches and also the magnitude of blocked voltage by the bidirectional switches is high.

In [7], another new topology has been presented, which reduces the number of bidirectional switches, power diodes and dc voltage source compared with the proposed topology in [6]. This structure consists of several sub multilevel converters and full bridge converters. But it requires a large number of bidirectional switches and gate driver circuits. A new structure for symmetric, asymmetric and cascade has been suggested in [14]. But it needs more number of bidirectional switches and dc sources. The fundamental frequency switching method has been utilized in this structure, because the fundamental frequency switching strategy has its low switching frequency in comparison with other methods, and it is an advantage [15].

This paper presents a new topology for the symmetrical multilevel inverter using a multi-output flyback converter [16]. This topology uses a single dc source which can be from renewable energy sources or energy storage devices. The dc input is fed to the multi-output flyback converter. The flyback converter used in this structure is a single input – three output converter. The output from flyback converter is fed to the multilevel inverter to generate a seven level output. This structure requires only few number of switches compared to the conventional type of MLI.

III. BASIC CIRCUIT OF PROPOSED MLI

The basic circuit of the proposed switched-diode multilevel inverter is shown in Fig. 1. The basic circuit consist of power electronic switch S, voltage sources V and a fast-recovery diode D. In this circuit, when the switch S is turned off, the current flows through the diode D and the load voltage will be 'V'. But, when the switch S is turned on, the diode D will be reverse biased and the current flows from the voltage source V and the load voltage will be '2V'. The load voltage will be controlled using this method. This method is the basic of proposed seven-level inverter.

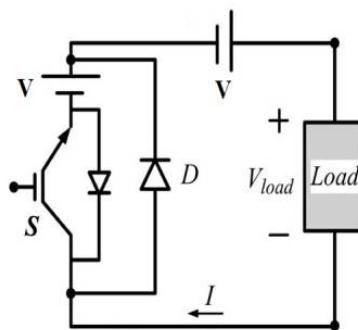


Fig. 1 Basic circuit of proposed MLI

IV. MULTI-OUTPUT FLYBACK CONVERTER

The proposed seven-level inverter uses a multi-output flyback converter. The principle of operation of this single input multiple output flyback converter is similar to a conventional flyback converter. The multi-output flyback converter uses a high frequency transformer with a multiple secondary winding. The Fig. 2 shows a multi-output flyback converter with a single input and three outputs. The flyback converter consists of an input dc supply 'Vin', a power electronic switch 'S', the diodes (D1, D2, D3), capacitors (C, C1, C2, C3), loads (R1, R2, R3), a magnetizing inductance 'Lm' and a high frequency multi-winding transformer. The capacitors C1, C2 and C3 are of equal values and also R1=R2=R3=R. The turn's ratio of the transformer is 1: n, where n decides the voltage to step up or step down.

In this paper, the numbers of turns in the secondary windings are equal to get an equal voltages 'V' as the output across the load 'R'.

The load voltage,

$$V_o = \frac{nxV_{in}D}{1-D} \quad (1)$$

From equation (1), 'n' is the turns ratio (number of secondary turns to the primary turns of the transformer) with same number of turns in the three secondary windings, 'Vin' is the input dc voltage, 'Vo' is the load voltage ($V_o = V$) and 'D' is the duty ratio of the flyback converter.

$$D = \frac{T_{on}}{T} \quad (2)$$

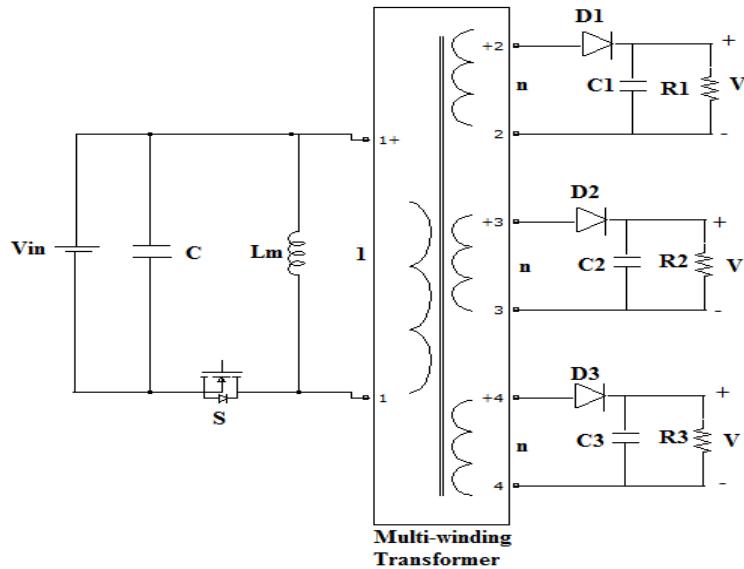


Fig. 2 Multi-output flyback converter

V. PROPOSED SEVEN-LEVEL INVERTER USING FLYBACK CONVERTER

The proposed structure is employed with a MLI and a multi-output flyback converter. Fig. 3 shows the proposed seven-level inverter using a multi-output flyback converter. The input dc supply is fed to the multi-output flyback converter. The flyback converter requires one power metal oxide semiconductor field effect transistor (MOSFET) for its operation. The output from the flyback converter is fed to the seven-level inverter circuit, which is based on the switched-diode MLI. The seven-level inverter consists of one full bridge or H-bridge and the basic circuits. It requires six insulated gate bipolar transistors (IGBTs) and two fast recovery diodes to make a seven-level inverter. The IGBT switches are T1, T2, T3, T4, S1 and S2. As the number of switches and the output voltage of flyback converter are incremented the number of levels of the proposed structure is also increases. The number of output voltages of multi-output flyback converter be 'K', number of output levels be ' N_{level} ', number of IGBTs be ' N_{IGBT} ' and the maximum output voltage be ' $V_{o,max}$ '. Then,

$$N_{level} = 2K + 1 \quad (3)$$

$$N_{IGBT} = K + 3 \quad (4)$$

$$V_{o,max} = KV \quad (5)$$

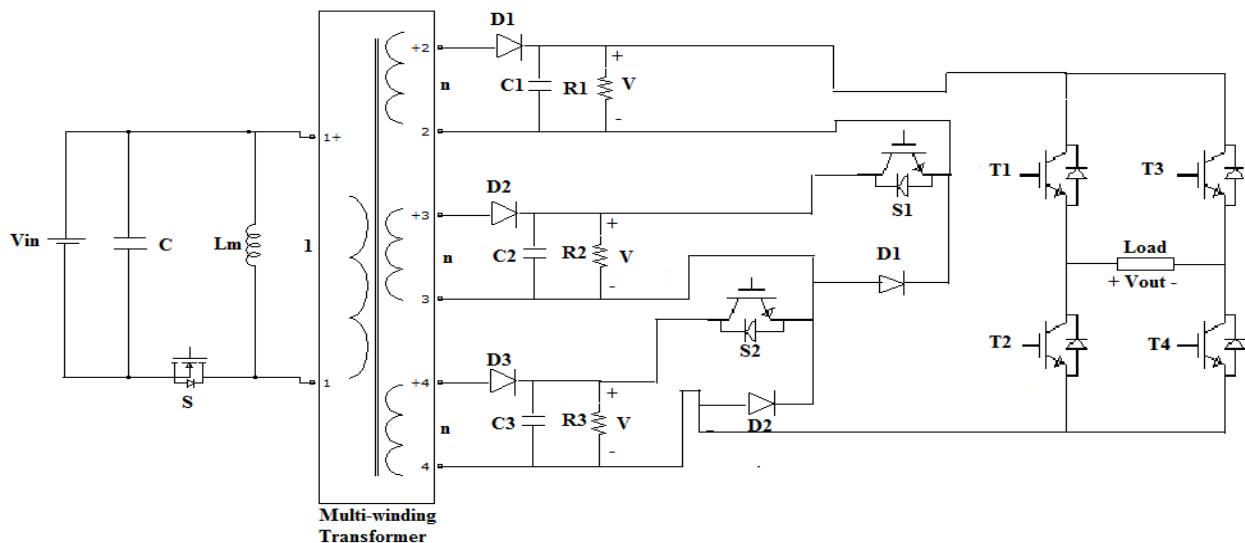


Fig. 3 Proposed seven-level inverter using flyback converter

Fig. 4 compares the number of IGBTs versus the number of output levels in the proposed switched-diode multilevel topology and the symmetric conventional cascade topology. This figure shows that he proposed converter requires the least number of IGBTs.

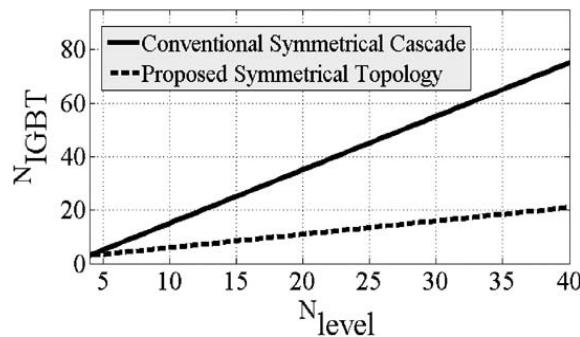


Fig. 4 Comparison of conventional symmetric cascade topology with the proposed switched-diode topology

The proposed structure uses a single dc input three symmetrical output flyback converter. The duty ratio of the switch 'S' is selected according to the voltages needed to the seven-level inverter. The operation of the multi-output flyback converter is similar to the basic flyback converter. The output across the load R1, R2 and R3 is also depending on the number of turns in the transformer windings. The operation of the proposed MLI is illustrated in the Table 1. The load voltages 'V' across the three loads are fed to the MLI circuit. In the table logic '1' is considered as the 'ON' state and the logic '0' is considered as the 'OFF' state of the switch. The IGBTs T1, T2, T3 and T4 forms the H-bridge in the MLI. The switches S1 and S2 are the selection switch to add the number of output levels in the MLI.

Table 1 Switching states of seven-level inverter

State	Switches States						Output Voltage
	S1	S2	T1	T2	T3	T4	
1	0	0	1	0	1	0	0
2	0	0	1	0	0	1	V
3	0	0	0	1	1	0	-V
4	1	0	1	0	0	1	2V
5	1	0	0	1	1	0	-2V
6	1	1	1	0	0	1	3V
7	1	1	0	1	1	0	-3V

Several modulation techniques have been developed for multilevel inverter topologies such as fundamental frequency switching, sinusoidal PWM, selective harmonic elimination, space vector PWM and so on. In this paper, the fundamental frequency-switching control method is adopted. It is a low switching frequency method compared to other control strategies.

VI. SIMULATION RESULTS

The simulink model of the proposed seven-level inverter using a single source is shown in Fig. 5. The simulations are performed using MATLAB. The simulink model mainly consists of the multilevel inverter circuit and a subsystem for the multi-output flyback converter. The load used for the system is an R-L load.

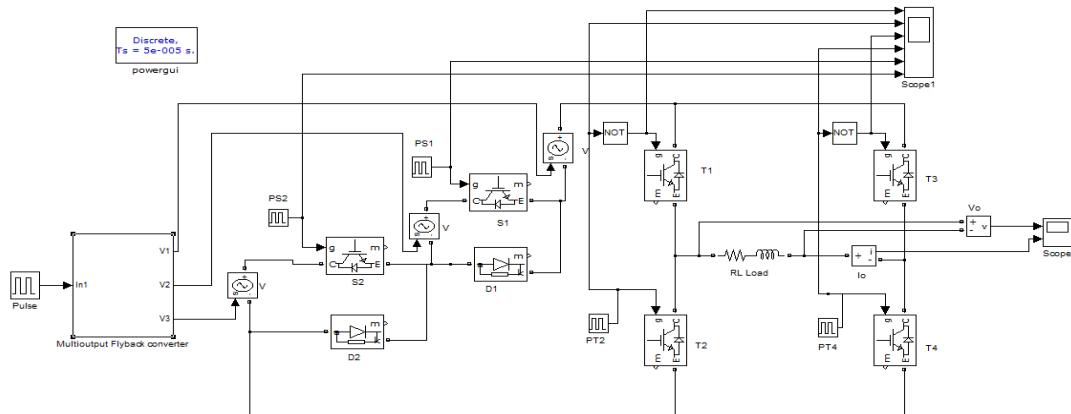


Fig. 5 Simulink model of proposed structure

The subsystem for the multi-output flyback converter is shown in Fig. 6. The input dc supply is given to the flyback converter. The power MOSFET is used as the switch ‘S’ in the flyback converter. The output voltage across the load R1, R2 and R3 is fed to the multilevel inverter circuit.

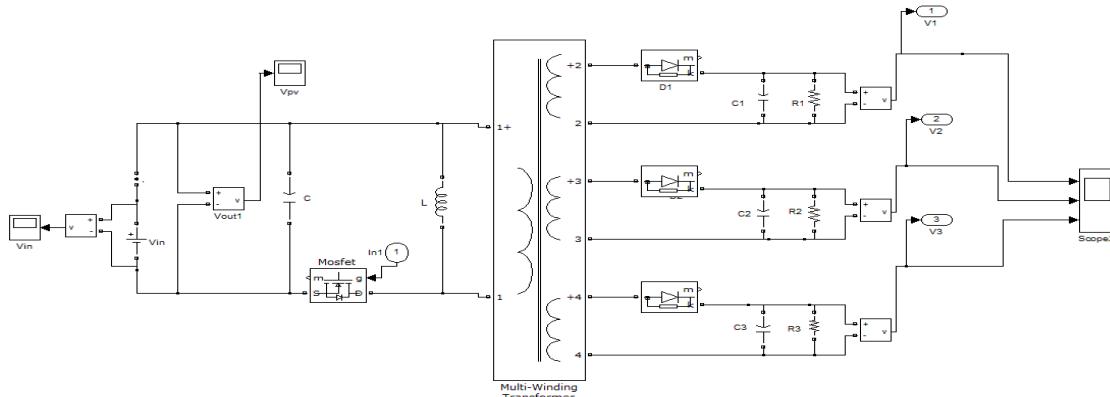


Fig. 6 Subsystem of multi-output flyback converter

The input dc supply given to the proposed structure $V_{in} = 50V$. The maximum voltage obtained across the seven-level inverter load is $98V$ with a $50Hz$ frequency. The output voltage across the load R_1, R_2 and R_3 is $36V$ each. The output voltage and output current across the load is shown in Fig. 7. The load used in this system is R-L load with $R = 260\Omega$ and $L = 40mH$. The maximum output voltage obtained in this structure is the sum of the load voltages of the multi-output flyback converter. The output waveforms are similar to sinusoidal waveforms. The output waveform is composed of seven output levels.

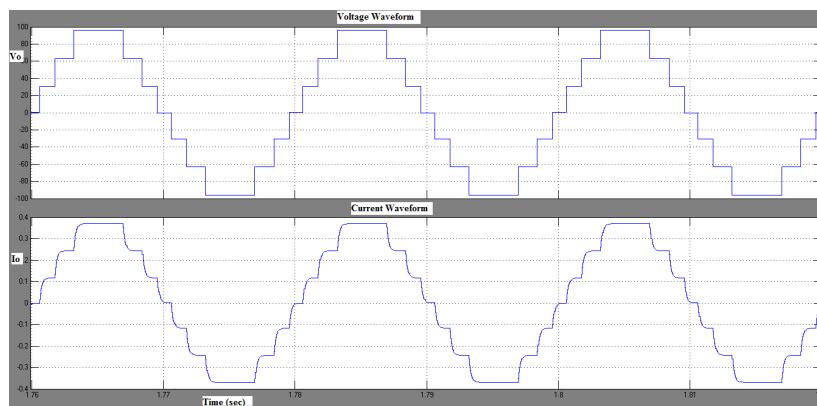


Fig. 7 Output voltage and output current waveforms of seven-level inverter

The gate pulse to the switches T1, T2, T3, T4, S1 and S2 are shown in Fig. 8. The fundamental frequency-switching method is adopted in this structure. The pulses are generated using pulse generator block with fundamental switching frequency. The total harmonic distortion of the proposed structure is shown in Fig. 9. The THD of the structure is 12.49%. The THD is very low compared to the conventional symmetric multilevel inverter.

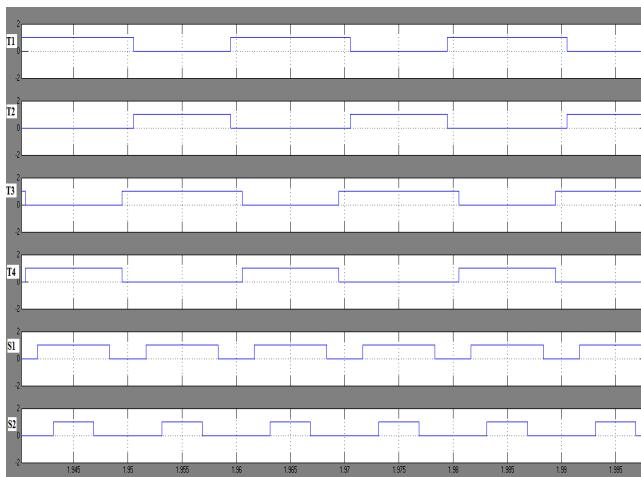


Fig. 8 Gate pulses to the seven-level inverter

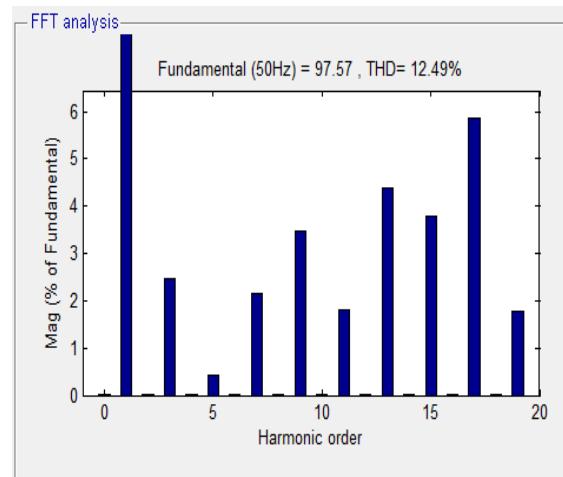


Fig. 9 THD of seven-level inverter

VII. CONCLUSION

In this paper, a seven-level multilevel inverter using a single dc source is proposed which requires minimum number of switches with increased output levels with near-sinusoidal output waveform. Compared with the conventional multilevel inverters, it requires less number of components to achieve the same number of output levels. Due to the use of minimum switches in the structure, an optimized circuit layout and low THD is possible. The structure and principle of operation of the proposed topology is detailed in this paper. The proposed structure is applicable in renewable energy sources, industrial drive applications etc. The operations of the seven-level switched-diode MLI using the flyback converter have been verified by MATLAB software.

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BIOGRAPHY



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