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INTELLIGENT CONTROLLER BASED ZERO-SWITCHING-METHOD MULTI-LEVEL BUCK-BOOST CONVERTER

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Abstract

In this current research, the authors suggest employing intelligent controllers to create a buck-boost converter with zero-switching. The converter uses a network of independent buck-boost converters operating at different levels. Inductors play a critical part in the bridge circuit arrangement of converters, which is crucial for maintaining lossless switching circumstances such as zero voltage switching intermissions. These inductors, in conjunction with the turns ratio, augment the buck-boost converters' high-voltage gain and conductivity. The output voltage and current from a multilevel inverter have lower harmonic losses than those from a single-conversion system with the same characteristics. This converter features an intelligent controller, such as a Fuzzy controller, which boosts the voltage and current at the optimal switching times. A simple and more dependable controller, the fuzzy logic controller achieves a quick transient response, reduced overshoots, and will decrease voltage and current harmonics. The traditional controller's converter efficiency is enhanced by the fuzzy logic controller's precise voltage regulation. All aspects of the converter, from implementation to design, are done in MATLAB/Simulink, taking into account the various switching requirements of actual operation.

Keywords: *Buck-Boost converter, Zero switching intervals, Harmonic minimization, Parallel Inductor, Fuzzy logic controller, Voltage andCurrent gains*

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1. Introduction

For many different uses, including dc/dc regulated power supplies, filters of dynamic voltage, control factor compensation networks, assumed ages, electric cars, etc., DC-DC converters are constantly put into action. [1]-[3]. The output voltage of these converters can be increased or decreased in accordance with the supply voltage serving as a point of reference. Here, you can get your hands on the thematic method. In advanced applications, buck-boost dc-dc converters are used due to their flexible design, which allows them to function in either buck or boost modes. These converters' high efficiency and low harmonic content are the result of their dependable modes of operation. Due to their low switching losses and high conduction properties, these converters are being considered for use in a wide variety of settings. The goal of the zero-switching process is to significantly reduce switching losses[5]-[8] by employing the ideas of Zero-Voltage Switching (ZVS) or Zero-Current Switching (ZCS). This proposed idea also takes into account the use of ZVS and ZCS methods together in a variety of contexts. Increases in converter efficiency, the reduction of harmonic losses at various voltage and current levels, and the standardization of high load power have all contributed to the diversification of converter use in recent years [9]–[12]. In [12], the zero-voltage switching of a parallel-operating converter is analyzed and assessed. To lessen the current harmonic contents between the two inverters, an inductor is constructed as an interleaved inductor between two parallel converters, which sets the current at the desired intervals [13]. There are two different proportional condition structures that define the operating system of this type of converter, and they both are affected by the resonating current state. This buck-boost converter's fundamental idea is to combine the power supply modes of the buck converter and the boost converter into a single, more efficient one. After reducing the amount of distortion in the system, the boost converter raises the output voltage from the reference value to the target voltage. The buck converter will regulate the input power supply to maintain a desirable voltage at the output level if the voltage there exceeds the absolute or specified value. It is necessary to recharge or charge the battery if the voltage drops below the standard level.

2. Multi-Level Buck-Boost Converters

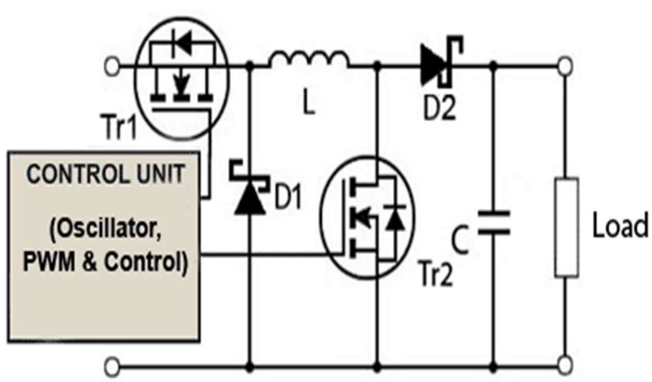

Figure 1 The circuit diagram of Buck-Boost converters with the PWM control

In order to identify the regulated voltage in the circuit, the buck-boost converter is built in accordance with the circuit diagram depicted in figure 1. [14]. It is planned to combine the typical components of the buck and boost circuits. To ensure that the power supply always functions properly, the converter circuit uses both MOSFETs and diodes. The diodes are intended to facilitate a more rapid operation; they have a low reverse recovery voltage and a high step-upduty ratio. Minimal switching losses, fewer voltage harmonics, and greater efficiency [15] characterize these MOSFET diodes. Closed-loop PWM controls are thought to be more stable and efficient in regulating loads. It has been proposed to use intelligent controllers, such as fuzzy logic controllers, to design and operate a multi-level closed-loop buck-boost converter with zero switching. The converter already exists; it's made up of three identical buck-boost converters placed in parallel. This converter circuit incorporates an inductor, which is crucial to achieving zero-switching operation with precisely timed switching intervals. The converter modules form a bridge through an inductor, allowing for zero-voltage switching (ZVS). In other words, the output of the system is kept constant by the fuzzy logic control system, even if the input is a dynamic state. When implemented, the proposed converter reduces switching losses, improves harmonic content, and boosts converter efficiency.

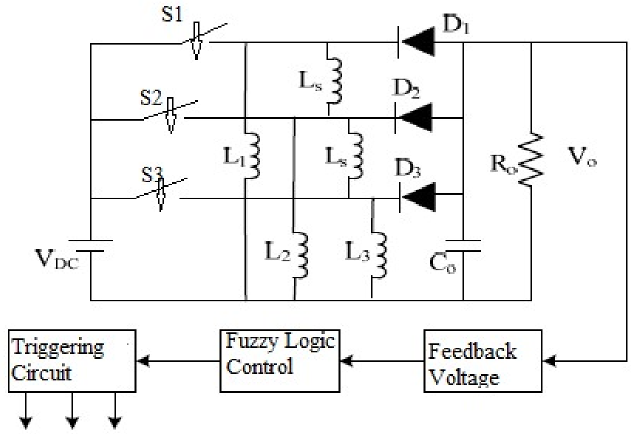

Figure 2 Closed-loop multi-level buck-boost converter

3. Fuzzy Logic Controllers

It is proposed that fuzzy logic controllers be used to improve switching losses in the multi-level buck-boost converter implementation, and they are started here. For superior system performance and excellent efficiency, look no farther than fuzzy logic control, a smart system that is straightforward to apply and simple to build. These fuzzy control systems make available high-level-concept knowledge regarding the modeling of approaches and varying modes of thought. With the based rule system, the fuzzy variables are separate from the system variables. Dividing the average output voltage by the input voltage yields the gain. To estimate efficiency and reduce switching losses, a fuzzy controller looks to be a viable option. In this work, a fuzzy controller is used to make an educated guess as to the harmonic content. Output voltage E and error in output voltage E are studied as inputs based on a fuzzy membership systems analysis. The input values being generated by the gain block will remain constant. Fuzzy logic controllers compare the delay between gate pulses to determine whether the output should be ON or OFF for a given converter PWM pulse value [16]. This information is gathered in the training set in order to derive the table rule. Membership function estimates are refined by iterative simulation and experimentation. Table 1 displays the various rule-setting collections. The membership rules for input and output variables are depicted in Figures 5 and 6.

Table1. Fuzzy rules of the buck-boost converter.

		Rate of Error (Δe)						
		PL	PM	PS	S	NS	NM	NL
Error	PL	PL	PL	PL	PM	PM	PS	Z
	MP	PL	PL	PM	PM	PS	Z	NS

(e)	S P	P L	P M	P M	P S	Z	N S	N M
	S	P M	P M	PS	Z	N S	N M	N M
	S N	P M	PS	Z	N S	N M	N M	N L
	M N	P S	Z	N S	N M	N M	N L	N L
	L N	Z	N S	N M	N M	N L	N L	N L

Fuzzification to defuzzification is accomplished by using a lookup table and the associated membership functions to translate between 0s and 1s. Large Negative, Medium Negative, Small Negative, Positive, Large Positive, Positive, Small, and Zero Error are all defined.

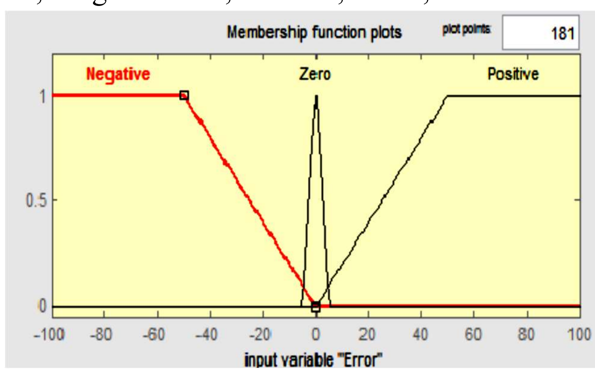

Figure 3 Error based membership function

There are several possible membership rules that may be developed to measure the inaccuracy of the input variable. Take Figure 3 as an example; it employs fuzzy-based regulations [17] for its membership criteria of input-variable error.

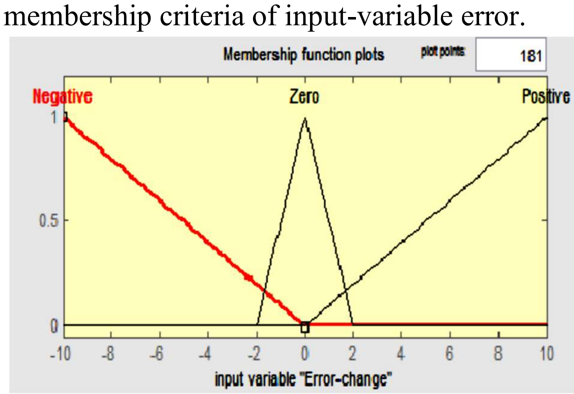

Figure 4 ΔE membership function

The input variable delta error can be evaluated using one of three possible membership rules. The input variable error's membership criteria are depicted in Figure.4.

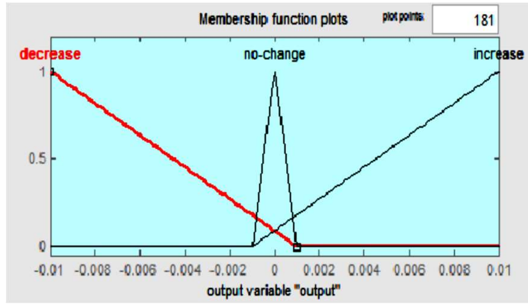

Figure 5 Output membership function

We will develop a set of three membership criteria to estimate the output variable. The membership criteria for the flexible output are depicted in Figure 5.There are seven possible membership functions for the input-1 error: NB, NM, NS, ZE, PS, PM, and PB.The Fuzzy control receives data from inputs 1 and 2.As a result, the seven membership rules (NB, N.M., NS, ZE, P.S., PM, P.B.) are applied to the output block as well.

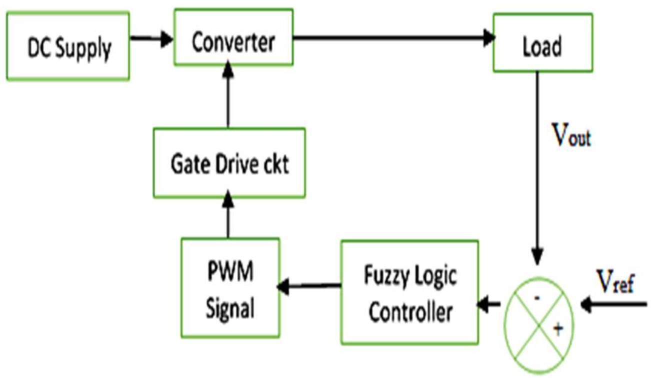

Figure 6 Closed-loop Control of the proposed multi-level buck-boost converter

The diagrammatic representation of the proposed converter layout is shown in Figure 6. This converter circuit's system stability and transient responsiveness will be maintained by the intelligent controller. At all times, the fuzzy logic controller takes into account Vo relative to Vref (Vref). The error signal is sent into the fuzzy logic controller. The fuzzy system's membership function is applied to the error signal, and the resulting signal is then sent into the PWM converter. The modulated signal may be sent to the soft switching gates using this PWM converter, which operates in on and off modes at variable switching intervals [18].

4. Modes of Operation

In mode I, the switch S1 is fired ON, and the switch S2 is turned OFF. In this circuit, the inductor is used to charge the capacitor while the first route carries power to the load. Since Cs2 is already turned off by S2, its voltage across will steadily grow, and S2's switch will see no voltage. To begin, Ls is subjected to a voltage of Vcs1. Due tothis negative voltage,Lswill be demagnetized.

$$Vo=\frac{D_E}{1-D_E}V_{Dc}$$

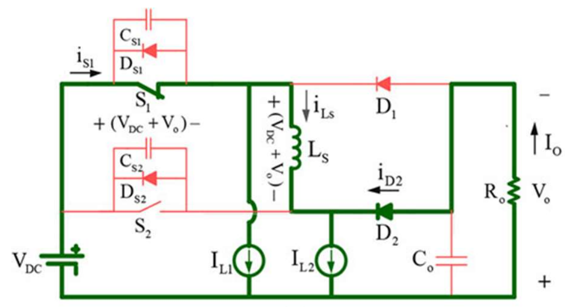

Figure 7 Mode I operation of the converter

In order for the freewheeling diode current to be at zero before switch S1 is switched OFF, switch S2 must be held in the OFF position. To reduce the current drawn from the capacitor, the resonant capacitor and an inductor will be routed through the Ls. When the voltage across C0 rises to a level higher than that across C1, the energy-transfer capacitor, the flow of current is reversed. The anti-parallel diode [2] acts as the conductor for the switch S1.

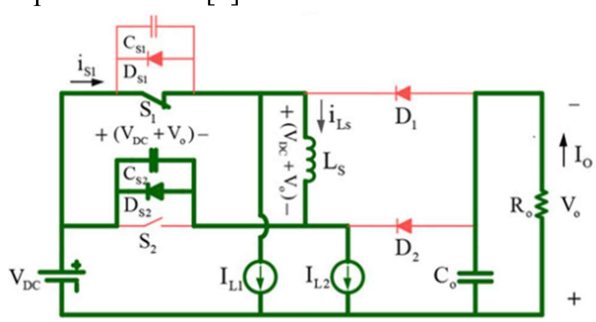

Figure 8 Mode II converter operation

The voltage across diode Ds2 is initially at zero and rises as this mode progresses. Although the voltage drops between S2 and Vcs2, it does not change when the current through S2 diminishes; this current is distinct from iLs and IL2. When the resonance capacitor Cris is fully charged, the voltage is maintained on Vcr, and switch S2 is activated at zero voltage. According to the schematic, power is indicated to be flowing from left to right in Figure 8.

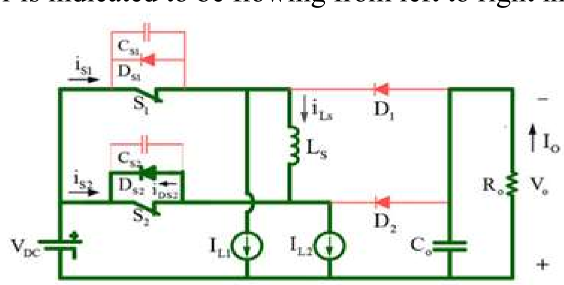

Figure 9 Mode III converter operation

Figure 9 depicts the converter operating in its third mode of operation. During this procedure, the input voltage is executed on VDC, allowing the capacitor CS1 to charge to V0 when the switch S1 is turned off and the switch S2 is activated. The presence of Ls will gradually enhance the current flowing through switch S2, leading to a zero-current turn on of S2. The voltage across switch S1 may be dropping as energy stored in the resonance capacitor Cr is progressively released via diode DS2. So, voltage across diode D1 drops to zero. The current then begins to grow at a freewheeling rate, and modes V–VIII may be described for the switch S1.

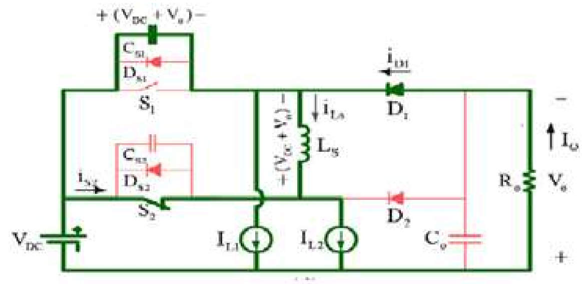

Figure 10 Mode IVconverter operation

5. Analysis, Design of Mathematical equation

The switches S_1 and S_2 duty ratio will be considered slight difference with 0.5 sec accordingly. The firing pulses of the switches will cover the operation, including the diodes duty ratio. The duty ratio of the diodes is lesser than the switches until the modes I to III and modes VI to VIII. the viable duty ratio D_E can be written as

$$D_E=\frac{T_S-T_C}{T_S} \quad (1)$$

where T_s and T_c are the converting time and for turnoff, $i_{Ls}$is varies approximately between the I_{L1} and $I_{L2}$the voltage across an inductor L_S is fixed at $V_{DC} + V_{.O.}$, the computation time can be written as:

$$T_C=\frac{L_S\,(I_L1+I_L2)}{V_{DC}+V_O}=\frac{L_S I_{in}}{V_{DC}+V_O} \quad (2)$$

Then the association among the output voltage and current of a distinctive buck-boost converter in the CCM are expressed as:

$$V_o=\frac{D_E}{1-D_E}V_{Dc} \quad (3)$$

$$I_o=\frac{1-D_E}{D_E}I_{in} \quad (4)$$

the equations (3) and (4) are replaced with(2), the turnoff time T_C will be taken with the input voltage and inductance L_S as:

$$T_C=\frac{D_E\,L_S}{V_{DC}}\,\mathrm{Io} \quad (5)$$

Then combining the equations (1) with (5), then the converter duty ratio will be written as

$$D_E=\frac{1}{1+\frac{f_S\,L_S\,\mathrm{Io}}{V_{DC}}} \quad (6)$$

The converter voltage ratio will be replacing the equation (6) with (3)from the frequency of switching, load resistance, inductance L_s

$$V_O=\sqrt{\frac{R}{f_S\,L_S}}\,V_{DC} \quad (7)$$

$$Ls = \frac{(1-D_E)V_{DC}}{fsIo} \qquad (8)$$

$$C_o = \frac{D_E}{4f_S R(\triangleq V_O/V_O)} \qquad (9)$$

From the Mode IV and I_{L1} + I_{L2}, the aggregate switching loss of the power can be written as :

$$P_{Loss}=2\int_{t_3}^{t_4}(V_{DC} + \text{Vo})\ t\ X\ (\text{IL}_1+\text{IL}_2)dt \qquad (10)$$

From the equations (3) and (4), P_{loss} is written as

$$P_{Loss} = \frac{I_{in}V_{DC}}{D_E(1-D_E)} \triangleq t^2 \qquad (11)$$

The proposed converter efficiency is estimated as

$$\text{Efficiency}=1-\frac{C_{S1}^2}{D_E(1-D_E)}R^2 \qquad (12)$$

6. Simulink Design and Results

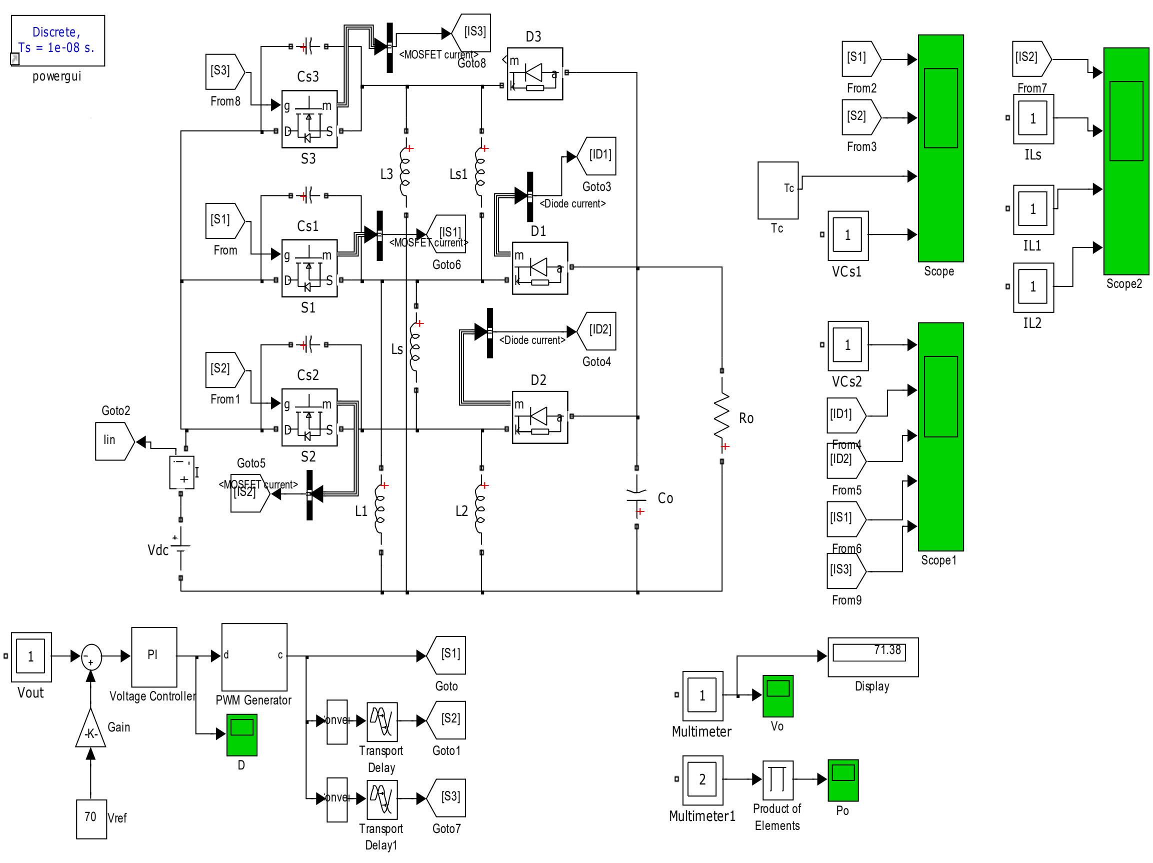

Figure 11 implementation of multi-level Buck-Boost Converter

The preceding schematic depicts the MATLab/Simulink process for developing a multi-stage buck-boost converter. One more switch is attached in this setup, with a dutyration of 0.35 seconds chosen to cut down on switching losses. Then, you must always stick to the ideal duty ratio of 0.7 seconds. Because of this, efficiency and gain have both increased. In addition, a closed-loop fuzzy logic controller that maintains output regardless of input is presented. After then, the closed-loop system will steadily improve the system's stability.

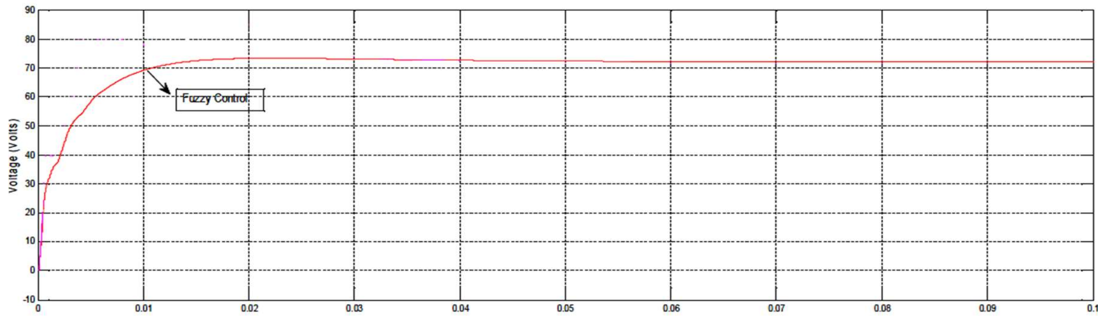

Figure 12 output voltage waveforms of the multi-level buck-boost converter

The improved performance and high efficiency of a multilevel buck-boost converter with fuzzy logic controllers are depicted in the waveforms of the output voltage in Figure 12. This fuzzy logic controller thereby offers more manageable harmonic content and a significantly smaller settling tome ratio. Fuzzy logic controllers, as seen in this graph, are effective in achieving both lossless switching and minimal ripple.

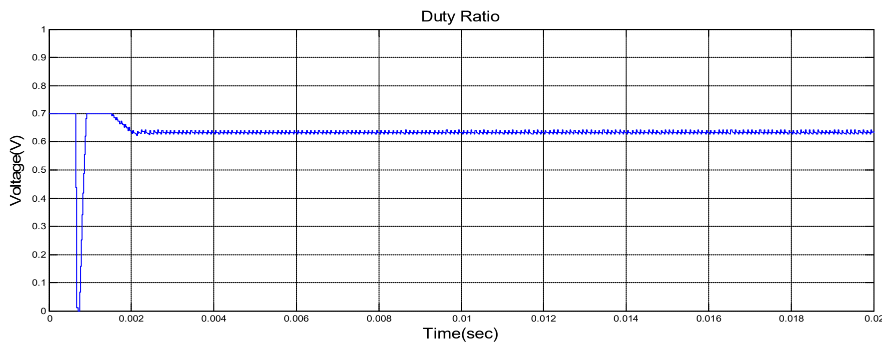

Figure 13 Effective Duty ratio

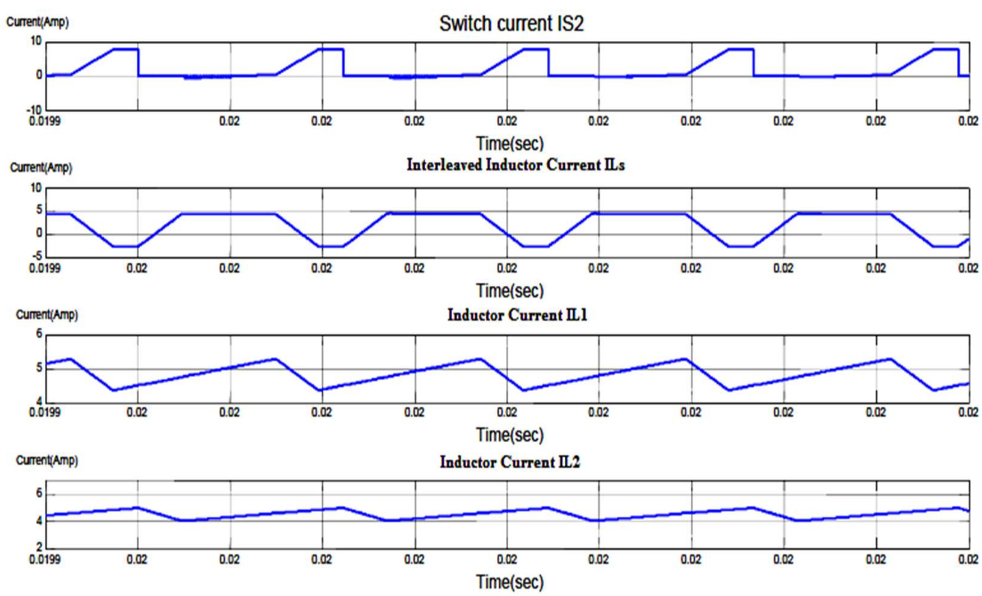

Figure 14 Current switching waveform $I_{.S.}$ and inductor currents I_{L1}, I_{L2}

Table I: System Parameters in MATLAB/Simulink

V_{dc}	**24V**
V_0	70V
Inductor	50µH
Capacitor	100µF
Gain	100
Switching Frequency	50KHz
Auxilaru L_1, L_2	150µH, 50µH
Output current	5.2A
Power	200watts

7. Conclusion

High-gain soft-switching operation was proposed and verified in this paper's proposed closed-loop multi-level buck-boost converter, which was developed with the help of fuzzy logic controllers. There is no difference in the voltage pressure between the switches. Because the switching sequence is improved by using the appropriate voltage and current, the capacitor and inductor sizes are decreased. Harmonics in the output voltage may be minimised by controlling the switching interval ratio, which the high rate does. The output voltage's waves have been minimised within the allotted time. MATLAB/Simulink is used to simulate the outcomes of fuzzy logic controls. With the use of mathematical modelling, the buck-boost converter's parameters are crafted. This is because the settling time is so short and the rising time is so short that there is no overshoot with the fuzzy logic controller. Fuzzy logic controllers, as a result, have been determined to be the most effective controllers for lowering the distortion levels of a buck-boost converter in a closed-loop setup. This system is the easiest to plan and implement, making it ideal for usage in PV and telecommunications installations.

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