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High voltage DC-DC converter with standalone application

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ABSTRACT

Designing DC-DC converters involves many voltage lift techniques. These techniques have been encouraged for their credible advantages. Most voltage lifting methods are applied in many areas of automotive, motor drives, telecom and electronic welfare in military applications. Voltage lifting techniques are known for their high voltage transfer gain and high efficiency. Ultra-lift converter yields very high output transfer gain with geometric progression compared to other voltage lift techniques such as super lift converters and classical boost converters. It also offers reduced size and improved efficiency when compared. In this proposed method ultra-lift converter operation is analyzed with continuous conduction mode.

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1. INTRODUCTION

The DC-to-DC converters are applied for stand-alone applications. The input of the converter is applied from a PV panel with the output connected to a battery source and a DC load. The capacity of the PV array is 50 W. The simulation and experimental results are verified by comparing different converters [1]. A reduced switch count-based ultra step-up DC to DC converter is presented and the implemented converter has less number of components such as diodes inductors capacitors when compared to conventional converters. This type of converter gives high efficiency with high transfer gain. The simulation results with different pulse widths are taken and verified for better output [2].

An improved voltage lift technique is proposed for high voltage DC to DC converter this paper focused on the mathematical analysis of the converter operation in the continuous conduction and the simulation results along with the hardware results are implemented. The results obtained do have not much difference in the output waveforms when done with simulation and hardware [3]–[5]. In this paper, the converter yields a voltage gain of 3 when the duty cycle is 50%, which when compared with the boost converter is 2 times greater. The converter implemented in this system has a voltage transfer gain that is equal to the boost converter with a 50% duty cycle [6]–[8]. The dynamic analysis of the converter has a major role in this converter, as voltage obtained by the converter alone consists of a high value of ripple factor, there increased necessity of a control technique to overcome the effects of the ripples produced. There are many control techniques implemented to the voltage lift converters with a closed loop system in which we used the proportional integral (PI) control technique along with the ultra-lift converter, by which the voltage yielded is improved along with the efficiency [9]–[12].

In this voltage lift technique, the voltage transfer gain is obtained step by step as symmetric progress. Which is several times greater than other converters such as boost and super lift converters [13]–[15]. The converter topology implemented in this paper gives negative voltage as output. as it supplies the requirements of many applications. It is more advantageous of using a PI controller which supplies the gate pulses to the converter and gives a good response for linear systems, by which we can get an accurate dynamic response for the system [16]–[18]. The proportional constants of the controller deal with the current rate of error and the integral constants deal with the previous rate of error. The modes of operation of the converter are also explained in this methodology [19].

The negative output superlift Luo converter (NOSLC) uses the VL approach to produce a large negative voltage. The closed loop block gives the required control output and the output of this system is generated as an error this error value is given as the input to the converter system by comparing the reference voltage to that of the error signal. The controller produces the duty ratio as a result. The switch that creates the necessary pulse for the system's operation is assigned this duty ratio as a result the required output is obtained with reduced ripple values [9]. The following assumptions are made: the MOSFETs, the diodes D1 and D2 are considered to be the three switches in the basic circuit. Theoretically, 2' distinct switch states will be created by n switches. Assuming a low value of ripple the steady state value is DC and the small value of AC ripples [20].

2. ULTRA-LIFT LUO CONVERTER

DC-DC converters play a role in modern energy [21]–[25]. There are many applications for DC-DC converters DC motors, solar power plants, and DC drives. This paper mainly focuses on the ultra-lift converter, the ultra-lift converter 4 to 5 times increase input voltage. Compared to the boost converter, the proposed converter has high efficiency. Figure 1 shows the circuit diagram of the ultra-lift Luo converter. The input applied is Vs and the output is V0. Ultra-lift converter works in two modes based on the switch position. The converter operated in 2 modes here we discuss one of them.

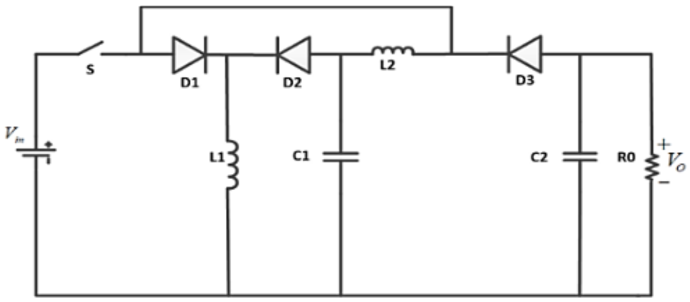

Figure 1. Ultra-lift converter

2.1. Mode 1

Figure 2 depicts the ultra-lift converter in mode 1 of operation. In this mode, the switch S is kept in the ON position A supply voltage is provided across an inductor L1, a forward-biased diode D1, and a pair of reverse-biased diodes D2 and D3. The inductor and capacitor are energy storage devices, and the figure depicts the current flow. When the switch is on the inductor current iL1 rises with a slope $+\frac{V_1}{L_1}$. The voltage across the inductor L1 is:

$$V_1 = L_1 \frac{diL_1}{dt} \tag{1}$$

applying the node analysis:

$$0 = L_1 \frac{diL_1}{dt} - L_2 \frac{diL_2}{dt} + V_3 \tag{2}$$

from (1) and (2):

$$\left(\frac{V_1+V_3}{L_2}\right) - \frac{diL_2}{dt} = 0 \tag{3}$$

$$\left(\frac{V_1-V_3}{L_2}\right) T_{ON} = \frac{diL_2}{dt} \tag{4}$$

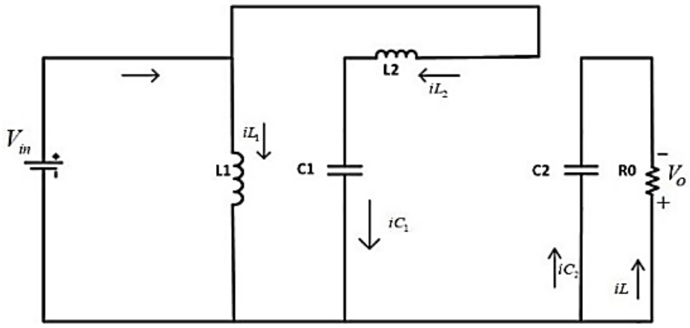

Figure 2. Mode 1: Switch is ON

2.2. Mode 2

Figure 3 depicts how the ultra-lift converter functions in mode 2. The switch S is in the off position in this mode. The inductor L2 discharges and the diodes D2, and D3 are forward-biased. When the inductor L2 transfers the stored energy in C2 through the diode, the current through the inductor iL2 diminishes and the inductor iL1 transfers stored energy in C2.

$$V_3 + V_{C2} - V_{C1} = 0 \tag{5}$$

Substituting V_{C2} as V_2 we get:

$$V_3 + V_2 + V_{C1} = 0 \tag{6}$$

$$-L_2 \frac{diL_2}{dt} + V_2 - V_3 = 0 \tag{7}$$

$$V_2 - V_3 = L_2 \frac{diL_2}{dt} \tag{8}$$

$$T_{OFF}\left(\frac{V_2 - V_3}{L_2}\right) = \frac{diL_2}{dt} = iL_2 \tag{9}$$

from (6) and (9):

$$KT\frac{V_1 + V_3}{L_2} = (1-k)T\left(\frac{V_2 - V_3}{L_2}\right) \tag{10}$$

where KT = switch ON time and $(1-k)\,T$ = switch OFF time. Evaluating (10):

$$KT\frac{V_1 + V_3}{L_2} = \left(\frac{V_2 - V_3}{L_2}\right)T - KT\left(\frac{V_2 - V_3}{L_2}\right) \tag{11}$$

$$KT(V_1 + V_2) = (V_2 - V_3)T \tag{12}$$

$$K = \left(\frac{V_2 - V_3}{V_1 + V_3}\right) \tag{13}$$

$$\left(\frac{V_1 + V_3}{V_2 - V_3}\right) = \left(\frac{1-K}{K}\right) \tag{14}$$

$$\frac{(V_1 + V_3)K}{(1-K)} = \frac{V_2 - V_3}{1} \tag{15}$$

$$\frac{(V_1 + V_3)K}{(1-K)} + V_3 = V_2 \tag{16}$$

$$V_3 = V_1\left(\frac{K}{1-K}\right) \tag{17}$$

$$V_2 = V_1\left(\frac{K}{1-K}\right) + \left[\frac{\left\{V_1 + V_1\left(\frac{K}{1-K}\right)\right\}K}{1-K}\right] \tag{18}$$

$$G = \frac{V_2}{V_1} = \frac{K(2-K)}{(1-K)^2} \tag{19}$$

the (19) depicts the ultra-lift converter's voltage transfer gain, which, when compared to conventional voltage lift converters, is larger.

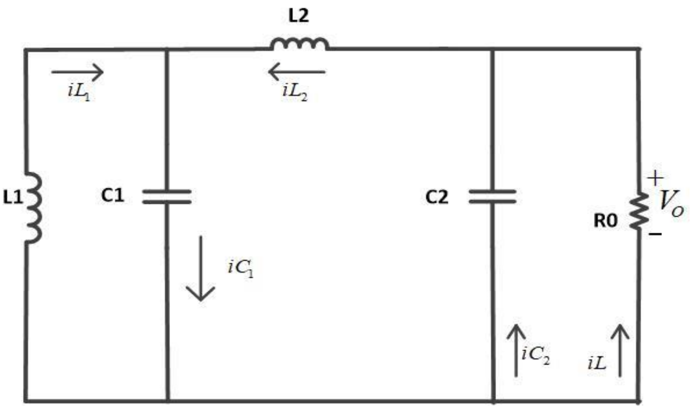

Figure 3. Mode 2: switch is OFF

3. PI CONTROLLER

Figure 4 shows the PI controller in this system. The proportional plus integral controller is another name for the proportional-integral controller. It's the result of combining proportional and integral control operations. As a result, it is known as a PI controller. The controller becomes more efficient when two separate converters are combined, eliminating the disadvantages of each controller. The suggested DC-DC converter can accomplish a high voltage transfer ratio, and low current ripple, according to the results. These data indicate that this converter is appropriate for use in a domestic FC system. Similarly, this Luo system can be employed in solar-powered Luo converters and electric vehicle (EV) chargers. Table 1 shows the pulse width modulation (PWM) and output voltage values.

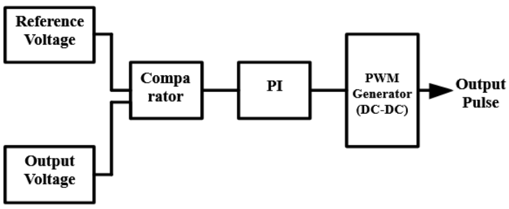

Figure 4. PI controller block

Table 1. Output values

S.L.	Pulse width (%)	Output voltage (V)
1	20	-11.7
2	40	-35.47
3	50	-59.69
4	60	-105.69
5	80	-404.5
6	90	-555.5
7	95	-209.9

4. SIMULATION RESULTS

Figure 5 shows the high voltage ultra-lift Luo converter is depicted in Figure 5. The circuit consists of a single MOSFET switch, a single load resistance, a single voltage source, two capacitors, two inductors, three diodes, and a pulse generator. Figure 6 shows that the ultra-lift converter output waveforms when the pulse width (PW) of the pulse generator is 50%. Vs is the input voltage of magnitude of 20 V. The capacitors C1 and C2 have voltages of magnitudes -20 V, -59 V. The output voltage magnitude across the load resistor is -59 V. Figure 7 shows that the ultra-lift converter output waveforms when the PW of the pulse generator is 60%. Vs is the input voltage of magnitude of 20 V. The capacitors C1 and C2 have voltages of magnitudes -30 V, -105 V. The output voltage magnitude across the load resistor is -105 V. Figure 8 shows that the ultra-lift converter output waveforms when the PW of the pulse generator is 80%. Vs is the input voltage of magnitude of 20 V. The capacitors C1 and C2 have voltages of magnitudes -70 V, -404 V. The output voltage magnitude across the load resistor is -404 V. Figure 9 shows that the ultra-lift converter output waveforms when the PW of the pulse generator is 90%. Vs is the input voltage of magnitude of 20 V. The capacitors C1 and C2 have voltages of magnitudes -50 V, -555 V. The output voltage magnitude across the load resistor is -555 V.

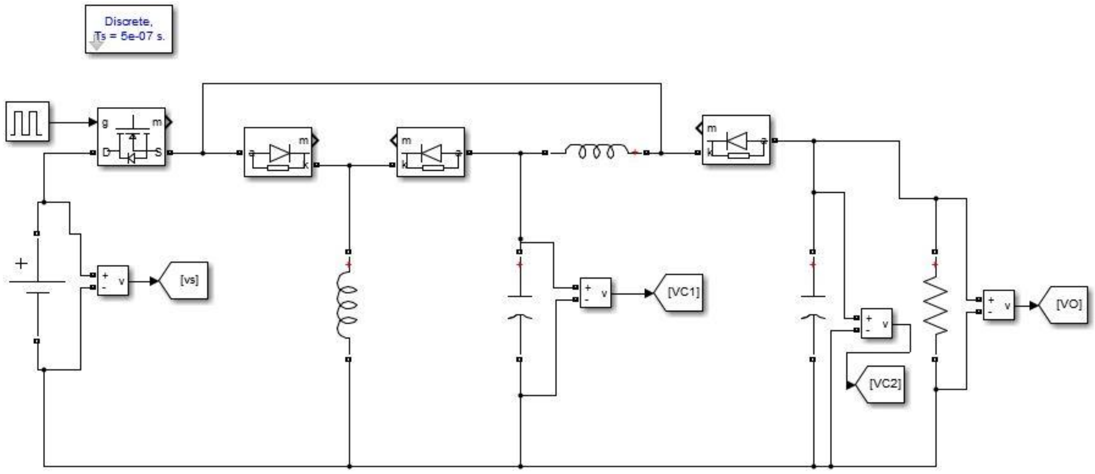

Figure 5. Ultra-lift Luo DC-DC converter

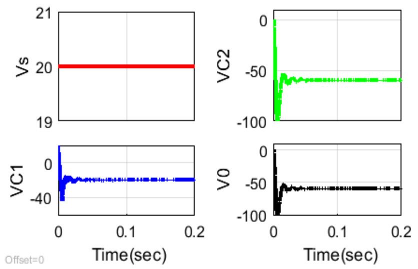

Figure 6. DC-DC converter with a PWM of 50%

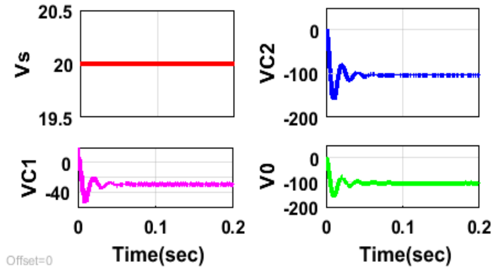

Figure 7. DC-DC converter with a PWM of 60%

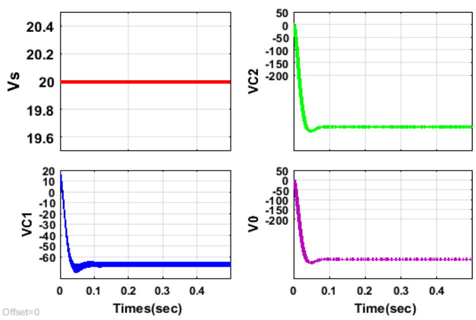

Figure 8. DC-DC converter with a PWM of 80%

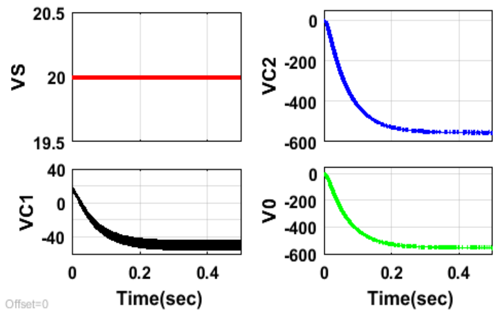

Figure 9. DC-DC converter with PWM of 90%

5. CONCLUSION

The ultra-lift converter operation is analyzed, and mathematical calculations and simulation results are verified. This converter produces a very high voltage transfer gain which is verified with different values of duty ratio. Good dynamic performance in the presence of input voltage variations and variant dynamic performance in the presence of varying operating conditions.

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