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DESIGN OF NEW POSITIVE OUTPUT SUPER-LIFT LUO CONVERTER FOR SOLAR INPUT IN COMPARISON WITH DIFFERENT DC-DC CONVERTERS

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Abstract - *In now a days, utilizing of the dc-dc converters are increased because of the vast applications like loco motives, mobile charging and for utilizing the power generated from Solar and wind power plants. In those converters, Super-lift converters are the advanced technology compared to basic converters and voltage-lift converters. A new design, Modified positive output super-lift dc-dc converter is developed in this paper to increase the gain and output power compare to normal super-lift converter. Voltage-lift converters will give gain in arithmetic progression but super-lift converters increase the gain in geometric progression. The gain and output power characteristics of buck-boost, voltage-lift, MPO super-lift and ultra-lift Luo converters at different duty cycles are discussed. A photovoltaic array is designed for the dc input to the converters. The photovoltaic array generates DC voltage by utilizing sun's irradiance and temperature. All the converters are design for the 10kHz frequency. The Simulink models for all the above converters with control strategy are designed by using MATLAB/SIMULINK software. And the performance results are produced to know the best converter.*

Key Words: super-lift Luo converter, gain comparison of Luo converters, buck-boost, voltage-lift, ultra-lift, Luo converter.

1.INTRODUCTION

There is so much importance to DC-DC converters in our daily life for fulfilling domestic, business, agricultural and the industrial needs. Modern power system has required equipment like small in size, reliable, high quality in the sense of efficiency and low cost devices. DC-DC converters are the best replacements to the linear controllers. So much research is done and many advanced dc-dc converter technologies has been invented[1,2]. These DC-DC converters has many applications like electric vehicle, solar cell applications, traction, machine drives and fuel cell applications[3,4,5].

DC-DC converters are mainly three types, those are: transformer less, resonant and isolated converters. Transformer less DC-DC converters are again three types; buck, boost and buck-boost [6, 7]. These converters are mainly called basic DC-DC converters. These basic converters have some limitations in voltage gain and power output and losses are also high across the switches and diodes.

Later resonant converters are introduced so switching losses is reduced and harmonic content is reduced in output ripple current and ZVS and ZCS is achieved across the switches and diodes respectively [8]. But these resonant converters are not suitable for wide voltage regulation. Later isolated converters are designed and these converters are best converters until before invention of Luo converters. Isolated converters are utilizes the transformer mutual inductance to feed the load and ZVS and ZCS is achieved for switches and diodes respectively and voltage stress across the switches is reduced [9, 10].But the drawback of isolated converters is, they have limited gain when duty cycle goes to unity due to parasitic effect of elements. Now a day's people are working with such an appliances which needs high power to run. So professor Luo designed Luo converters with the voltage-lift technology. Luo converters have no parasitic effect because of voltage-lift technology and the output voltage of the converter is lifted with the help of inductor and capacitor arrangement so that increase in the gain and power [11].

Voltage-lift technique has three types, those are: self-lift, super-lift and ultra-lift converters [12, 13]. In this paper, a new, modified positive output super-lift converter(MPO SLC) is proposed to increase the gain and output power of normal super lift converter. And this MPO super-lift Luo converter is designed for the resistive load and these characteristics are compared with other converters namely buck-boost, voltage-lift, super-lift and ultra-lift Luo converters. A solar panel is designed to work as source for the DC-DC converter [14, 15]. The DC output voltage of solar panel is directly proportional to sun's irradiance and surface temperature of panel. In designing of solar no MPPT technique is used because to compare the converters at different duty cycle. The converters are designed for the same 10 kHz frequency, same input voltage and the same output load.

2. PHOTOVOLTAIC ARRAY

Photovoltaic array is a combination of solar cells connected in series and in parallel. This photovoltaic array is generated the DC power by taking sun's irradiance and temperature as input. The basic equivalent diagram of solar cell is shown in below figure.

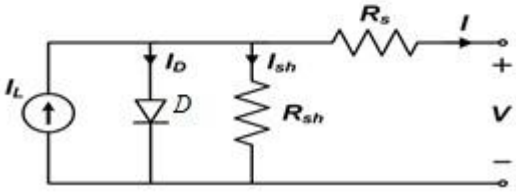

Fig: 1. Equivalent circuit diagram of solar cell.

The output voltage of solar is driven by using open circuit voltage at shunt resistance R_{sh} and is given by the equation

$$V = V_{sh} - IR_s \tag{1}$$

The current generated by the solar cell is given by the following equation

$$I = I_l - I_D \tag{2}$$

where I_L is current driven by solar cell, I_D is current through diode. Solar cell current is dependent on the irradiation and temperature on the surface of the solar cell which is given by the following equation 3.

$$I_L = G \times \frac{I_{sc(Tr)}}{G_r}\left(1 + K_{Isc}(T - T_r)\right) \tag{3}$$

Diode current is directly proportional to sun temperature and is given by the equation 4,

$$I_D = I_O\left(e^{\frac{q(V+IR_S)}{nkT_rN_S}} - 1\right) \tag{4}$$

Where,

$$I_O = I_{O(Tr)} \times \left(\frac{T}{T_r}\right)^3 \times e^{\frac{qV_g}{nk} \times \left(\frac{1}{T_r} - \frac{1}{T}\right)} \tag{5}$$

$$I_{O(Tr)} = \frac{I_{sc(T_r)}}{e^{\left(\frac{qV_{oc(T_r)}}{nkTN_s}\right)} - 1} \tag{6}$$

By using above equations photovoltaic array is designed in Simulink. This array is given to converters as input DC voltage.

3. CONVERTER DESIGN

Super-lift Luo converter is superior to voltage lift Luo converter. Super lift Luo converter has more important technique in DC-DC conversion. Super-lift Luo converter is shown in below figure 2.

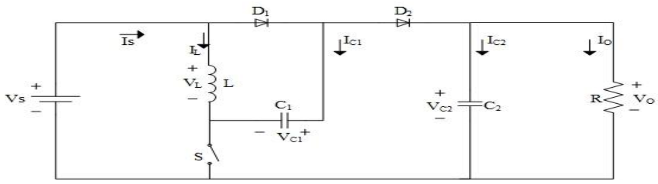

Fig: 2. Normal super-lift Luo converter.

Super-lift Luo converter has given less output voltage and discontinuity in power feeding to load. Modified positive output super-lift Luo converter has high output voltage rating compare to super-lift Luo. Modified positive output super-lift Luo converter is shown in below figure 3. Super-lift Luo has inductor parallel to voltage source. But modified super-lift Luo has inductor in series with the voltage source.

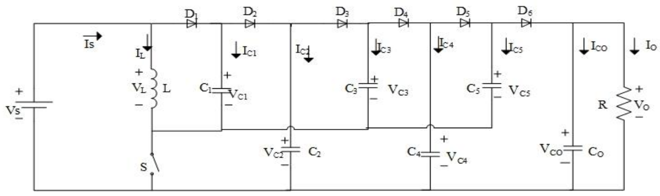

Fig: 3. Modified super-lift Luo converter.

Super-lift Luo has switch parallel to voltage source. But MPO super-lift Luo has switch in series with the voltage source. And it has capacitors in parallel with the inductor when switch is on. Due to this arrangement MPO SL has better performance than remaining converters. This modified positive output super-lift Luo converter is compared with the remaining converters for the performance analysis.

4. CONTROL AND OPERATION

In this paper, the performance analysis of buck-boost, voltage-lift, super-lift, MPO super-lift and ultra-lift Luo converters are compared.

4.1. Buck-Boost Dc-Dc Converter

The Buck-Boost DC-DC converter is a combination of both buck and boost converter. The buck-boost converter gives the improved voltage or reduced voltage depends upon the duty cycle. The circuit diagram for buck-boost converter is shown in below figure 4(a).

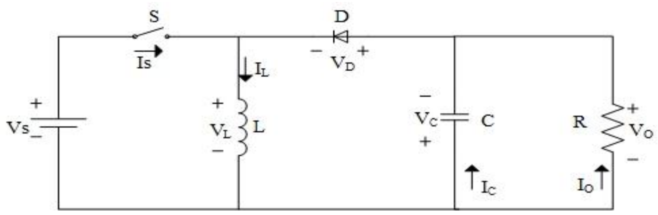

Fig: 4(a). Buck-Boost converter elementary circuit diagram.

The analysis of buck boost converter is evaluated by using volts-seconds method. Below figures shows the ON and OFF stage circuit diagrams of buck-boost converter.

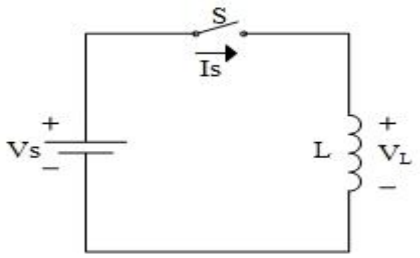

Fig: 4(b). On stage equivalent circuit diagram.

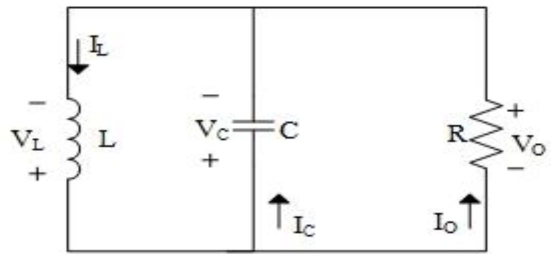

Fig: 4(c). Off state equivalent circuit diagram.

By using volts-second method,
The forward voltage gain of buck-boost converter is

$$A_V = \frac{V_O}{V_S} = -\frac{D}{1-D} \qquad (7)$$

The forward current gain of buck-boost converter is

$$A_I = \frac{I_O}{I_S} = -\frac{1-D}{D} \qquad (8)$$

4.2. Positive Output Voltage-Lift Luo Converter

The voltage-lift Luo converter is advanced technology than buck-boost converter. Due to the effect of parasitic elements buck-boost converter gain is limited. Voltage-lift Luo converter will eliminates the parasitic effect and increase the output voltage thus gain. The circuit diagram for voltage-lift converter is shown in below figure 5.

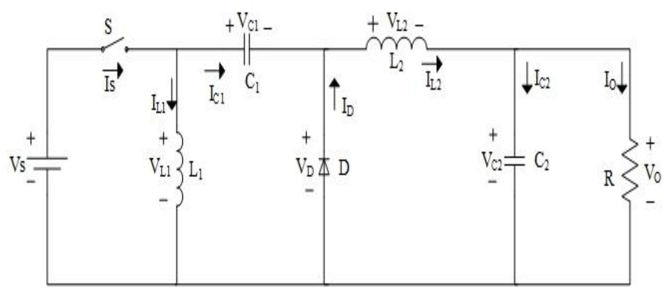

Fig: 5(a). Positive output voltage-lift Luo converter circuit diagram.

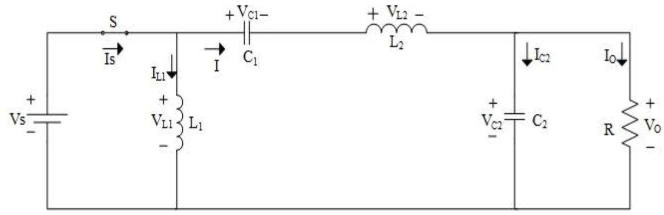

Fig: 5(b). Positive output voltage-lift Luo converter circuit diagram during on state.

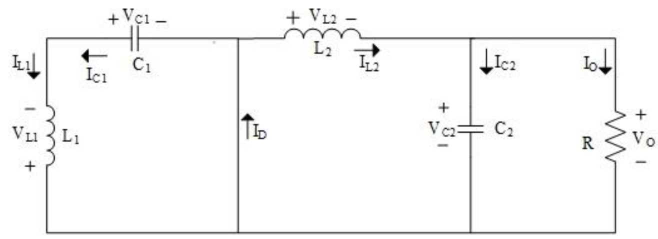

Fig: 5(c). Positive output voltage-lift Luo converter circuit diagram during off state.

The forward voltage gain of PO voltage-lift Luo converter is

$$A_V = \frac{V_O}{V_S} = \frac{D}{1-D} \qquad (9)$$

The forward current gain of PO voltage-lift Luo is

$$A_I = \frac{I_O}{I_S} = \frac{1-D}{D} \qquad (10)$$

4.3. Super-Lift Luo Converter

The super-lift Luo converter is superior than voltage-lift Luo converter. Super-lift Luo converter elementary circuit and switch on and off equivalent is shown in below figure 6.

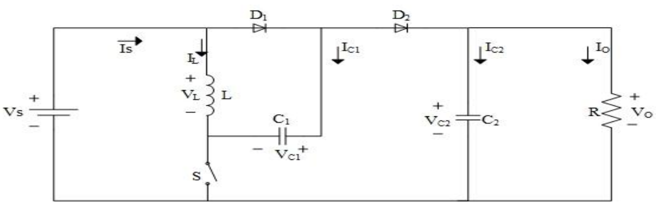

Fig: 6(a) Circuit diagram of super-lift Luo converter.

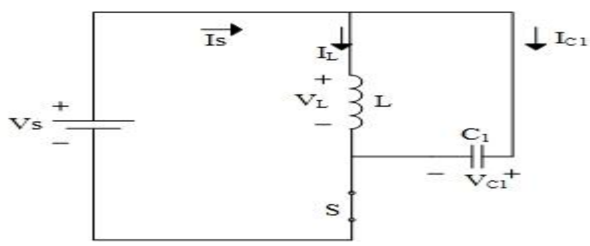

Fig: 6(b). Switch on equivalent circuit diagram of super-lift Luo converter.

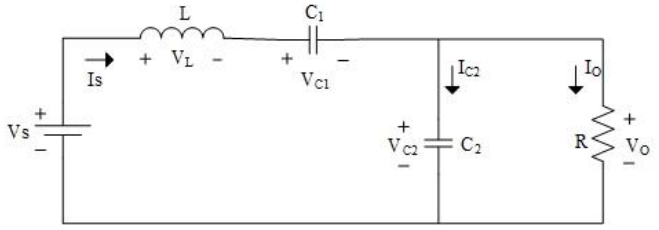

Fig: 6(c). Switch off equivalent circuit diagram of super-lift Luo converter

The forward voltage gain of super-lift Luo converter is

$$A_V = \frac{V_O}{V_S} = \frac{2-D}{1-D} \qquad (11)$$

The forward current gain of super-lift Luo converter is

$$A_I = \frac{I_O}{I_S} = \frac{1-D}{2-D} \qquad (12)$$

4.4. MPO Super-Lift Luo Converter

MPO super-lift Luo has advanced than voltage lift and buck-boost converters. The MPO super-lift Luo elementary circuit, switch ON and switch off circuits are shown in below figure 7.

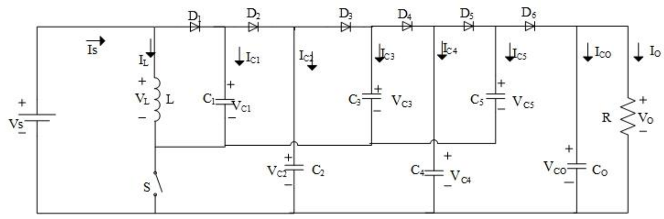

Fig: 7(a). MPO super-lift Luo converter circuit diagram.

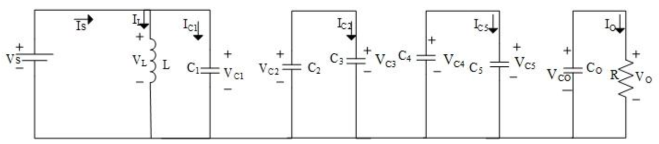

Fig: 7(b). MPO super-lift Luo converter circuit diagram when switch is on.

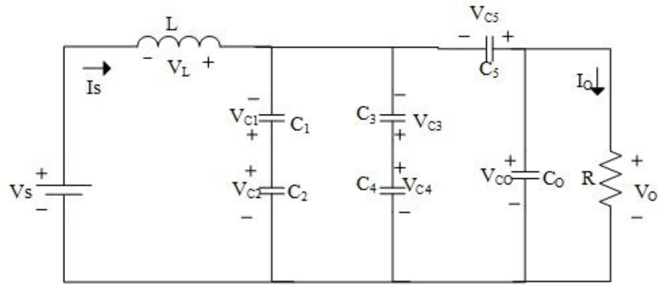

Fig: 7(c). MPO super-lift Luo converter circuit diagram when switch is off.

The forward voltage gain of MPO super-lift Luo converter is

$$A_V = \frac{V_O}{V_S} = \frac{3-D}{1-D} \qquad (13)$$

The forward current gain of MPO super-lift Luo converter is

$$A_I = \frac{I_O}{I_S} = \frac{1-D}{3-D} \qquad (14)$$

4.5. Ultra-Lift Luo Converter

Ultra-lift Luo converter is high performance gain converter whose output voltage is equal to the product of both PO voltage-lift and MPO super-lift Luo converters output voltage. The elementary circuit, switch on state and switch off state circuit diagrams are shown in below figure 8.

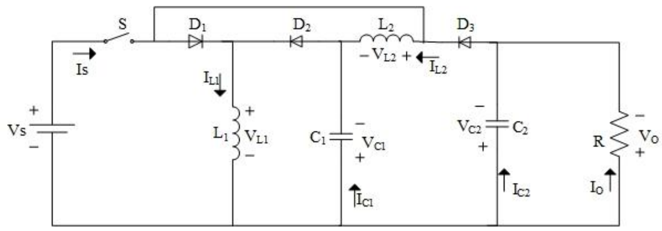

Fig: 8(a). Ultra-lift Luo circuit diagram.

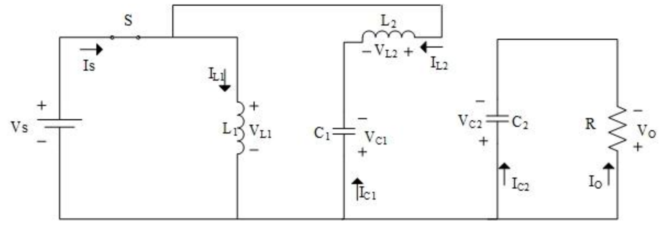

Fig: 8(b). Ultra-lift Luo circuit diagram when switch is on.

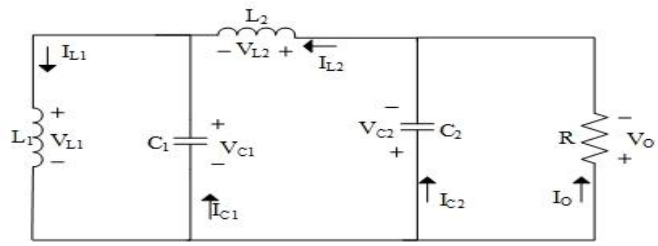

Fig: 8(c). Ultra-lift Luo circuit diagram when switch is off.

The forward voltage gain of ultra-lift Luo converter is

$$A_V = \frac{V_O}{V_S} = \frac{D(2-D)}{(1-D)^2} \qquad (15)$$

The forward current gain of ultra-lift Luo converter is

$$A_I = \frac{I_O}{I_S} = \frac{(1-D)^2}{D(2-D)} \qquad (16)$$

5. SIMULATION OF PHOTOVOLTAIC ARRAY

The simulation diagram of solar module is shown in figure 9.

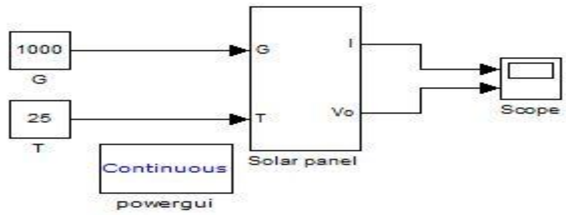

Fig 9(a) Simulink diagram of photovoltaic array

The subsystem Simulink diagram for photo current and diode current is shown in below figure.

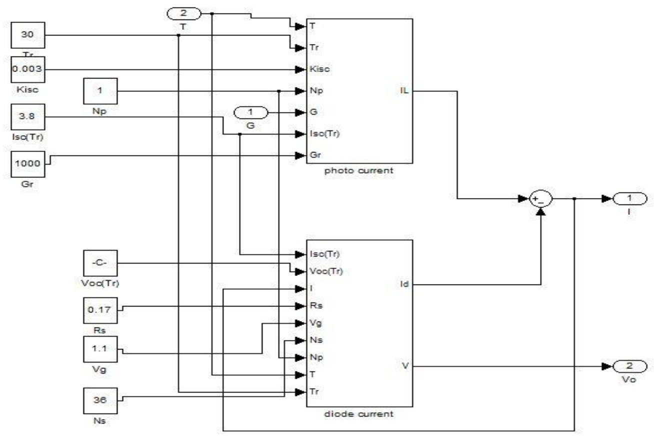

Fig: 9(b). Simulink of photo current and diode current diagram

The output waveforms of voltage and current for photovoltaic diagram is shown in figure.

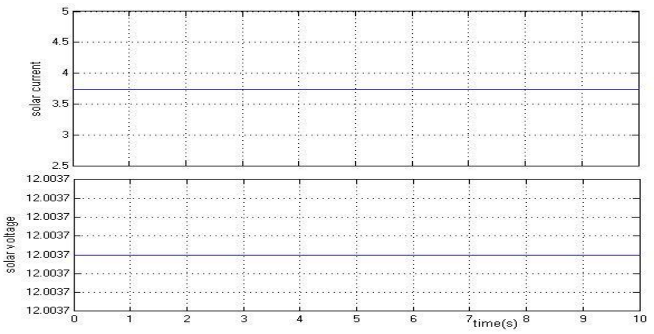

Fig: 9(c). Output current and voltage waveforms of photovoltaic array

6. SIMULATION OF CONVERTERS

The simulation of the modified positive output super-lift converter is done by using Simulink. Below figure 10 shows the main Simulink diagram to compare the gain and output power of converters.

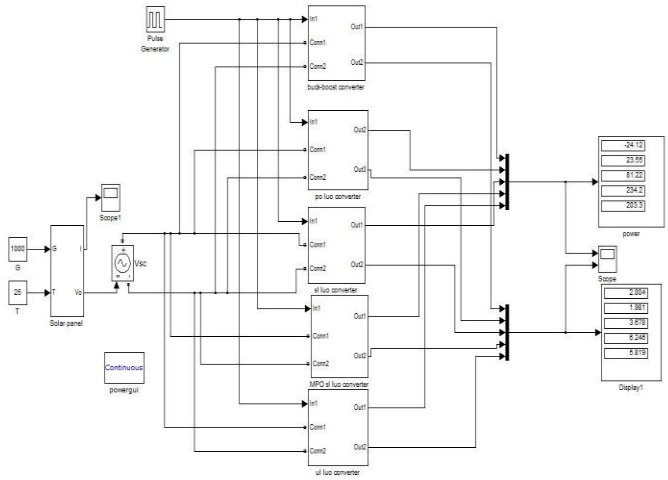

Fig: 10(a). Simulink circuit diagram of DC-DC converters.

The main Simulink block contains the DC voltage source connecting to the five DC-DC converters and pulse generator is common to these all converters. The simulating gain and output waveforms are shown below

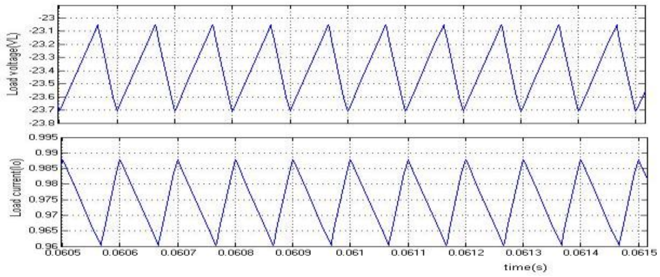

Fig: 10(b). The output voltage and current waveforms of buck-boost converter.

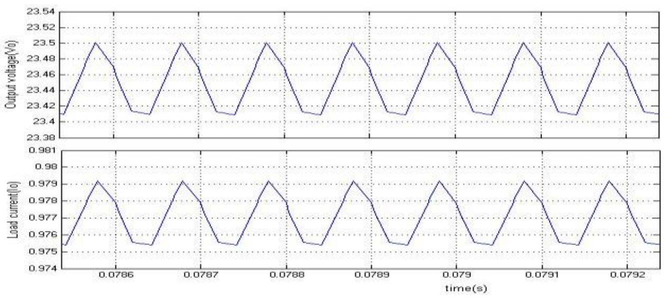

Fig: 10(c). Positive output voltage-lift Luo converter load voltage and load current wave forms.

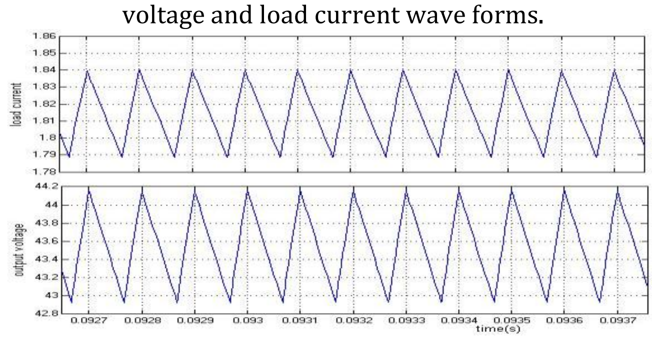

Fig: 10(d). Load current and output voltage characteristics of super-lift Luo converter.

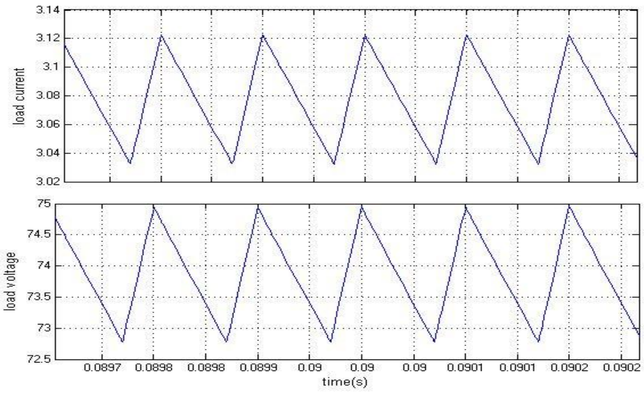

Fig: 10(e). Load current and output voltage characteristics MPO super-lift Luo converter.

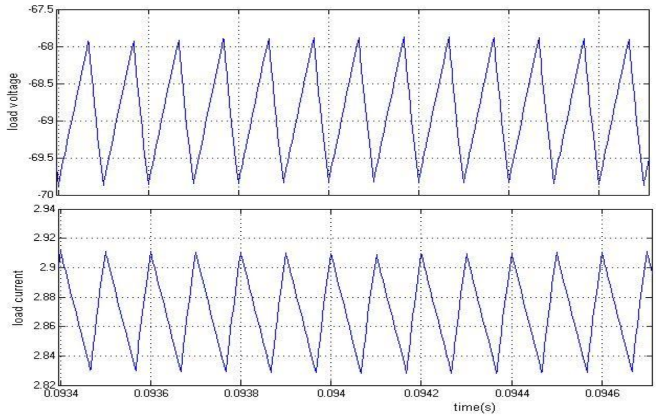

Fig: 10(f). Load voltage and load current waveforms of the ultra-lift Luo converter.

For all the converters, the photovoltaic array is connected through conn1 and conn2 blocks. And the load voltage and current waveforms are evaluated at the duty cycle D=0.66. The load voltage and current waveforms buck-boost converter is least compared to remaining converters. Mpo super-lift Luo converter has the maximum load characteristics compare to remaining converters. MPO super-lift Luo converter has superior than all converters at all the duty cycles.

The gain and output power characteristics of compared converters are shown in below figures 10(g) and 10(h).

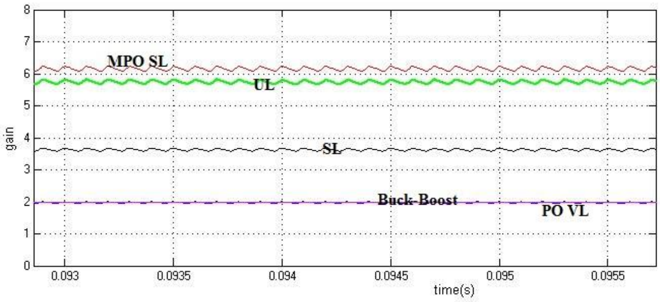

Fig: 10(g). Gain waveform of converters at duty cycle D=0.66.

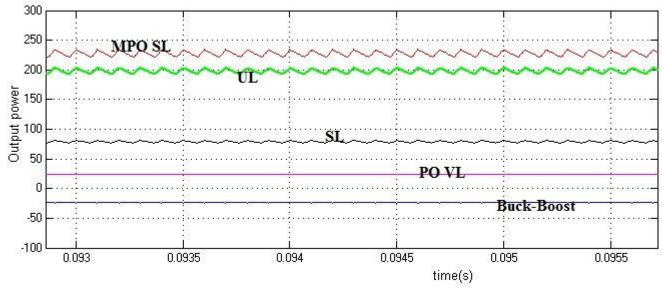

Fig: 10(h). Output power waveform of converters at duty cycle D=0.66.

7. EXPERIMENTAL RESULTS

Modified positive output super-lift Luo converter is designed with the help of Matlab/Simulink which has better gain characteristics compared to super-lift Luo converter for the solar input. The gain and power characteristics of modified positive output super-lift Luo converter is compared with the buck-boost, positive output voltage-lift Luo converter, super-lift Luo converter and ultra-lift Luo converter.

The input voltage is 12V DC, inductor value L=1mH, capacitor value C=100uF, and load is R=24ohms. Switching frequency f_s=10 KHz. The gain of different converters for different duty cycles is tabulated as below

Table-1: The gain of different converters at D=0.67

D	0.2	0.4	0.66	0.8
Buck-boost	0.254	0.670	2.004	3.469
POVL	0.328	0.657	1.991	3.868
SL	2.034	2.423	3.678	4.955
MPO SL	3.378	4.579	6.246	5.37
UL	0.604	1.886	5.819	4.064

Table shows that buck-boost and positive output voltage-lift converters are the almost same gain characteristics but voltage-lift Luo converter will give positive gain characteristics due to output voltage is positive. MPOSL Luo has high gain characteristics for all duty cycles than SL and UL. After the duty cycle above 40%, ultra-lift converter has good gain characteristics compared to other converters except MPO SL. The output power characteristics of the converters are shown in below table 2.

Table-2: Output power of converters at D=0.67

D	0.2	0.4	0.66	0.8
Buck-boost	-0.369	-2.696	-24.12	-72.25
POVL	0.646	2.548	23.55	89.84
SL	24.84	35.28	81.22	147.4
MPO SL	68.5	125.9	234.2	171
UL	2.195	21.36	203.3	99.13

Table 2 shows that buck-boost and positive output voltage-lift converters as the same output power characteristics but voltage-lift Luo converter will give positive characteristics due to output voltage is positive. For all duty cycles MPOSL Luo has high power characteristics over remaining converters. SL is delivering more power to load compare to UL for duty cycles less than 40%.

8. CONCLUSION

This paper presents the a new technology solar input super-lift Luo converter which has improved output voltage and output power compared to normal super-lift Luo converter. This modified super-lift Luo converter is also compared with the buck-boost, positive output voltage-lift Luo converter and ultra-lift Luo converters. By concern the simulation results modified super-lift Luo has better performance characteristics than the super-lift and ultra-lift. The theoretical values are validated with simulation results. MPO super-lift Luo converter is simple in circuit design, small in size and low cost. And also the losses in ultra-lift converter are more compared to MPO super-lift converter because of voltage drop across the energy stored elements. MPO super-lift Luo converter is better choice for any type of load like high power or low power applications as compared to super-lift and ultra-lift converters.

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