

## Effect of switched-capacitor on super-lift Luo converter

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### Article Info

#### Article history:

Received Jan 8, 2022

Revised Jul 25, 2022

Accepted Aug 31, 2022

#### Keywords:

DC-DC converters

High gain converters

Input pulsating current

Super-lift Luo converter

### ABSTRACT

With the increasing need for solar energy and the need for DC-DC converters that are more efficient, smaller in size, less expensive, and faster in response, in this paper, we will modify the positive output super-lift Luo converter using a switched-capacitor cell. It consists of two capacitors that are charged in parallel and discharged in series to raise the output voltage, the use of capacitors in-stead of inductors increases the voltage, because capacitors are more efficient and have a smaller size than inductors and provide faster and smoother charging and discharging than inductors, so a capacitive cell has been used. The circuit was simulated using the physical security information management (PSIM) program. The current, voltage, and gain co-efficient waves were analyzed and the theoretical equations were proven. The circuit was also linked with the maximum power point tracker using the same program with a solar cell to get the most benefit from the solar energy using this type of converter.

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## 1. INTRODUCTION

The need for DC-DC switching power converters is growing as more feasible alternatives to traditional carbon-producing energy sources emerge [1]-[4]. DC-DC power converters are compact and dependable power conversion systems [4]. The use of DC-DC converters in this application, on the other hand, adds new problems to the system [5], [6]. One of the key concerns is achieving a large step-up voltage gain while minimizing switch stress [7], [8].

Another important consideration with these converters is their great efficiency. Various DC-DC converters, such as interleaved converters, have been presented in the literature during the last few years to solve these issue [9], [10]. Soft-switching converters [11], [12] coupled-inductor structures [13], [14] and voltage multiplier converters [15], [16]. However, these structures are still in the development phase for answering the tough requirements.

One of the most important challenges of DC-DC converters used in solar energy systems is to obtain a high voltage gain at a small duty cycle to achieve high working efficiency [17], [18] reduce stress on the switch, reduce connection losses to a minimum, and reduce the effect of the input pulsating current that reduces the lifetime of the power source and reduce the system efficiency [19]. On the other hand, we should not depend on increasing the voltage gain on the improvement by using more inductors, because they are simply high in weight and high in cost [20]. Also, the use of many inductors leads to undesirable electromagnetic interference. In this article, it is proposed to develop a positive-output Luo converter using a simple structure consisting of two capacitors and three diodes in a three-terminal cell that is placed in the

place of the first capacitor in the traditional Luo converter to achieve high gain and efficiency without the need for any additional inductors and operate it as part of the solar energy system and to simulate the system suggested by program physical security information management (PSIM). Figure 1 shows the complete system of PV panel and modified converter with MPPT controller.

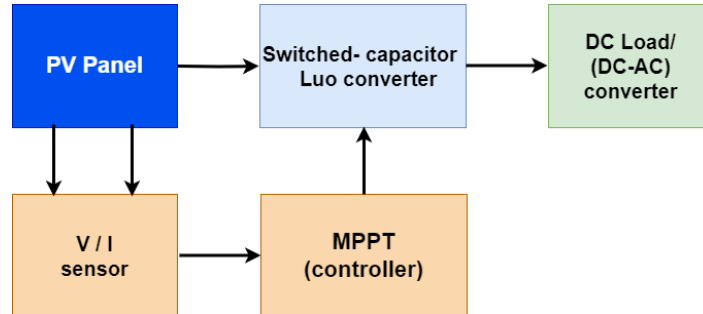


Figure 1. Block diagram of the proposed system

**2. ELEMENTARY POSITIVE OUTPUT SUPER-LIFT LUO CONVERTER**

PV systems employ DC-DC step-up converters to control the voltage generated by PV modules and to raise the module voltage [21]-[23]. One switch (S), one inductor (L), capacitors (C1&C2), and two diodes make up the positive output super-lift Luo converter (POS LC). Figure 2 depicts the POS LC circuit architecture, as well as its modeling (1) (on-state) and (2) (off-state) for displaying the output voltage gain [24]:

$$V_{in} = VL = V_{c1} = L \Delta i / dt \tag{1}$$

$$\Delta i = VL \frac{(1-D)T}{L} = V_o - 2V_{in} \frac{(1-D)T}{L} \tag{2}$$

$$G = \frac{V_o}{v_{in}} = \frac{2-D}{1-D} \tag{3}$$

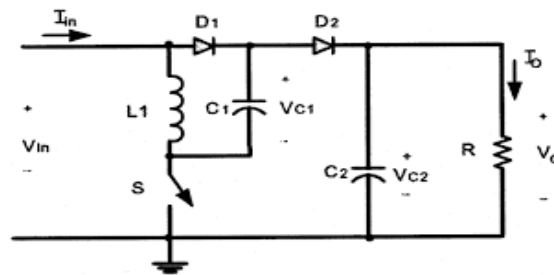


Figure 2. Elementary circuit of POS LC [25]

**3. MODIFICATION OF POS LC USING SWITCHED-CAPACITOR CELL**

The update of the POS LC converter, as shown in Figure 3, it is different from the elementary by using a capacitor switching cell. The difference in the cell is the replacement (C1) by cell constructed from three capacitors (C1 and C2). The proposed converter work as follows: at the switch-on, the passive element (inductors and the three capacitors) will be charged, the path of a current charge become as follows: diode (D2) is a reverse bias, and the diode (D1) in the forward bias, the capacitor (C1), capacitor (C2), capacitor (C3), and inductor (L1) in parallel connection.

At the switch-off state, the diode (D1&D2) in the forward bias, the discharge path of current C1, C2, C3, and L1 in series connection to the capacitor (Co) and then to the load. When the circuit is at the steady-state, notice that the diode (D2) has a second function, which is to prevent the charge stored in the capacitor (Co) from reversing to the circuit elements. The main reason for increasing voltages more than an elementary circuit is that each element (L1, C1, C2, and C3) stores energy as much as the source energy. Then the energy

combined is pumped at the same time into a load. Figure 3 shows the modified converter and on-off states configuration.

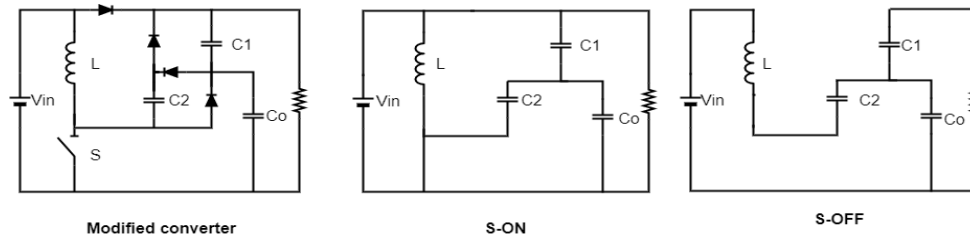


Figure 3. Modified positive output super-lift Luo converter

**4. MATHEMATICAL MODELLING**

Mode 1: (0~DT): switch ON,

$$v_{in} = v_L \tag{4}$$

$$v_{C1} = v_{Co} \tag{5}$$

$$v_L = v_{C1} + v_{C2} \tag{6}$$

C1 and C2 must be equal value to reduce ripple. According to (3) it out the same result at the switch-on state. Mode 2: (DT~(1-D) T): switch OFF,

$$v_o = v_{C1} + v_{C2} \tag{7}$$

$$v_{C1} = V_{C2} \tag{8}$$

The average inductor voltage for a period of time is:

$$V_{in}D + (V_i - V_{Co})(1 - D) = 0 \tag{9}$$

$$V_{in} = V_{Co} - V_{Co} D \tag{10}$$

$$V_{Co} = \frac{1}{1-D} V_{in} \tag{11}$$

Sub (10) in (11) we get,

$$V_o = 2 V_{Co} \tag{12}$$

Now sub (10) in (12),

$$\frac{V_o}{v_{in}} = \frac{2}{1-D} \tag{13}$$

Finally, (13) of output voltage in the modify circuit and we notice that the proposed converter. It gives a higher lift rate to voltage according to the original circuit.

Figure 3 shows the circuit at switch-off with the current path and supply a load. Figure 4 shows the elementary and modified converters implemented in PSIM. Table 1 shows the values of all parameters ant units.

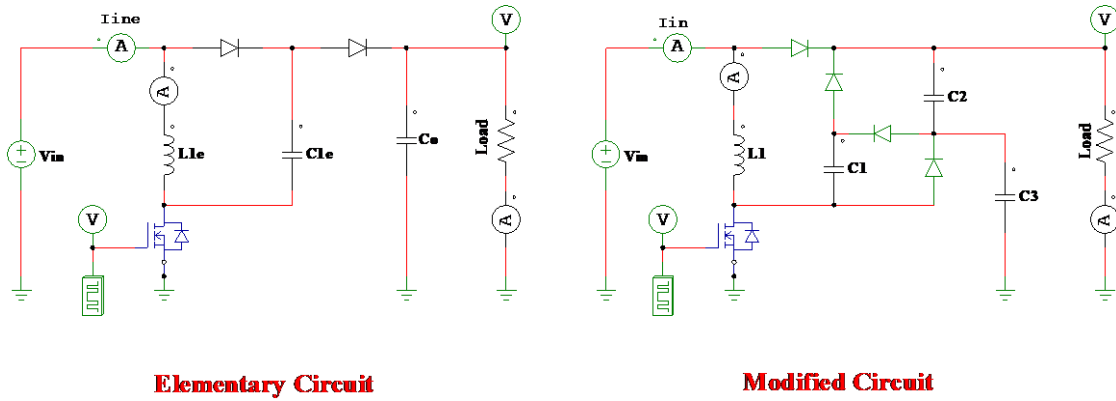


Figure 4. Elementary and modified converters implemented in PSIM

Table 1. Parameters of the converters

Parameter name	Symbol	Value	Unit
Inductors	(LI, LLe)	1	mH
Load resistance	R	50	Ω
Capacitors	(C1,2,3,e,o)	220	uH
Switching frequency	f	60	kΩ

**5. MATHEMATICAL MODELLING AT DISCONTINUOUS CONDUCTION MODE**

Mode 1: (0 DT): switch-ON,

$$v_{in} = v_L \tag{14}$$

$$\Delta i = \frac{v_{in} D T}{L} \tag{15}$$

Mode 2: (DT~(1-D) T): switch-OFF,

$$V_{in} D + (V_i - V_{co})(1 - D) = 0 \tag{16}$$

$$(1 - D) = \frac{-V_{in} D}{V_i - V_{co}} \tag{17}$$

$$I_{CO} = \frac{1}{2} D' \Delta i_L - I_o \tag{18}$$

At steady state  $I_{CO} = 0$ ,

$$I_o = \frac{1}{2} D' \Delta i_L \tag{19}$$

$$\frac{1}{2} \frac{V_{in} D}{V_i - V_{co}} * \frac{v_{in} D T}{L} = \frac{V_o}{R} \tag{20}$$

By simplify (20) we get:

$$\tau = \frac{D^2}{2((\frac{1+D}{1-D})^2 - 1)} \tag{21}$$

Note: to minimize ripple in circuit that involve a cell, the capacitors values of (C1) and (C2) must be equal value when designing. Because the ripple is the result of a switching process that occurs on inductance or capacitor. When adding a cell whose capacitors are equal in values, this increases the value of the capacitance impedance and thus prevents ripple.

Plotting equation ( $\tau$ ) with duty cycle (D) producing a Figure 5. From the chart of boundary condition continuous conduction mode & discontinuous conduction mode (CCM&DCM), can note area of working of a converter. We note area DCM decreases with an increasing duty cycle (D).

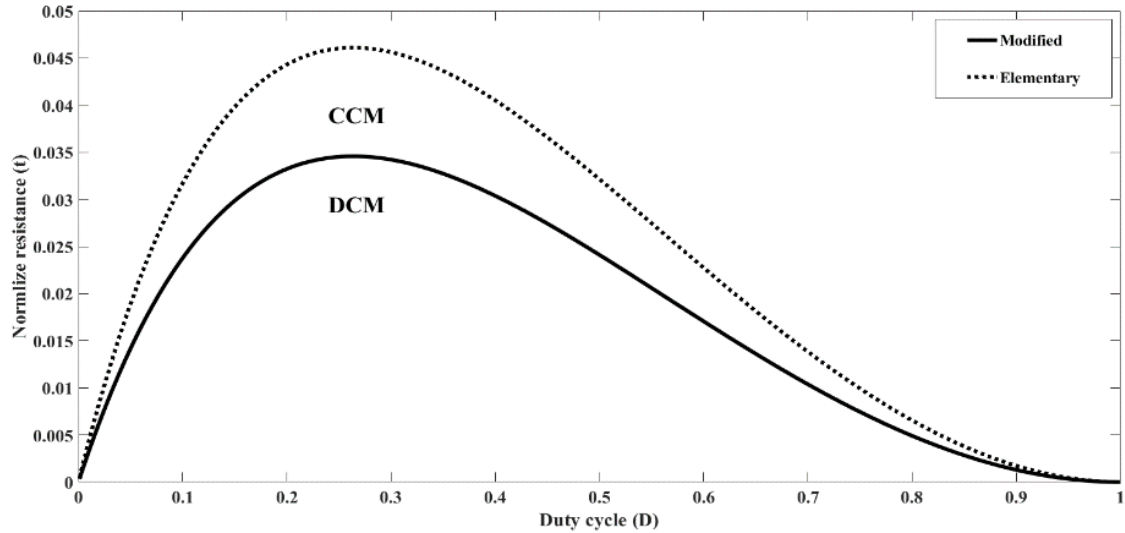


Figure 5. Boundary conditions between CCM and DCM of modified converter

**6. RESULTS AND DISCUSSION**

Figure 6 shows the ratio of the output voltage at (13) with respect to a duty cycle at the proposed converter. Increasing the duty cycle leads to lifting voltage. In Figure 7, it is very clear that at an input voltage of 10 V, the output voltage is 30 V at the traditional converter and 40 V at the proposed converter at (D=0.5). Figure 8 shows the input current of the elementary converter ( $I_{in}$ ) and the input current of the proposed converter ( $I_{in}$ ), the continuous (low ripple) input current of the proposed converter is too obvious, and this property make the modified Luo converter is much better than the elementary Luo converter because the input pulsating current reduce the efficiency and the life time of the power source. Figure 9 shows the maximum power point tracker controller of the converter since the ( $P_{max}$ ) is the maximum power the PV panel could generate it at 1,000 and 800  $w/m^2$ , while the ( $P_O$ ) is the real output power of the panel coming to converter.

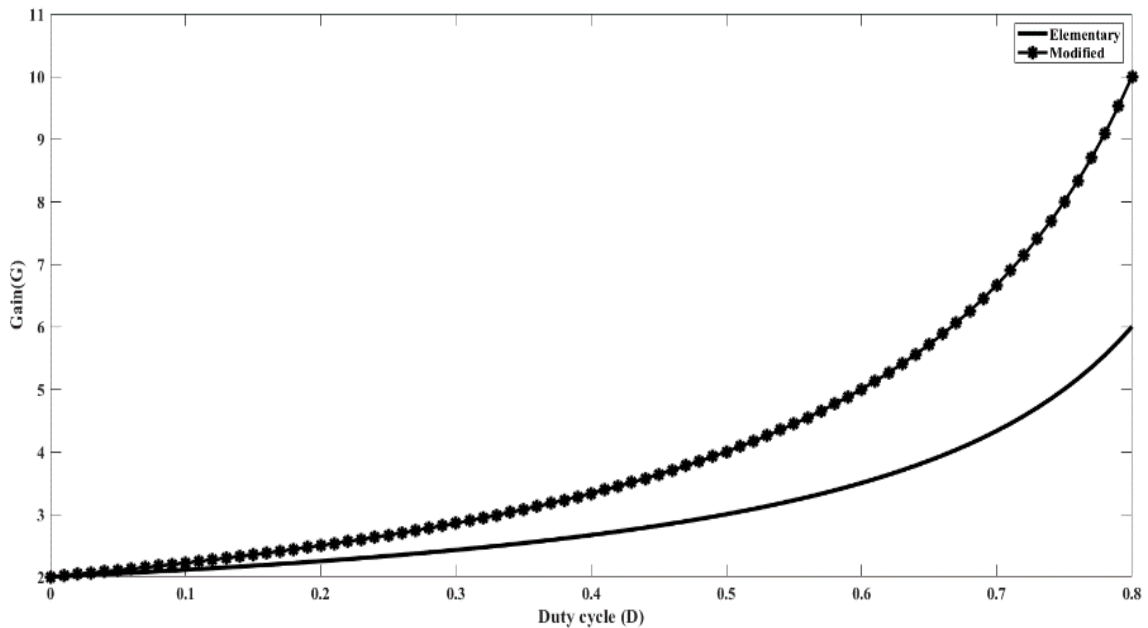


Figure 6. Relationship between gain and duty cycle

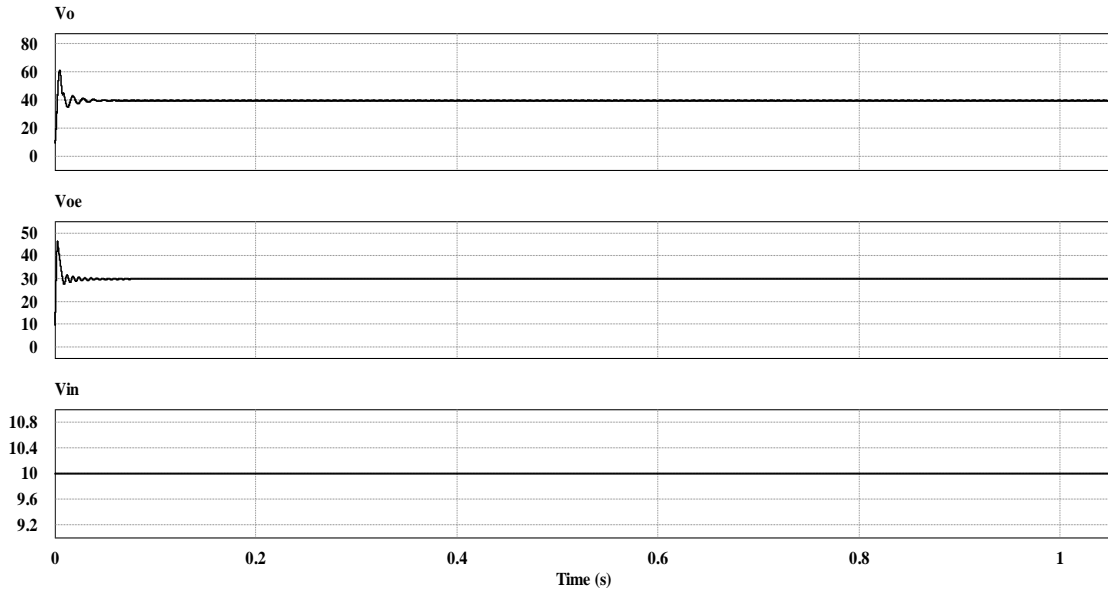


Figure 7. Input and output voltages of the elementary (Voe) and modified (Vo) converters

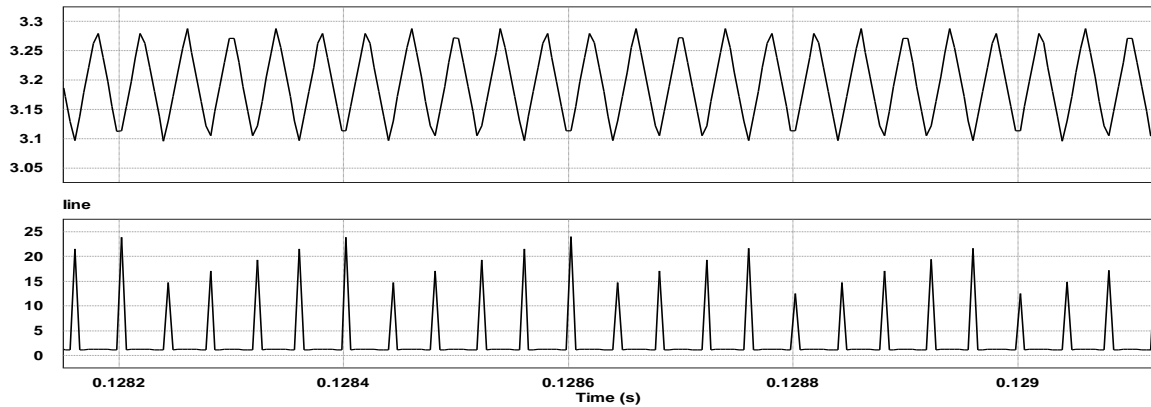


Figure 8. Input current for both elementary and modified converter

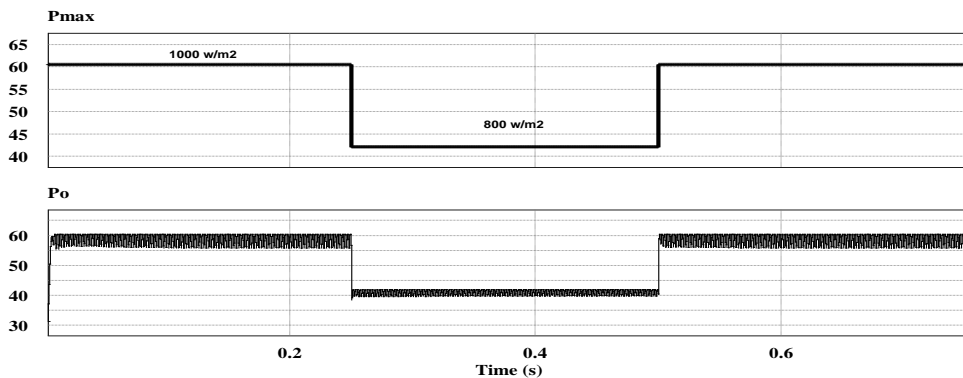


Figure 9. Maximum power point of the PV panel and output power of the panel

## 7. CONCLUSION




A new modification of the Luo converter has been presented in this article. This converter has been modeled and simulated using PSIM program and the simulation results satisfied the theoretical results. When

DC-DC Luo converter with a higher voltage gain than the traditional Luo converter is needed in the photovoltaic power system, this proposed Luo converter is used. It has the ability to raise a higher voltage, so it reduces stress on the switch. It does not depend on more inductors, as in many of the proposed solutions, as it reduces electromagnetic interference and reduces weight and cost (depending on the capacitors in increasing the voltage). Most important of all, the proposed Luo converter can be used in applications that require a continuous input current. It eliminates the input pulsating current significantly.




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