ISSN 2347 - 3983
Volume 8. No. 10, October 2020
International Journal of Emerging Trends in Engineering Research
Available Online at http://www.warse.org/IJETER/static/pdf/file/ijeter778102020.pdf
https://doi.org/10.30534/ijeter/2020/778102020

Comparative analysis of PV powered KY and Luo converter

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ABSTRACT

PV power is the one of best alternatives for conventional energy sources. The main drawback of renewable power is not a reliable/constant one. So it requires a suitable converter that will quickly respond depends on the changes in the input supply. There are many types of DC-DC converters are available. These converter output voltages can be changed by varying the duty cycle ratio of the switches present in the converter. The Luo and KY converters are in emerging trends used for the PV energy conversion system. In this paper, the parameters like switching losses, transient response, output voltage, and efficiency are compared with each other. Also, the circuit diagram of Luo and KY converters are simulated using MATLAB/Simulink and the output results of these converters are compared and analyzed.

Key words : DC-DC converter, KY converter, Luo converter and Photovoltaic(PV)

1. INTRODUCTION

Now a day's most of the world is replacing the conventional sources by renewable energy sources. But the renewable energy output power is very less compared with conventional energy sources. It requires a suitable converter to boost up the voltage and respond depends on the continuous variation in the input side. So it needs more concentration on the converter side to improve the voltage gain and efficiency with fewer harmonics. The renewable energy system requires a high gain boost converter explained and implemented in [1]-[2]. The major demerits are pulsating output current which will affect the output voltage. So overall output efficiency is reduced. In [3], presents the high performance of an integrated KY converter. It describes small output voltage ripples and fast transient response compared with a boost converter. The voltage boosting converter is presented in [4]. In this paper, 1-plus-2D and 2-plus-D converters are explained with the same structure with different PWM techniques. The KY converter provides low output voltage ripples and a very fast transient response. The step-up boost converter is also called a KY converter [5] which works in transient response in CCM mode, provides low output current ripples, and low output voltage ripple. Also, the output voltage gain is very high. In [6] presents a voltage lift Luo converter which has a simple structure, very low ripple output voltage, and high efficiency. The positive output super lift re lift Luo converter [7] presents regulating the output voltage by feedback signal and its gain is improved. Also, it overcomes the phase obstacle by a DC-DC boost converter. In this paper, the KY and Luo converters are compared and discussed the performances like switching losses and transient response.

2. CIRCUIT CONFIGURATION

2.1.KY Converter

The KY converter is a step-up DC-DC converter. The transient response operating in CCM is always with low ripple voltage with the non-pulsating current. It consists of two bidirectional switches S1, S2, one diode Db, one energy transferring capacitor Cb, one inductor L, one output capacitor Co and Load resistor R. The circuit diagram of KY converter is shown in Fig 1.

The operation of the KY converter is divided into two modes. Mode 1: When the switch S1 is ON and switch S2 is OFF condition, the voltage across the inductor L is equal to inductor voltage (VL) added with capacitor voltage (Vc) minus the output voltage (Vo) thereby causing inductor L to be magnetized. The capacitor current is equal to the current flowing through the inductor L minus the current flowing through the load (Vo/R). In this mode, the capacitor Cb is discharged. The mode 1 power flow diagram is shown in Fig 2.

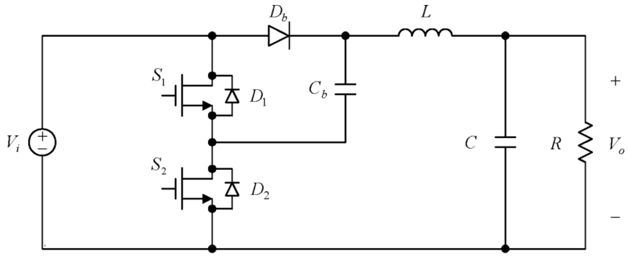

Fig 1. Circuit diagram of KY converter

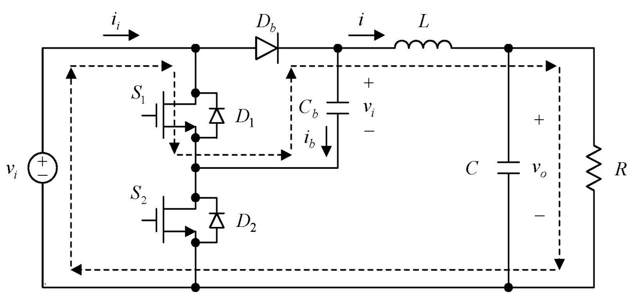

Fig 2. Power flow diagram of KY converter in Mode 1.

Mode 2: When the switch S_1 is OFF and switch S_2 is ON condition, the voltage across the inductor L is equal to the input voltage (Vi) minus the output voltage (Vo) thereby causing inductor L to be demagnetized. The capacitor current is equal to the current flowing through the inductor L minus the current flowing through the load (Vo/R). In this mode, the capacitor C_b is abruptly charged to input voltage Vi with a very short period. The mode 2 power flow diagram is shown in Fig 3.

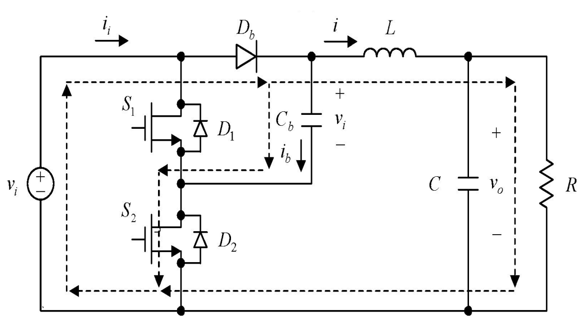

Fig 3. Power flow diagram of KY converter in Mode 2.

The voltage gain is given as

$$Vout/Vi/p = 1 + D \tag{1}$$

where, D is Duty cycle.

The design specifications of the KY converter are given as follows:

Output current is calculated as

$$Iout = Pout/Vout \tag{2}$$

Input current is given as

$$Ii/p = Pi/p \,/\, Vi/p \tag{3}$$

Voltage gain is calculated as

$$Gain = Vout/Vi/p \tag{4}$$

In mode 1, the voltage across the inductor is

$$V_L = 2Vi/p - Vout \tag{5}$$

The inductor voltage current basic relation is

$$V_L = L * dI/dt \tag{6}$$

$$L = V_L * dt/dI \tag{7}$$

Where dt = duty cycle / frequency

Assume that inductor ripple current = 40% of inductor current

$$dI = 40\% * I_L \tag{8}$$

The capacitor voltage current basic relation is

$$I = C * dV / dt \tag{9}$$

Where dV is output ripple voltage.

Assume that output ripple voltage is about 0.05% of output voltage

$$C = Ii/p * dt/dV \tag{10}$$

Where dt = duty ratio/frequency

$$C = Ii/p * D/(F * dV) \tag{11}$$

$$C = Iout * dt/dV \tag{12}$$

Where dt = duty ratio/frequency

$$C = Iout * D/(F * dV) \tag{13}$$

Table 1. Simulation parameters of KY converter

Parameter	Value
Vin	12V
Frequency	1KHz
Inductor(L)	1.8e-5 H
Capacitor (Cb)	1.7e-3 F
Capacitor(C)	1F
Duty cycle	50%
R Load	300 Ohm

2.2 LUO Converter

The circuit diagram of the Luo converter is shown in Fig 4. In this circuit, two switches are used. One is the controllable switch (Power MOSFET) and the other is an uncontrollable switch (Diode). The diode is used as a freewheeling diode. The passive energy storage elements L1, L2, C1, and C2 are used. Resistive load R is used in output. The operation of the Luo converter divided into two modes.

Mode 1: when switch ‘S’ is closed, the supply voltage V_{in} appears across the inductor and it is getting charged. The capacitor C_1 and inductor L_2 are connected in series and start discharging. The capacitor energy C_1 is transferred to the resistive load R through L_2. Hence the current in the inductor increases until the switch ‘S’ is off condition.

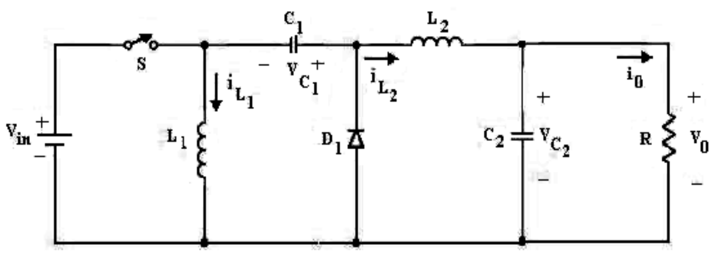

Fig 4. Circuit diagram of Luo converter

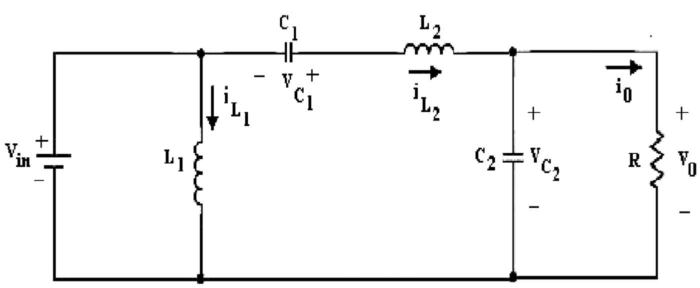

Fig 5. Operation of LUO converter in Mode 1

Mode 2: When the switch ‘S’ is open, the supply is disconnected from the load. The inductor current i_{L1} flows through freewheeling diode D_1 and it will charge the capacitor C_1. The inductor current i_{L2} flows through the capacitor C_2 and resistor load R and freewheeling diode D_1. This makes the circuit in continuous conduction mode.

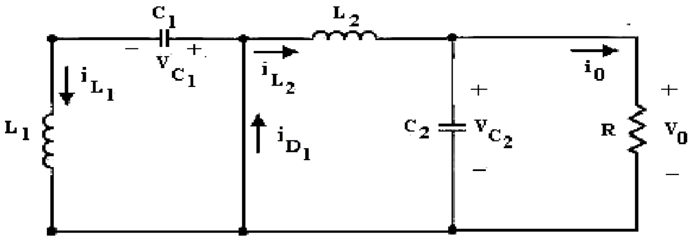

Fig 6. Operation of LUO converter in Mode 2

The average output voltage is calculated as

$$V_{out} = D/ 1\text{-}D * V_{i/p} \quad (14)$$

The average output current is calculated as

$$I_{out} = D/ 1\text{-}D * I_{i/p} \quad (15)$$

The voltage gain of the converter is calculated as

$$V_{out}/ V_{i/p} = D/1\text{-}D \quad (16)$$

The inductor current I_{L2} calculated as

$$I_{L2} = 1\text{-}D / D * I_{L1} \quad (17)$$

Duty cycle

$$D = T_{on}/T \quad (18)$$

Where T is total time

Average voltage across the inductor is

$$V_{c1}= D/ 1\text{-}D * V_{i/p} \quad (19)$$

Peak to peak inductor current L1 is ,

$$\nabla I_{L1} = DTV_{i/p} / L1 \quad (20)$$

Inductor L1 is calculated as

$$L1=DTV_{i/p} / \nabla I_{L1} \quad (21)$$

Peak to peak inductor current L2 is ,

$$\nabla I_{L2} = DTV_{i/p} / L2 \quad (22)$$

Inductor L1 is calculated as

$$L2 = DTV_{i/p} / \nabla I_{L2} \quad (23)$$

Peak to peak ripple voltage across the capacitor C1 is ,

$$\nabla V_{C1} = 1\text{-}D\ TI_{L1} / C1 \quad (24)$$

Capacitor C1 is calculated as

$$C1=1\text{-}\ DT\ I_{L1} / \nabla V_{C1} \quad (25)$$

Table 2. Simulation parameters of LUO converter

Parameter	Value
Vin	12V
Frequency	1KHz
Inductor(L1)	100 µH
Inductor(L2)	100 µH
Capacitor (C1)	10 µF
Capacitor(C2)	10 µF
Duty cycle	50%
R Load	300 Ohm

3. SIMULATION CIRCUIT AND RESULTS

The simulation circuit for KY and Luo converter is shown in Fig.7. The simulation circuit of KY and Luo converter is designed using MATLAB/Simulink. In this circuit, the input source is used as a controlled voltage source instead of using a PV panel. The input voltage range is from 10 V to 15 V, the frequency is 1 kHz and the duty cycle is 50% for both the converters. The input voltage disturbance is given to both the converter at the same time and the performance analyses are observed from the output waveforms.

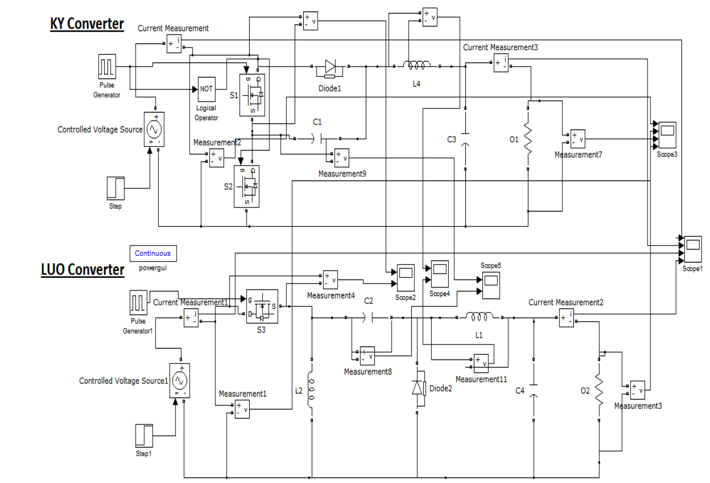

Fig 7. Simulation circuit of KY and LUO converter

The KY and Luo converters are working under continuous conduction mode (CCM). The input voltage waveform of KY and Luo converter is shown in fig. 9. The initial voltage is given as 12V for both KY and Luo converter through controlled voltage source for 8 sec. The output voltage of KY and Luo converters are 25V and 42V respectively. From the output waveforms of KY and Luo converters its observed that, the rise time of Luo converter very less with compared to KY converter. Now the disturbance in the input voltage is given to both converter at the same time. The output voltage of KY and Luo converters are increased to 33V and 55V respectively. From the output waveforms its observed that, for any changes in the input voltage, the Luo converter is responding very quickly with compared with KY converter. Also the voltage stress across the switches are very less with compared to KY converter is shown in fig.8.

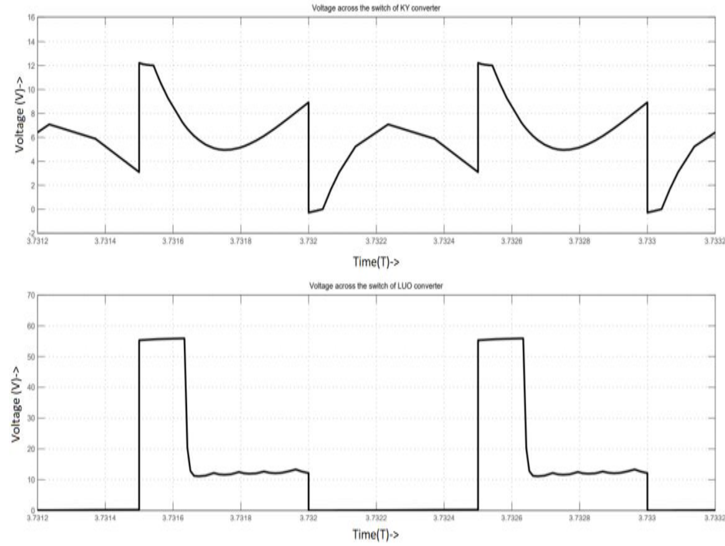

Fig 8. Voltage across the switch of KY and Luo converter

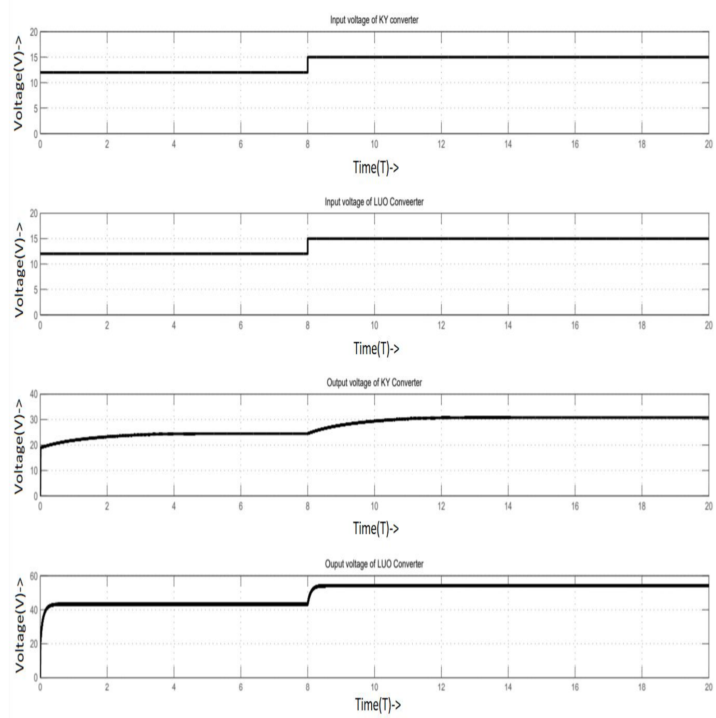

Fig 9. Input voltage and output voltage waveforms of KY and LUO converter

The input current and out current waveform of KY and Luo converter is shown in Fig.10 and Fig.11. The KY and Luo converter output currents are 0.08 A and 0.15 A respectively for the input voltages of 12V for both the converter. The output current value is increased to 0.1A and 0.18A for the sudden changes of 12V to 15V. From the output current waveforms of fig.10 and fig.11, its observed that the rise time of Luo converter is very less with compared to KY converter also the ripple current is very less in Luo converter.

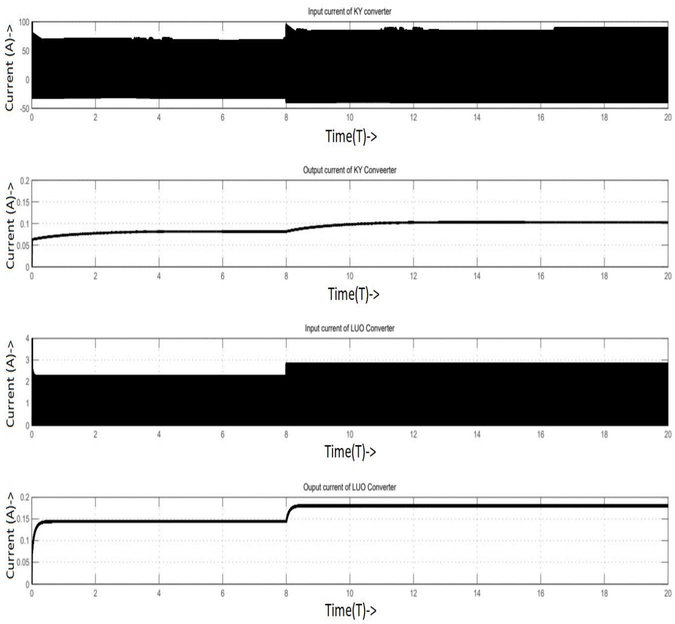

Fig 10. Input current and output current waveforms of KY and LUO converter

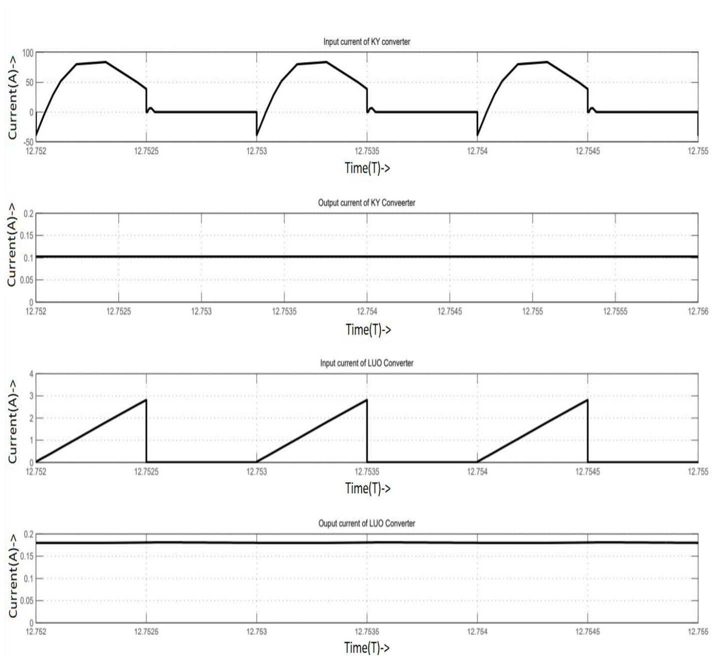

Fig 11. Input current and output current waveforms of KY and LUO converter (zoom view)

The performance parameters of KY and Luo converters are tabulated below.

Table 3. Comparison of parameters from waveforms of KY and LUO converter

Parameters	KY Converter	LUO Converter
Input voltage	12 - 15 V	12 - 15 V
Output voltage	25 – 35 V	45 – 55 V
Output current	0.05 – 0.1 A	0.15 – 0.18 A
Transient response	4 Sec	0.3 Sec
Gain	2.08	3.75

4. CONCLUSION

The Luo and KY converters are modeled and simulated using MATLAB/Simulink. The simulation has been performed for the same input voltage of both the converters with the same frequency and duty cycle of 50%. The input disturbance is applied simultaneously to both the converter and the performances are analyzed and the parameters are tabulated for the above converters. The results are observed from input and output voltage and current waveforms. The voltage stresses across the switches and ripple current waveform also observed. From the waveforms and tabulations, it's concluded that the Luo converter is performed better while the disturbance is applied and the gain of the Luo converter also better than the KY converter. From the above observations, it's concluded that Luo converter is suited for renewable energy sources.

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