Cumhuriyet Science Journal
e-ISSN: 2587-246X
ISSN: 2587-2680
Cumhuriyet Sci. J., 41(2) (2020) 472-481
http://dx.doi.org/10.17776/csj.474664

Fuzzy control of single-input step-up switched-capacitor- inductor dc-dc converter

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Abstract

The main objective of this paper is fuzzy control of single-input Step- Up Switched Capacitor-Inductor DC-DC converter. For this purpose, we first introduce the basic structures of capacitor switched converter. Then, a single-input step-up switched capacitor inductor DC-DC converter is investigated. The most important advantage of this category of these converters is that the energy flowing from the source is transmitted directly to the two C1 and L1 elements and is sent directly to the output terminal, thus, they can generate high voltage gain without the need for cascading structures or multiple Floor there. The simulation results show the correctness of the converter's performance.

Article info

History:
Received: 25.10.2018
Accepted: 20.04.2020
Keywords: DC-DC converter, switched - capacitor , single input converter, fuzzy control.

1. Introduction

Capacitor-inductor Switched Converters:In recent years, capacitor switched structures (SCs) have been seemed highly[1-2]. Due to the lack of magnetic elements such as inductors and trans, these converters have a small size, small size, low cost and high efficiency, and they can produce a high gain, both in decreasing form and in increments[19]. The most important problem with these converters is their low power level[14-6].

Recently, many researchers have used a combination of structures for base converters with SC structures to create high-gain converters at higher power levels.

A different category of DC-DC converters, called capacitor-inductor switched, is used in two types of capacitor and inductor switched cells:

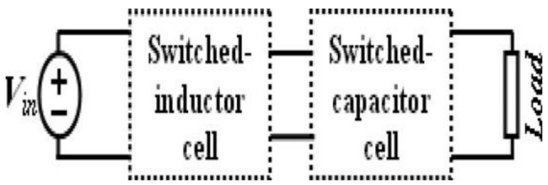

Figure 1. The general structure of inductor-capacitor switched models

The main advantage of this class of converters is that the energy flowing from the source is transmitted directly to L1 and C1 and transmitted directly to the output[9-11]. As a result, they can generate high voltage gain without the need for cascading or multi-storeystructures.The main objective of this study is to apply fuzzy control to a single-input step-up capacitor-inductor DC-DC converter. The important advantage of using fuzzy control is that it does not need to have a precise mathematical model[20].

2. Single Input Step-up Converter

A family of switched mode converter with different voltage ratios is presented. All family members consist of the same number of electronic components: they include two energy transfer units, for example, one C1 in SC and L1 in a variable inductor, a small LR resonant inductor used to limit the flow of peak flow from SC, three The switch is active or inactive and a filter capacitor output. The most important feature of these converters is

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that the current energy from the input power supply is directly connected to two components, C1 and L1, and then connected to the output terminal.

For example, these converters are really single-phase convertors, such as converters that have received high voltage gain through a cascade method. When the two parts of the energy transition act in parallel in the charging step, then in series during the discharge period, the highest output level can be generated and the members of the increase of the family of converters can be derived. Similarly, the downsizing members are derived by two series of energy transfers during the period of charge and then in the parallel phase at the time of discharge. This principle is not only suitable for the extraction of single-entry converters, but can be used for two-way DC-DC converters commonly used in a two-level DC dual-level renewable energy distribution system. To detect the family of converters from SC / I switches The proposed convertors are called single-step switching inductor / capacitor switched pulse width modulators (SCIs).

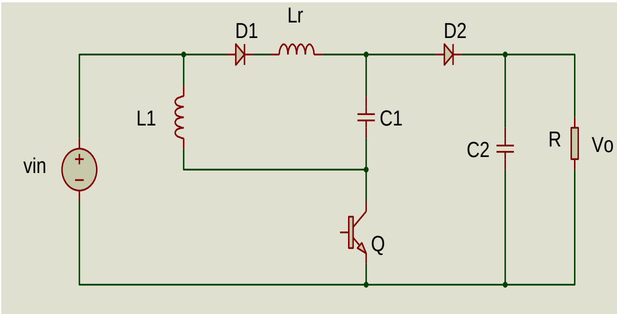


Figure 2. Circuit of single input step-up converter

First state (t0 to t1): Q connects and D1 directs and D2 is disconnected:

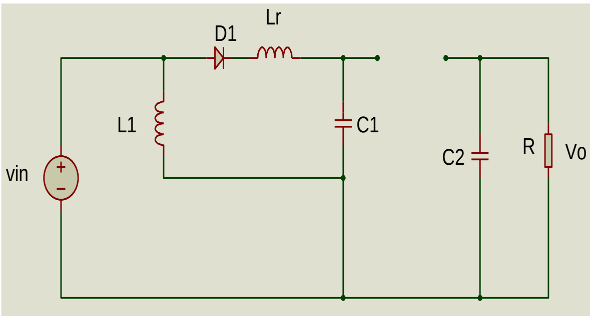


Figure 3. Circuit of figure .2. (t0-t1)

In the case of Lr and C1, they form a series of resonant tanks, thereby increasing the capacitor C1 through zero sinusoidally, and the voltage of the C1 capacitor begins to increase. The inductor current L1 increases linearly. In this situation, inductor L1 current(il1), capacitor c1 voltage(vc1):

$$i_{L1} = I_d \sin \omega_0 (\mathrm{t} - \mathrm{t}_0) \quad (1)$$

$$V_{C1} = V_{in} - \frac{\Delta V_{C1}}{2} \cos \omega_0 (\mathrm{t} - \mathrm{t}_0) \quad (2)$$

$$\mathrm{i}_{L1} = I_{L\min} + \frac{V_{in}}{L_1} (\mathrm{t} - \mathrm{t}_0) \quad (3)$$

$$\omega_0 = \frac{1}{\sqrt{L_r C_1}} = \qquad \text{resonance frequency} \tag{4}$$

After half a cycle of resonance, at the instant t1, the current of the capacitor C1 reaches zero and its voltage will be maximized and the diode D1 will be cut off. The maximum capacitor voltage will be as follows:

$$(V_{C1})_{max} = V_{in} + \frac{\Delta V_{C1}}{2} \tag{5}$$

Second state (t1 to t2): In this situation, Q continues to guide itself, D1 is cut off, and L1 is still charged linearly and the capacitor C1 will remain constant.

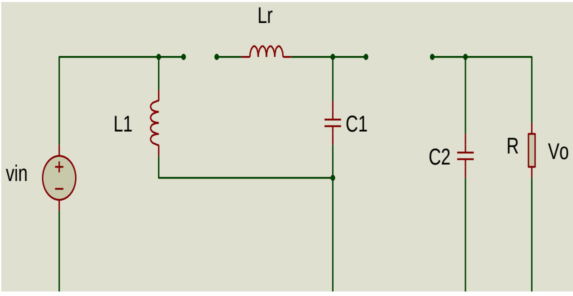


Figure 4. Circuit of figure.2. (t1-t2)

This situation continues until t2, at this moment Q will be cut off and the current L1 will be maximized:

$$(I_{L1})_{max} = (I_{L1})_{min} + \frac{V_{in}}{L_1} DT \tag{6}$$

That D is the duty cycle of the switch and T is the keying cycle. Third status (t2 to t3): In this situation, Q and D1 will be cut and D2 will be directed:

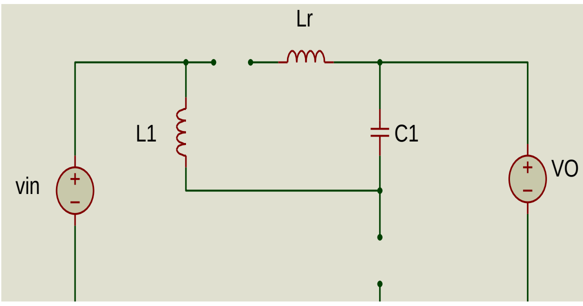


Figure 5. Circuit in state (t2-t3)

In this situation, L1 and C1 are in series with the input and output and discharged:

$$i_{L1} = -i_{C1} = (I_{L1})_{max} - \frac{V_O - V_{in} - V_{C1}}{L_1}(t - t_2) \tag{7}$$

$$V_{C1} = (V_{C1})_{max} - \frac{I_O}{(1-D)C_1}(t - t_2) \tag{8}$$

At the end of this state, the instant t3 of the inductor L1 and the C1 capacitor voltage reaches its minimum.

$$(\mathrm{I_{L1}})_{\min} = (\mathrm{I_{L1}})_{\max} - \frac{V_O - V_{in} - V_{C1}}{L_1}(1-\mathrm{D})\,\mathrm{T} \qquad (9)$$

$$(\mathrm{V_{C1}})_{\min} = (\mathrm{V_{C1}})_{\max} - \frac{I_0 T}{C_1} \qquad (10)$$

At this moment, the switch will be reconnected and will come back to the first position.

3. Calculating of Voltage Relationship

At the time t0 to t2, where the switch is connected (DT), the voltage of the headlamp head L1 is equal to Vin. However, in the range t2 to t0, the switch is disconnected ((1- D) T) The voltage of the inductor L1 is Vin + Vc1-Vo. If the voltage of the capacitor C1 is approximately equal to Vin, the inductor L1 will be equal to 2Vin-Vo. Now, if we write the balance of the second Volt L1, we will have:

$$(\mathrm{V_{in}})(\mathrm{DT}) + (2\,\mathrm{V_{in}} - \mathrm{V_O})(1-\mathrm{D})\,\mathrm{T} = 0 \qquad (11)$$

as a result:

$$\mathrm{V_{in}}\mathrm{D} + 2\,\mathrm{V_{in}} - 2DV_{in} - V_o + DV_o = 0 \qquad (12)$$

then:

$$V_O = \frac{2-D}{1-D} V_{in} \qquad (13)$$

4. Simulation Results

As mentioned, the main purpose of this paper is to use a fuzzy control method to control the capacitor-inductor single-input step-up DC-DC converter. In general, the use of the fuzzy method for various systems has found application. This method has been used in electrical systems and in various branches of electrical engineering, including the following:

- Types of electric drives
- Flexible AC Transmission Systems (FACTS)
- Controlling Electronic Power Controllers
- Electromechanical systems
- Distributed production systems

An important advantage of the fuzzy method is that it can provide proper control for the system without having to know the exact mathematical model of the system..

4.1.Fuzzy control in DC-DC converters

The block diagram of the overall fuzzy control in DC-DC converters is as follows:

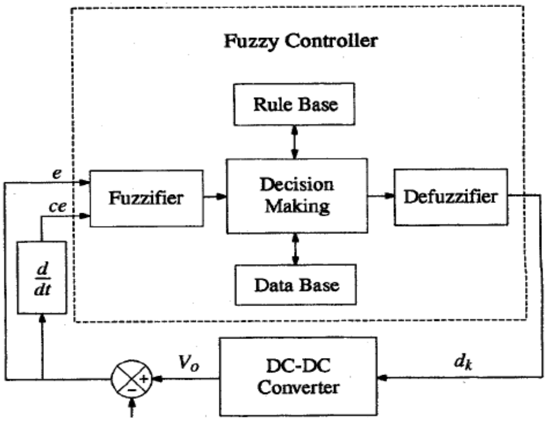


Figure 6. block diagram of the fuzzy control of the converters

As shown in this figure, the error and error derivative are applied as input to the fuzzy controller and the fuzzy controller output determines the duty cycle of the switch. Now, comparing the output of the fuzzy controller with a sawdust waveform, the command signal to the switch is generated, as shown below:

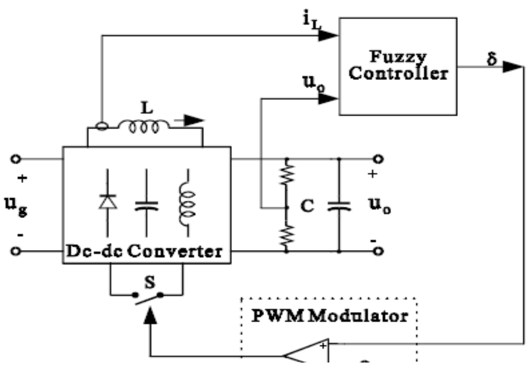
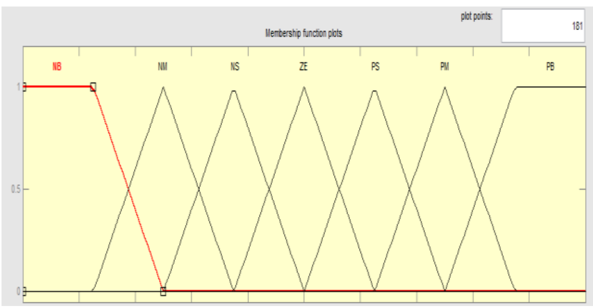


Figure 7. How to generate the command signal to the switch

4.2. Fuzzy control simulation

For this purpose, the fuzzy control toolbox is used in MATLAB software. In this thesis, two inputs for the fuzzy controller are considered, which are voltage error (e) and voltage derivative (ce). The voltage error is obtained from the differential voltage output and reference voltage.The membership functions used for these inputs are as follows:



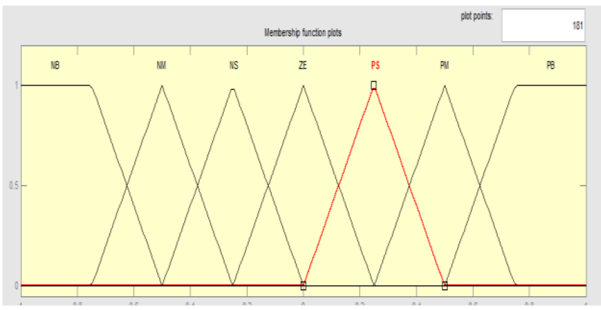


Figure 8. Membership function e

Figure 9. Membership function ce

The controller output membership function is as follows:

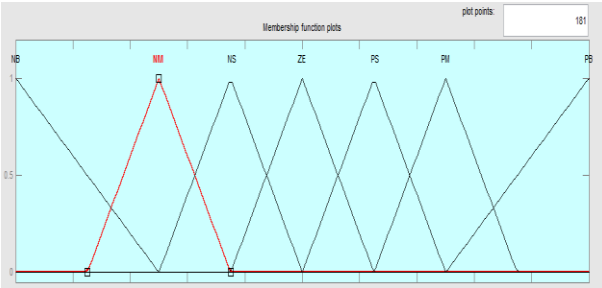


Figure 10. Membership function of output

The fuzzy rules used are as follows:

change in error(ce) \ error(e)	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NB	NB	NM	NS	ZE	PS
NS	NB	NB	NM	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PM	PB	PB
PM	NS	ZE	PS	PM	PB	PB	PB
PB	ZE	PS	PM	PB	PB	PB	PB

Figure 11. Fuzzy rules

The following principles have been used to write the fuzzy rules:

- When the output voltage is far from the reference value, the duty cycle of the switch must be large.

- When the output voltage approaches the reference value, the duty cycle must be small.

- When the output voltage reaches the reference value and remains stable, the duty cycle must remain unchanged.

- When the output voltage reaches the reference value but is still changing and not stable, the duty cycle should be small.

When the output voltage is greater than the reference value, the duty cycle changes must be negative and vice versa.

4.3. Simulation result

The results of the simulation of Fuzzy Control of Single-Input Step-Up Switched Capacitor- Inductor DC-DC Convertorare under the following simulation parameters :

Vin= 22 (V)

L1=95 (uH)

Lr = 0.3 (uH)

C1= 4.7 (uF)

C2=100(uF)

R=20 (ohm)

F=100 (KHz)

In this simulation, the 66 volt reference voltage is applied to the control system to indicate the correct operation of the controller. To reach this voltage, the switch in the converter is switched on at 100 kHz and its duty cycle is 50%. The following figure shows the command signal to the switch:

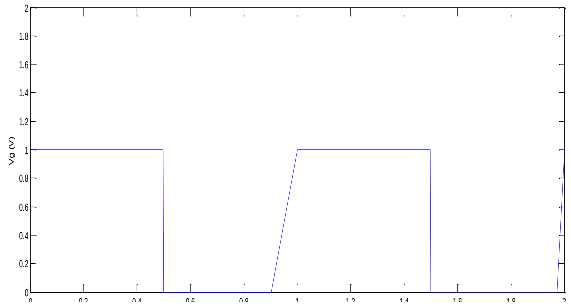


Figure 12. The command signal to switch

In this situation, the output voltage waveform of the converter will be as follows:

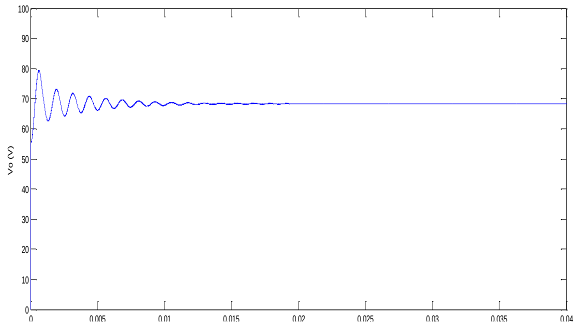


Figure 13. Output voltage

As shown in this figure, the output voltage is about 66 volts and has been able to track the reference value. In this situation, the shape of the capacitor C1 is as follows:

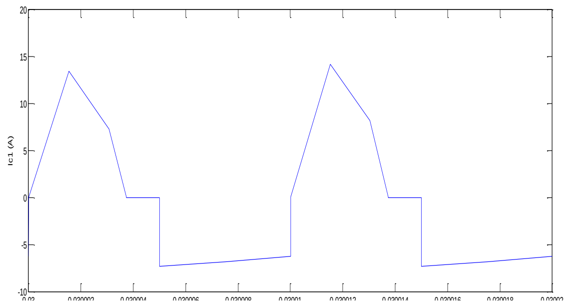


Figure 14. Capacitor c1 current

As shown in this figure, the capacitor C1 has been almost sinusoidally changed in the first state of the circuit, ie, the interval t0 to t1 due to the C1 capacitor and the predecessor Lr being serially formed and forming a resonant tank. In the second state of the circuit, ie, the time interval t1 to t2, the capacitor C1 reaches zero and remains at zero in this interval. In the third state of the circuit, ie, the time interval t2 to t3, the C1 capacitor is serially coupled to the inductor L1 and the current of the inductor L1 being discharged will inverts the capacitor C1. The voltage waveform of the C1 capacitor is as follows:

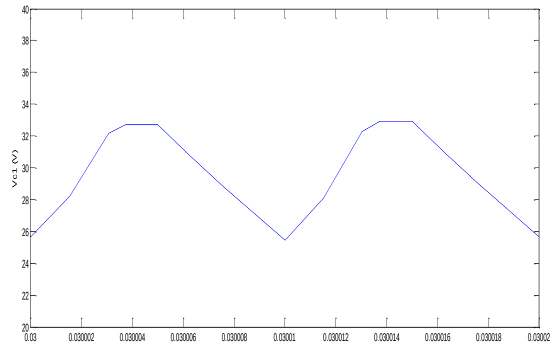


Figure 15. Capacitor c1 voltage

As seen in this figure, in the first state of the circuit,

ie, the time interval t0 to t1, because the capacitor C1 and predecessor Lr are in series and formed a resonant tank, and the current of the capacitor C1 has been changed almost sinusoidally, the voltage The capacitor will change in cosine. In the second state of the circuit, ie, the time interval t1 to t2, the capacitor C1 reaches zero and remains in this range zero, thus, the capacitor C1 voltage remains unchanged.

In the third position of the circuit, ie, the time interval t2 to t3, the C1 capacitor is serially located with the inductor L1 and the current of the inductor L1 being discharged will inverts the C1 capacitor. So the C1 capacitor voltage begins to decrease.

The flow pattern of the inductor L1 will be as follows:

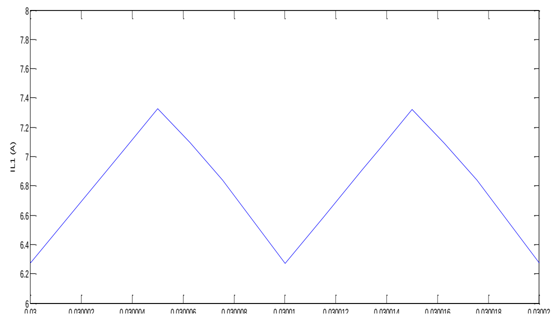


Figure16. Inductor L1 current

As seen in this figure, in the first position of the circuit, ie, the time interval t0 to t1, the inductor L1 starts charging linearly because the switch is connected and the L1 series inductor is placed with the Vin source. In the second state of the circuit, ie, the time interval t1 to t2, the same as the first one, the inductor L1 starts to charge linearly. In the third position of the circuit, ie, the time interval t2 to t3, the C1 capacitor will be serially coupled to the inductor L1 and will be coupled to the output voltage. As a result, the L1 inductor starts to discharge.

The waveform of the switch current will be as follows:

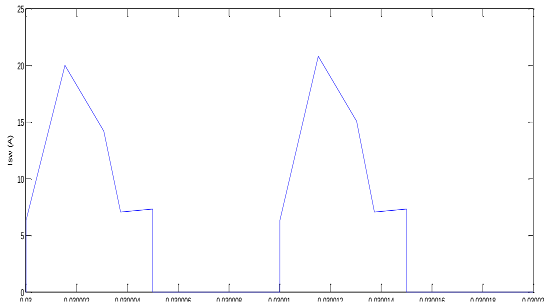


Figure 17. Switch current

As seen in this figure, in the first state of the circuit, ie, the time interval t0 to t1, because the switch is connected and the L1 series follower is placed with the source V2, the switch current will be obtained from the sum of the capacitor C1 and the inductor L1 Came. In the second state of the circuit, ie, the time interval t1 to t2, the same as the first one, the inductor L1 starts to charge linearly, but because in this situation the capacitor current C1 is zero, the switch current will be equal to the inductor L1. In the third position of the circuit, ie, the time interval t2 to t3, the switch is disconnected and therefore the current will be zero. The inductor Lr current waveform, which is actually the same current of the diode D1 (given the circuit shape and the series of these two elements), will be as follows:

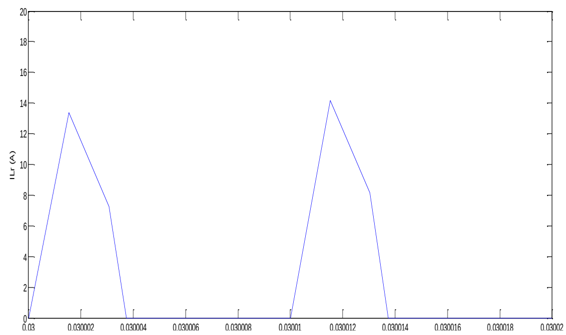


Figure 18. InductorLr current

As it is seen, in the first circuit, the period t0 to t1 by connecting switches and diodes D1 and cut D2, because the capacitor C1 and the inductor Lr series and the formation of tanks resonance have , The current of the C1 conduit, which is the current of the inductor Lr, has been roughly sinusoidized. In the second circuit, the period of time t1 and t2, the capacitor C1 to zero and remained in the range of zero. So the diode D1 is disconnected and the current of the inductor Lr will be zero. In the third circuit, the time t2 and t3, similar to the second situation, the diode D1 Lr still cut off and the inductor current is zero.

The waveform of the diode current D2 will be as follows:

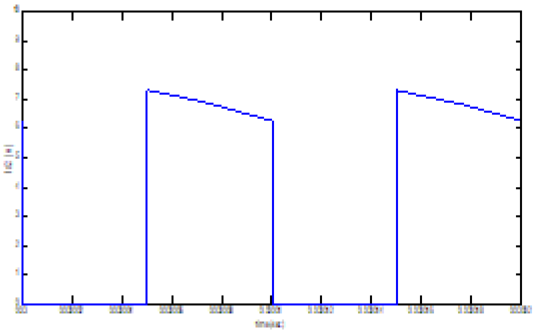


Figure 19. Diode D2 current

As seen in the figure above, in the first and second states of the circuit such as the diode D2, the current is zero and in the third state it will be equal to the inductor L1.

5. Conclusion

The main objective of this paper is to Fuzzy Control of Single-Input Step-Up Switched Capacitor- Inductor DC-DC Converter. For this purpose, first the Single-Input Step-Up Switched Capacitor- Inductor DC-DC Convertor was investigated.

The most important advantage of this category of these converters is that the energy flowing from the source is transmitted directly to the two C1 and L1 elements and is sent directly to the output terminal, thus, they can generate high voltage gain without the need for cascading structures or multiple Floor there.

This structure can be generalized not only for single-converter converters, but also for dual-input converters, with two input modes commonly used in non-renewable energies. The simulation results show the accuracy of the converter's performance.

Conflicts of interest

There is no conflict of interest.

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