Study on Performance Analysis of Luo Converter with Fuzzy Controller

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Abstract: DC/DC converter occupies a major parte in generation of electric power from Renewable Energy Resources (RES). However, because of varying weather nature, the conventional converter exhibits poor conversion efficiency. Thus, this work proposed a Positive Output Luo Converter to have increased conversion efficiency. To extract maximised power from a PV system, P and O tracking system has been implemented. Thus, the performance of this proposed converter with FLC is examined using MATLAB. The results clearly stated that this proposed topology has higher ability to extract maximum power from a PV and thus reveals higher efficiency.

Keywords: Renewable Energy Resources, positive output Luo Converter, FLC

1. Introduction

The environmental problems such as pollution etc., caused by fossil fuel makes the world to move towards utilization of RES in power generation [1]. Among the RES, solar becomes more dominant one because of its plentiful availability. Unfortunately, their conversion efficiency is very low (10-18%). Thus, the power provided by the PV system varies in accordance with weather condition. Hence, further to enhance the output of PV meet out load requirement, DC converters are utilized. They act as a intermediate unit between PV system and load. Thus, by varying the duty cycle of the converter, the output power can be varied during the absence of sunlight.

Another challenge concerning the PV systems is the unavailability of power in night time and cloudy weather. So, a storage element is necessary in such systems which can provide power to the load in the absence of PV power. To increase the life of the battery used, it need to be prevented from overcharging as well as over discharging[2,3].

SEPIC converter with pulsating current at the output requires high current handling capability. Luo Converter is utilized because of its minimized ripple at current and voltage. However, the power transfer capability and output voltage of the converter gets affected due to the effects of parasitic elements.

To overcome this drawback, Luo converter is designed with lesser number of components. Thus, the gain of this converter can be increased by cascading its stages. Thus, its implements voltage lift concept and thus, enhances its voltage gain. This VL topology becomes more popular and is widely utilized in many electronic circuits. Similarly, to solve the existing divergence property of Luo converter, super lift converters have been introduced. This type of Luo converters exhibits high voltage gain than classic converters.

MPPT is highly essential to obtain maximized power from a PV. So many MPPT techniques like P&O [4], Inc [5], ANN [6], sliding mode [7] have been formulated to enhance the effectiveness of a PV system. However, during time insolation change, P&O exhibits drift problem. Hence, to overcome this, a numerous MPPT techniques were presented.

MPPT is highly essential to obtain maximized power from a PV. So many to enhance the efficiency of a PV system. Thus, an ACO along with PSO is proposed by [1].

Double closed loop based controllers have been formulated to obtain higher output voltage. Furthermore, four types Luo converters namely POLC, POLC with relift, NOLC with super lift concepts have been developed [2]. Thus, all these above said converters exhibits higher gain under both discontinuous and continuous mode of operation.

Drift tree MPPT topology with PSO has the ability to attain maximum power under all-weather condition. Thus, it tracks maximized power and also eliminates drift under varying weather condition. Hence, this work formulated an efficient positive output self-lift converter (POSLLC).

2. Methodology

Figure 1 represents the topology of the proposed system.

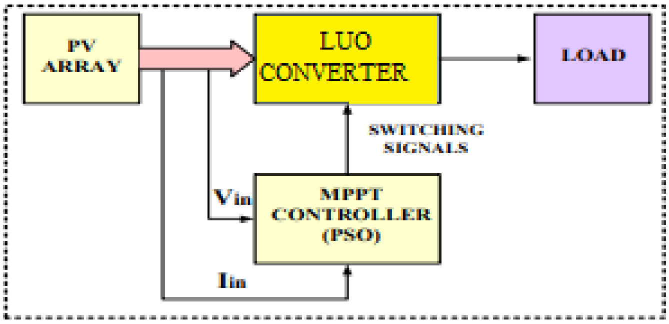

Figure 1. Topology of the proposed system

PV array modelling

PV array consists of PV calls. Thus, the model of a single PV cell is portrayed in figure 2.

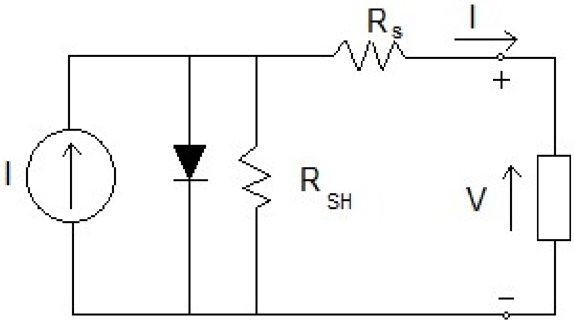

Figure 2. PV cell -Model

Thus, output current obtained from PV is given as

$$I = I_{sc} - I_d \quad (1)$$

However, the changes in the weather will directly affects the output of the PV system. Hence an active tracking system is mandatory to derive maximized power from PV.

MPPT

A MPPT is an electronic scheme which operates the PV modules so as to yield maximum power. Hence, to provide maximum power, the MPPT accordingly modifies the electrical operative point of the modules.

Thus, Various MPPT algorithms are accessible to enhance the performance of PV system. Among those, P&O and InC algorithms are commonly implemented in PV based systems because of its high efficiency and simplicity [11-15].

Thus the algorithm adopted in Perturbation & Observation technique is shown in Figure 3.

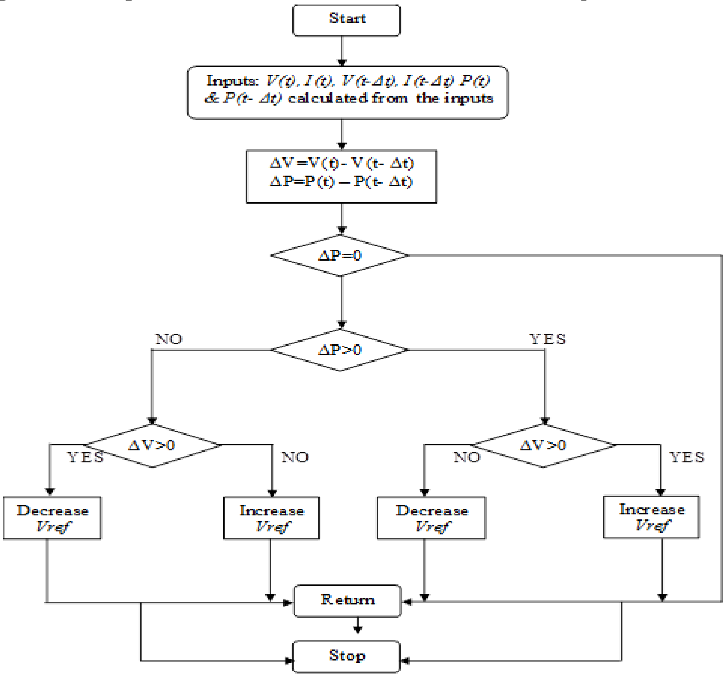

Figure 3. P&O Topology

Hence, to obtain maximum power, MPPT passed through a converter. Here, MPPT controls the output of the DC-DC converter by adjusting gating signals applied to the switch of the converter.

Design Of Converter

This proposed converter design is depicted in Fig. 4. It is the switched Luo converter transfer from unregulated source to regulated one. The converter will be more compact in size and exhibits higher power density. The lift in voltage will reduce the parasitic elements in the circuit [8-10].

In this converter, the conversion is from positive voltage to positive boosted voltage.

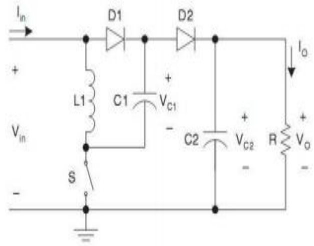

Fig 4(a): Elementary Circuit

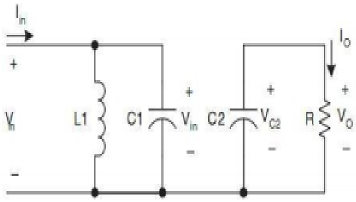

Fig 4(b): Mode1: SWITCH ON

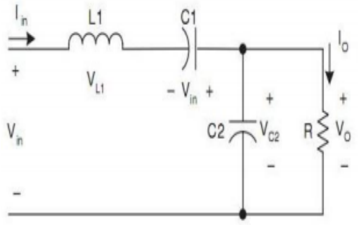

Fig 4(c): Mode2: SWITCH OFF

The basic circuit of a proposed topology and its mode of operations are depicted in figure 4a.

During 'OFF' condition, the voltage across the capacitor is V_{in} and hence, the current through inductor (L_1) increases.

The ripple voltage is:

$\Delta i_{L1} = \frac{V_{in}}{L_i} KT$ ………. (1)

$\Delta i_{L1} = (V_0 - 2V_{in})(1-k)\, T/L_1$

$V_0 = \frac{(2-k)}{1-k} V_{in}$ ………… (2)

Voltage transfer gain,

$$G = \frac{V_0}{V_{in}}$$

$G = \frac{2-k}{1-k}$ ……..... (3)

During 'ON' condition, input current is equal to (i_{L1}+ i_{C1}) and it becomes i_{L1} under 'OFF' condition.

Hence, average output current can be given as

$i_{in} = k(2-k)I_{L1}$ …………… (4)

Considering,

$\frac{V_{in}}{I_{in}} = \left(\frac{1-k}{2-k}\right)^2 \frac{V_0}{I_0} = \left(\frac{1-k}{2-k}\right)^2 R$ ………….. (5)

Then, ripple at the output voltage V_o can be represented as.

$\Delta V_0 = \frac{\Delta Q}{C_2} = \frac{I_0 kT}{C_2} = \frac{k}{fC_2}\frac{V_0}{R}$ …………… (7)

Hence, the variation at the output voltage is as follows.

$\varepsilon = \frac{\Delta v_0/2}{V_0} = \frac{k}{2RfC_2}$ ………….. (8)

Design Of Flc

FLC is widely implemented as a controller in recent years because of its effectiveness. Here 7 triangular MF have been implemented in this topology and is represented in fig. 5.

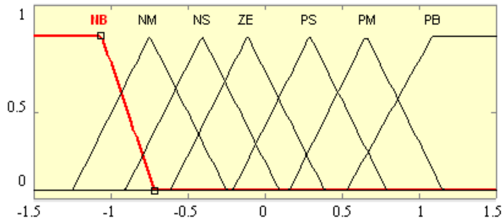

Figure 5.a. MF (e).

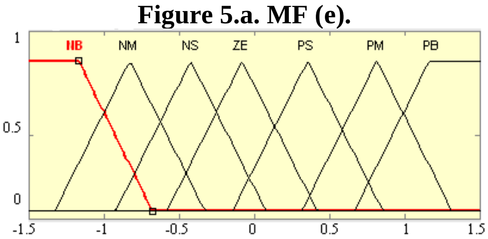

Figure 5.b. MF (Δe)

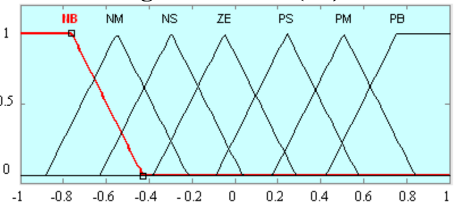

Figure 5.c. MF (Δu).

Rules form the basis for the fuzzy logic to obtain the fuzzy output. The defuzzification operation is performed by the center of gravity method

3. Results And Discussion

Thus, the performance analysis of the proposed converter with PV is discussed here. Table 1 displays the Specification of PV panel utilized in this work.

Table 1. Specification of PV panel

S.NO	PARAMETERS	SPECIFICATIONS
1	Maximum power (P)	500W
2	Irradiation	$1000W/M^2$
3	Cell temperature	25^oc

Thus the performance analysis of this proposed converter is examined with different controller (PI and fuzzy) is deliberated in figure 7 and 8. In this mode, the designed PV array delivers power at 1000 W/m^2 solar radiation.

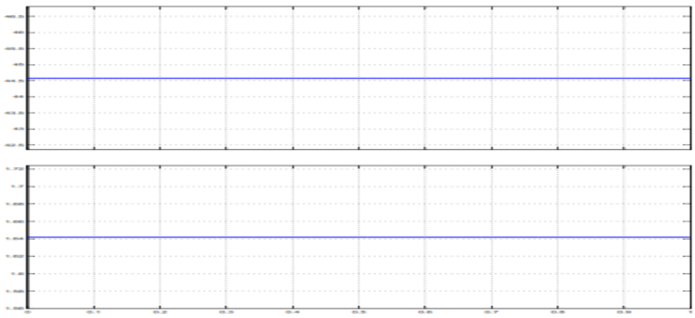

Figure 6. Voltage & current waveforms of PV array.

Figure 6 shows the input voltage and current of converter.

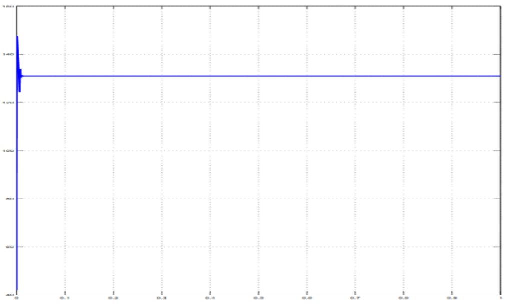

Figure 7. Output voltage of converter (PI controller).

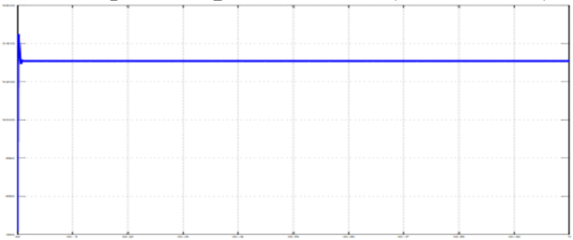

Figure 8. Output voltage of converter (Fuzzy controller)

From the results obtained, it is clearly observed that the variation in the input voltage have no effect on its output voltage. Because the controller exactly tracks the changes of an input voltage and maintains a constant output. Although two converters exhibits higher tracking ability, from the figure 8, it is obvious that the converter with FLC exhibits faster response to irradiation variation and thus reduces the ripple considerably.

Table 2 shows the comparison of simulation results of the controllers PI, fuzzy in terms of rise, settling time and overshoot.

Table 2. Performance Comparison

Controller	Rise time	Settling Time	overshoot
PI	5.95e-004	0.0084	12.49
Fuzzy	7.19e-004	0.0050	10.49

From the table 2, it is witnessed that the settling time of the PI controller is 0.0084 sec and is about 0.0050 sec for the FLC. Hence, it clearly states that the LUO converter with FLC is 50% faster than the existing control topology and hence it is more suitable for PV applications.

4. Conclusion

Thus, this work proposed a high gain DC converter with high power density for PV applications. Here, P&O topology is incorporated to extract maximised power from a PV system. FLC is tailored to maintain the converter output constantly. Finally, the performance of this proposed converter with FLC is examined with MATLAB/Simulink. Thus, results proven that with the implemented P&O topology, this converter achieves high gain even under the rapidly changing weather conditions.

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