PV BASED NEGATIVE OUTPUT SUPERLIFT LUO CONVERTER FOR GRID CONNECTED SYSTEM USING FUZZY LOGIC CONTROLLER

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ABSTRACT

Photovoltaic based power generation is employed to meet the increasing demand for energy by cleaner means. These PV cells when connected in series should have identical electrical characteristics. For this, converter circuits are employed. A negative output super lift Luo converter (NOSLC) aims at producing negative voltages of comparatively higher range than conventional types. The voltage ranges are obtained at a lower gain value of 0.7. The voltage building can be done using super lift technique where the output voltage rises in geometric progression which results in high voltage gain with reduced ripples. This makes it much suitable for connecting with grid systems. In this paper, fuzzy logic controller is used to obtain better voltage control. The performance of PV based NOSLC with and without fuzzy control have been simulated and compared using MATLAB/SIMULINK.

Key words: Fuzzy Logic Controller (FLC), High Gain Converter, PV Cell, Negative Output Super lift Luo Converter (NOSLC)

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1. INTRODUCTION

Amongst all the recently developed and the already available renewable resources, the most highly suggestible and the prevalent type is solar energy. This is because of its clean and pure generation of energy and the source abundance [1]. Though solar power generation has such advantages, on the other hand, there are a few disadvantages too. PV cells have very low voltage rating of about 0.5V per cell. In order to obtain higher output voltages, these PV cells have to be connected in series. Under such circumstances, the cells that have been connected in series should have identical electrical properties. Practically, maintenance of identical electrical properties is difficult. This would eventually result in ripples at the output voltage and current which thereby leads to reduced efficiency at the output [2]. A negative output super lift Luo converter basically boosts the input DC voltage in a geometric progression manner [3], [4]. The most important reason for adopting the super lift technique is that, much higher output voltages can be obtained with lesser gain values when compared to the other voltage building techniques for converters [5]. At the same time, the ripple content in the output voltage and current are reduced and relatively high output voltage gain is obtained.

2. OPERATION OF NOSLC

The circuit diagram of the NOSLC is shown in Fig.1. The circuit consists of a MOSFET switch S, Inductor L1, Diodes D1 and D2, Capacitors C1 and C2, and a load resistance R [4]. The design values for the negative output super lift Luo converter are derived based on the considerations [6] as follows: The input voltage (V_S) to the NOSLC is taken as 12V which is provided by a DC source. The output voltage (V_o) for the load R of 100 Ω is obtained as 36 V.

Figure 1 Circuit Diagram of NOSLC

The value for gain (K) is derived from,

$$\frac{V_o}{V_S} = \frac{1}{1 - K}$$

Thus,

$$1 - K = \frac{V_s}{V_o} = \frac{12}{36}$$

$$K = 1 - \frac{12}{36} = 0.666$$

$$K = 0.666$$

The operating frequency (f_s) of the NOSLC is 50 kHz.

The output current I_o is obtained from,

$$V_o = I_o R_o$$

$$I_o = \frac{V_o}{R_o} = \frac{36}{100} = 0.36A$$

Using $V_s I_s = V_o I_o$ for

$$I_s = \frac{V_o I_o}{V_s} = \frac{36 * 100}{12} = 1.08A$$

Let 5% be the ripple conduct in the output current.

$$\Delta i_{L1} = 5\% \text{ of } I_s$$

Thus,

$$\Delta i_{L1} = \frac{5}{100} * 1.08$$

$$\Delta i_{L1} = 0.054$$

Variation ratio of inductor current,

$$\xi_1 = \frac{\Delta i_{L1} / I_{L1}}{G_1} = \frac{K(1-K)}{G_1} \frac{R}{2fL_1}$$

$$\text{The gain, } G_1 = \frac{V_o}{V_s} = \frac{36}{12}$$

$$G_1 = 3$$

The value of inductor L_1 is calculated using the formula,

$$L_1 = \frac{K(1-K)}{G_1} \frac{R I_{L1}}{2f \Delta i_{L1} / 2}$$

$$L_1 = \frac{0.666(1-0.666)}{3} * \frac{100 * 1.08}{2 * 50000 * 0.054/2}$$

$$L_1 = 2.96592 * 10^{-3} H$$

Assuming 5% of ripple in output voltage, the value of ΔV_o is,

$$\Delta V_O = 5 \% \text{ of } V_O = \frac{5}{100} * 36 = 1.8 \text{ V}$$

Variation ratio of output voltage,

$$\varepsilon = \frac{\Delta V_O / 2}{V_O} = \frac{1 - K}{2\pi f C_2}$$

The expression of C_2 is given as,

$$C_2 = \frac{1 - K}{2\pi f} \frac{V_O}{\Delta V_O / 2} = \frac{(1 - 0.666) * 36}{50000\pi * 1.8}$$

The values of both the capacitances are equal and thus, $C_1 = C_2$

$$C_1 = 43.29 * 10^{-6}$$

Table 1 Design values for Negative output super lift luo converter

Parameters Name	Symbol	Values
Supply Voltage	V_S	12 V
Output Voltage	V_o	36 V
Inductor	L_1	$2.96592 * 10^{-3} \text{ H}$
Capacitor	C_1	$43.29 * 10^{-6} \text{ F}$
Capacitor	C_2	$43.29 * 10^{-6} \text{ F}$
Load Resistance	R	100Ω
Duty Cycle	K	0.666

3. PV SUBSYSTEM

As stated earlier, large number of PV cells are connected in series in order to produce higher magnitudes of output voltage [7]. For this paper, the PV cells are arranged in such a way that it produces open circuit voltage of 12V and short circuit current of 10.62 A as derived in the design procedure. The PV subsystem is designed as follows:

Figure 2 Circuit Diagram of NOSLC

In Fig.2 Three subsystems containing such solar cells are connected in series. This arrangement produces an output of rating 4V, 10.62A for each subsystem. The signals from the voltage and current sensor are converted using a controlled current source. This system is followed by a filter circuit. Thus, the total voltage produced by this PV subsystem is 12V and current is 10.62A which is shown in Fig.3. This is fed as input to the NOSLC.

Figure 3 Solar Subsystem

4. OPEN LOOP CONFIGURATION

Initially, the open loop configuration for the proposed PV based NOSLC has been designed according to the derived circuit parameter values. The model for the open loop system is as shown in Fig.4.

Figure 4 Circuit diagram for open loop

When this PV fed NOSLC is operated at 12V input supply and switching frequency of 50 kHz, the output voltage obtained is about -36.02V. The simulated output voltage is shown as below in Fig.5.,

Figure 5 Output voltage for PV fed open loop

From this Fig.5, we can infer that initially there are oscillations and ripples displacing the output voltage for about 6V from the required output voltage and stabilizes further. This major disadvantage of uncontrolled voltage of open loop system demands for a better control technique. Thus, closed loop for NOSLC is designed.

5. CLOSED LOOP CONFIGURATION

Closed loop provides voltage control over the generated output due to the implementation of feedback system provided as the switching gate pulse to the MOSFET. This ensures better performance of the converter by reduced ripples in the output. The MATLAB simulation for the closed loop voltage control for PV fed NOSLC is given in Fig.6.

Figure 6 Circuit diagram for closed loop with gain

From the scope output of MATLAB simulation, we can observe that the transient instability and the ripples in the output voltage have been reduced comparatively to the open loop type.

Figure 7 Output voltage for PV fed closed loop

6. FUZZY LOGIC CONTROL

To obtain further precise and accurate output values, fuzzy logic (FL) control is employed. The theory of fuzzy sets relates to classes of objects with unsharp and imprecise boundaries in which membership is a matter of degree [8]. The FL involves variables, which are much linguistic rather than numerical and thus exploits the tolerance for imprecision. This fuzzy controller adapts to varying operating points and controls the output voltage of the NOSLC using Mamdani style inference system. Duty cycle(k) is obtained as the output variable, when the error value (e) is fed to controller. This paper aims at controlling the output voltage of the PV based NOSLC and to provide better output performances when compared to that of general closed loop voltage control [9]. The input variable is divided into nine groups as follows: NS (Negative Small), NM (Negative Medium), NB (Negative Big) and NBB (Negative Big Big), PBB (Positive Big Big), PB (Positive Big), PM (Positive Medium), PS (Positive Small), Z (Zero). Similarly, the output variable is also divided into nine groups with the same names. A set of rules has been developed and the output has been determined using fuzzy controller, with these input variables and output variables.[10].

Figure 8 Circuit diagram for fuzzy control

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The membership function plots for both input and output variables are depicted as below:

Figure 9 Ruler view: Membership function plot of error[e]

Figure 10 Ruler view: Membership function plot of gain [K]

Table 2 FIS Editor Values

V_{ref}	V_o	Error	K	FIS Editor values
36	24	12	0.5	0.5
36	25	11	0.52	0.516
36	26	10	0.5384	0.531
36	27	9	0.5555	0.55
36	28	8	0.5714	0.569
36	29	7	0.5862	0.584
36	30	6	0.6	0.6
36	31	5	0.6129	0.602
36	32	4	0.625	0.606
36	33	3	0.6363	0.614
36	34	2	0.647	0.635
36	35	1	0.6571	0.652
36	36	0	0.6666	0.669

Using these fuzzy rules, the output obtained from simulating is shown in Fig.11.

Figure 11 Output voltage for PV based fuzzy control

7. CONCLUSIONS

This paper has implemented the design and testing of the NOSLC with open loop and closed loop. Two closed loop method such as voltage control and fuzzy logic control effectively done and it is simulated in MATLAB environment. In this article for the various value of the duty cycle the output voltage measured with minimized error. The K values change from 0.5 to 0.6 and the voltage at the load side varied from 24 V to 36 V for the supply voltage 12 V. Negative output super lift Luo converter performance with fuzzy logic control have reduced the ripples, transient instability and faster response to produce the output voltage with improved gain and less losses. The simulation results of output voltage for fuzzy logic control is obtained and verified.

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