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Energy Procedia 117 (2017) 651–657

Energy Procedia

www.elsevier.com/locate/procedia

1st International Conference on Power Engineering, Computing and Control, PECCON-2017, 2-4 March 2017, VIT University, Chennai Campus

Design of an Efficient Positive Output Self-Lift and Negative Output Self-Lift Luo Converters using Drift Free Technique for Photovoltaic Applications

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Abstract

DC-DC converter plays a vital role in recent years due to its development in generation of electrical power by using renewable energy resources such as solar, wind etc. Fundamental DC-DC converter with Maximum Power Point Tracking (MPPT) technique in solar applications gives poor output power density due to the changeable sunlight and weather condition. In this work a Positive Output Self-Lift Luo Converter (POSLLC) and a Negative Output Self-Lift Luo Converter (NOSLLC) with Drift Free MPPT Technique has been designed and simulated using MATLAB/Simulink Software. Results demonstrate that the Drift Free MPPT Technique along with POSLLC and NOSLLC has the ability to track maximum power even in fast changing weather conditions. Further, the output voltage of a POSLLC and a NOSLLC are ten times greater than that of the input given to the converters.

Peer-review under responsibility of the scientific committee of the 1st International Conference on Power Engineering, Computing and CONtrol.

Keywords: Self-Lift Luo Converters; Maximum Power Point Tracking; Drift Free Technique; High Power Output.

1. Introduction

Nowadays, the depletion of fossil fuel reservoirs and increase in environmental issues gains more affinity towards renewable energy power generation [1]. Out of many renewable energy resources, solar is predominant due to the abundant availability in nature. Solar energy power generation is advantageous because it is omnipresent,

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Peer-review under responsibility of the scientific committee of the 1st International Conference on Power Engineering, Computing and CONtrol.
10.1016/j.egypro.2017.05.167

environment friendly, no rotating parts in construction. Solar energy power generation has obvious drawbacks such as poor output power delivery, unstable output voltage etc. due to the changeable sunlight and weather condition [2]. Conventional converters such as Buck, Boost and Buck-Boost cannot be used to track maximum power in changeable weather conditions. Further, there are many topologies of DC-DC converters; the Self-Lift Luo Converter is very popular due to its high voltage transfer gain [3].

Nomenclature

k	duty cycle
B	switch repeating period
Z_N	normalized load

Maximum power point tracking is one of the vital functions that should be included in every Photovoltaic (PV) cell. The MPPT techniques such as perturb and observe (P&O) [4], incremental conductance [5], neural network [6], sliding mode [7] have been developed to increase the efficiency of the PV system. P&O technique has drift problem due to time insolation change. Drift free MPPT technique were introduced in order to overcome the problem of the drift effect [4].

Sunareswaran et al. (2016) [1] have integrated an ant colony optimization (ACO) and P&O method to yield faster and efficient convergence under partially shaded conditions. Further, the authors have found that the ant colony optimatimization with traditional P&O method tracks maximum power and extracts more energy from the PV system. Shan *et al.* (2012) [2] have designed a solar panel power system using the voltage-Lift Luo Converter with a closed-loop control. Further, the authors have implemented a double closed-loop control to obtain the desired voltage. He and Luo (2005) [3] have analyzed four different types of Luo converters such as positive output self-lift Luo converter, positive output re-lift Luo converter, negative output self-lift Luo converter and the positive output super-lift Luo converter. Further, the authors have derived the voltage transfer gains and boundary conditions for both continuous and discontinuous modes of operation of all the four types of Luo converters.

Killi et al. (2015) [4] have proposed drift free Perturb and Observe (P&O) MPPT algorithm to track the maximum power in varying weather conditions. Further, the authors have observed that the drift free P&O MPPT algorithm tracks the maximum power more accurately and avoids the drift in fast changing weather conditions.

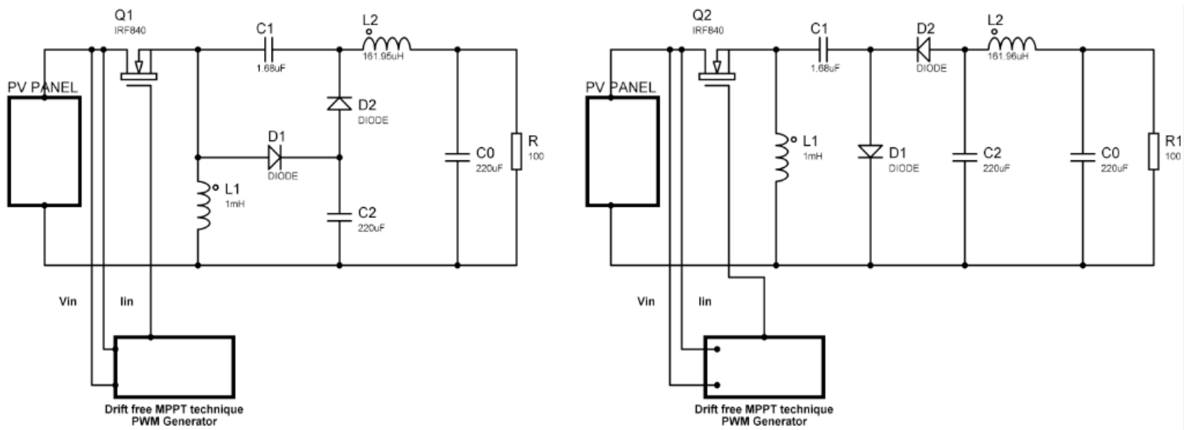
Luo (2008) [8] has investigated the effect of capacitor voltage drops of Super-Lift Luo-Converters and modified the variations on output voltage. Further, the author has compared Voltage-Lift converters have very high voltage transfer gains than the fundamental converters.

The objective of this work is to design and develop an efficient Positive Output Self-Lift Luo Converter (POSLLC) and Negative Output Self-Lift Luo Converter (NOSLLC) using Drift Free MPPT Technique for Photovoltaic applications.

2. Methodology

2.1. Positive Output Self-Lift Luo Converter (POSLLC) and Negative Output Self-Lift Luo Converter (NOSLLC)

Fig.1. shows the circuit diagram of a Positive Output Self-Lift Luo converter and a Negative Output Self-Lift Luo converter. The input of the converters is sourced by PV panels and the output of the converters is connected to a resistive load. The input of the converters is changed by varying an irradiance (W/m^2) values and the different output power values have been obtained for both POSLLC and NOSLLC. Capacitor C_0 in figure 1 is an output capacitor; it transfers the energy from the inductor L_2 to the output side. The average voltage V_c across the capacitor C0 is equal to the output load voltage V_0. The decrease in load resistance, the capacitor value C_1 or the switching frequency will decrease the voltage transfer gain (VTG) [3], [10].



(a) (b)

Fig. 1. (a) Circuit diagram of a POSLLC and; (b) NOSLLC.

The circuit parameters for a POSLL converter and a NOSLL converter are presented in the Table 1. The POSLL converter with resistive load of 100Ω, when fed by 24V DC from solar panel gives the output voltage of 230.9V. The NOSLL converter with resistive load of 100Ω, when fed by 24V DC from solar panel gives the output voltage of -240V.

Table 1.Circuit Parameters.

Parameter's Name	**Symbol**	**POSLL converter Value**	**NOSLL converter Value**
Input Voltage	V_{in}	24V	24V
Output Voltage	V_o	230.9V	-240V
Inductors	L_1, L_2	1mH,161.95uH	1mH,161.95uH
Capacitors	C_1, C_2	1.68uF,220uF	1.68uF,220uF
Nominal Switching Frequency	F_s	50KHz	50KHz
Load Resistance	R	100Ω	100Ω

The percentage efficiency (%η) of the POSLL Efficiency can be expressed as [3], [10]

$$\%\eta = \frac{t_1 - kT}{(1-k)T} \times 100 \tag{1}$$

where k is the duty cycle and T is the switch repeating period $\left(T = 1/f\right)$. For the normalized load Z_N of the NOSLL converter, the percentage efficiency (%η) can be expressed as [3], [10]

$$\%\eta = \frac{1 + \sqrt{1 + 2\lambda_1 Z_N k^2}}{\lambda_1 Z_N k(1-k)} \times 100 \tag{2}$$

where k is the duty cycle and λ_1 is the ratio between actual and ideal Voltage Transfer Gain $\left(VTG\right)$.

2.2. Drift Avoidance Modified P&O MPPT Technique

Fig.2. shows the flowchart of drift free P&O MPPT technique. In Fundamental P&O MPPT Technique, the drift issues are vigorous in case of rapid change in insolation values. It is seen that the parameters $V(p)$, $I(p)$ and $P(p)$ are PV panel voltage, current and the power respectively. The operating parameters such as dV, dI and dP represents the change in voltage, current and power. For a single insolation the parameters dV and dI can never have the same sign. Both dV and dI will be positive when there is an increase in insolation. An increase in insolation can be detected by incorporating dI into an algorithm loop and the drift problem can also be eliminated by prompting the operating point nearer to the maximum power point [4].

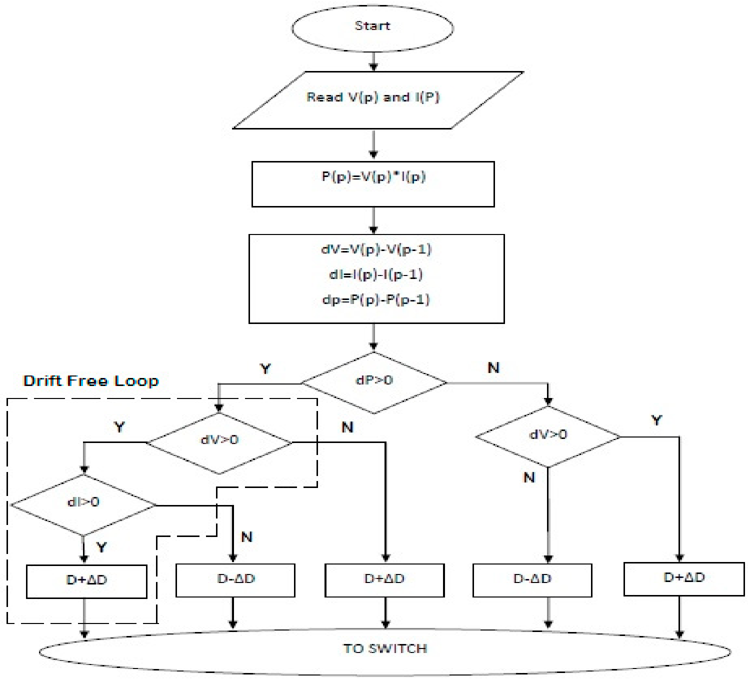
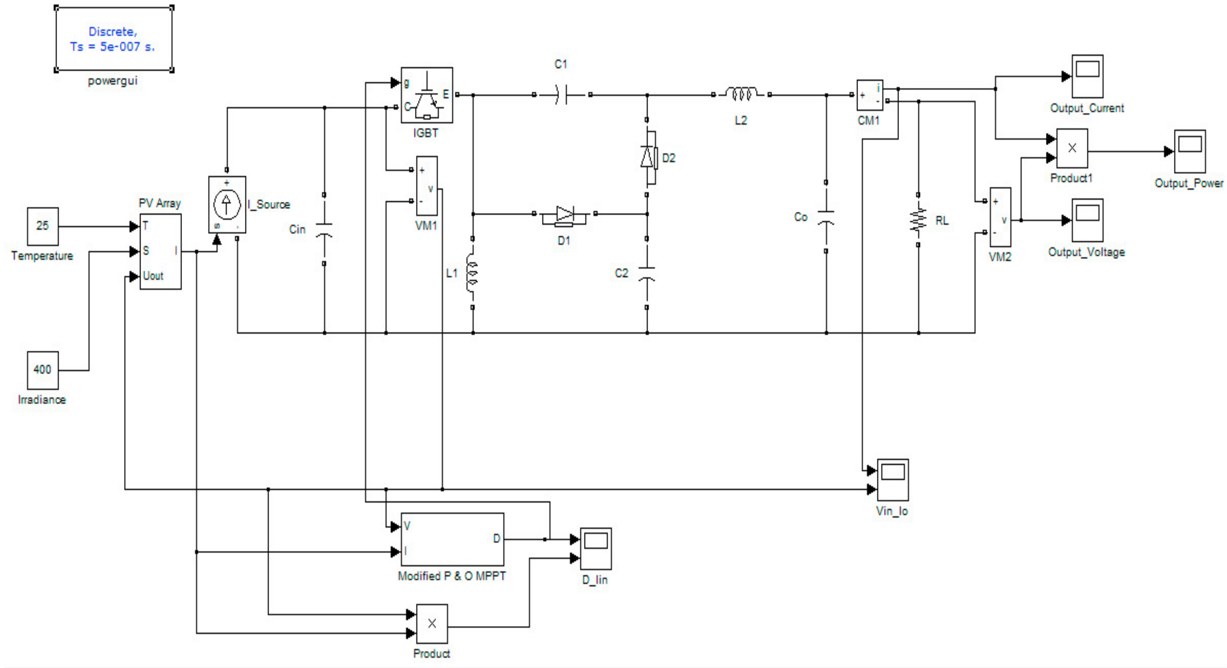


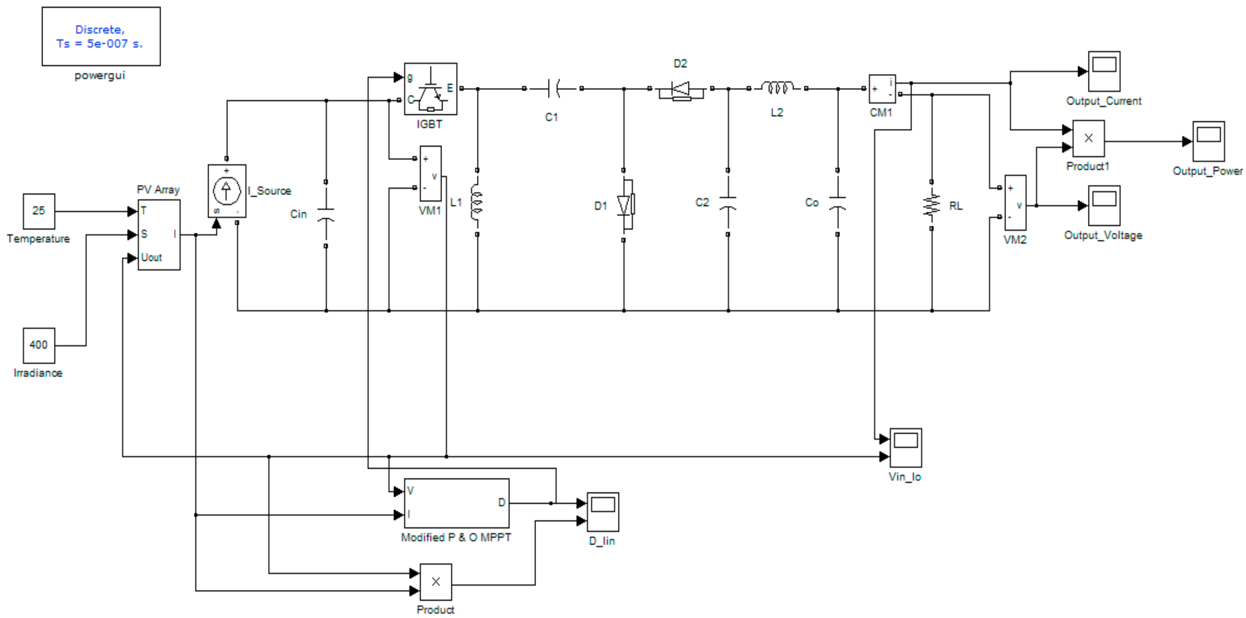
Fig. 2. Work flow of drift free P&O MPPT technique

3. Results and Discussion

Figure 3 show the MATLAB/Simulink model of the POSLL and NOSLL Converters. The PV system is modeled using the standard circuit parameters. Figure 4 show the input voltage, output voltage, output current and output power of POSLL converter with respect to time. It is seen that the average MPP voltage is 24v, corresponding to the various irradiance level. Further, it is observed that the presented POSLL converter gives positive output voltage of 240v and positive output current of 2.4A for a 100 ohm resistive load connected at the output side. Further, it is found that the output voltage of POSLL converter is ten times greater than the input voltage. The maximum power is tracked using drift free MPPT technique at changing input values. Figure 5 show the input voltage, output voltage, output current and output power of NOSLL converter with respect to time. It is found that the presented NOSLL converter produces negative output voltage of -240v and negative output current of -2.4A for a 100 ohm resistive load connected at the output side. Further, it is observed that the output voltage of NOSLL converter is ten times greater than the input voltage which is in negative. The output current of the NOSLL converter is also negative and by multiplying both voltage and current value gives positive output power.



(a)



(b)

Fig. 3. MATLAB/Simulink Model of (a) POSLL Converter; (b) NOSLL Converter

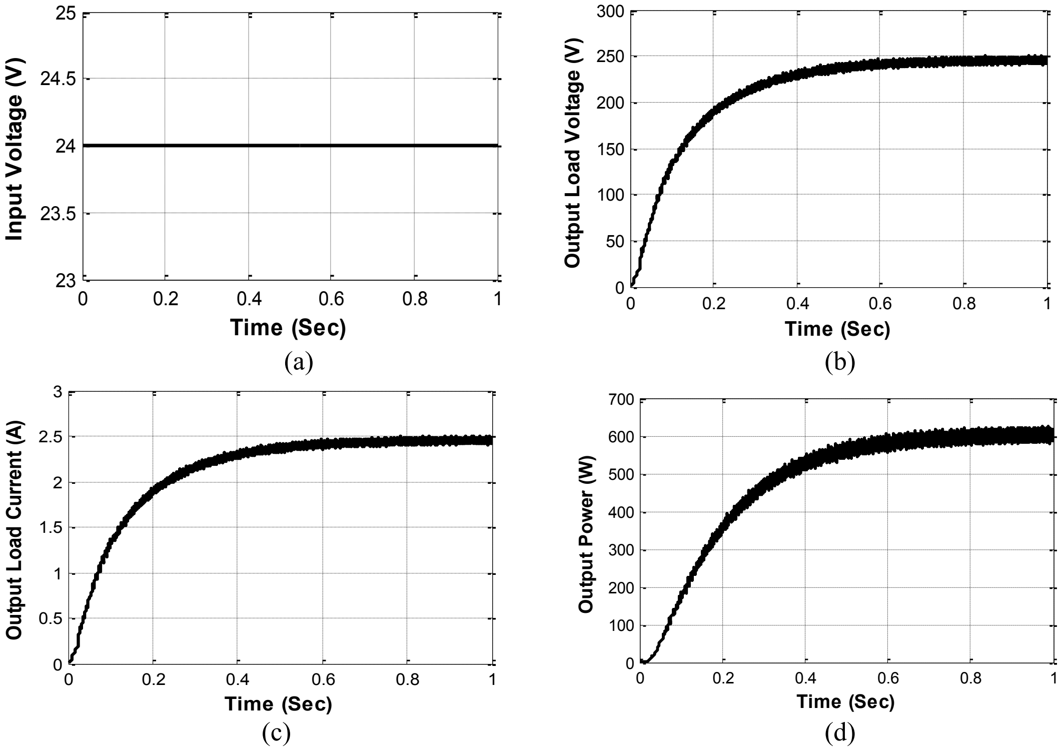


Fig. 4. POSLL converter (a) Input Voltage; (b) Output Voltage; (c) Output Current; (d) Output Power

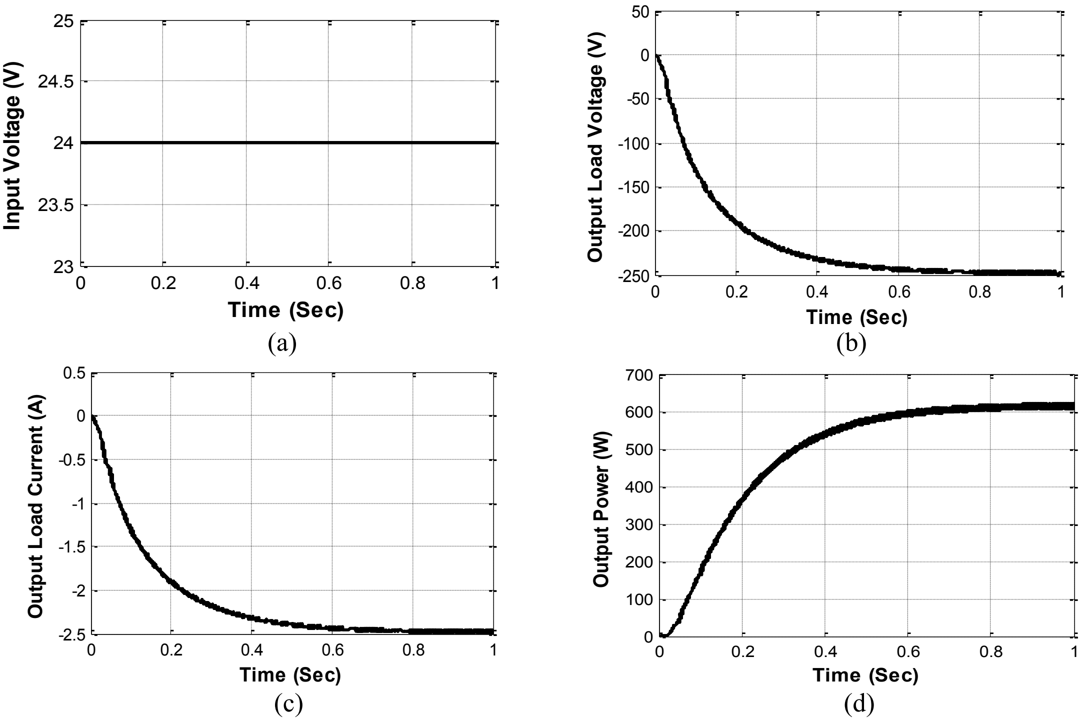


Fig. 5. NOSLL converter (a) Input Voltage; (b) Output Voltage; (c) Output Current; (d) Output Power

Table 2. Output Power of POSLLC and NOSLLC at different irradiance values.

Irradiance (W/m^2)	Output Power of POSLLC (W)	Output Power of NOSLLC (W)
100	148	151
200	298	301
300	452	455
400	617	620

The input of the converters is changed by varying an irradiance (W/m^2) values and the different output power values have been obtained for both POSLLC and NOSLLC and is presented in the Table 2. An increase in irradiance of PV panel from 100 W/m^2 to 400 W/m^2 increases the output power of both POSLLC and NOSLLC. It is seen that the modified drift issue free P&O technique has no drift when compared to the fundamental P&O Technique. The presented work exhibits an efficiency around 91.2% under 100-watt of load.

4. Conclusion

The DC-DC conversion technique has been developed to accomplish high power density, high efficiency etc. Among, the several DC-DC converter topologies such as Buck-Boost converter, Cuk converter, single-ended primary-inductance converter (SEPIC) etc.; the Self-Lift Luo Converter is very popular due to its high voltage transfer gain. Conventional DC-DC converter with Maximum Power Point Tracking (MPPT) technique in solar applications gives poor output power density due to the changeable sunlight and weather condition. In this work a Positive Output Self-Lift Luo Converter (POSLLC) and a Negative Output Self-Lift Luo Converter (NOSLLC) with Drift Avoidance MPPT Technique has been designed and simulated for fast changing irradiance of input PV panel using MATLAB/Simulink Software. Simulation results demonstrate that the Drift Free MPPT Technique along with POSLLC and NOSLLC has ability to track maximum power even in fast changing weather conditions. Further, it is seen that the output power of a POSLLC and a NOSLLC increases with increase in irradiance of PV panel and the output voltage is ten times greater than the input of the converters. The proposed design is of highly efficient and accurate tracking of maximum power in changing weather conditions.

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