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Performance Of A Photovoltaic Luo-Converter With Multiple-Lift Push-Pull Switched Capacitors

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Abstract
The performance of a Multiple-Lift Push-Pull Switched-Capacitor Luo-Converter for Photovoltaic (PV) applications is investigated in this paper. Further, the two different control algorithms namely PI and Fuzzy algorithms are adopted to maintain constant output voltage. To track maximum power, the drift avoidance Perturb & Observe (P&O) Maximum Power Point Tracking (MPPT) technique has been used. The simulation output justifies that the better steady state and high settling time in the output voltage is achieved with Multiple-Lift Push-Pull Switched-Capacitor Luo (PPSCL) Converter with fuzzy control when compared to Multiple-Lift PPSCL with PI controlled converter.

Keywords: Luo Converters; Photovoltaic; closed loop control; fuzzy control; maximum power point tracking.

1. INTRODUCTION

Due to increase in use of non-conventional energy sources, the importance of DC/DC converters has seen a surge [1]. One of the influential DC/DC converters is the Buck Boost Converter [2],[3]. This converter can be applied for Photovoltaic and Electric Vehicle Applications [4].
Switched Capacitors are effective in filling Integrated Circuits with Higher order filters [5]. Employing Switched Capacitors along with Luo Converters will pave way for development of converters with HIGH POWER DENSITY AND SMALL SIZE. Voltage lift techniques are been extensively used in Luo Converters and here multiple lift method is used for analysis of the converter. The word 'Positive Output' employs voltage boosting from positive to positive voltages by adopting voltage - lift technique. It is a first quadrant Operations and large voltage amplifications can be obtained[6-8].
Fang Lin Luo had proposed the six stages of the series of Positive output multiple-lift PPSC DC/DC Luo Converters [9-11]. They are Two-Lift Circuit (as a essential circuit), Four-Lift Circuit, and Eight-Lift Circuit in main series and Three-Lift Circuit, Six-Lift Circuit, Twelve-Lift Circuit in auxiliary sequence, correspondingly. Further, the author had concluded that the simulation and experimental results confirmed the design and calculations. These converters are small in size and ensure with high power density and voltage transfer gain which will be suitable for many industrial applications[12].

To have a control over the output voltage obtained, the necessity of controllers arises. Controllers with high accuracy and low disturbances need to be selected so that it does not affect the converters performance in a major way[13]. The objectives to be achieved while using Controllers are Less peak overshoot, Less Peak Time and Less settling time [14-17].

Fuzzy Logic Controller is used to realize the desired output. Common examples like control of room temperature with air conditioner, traffic lights, and anti-braking systems in vehicles use Fuzzy logic for their control operation[18]. The Fuzzy control rules, mostly IF-THEN rules are employed in controller design. The blocks of Fuzzy Controller are Preprocessing, Fuzzification, Rule base, Inference engine, Defuzzication and Post processing. Fuzzification is correlation of input data and Fuzzy control rules to check the data matches or not. Choice of Fuzzy rules is derived from the characteristics of the controller [19].

The objective of this work is to analyze the behavior of Multiple-Lift PPSCL-Converter for Photovoltaic Applications.

2. METHODOLOGY FOR MULTIPLE-LIFT PPSCL-CONVERTER

The circuit diagram for Multiple-Lift PPSCL-Converter is shown in Figure 1. It is seen that two different MOSFET switches M_1 & M_2, four Diodes D_1, D_2, D_3 & D_4, four capacitors C_1, C_2, C_3 & C_4 are used. Further, the four different feedbacks are taken; voltage and current feedbacks from the output side and two feedbacks namely PV voltage and PV current at the input side. The PV panel is connected as an input source and the resistor (R-Load) is connected as a output load. Further, the two different closed loop control algorithms namely PI and Fuzzy algorithms are adopted to retain the stable output voltage since the input source varies with change in temperature and solar irradiance. Also, the drift free P & O MPPT method is adopted to track maximum power at the input source side [20-21]. Figure 2 shows the flowchart for drift free P & O MPPT technique.

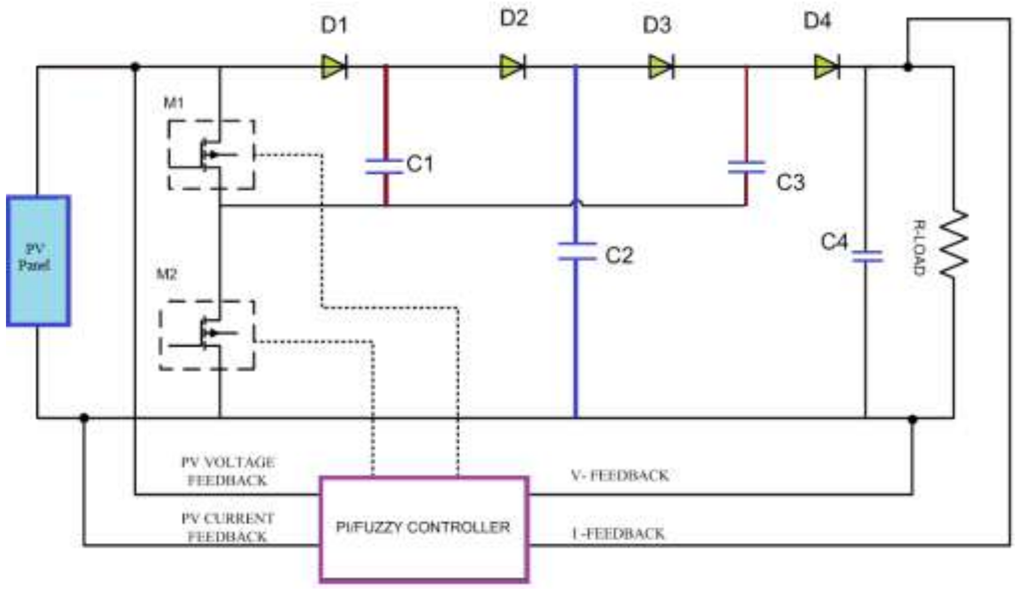

Figure 1. Circuit diagram for Multiple-Lift Push-Pull Switched-Capacitor Luo-Converter

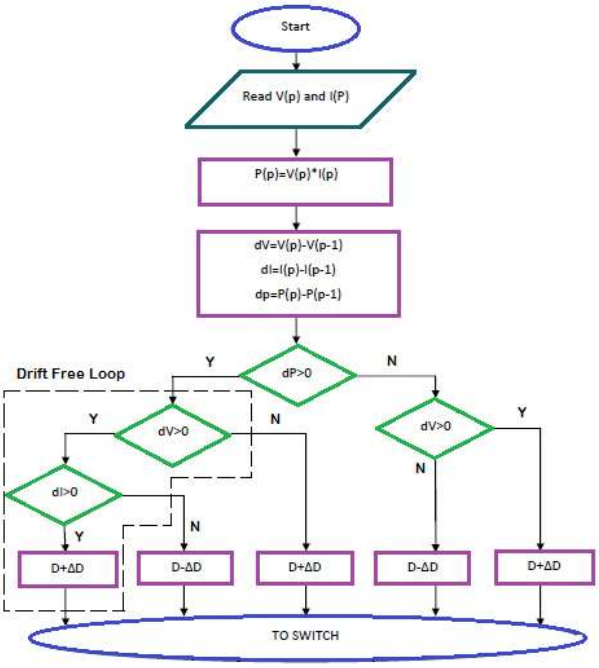

Figure 2. Flowchart for Drift - Free P&O MPPT technique

2.1. PI -Closed loop Controller

The proportional integral (PI) controller was proposed for providing control over the deviation of input voltage (V_i). The major aspect of this controller is to retain the steady state error as zero with respect to step change. The combination of P and I Controller is given by the Equation (1),

$$u = K_p \left(e + \frac{1}{\tau_N} \int e d\tau \right) \quad (1)$$

Where, error is expressed as 'e' is the, 'K_P 'is the Proportional gain, 'K_i' is denoting Integral gain, τ_1 or τ_N is the Reset / integration time. To achieve the desired performance, the Controller gain values are set. The K_i value decreases the rise time while increasing the settling time. It also removes the steady state error.

2.2. Closed loop Fuzzy Logic Controller

The Fuzzy Logic Controller (FLC) deals with fuzzy sets and functions with both linguistic language and Boolean logic. The FLC can perform better than many traditional controllers. The FLC consists of four elements. They are Fuzzifier, Knowledge Base, Inference Engine, and Defuzzifier. It's basically the MISO system.

The formation of rules is based on 'e', the rate of change of error 'ΔE' and change in the control signal 'ΔU'. At the instant of sampling k the error is given by Equation (2).

$$e(k) = r(k) - y(k) \quad (2)$$

And the derivative of error is $d_e(t)$ / dt in continuous time. For discrete time instant k is shown as in Equation (3)

$$\Delta e(k) = [e(k) - e(k-1)] \quad (3)$$

In FLC, seven triangular membership functions were used to frame 49 rules. The defuzzification technique used in this is the centroid type. The Fuzzy controller's step response lowers peak overshoot, rise time, and settling time. Table 1 represents the circuit

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parameters of Multiple-Lift (PPSCL) converter, Where V_R is the reference output voltage, V_L is the load voltage. If the error becomes zero, the desired output is regulated..

Table 1. Circuit Parameters of Multiple-Lift PPSCL converter

Parameters	Values of Multiple-Lift PPSCL Converter
Input Voltage (V_{in})	16V
Output Voltage(V_o)	42V
Capacitors (uF) (C_1, C_2, C_3 & C_4)	1000uF
Load Resistance (Ω) (R_L)	50Ω

3. SIMULATION ANALYSIS OF MULTIPLE LIFT PPSCL

The Output voltage of Multiple Lift PPSCL converter integrated with PI control is as shown in Figure 3. It is seen that the load resistor R_L = 50Ω is connected at the load side and the input PV panel is connected at the input source side. Further, the temperature and sunlight intensity is varied at the input side and output voltage is maintained constant to a desired value. The output voltage of Multiple Lift PPSCL converter integrated with PI control is maintained at 26 V. Also, the output power of the same converter is 26W shown in the Figure 4. Figure 5 shows the Input electrical and physical parameters of Multiple Lift PPSCL converter integrated with PI control. The physical parameters namely temperature is 25^o and the sunlight intensity is 500.

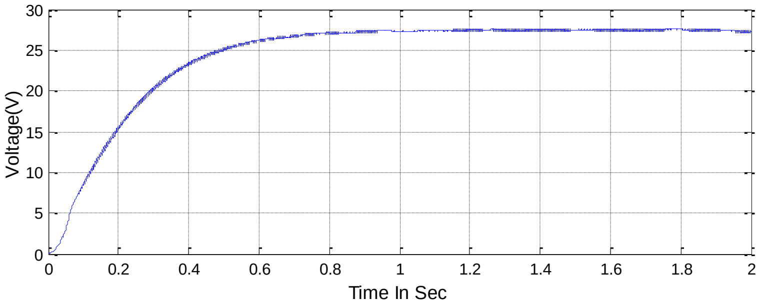

Figure 3. Output voltage of Multiple Lift PPSCL converter with PI control

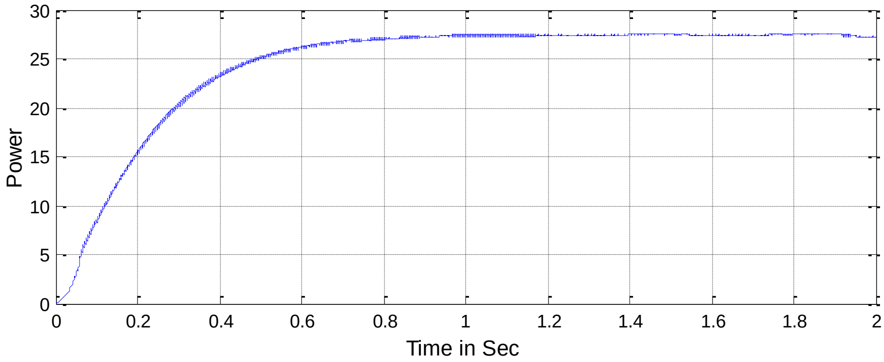

Figure 4. Output power of Multiple Lift PPSCL converter with PI control

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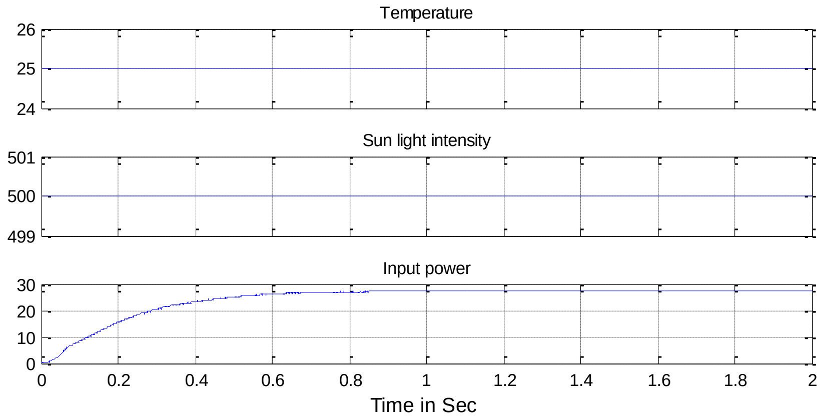

Figure 5. Input electrical and physical parameters of Multiple Lift PPSCL converter with PI control

Figure 6 shows the Output voltage of Multiple Lift PPSCL converter integrated with FLC. It is seen that the same load resistor $R_L = 50\Omega$ is connected at the load side and the input PV panel is connected at the input source side. Further, the temperature and sunlight intensity is varied at the input side and output voltage is maintained constant to a desired value using closed loop fuzzy controller. The output voltage of Multiple Lift PPSCL converter integrated with PI control is maintained at 42 V. Also, the output power of the Multiple Lift PPSCL converter with integrated fuzzy controller is shown in the figure 7. Figure 7 and 8 shows the Input electrical and physical parameters of Multiple Lift PPSCL converter integrated with fuzzy controller. The physical parameters namely temperature is maintained at same 25^{o} whereas the sunlight intensity is changed to 700 and the desired output voltage value of 42V is maintained [23, 24].

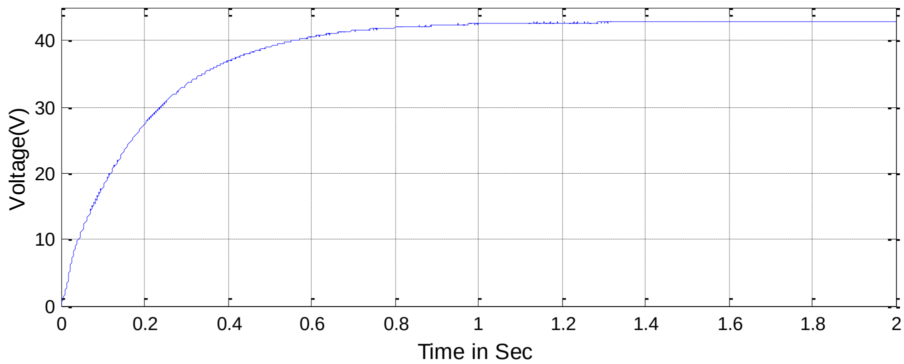

Figure 6. Output voltage of Multiple Lift PPSCL converter with Fuzzy control

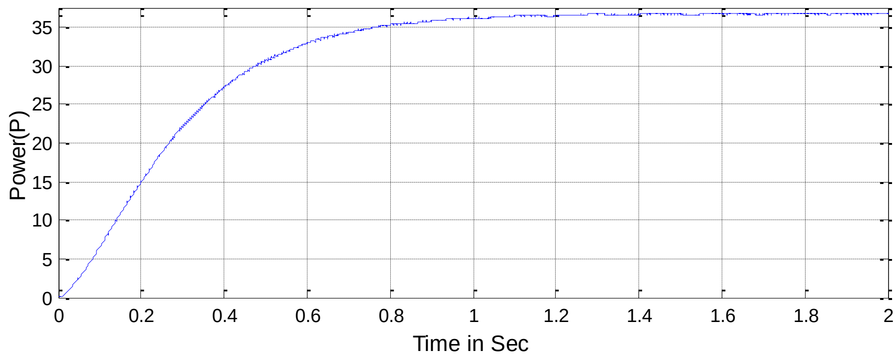

Figure 7. Output power of Multiple Lift PPSCL converter with Fuzzy control

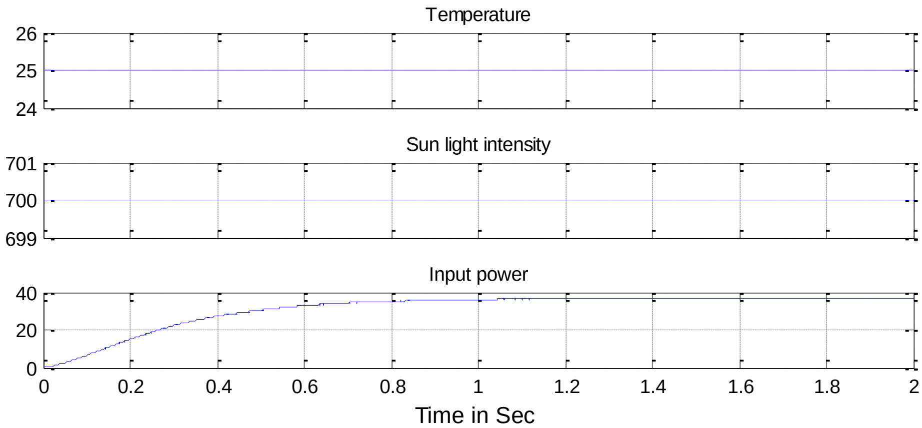

Figure 8. Input electrical and physical parameters of Multiple Lift PPSCL converter with Fuzzy control

While comparing the Multiple-Lift PPSCL converter integrated with PI control and fuzzy control, the Multiple-Lift PPSCL converter with fuzzy controller has better steady state value [20,21]. However, the settling time of Multiple-Lift PPSCL converter with fuzzy controller is quite high; the better steady state helps the converter to eliminate fluctuations at the output values.

4. CONCLUSION

An advanced version of Buck Boost Converter is a Luo-Converter which eliminates fluctuations in Output and improves Output Voltage levels. In this work, the performance of Multiple-Lift Push-Pull Switched-Capacitor Luo-Converter integrated with closed loop PI and Fuzzy control algorithm are analyzed for renewable applications. Further, the drift avoidance Perturb & Observe (P&O) Maximum Power Point Tracking (MPPT) is adopted to track maximum power point at the input source side. Also, the simulation work was carried out using MATLAB Simulink and the simulation results were obtained to analyze the performance of the Multiple-Lift PPSCL Converter. Results demonstrates that the output voltage of the Multiple-Lift PPSCL Converter with fuzzy control was better steady state when compared to Multiple-Lift PPSCL Converter with PI control. Also, the settling time of Multiple-Lift PPSCL Converter integrated with PI control is lesser when compared to Multiple-Lift PPSCL Converter with fuzzy control.

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