International Journal of Research, Science, Technology & Management
ISSN Online: 2455-2240, Volume 19 Issue III, June 2020

APPLICATION OF POSITIVE OUTPUT TRIPLE LIFT LUO CONVERTER FOR PHOTO VOLTAIC SYSTEM USING FUZZY LOGIC CONTROLLER

Shiva Raje, Kamli Maithil

ABSTRACT

The positive output triple lift Luo converter is a newly developed advanced DC-DC converter. The object of this paper is to design and analyze a Fuzzy Logic Controller for positive output triple lift Luo converter (POTLLC). Fuzzy logic is recently increasing emphasis in process control applications. Properties of the proposed controllers are: 1) robustness around the operating point, 2) good performance of transient responses under varying loading conditions and/or input voltage, and 3) invariant dynamic performance in the presence of varying operating conditions. The positive output triple lift Luo converter performs the voltage conversion from positive source voltage to positive load voltage. The simulation model of the positive output triple lift Luo converter with its control circuit was developed in Matlab/Simulink.

Key words—*pv cells, triple lift converter, voltage lift technique, Arithmetic/Geometric progression, Voltage Transfer Gain, Fuzzy logic controller.*

1. INTRODUCTION

DC-DC switching converters are a traditional benchmark for testing nonlinear controllers, due to their inherent nonlinear characteristics. After the pioneering studies of Middle brock [1], a great deal of research has been directed at developing techniques for averaged modeling of different classes of switching converters [2] and for an automatic generation of the averaged models [3]. The motivation of such studies was the selection of continuous models as simple as possible, but adequate to capture all the main features of the switching converters in terms of stability, dynamic characteristics and effectiveness for designing closed loop regulators. A large number of possible nonlinear controllers have been proposed: among others sliding mode control strategies [4], nonlinear PI controllers based on the method of extended linearization [5] and nonlinear H_∞, controllers [6]. A recent interesting paper [7] presents the results of an experimental comparison of five control algorithms on a boost converter: linear averaged controller, feedback linearizing controller, passivity-based controller, sliding mode controller, sliding mode plus passivity-based controller are compared along with their adaptive versions in order to cope with the parameter uncertainty due to a load resistance change. Advantages and drawbacks of the proposed control strategies are tested under a fixed output voltage with load variations.

All the quoted literature comply with the more general problem of applying nonlinear control techniques to complex real world technical problems such classical approach has undoubtedly the advantage of designing analytical controllers and to evaluate quantitatively their stability bounds. The major problem of the classical approach remains that as the complexity of system increases, our ability to make precise and yet significant statements about its behavior diminishes [8].

In our opinion the control of switching converter constitutes at the present time a borderline problem, which can be handled both with conventional nonlinear control strategies and with fuzzy logic-based technologies. Why can be fuzzy logic chosen as an alternative design method to nonlinear controllers? An important answer was given in [9]: a nonlinear controller such as fuzzy logic can be inexpensively implemented with DSP-based micro-controller. As a matter of fact many researchers focused their efforts on the application of fuzzy technology for controlling switching converters. In [9] the advantages of a low cost micro- controller implementation of a fuzzy direct control were pointed out. A model- based fuzzy controller (fuzzy indirect control) for a Buck converter was proposed in [10]. Bonissone [11] proposed a successful application for resonant converters, by using suitable scaling factors. In [11] the fuzzy controller performs a variable action depending on the difference between the desired and the actual output voltage.

Such implementation considers an optimization of the scaling factors around a single output operating point. Our goal is to implement a robust fuzzy controller that can achieve the following properties: 1) Robustness around the operating point (e.g. in the case of a load change; 2) Good dynamic performance (i.e. rise time, overshoot, settling time and limited output ripple) in the presence of input voltage variations (and load changes); and 3) Invariant dynamic performance in presence of varying operating conditions. To the best of our knowledge, property 1 has been fulfilled in all related literature. Property 2 requires the synthesis of a complex controller (fuzzy or nonlinear) able to optimize the transient performance. Property 3 (along with I and 2) implies the synthesis of a global controller, with optimized parameters for varying operating conditions. Such task seems to be extremely hard; however we believe that a complex nonlinear controller could be accomplished using fuzzy based controller. In this paper, using advanced DC-DC converters fuzzy logic controllers (FLCs) are developed and presented

International Journal of Research, Science, Technology & Management
ISSN Online: 2455-2240, Volume 19 Issue III, June 2020

2. PHOTOVOLTAIC

With the deregulation of electricity markets and thrust to reduce greenhouse gas emissions from the traditional electric power generation systems, renewable energy resources such as wind turbines, photovoltaic panels, gas turbines and fuel cells, has gained a significant opportunity as new means of power generation to meet the growing demand for electric energy. Solar energy is considered to be one of the most useful natural energy sources because it is free, abundant, pollution-free, and most widely distributed. It can be used either at remote regions as standalone apparatus or in urban applications as grid interactive power source [12].

The word photovoltaic is a combination of the Greek word for light and the name of the physicist alessandro volta. It identifies the direct conversion of sunlight into electricity by means of solar cells. Photovoltaic technology is used to produce electricity in areas where power lines do not reach. In developing countries, it is improving living conditions in rural areas especially in healthcare, education, and agriculture. In the industrialized countries, they have been extensively and integrated with the utility grid. Photovoltaic cells convert solar rays to electrical currents. PV array system should be designed to operate at their maximum output power as well as voltage with minimum harmonic distortion under all operating conditions.

3. ADVANCED DC-DC CONVERTERS

According to incomplete statistics, there have been more than 500 proto- types of DC/DC converters developed in the past six decades.[13] DC-DC conversion technology has been developing rapidly, and DC-DC converters have been widely used in industrial applications such as dc motor drives, computer systems and medical equipments[14]-[15].All existing DC/DC converters were designed to meet the requirements of certain applications. They are usually called by their function, for example, Buck converter, Boost converter and Buck-Boost converter, and zero current switching (ZCS) and zero voltage switching (ZVS) converters [13]. The large number of DC/DC converters had not been evolutionarily classified until 2001. Fundamental pumps are developed from fundamental DC/DC converters just like their name:[13]

- Buck pump
- Boost pump
- Buck-boost pump

Developed pumps are created from the developed DC/DC converters just like their name:[13]

- Positive Luo-pump
- Negative Luo-pump
- Cuk-pump

The voltage lift technique is a popular method that is widely applied in electronic circuit design. This technique effectively overcomes the effects of parasitic elements and greatly increases the output voltage. Therefore these converters perform DC-DC voltage increasing conversion with high power density, high efficiency and high output voltage with small ripples [13]. Compared with conventional dc-dc converters, triple-lift Luo converters can implement the output voltages by increasing stage by stage along a geometric progression and obtain higher voltage transfer gains. They are divided into various categories according to their power stage numbers, such as the elementary circuit (single power stage), re-lift circuit (two power stages), triple-lift circuit (three power stages) etc.[16].

Due to the time variations and switching nature of the power converters, their static and dynamic behavior becomes highly non-linear.[17]. A good control for DC-DC converters always ensures stability in arbitrary operating condition. Moreover, good response in terms of rejection of load variations, input voltage variations and even parameter uncertainties is also required for a typical control scheme.

4. POSITIVE LUO-PUMP

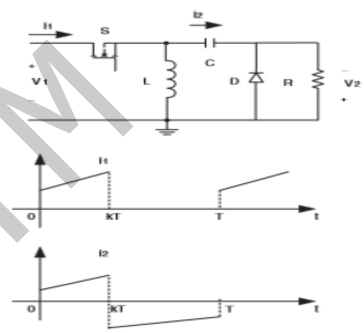

Figure 1: Positive Luo Pump

The circuit diagram of the positive Luo-pump and some current and voltage waveforms are shown in Fig. 1 Switch S and diode D are alternately on and off. Usually, this pump works in continuous operation mode, inductor current is continuous in this case. The output terminal voltage and current is usually positive.

5. TRIPLE LIFT LUO CONVERTER

Triple lift luo circuit is shown in fig.2 and it consists of two switches S and S_1, four inductors L_1,L_2,L_3 and L_4, five capacitors C,C_1,C_2,C_3 and C_0 and five free wheeling diodes[3].

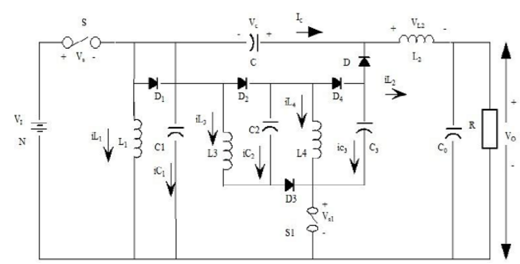

Figure 2: Triple Lift Luo Circuit

Capacitor C_1,C_2,C_3 perform characteristics to lift the capacitor voltage V_C by three times the source voltage V_1.L_3 and L_4 perform the ladder joints to line[16].

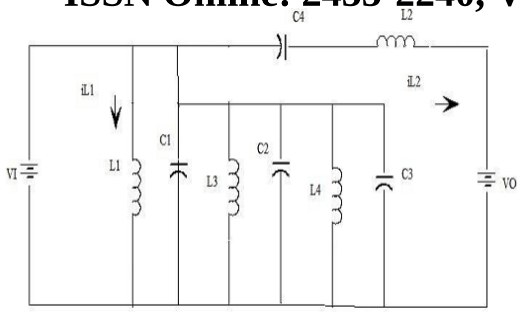

Figure 3: Switches S and S1 are ON

In the description of the converter operation, it is assumed that all the components are ideal and positive output triple lift converter operates in a continuous conduction mode. Fig. 4 and 5 shows the modes of operation of the converter.

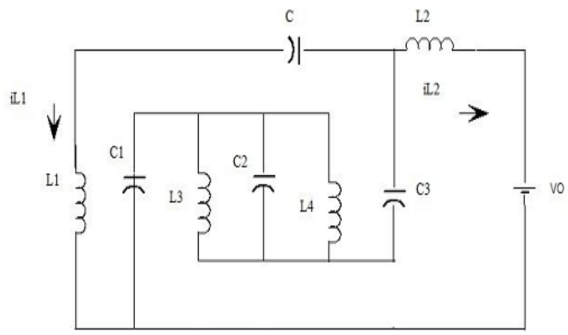

Figure 4: Switches S and S1 are Open

The current iL_2 increases in switches are in ON period kT. And it decreases in switches are in OFF period (1-kT). The output voltage and current are

$$V_O = \frac{3V_1}{1-k} \quad (1)$$

$$V_O = \frac{(1-k)I_1}{3} \quad (2)$$

The voltage transfer gain in continuous mode is

$$M_T = \frac{V_O}{V_1} = \frac{3V_1}{1-k} \quad (3)$$

Average current

$$I_{L1} = \frac{kI_O}{1-k} \quad (4)$$

$$I_{L2} = I_o \quad (5)$$

$$I_{L3} = I_{L4} = I_{L1} + I_{L2} = \frac{I_O}{1-k} \quad (6)$$

Current variations

$$\eta = \frac{k}{M_{T_0}} \frac{3R}{2fL} \quad (7)$$

Therefore variations ratio of the output voltage Vc is

$$\varepsilon = \frac{k}{8M_T} \frac{1}{f^2 C_0 L_2} \quad (8)$$

The converter may work in discontinuous mode when f is small, duty cycle k is small, inductor L is small, and load current is high.

6. DESIGN OF FUZZY LOGIC CONTROLLER FOR POTLLC

Fuzzy control can be used to improve existing traditional controller systems by adding an extra layer of intelligence to the current control method. The process of converting a crisp input value to a fuzzy value is called "fuzzification".

The fuzzy controller utilizes triangular membership functions on the controller input. The triangular membership function is chosen for its simplicity.

Fuzzy control rules are obtained from the analysis of the system behavior. The operating condition greatly improve the converter performance in terms of dynamic response and robustness. To obtain the control decision the min-max inference method is used. The rule viewer for the fuzzy logic controller is shown in figure-5.

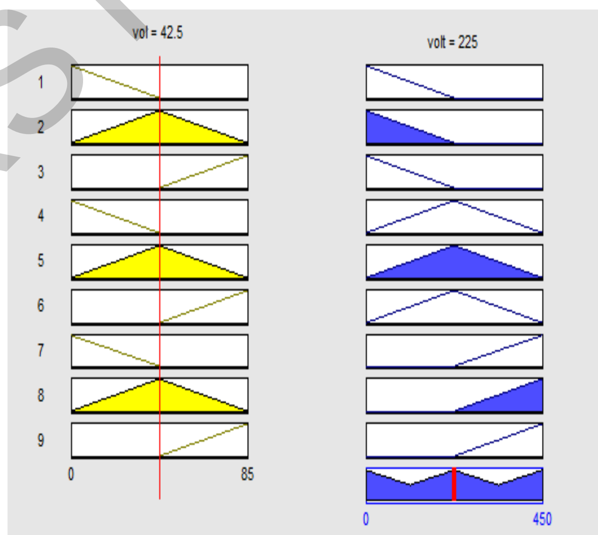

Figure 5: Rule Viewer

7. SIMULATION OF TRIPLE LIFT CONVERTER

The simulation has been performed on the positive output triple lift Luo converter for pv system using fuzzy logic controller circuit with parameters listed in Table1.

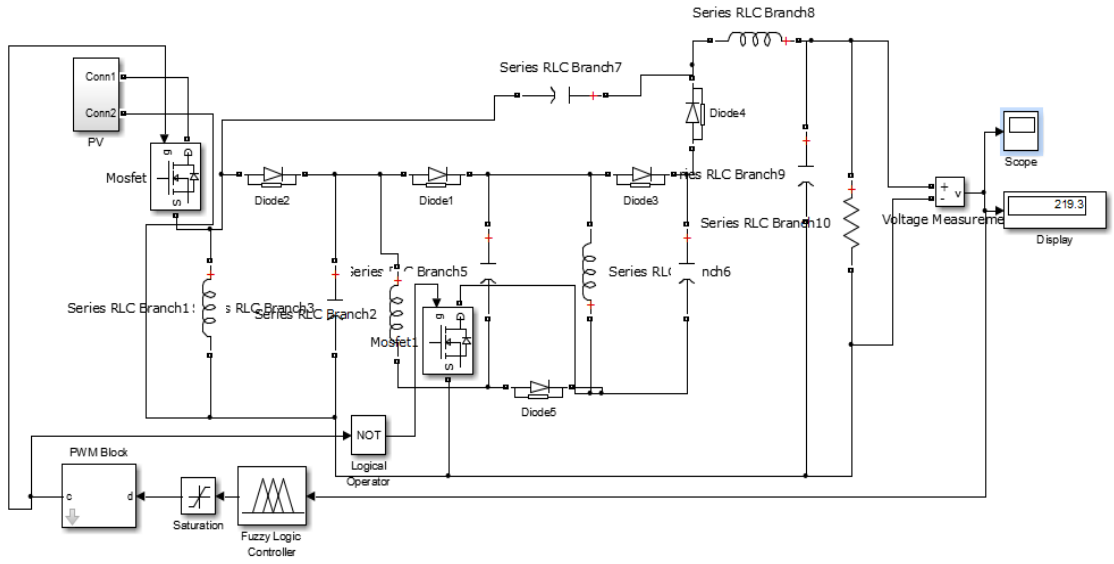

Figure 6: Simulink Model for Proposed Scheme

Table: 1 PARAMETERS TO DESIGN POTLLC

Parameters name	**Symbols**	**Value**
Input voltage to converter	VI	45 volts
Output voltage	Vo	223 volts
Inductors	L_1 ,L_2 , L_3	100µH
Capacitors	C_1,C_2,C_3	5 µf
Capacitor	C_0	300µf
Switching frequency	f_s	100kHz
Load resistance	R	100Ω

8. SIMULATION OUTPUT

The positive output triple lift luo converter is designed and developed using fuzzy logic controller in MATLAB/Simulink and the output voltage from converter with and without fuzzy logic controller is shown in fig-9 and 10. When load resistance increased the settling time is reduced. When load resistance decreased the settling time increased.

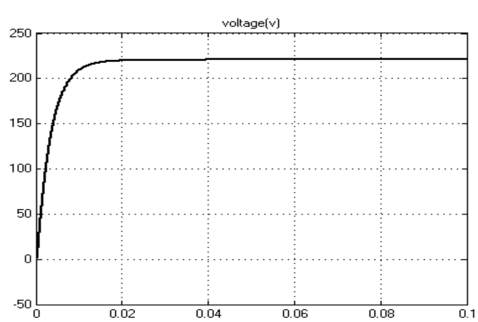

Figure 9: Output Voltage from POTLLC with FLC

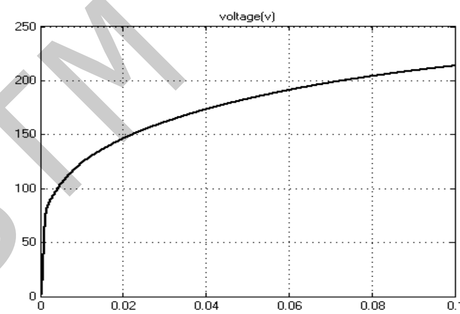

Figure 10: Output Voltage from POTLLC without FLC

9. CONCLUSION

The positive output triple lift luo converter performs the voltage conversion from positive source voltage to positive load voltage. The application of positive output triple lift luo converter in solar pv system produces voltages increasing in geometric progression. It produces output voltage of 220V for the input voltage of 40V from solar pv system.The fuzzy logic controller have proved to be Robustness around the operating point, Good dynamic performance in the presence of input voltage variations and Invariant dynamic performance in presence of varying operating conditions.

REFERENCES

[1]. R. D. Middlebrook and S. Cuk, Advances in Switched Mode Power Conversion, vol. 1 and 2, TESLAco, Pasadena, CA, 1981.

[2]. S.R. Sanders, J.M. Noworolsky, X.Z. Liu and G.C. Verghese, “Generalized averaging method for power conversion circuits,” IEEE Trans. Power Electronics, vol. 6, pp. 251-259, Apr. 1991.

[3]. J. Sun and H. Grotstollen, “Symbolic analysis methods for averaged modeling of switching power converters,” IEEE Trans. Power Electronics, vol. 12, pp. 537-546, May

1997.

[4]. H. Sira-Ramirez, "Sliding motions in bilinear switched networks," IEEE Trans. Circuits Systems, vol. CAS-34, pp. 919-933, Aug. 1987.

[5]. H. Sira-Ramirez, "Design of P-I controllers for DC-to-DC power supplies via extended linearization," Int. J. Control, vol. 51, no. 3, pp. 601-620, 1990.

[6]. Kugi and K. Schlacher, "Nonlinear &-controller design for a DC-to-DC power converter," IEEE Trans. Contr. System Technology, vol. 7, pp. 230-237, Mar. 1999.

[7]. G. Escobar, R. Ortega, H. Sira-Ramirez, J.P. Vilain and I. Zein, "An experimental comparison of several nonlinear controllers for power converters," IEEE Control Systems, vol. 19, no. 1, pp. 66-82, Febr. 1999.

[8]. L.A. Zadeh, "Outline of a new approach to the analysis of complex systems and decision processes," IEEE Trans. System, Man & Cybernetics, vol. SMC-3, pp. 284, 1973.

[9]. T. Gupta, R.R. Boudreaux, R.M. Nelms and J. Hung, "Implementation of a fuzzy controller for DC-DC converters using an inexpensive 8-b microcontroller," IEEE Trans. Industrial Electronics, vol. 44, no.5, pp. 661-669, Oct. 1997.

[10]. Carbonell and J.L. Navarro, "Local model-based fuzzy control of switch-mode DCDC converters," in Proc. 14" IFAC Triennal World Congress, pp. 237-242, 1999.

[11]. P.P. Bonissone, P.S. Khedkar and M. Schutten, "Fuzzy logic control of resonant converters for power supplies," in Proc. of the 4th IEEE Conference on Control Applications, pp. 323-328, 1995.

[12] Shimizu T, Hashimoto O, Kimura G. A novelhigh

performance utilityinteractive photovoltaic inverter system. IEEE Trans Power Electron 2003;18:704–11

[13] Fang Lin Luo and Hong Ye " Advance DC/DC Converters". CRC Press, London, U.K. Pg:38-41

[14] F.L.Luo and H.Ye "Positive output super lift converters," IEEE Transaction on power electronics, Vol.18, No. 1, pp. 105-113, January 2003.

[15] K. Ramesh kumar and S. Jeevanantham." PI Control for positive output elementary super lift luo converter,'' World Academy of Science, Engineering and Technology. pp. 732-737, March 2010.

[16] R Kayalvizhi, S.P. Natarajan and AnnRosella. "Design and simulation of PI controller for Positive output elementary Luo converter",Journal of Engineering and Technology AUJET. pp. 90-93.

[17] T. S. Saravanan , R. Seyezhai and V. Venkatesh "modeling and control of split capacitor type elementary additional series positive output super lift converter", ARPN Journal of Engineering and Applied Sciences, vol. 7, no. 5, may 2012

[18]W. C., Tse C. K., 1996. Development of a Fuzzy Logic Controller for DC/DC Converters: Design, Computer Simulation and Experimental Evaluation. IEEE Trans. on Power Electronics, vol. PE11, January.