A High Step-up LUO Converter for Standalone Photovoltaic System

K. Mohanraj, Sampada Raghatate, Astha Gupta, Srishti Tripathi

Abstract--- This paper shows a prototype of a standalone PV system that is used to power a DC motor using a high step up LUO converter. LUO Converter is used for this conversion, because it satisfies larger output range, high power density, low inrush current etc. Solar energy is one of the clean energy sources without polluting the environment. The PV module can feed power to the system through a DC-DC converter (LUO Converter). A Maximum Power Point Tracking (MPPT) control technique is required for the PV system to operate the maximum power point. This project uses the P&O (perturb and observe) algorithm for the maximum power extraction. The MATLab simulation of the hardware is also carried out giving the output results. The focus of this paper is to power a separately excited DC motor with the help of PV panel (standalone system) using a LUO converter. The standalone system used here can be very beneficial for places where grids cannot be connected.

Keywords--- PV Systems, LUO Converter, MATLabSimulation, MPPT, Perturb & Observe Algorithm

I. INTRODUCTION

Solar energy being a renewable energy source is attaining more attention and is in demand in the global energy market. Many industrialized nations have installed significant solar power capacity into their electrical grids to supplement or provide an alternative to conventional energy sources while an increasing number of less developed nations have turned to solar energy to reduce the dependence on expensive imported fuels [1]. Solar energy in India has become the fast growing industry. India is ranked number one in solar electricity production per watt installed with an insolation of 1700 to 1900KWhr per KW peak.

In recent years, the modern power electronic systems require power supply with high reliability, high efficiency and low input ripple. Such DC-DC converter used here is the LUO converter. It is a boost converter that steps up voltage [9] (while stepping down the current) from its input supply to the output load, being highly efficient, cost effective and its advantage over normal boost converter. Extraction of maximum power/energy from solar array is a matter of concern, in the photovoltaic systems, because of the nonlinear characteristics of the PV array, lower conversion efficiency of the PV cells and higher implementation cost of the system [13].

Through the first generation of DC/DC converters, we'll interest mostly to some types such as: the boost converters (from the Fundamental series), the P/O Luo converter (from the developed structure) [21]. Maximum power point tracking (MPPT) is an electronic DC-DC converter that optimizes the match between the solar array and the battery bank [4]. Each solar cell has a point at which the current I and voltage V output from the cell result in the maximum power output of the cell. The principle is that is the output from the cell can be regulated to the voltage and current levels needed to achieve a power output at this point, then the power generated by solar cell will be used most efficiently, to attain so certain MPPT algorithms are necessary in PV applications [7].

The maximum power point of a solar panel varies with the irradiation and temperature, as these two constraints are not constant throughout the day. There are many MPPT algorithms such as incremental conductance (INC), perturb and observe (P & O) constant voltage method (OCV) and short circuit current mode (SCC)[18].

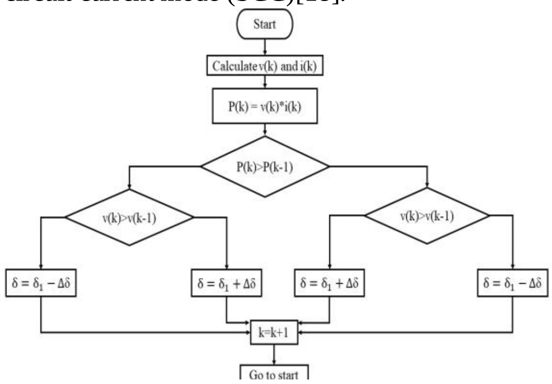

Fig. 1: Flowchart of P&O method

Here we use perturb and observe method also referred as hill climbing method, because it depends on the rise of the curve of power against voltage below the maximum power point, and the fall above that point. In this method the controller adjusts the voltage by a small amount from the PV array and measures power; if the power increases, further adjustments in that direction are tried until power no longer increases. The algorithm of P&O method is shown in Fig. (1).

II. BLOCK DIAGRAM

The block diagram as shown in fig2 shows a PV panel, batteries as the source of the LUO converter. A PV panel is group of several PV modules, which are connected in series and parallel to generate required voltage and current with solar energy as its primary source.

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During night batteries are used as the source. Microcontrollers are used to generate the PWM pulses.

The generated PWM pulses are amplified using buffer circuit. TLP250 driver circuit drives the PWM pulses generated using the MOSFET in the LUO converter that is it provides gating signal to the MOSFET present, hence the output voltage obtained is high due to the presence of LUO converter.

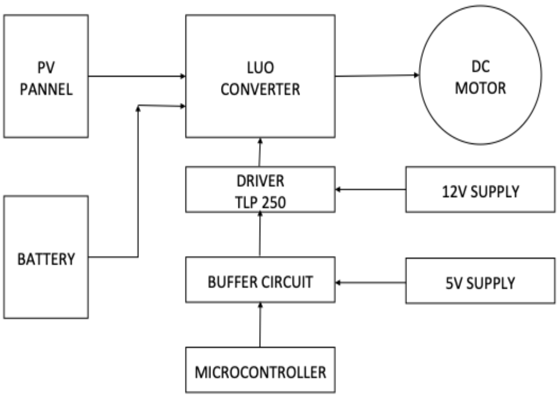

Fig. 2: Basic Block Diagram

This increased output voltage goes to the load using DC motor. Buffer circuit is given external voltage of 5V and 12V supply to the driver circuit. The basic block diagram of the system is displayed in Fig. (2). It shows the interconnection between the solar panel the LUO converter its controller and the load as DC motor.

III. LUO CONVERTER

In order to improve the performance of the photovoltaic system and to decrease the disadvantages of the ripples, LUO converters are used. Elementary circuit of LUO converter is shown in Fig. (3). The LUO converters are a simplest form of DC-DC converters which operate on voltage lift technique. The LUO converter operates on push-pull state.

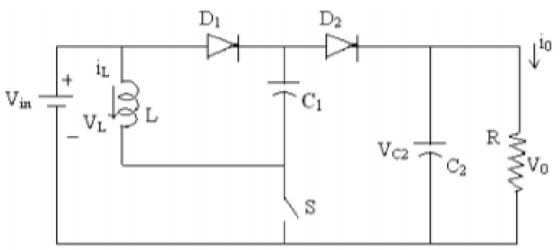

Fig. 3: LUO converter

The inductor current IL2

$$Il_2 = \frac{(1-a)}{a} Il\_1 \quad (1)$$

The duty cycle,

$$a = \frac{T_{on}}{T} \quad (2)$$

Output voltage equation,

$$V_0 = \frac{a}{1-a} V_{in} \quad (3)$$

Average voltage across the capacitor C1 is,

$$V_{c1} = \frac{a}{1-a} V_{in} \quad (4)$$

Peak to peak inductor current is,

$$\nabla IL_1 = \frac{aTV_{in}}{L_1} \quad (5)$$

From above equation inductor L1 value,

$$L_1 = \frac{aTV_{in}}{\nabla IL1} \quad (6)$$

Peak to peak inductor current L2,

$$\nabla IL_2 = \frac{aTV_{in}}{L_2} \quad (7)$$

From above equation inductor L2 value,

$$L_2 = \frac{aTV_{in}}{\nabla IL_2} \quad (8)$$

The charge on series capacitor (C1) increases during off period by IL2 (=Io) and decreases during on period by IL1. The change in charge on C1 must be zero Peak to peak ripple voltage across the capacitor C1,

$$\nabla VC_1 = \frac{1-a}{C_1} Tl_1 \quad (9)$$

From above equation C1 value,

$$C_1 = \frac{1-a}{\nabla VC_1} Tl_1 \quad (10)$$

Using equation 3 here for input voltage as 62V and output voltage as 60V we get the value of a(duty cycle) as 0.489.

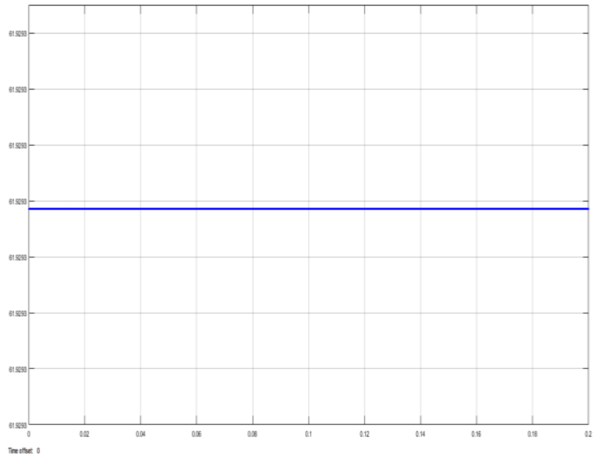

Fig. 4: Input Voltage

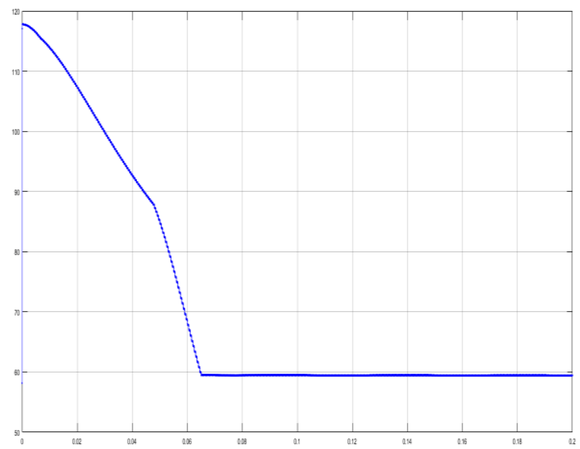

Fig. 5: Output Voltage

From Fig. (4) and Fig. (5) we can see that for input voltage 62V and setting the duty cycle as 0.489 we get the output voltage as 60V which further increases as we increase the duty cycle and the output voltage increases from 15.5V at 0.2 duty cycle to 588V when duty cycles reaches 0.9.

Table 1: Output voltage Vs duty cycle

DUTY CYCLE	VOLTAGE INPUT	VOLTAGE OUTPUT
0.2	62V	15.5V
0.4	62V	41.33V
0.5	62V	60V
0.7	62V	144.66V
0.9	62V	588V

As we can see from the above table several values of duty cycle are considered for the simulation, and after simulating the LUO converter, output voltage of the LUO converter for various values of the duty cycles are tabulated in table 1. Hence, from this we can infer that the output voltage depends on the duty cycle and not on the input voltage.

Modes of Operation

MODE 1: when the switch S is ON, the inductor L1 is charged by the supply voltage E. Then the same time, inductor L2 absorbs the energy from the voltage source and capacitor C1. The circuit of LUO converter in mode1 is shown in Fig. (6).

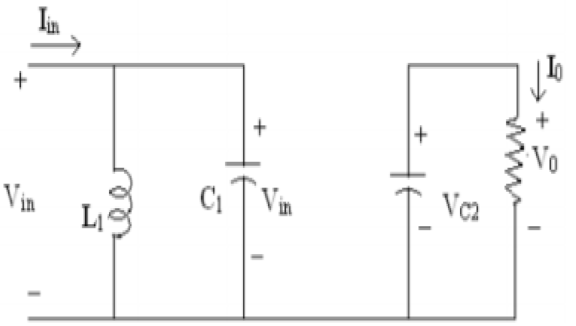

Fig.6: Mode 1(ON STATE)

MODE 2: when the switch S is in OFF state, the current given by the source becomes zero, the current IL1 flows through the freewheeling diode to charge the capacitor C1. Current IL2 is flowing through capacitor C2 to freewheeling diode D to keep itself continuous.Fig. (7)Depicts the OFF State of the Luo Converter.

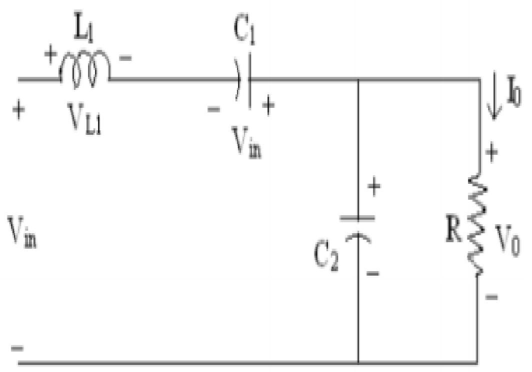

Fig.7: Mode 2(OFF STATE)

Apply KVL Determine A, B, C, E Matrices Fig. (3)shows elementary Luo converter. In this positive output Luo converter, there are two states i.e., when switch is on and when switch is off. During each state we write the following Equation 11 and 12:

$$x = A_1 x + B_1 V_d \text{ DuringdTs} \quad (11)$$

$$x = A_2 x + B_2 V_d \text{ DuringTs (1-d)} \quad (12)$$

Where, A1+ A2 are state matrices and B1 and B2 are vectors.

For turn on:

$$\begin{pmatrix} x_1^1 \\ x_2^1 \\ x_3^1 \end{pmatrix} = \begin{pmatrix} 0 & \frac{1}{L} & 0 \\ -\frac{1}{C_1} & -\frac{1}{R_i C_1} & 0 \\ 0 & 0 & -\frac{1}{RC_2} \end{pmatrix} \begin{pmatrix} x_1 \\ x_2 \\ x_3 \end{pmatrix} + \begin{pmatrix} 0 \\ \frac{1}{R_i C_1} \\ 0 \end{pmatrix} V_d \quad (13)$$

For turn off:

$$\begin{pmatrix} x_1^1 \\ x_2^1 \\ x_3^1 \end{pmatrix} = \begin{pmatrix} 0 & \frac{1}{L} & -\frac{1}{L} \\ -\frac{1}{C_1} & 0 & 0 \\ -\frac{1}{C_2} & 0 & -\frac{1}{RC_2} \end{pmatrix} \begin{pmatrix} x_1 \\ x_2 \\ x_3 \end{pmatrix} + \begin{pmatrix} \frac{1}{L} \\ 0 \\ 0 \end{pmatrix} V_d \quad (14)$$

$$A = A_1 D + A_2(1-D) \quad (15)$$

$$B = B_1 D + B_2(1-D) \quad (16)$$

$$A = \begin{pmatrix} 0 & \frac{1}{L} & -\frac{1-D}{L} \\ -\frac{1}{C_1} & -\frac{D}{R_i C_1} & 0 \\ \frac{(1-D)}{C_2} & 0 & -\frac{1}{RC_2} \end{pmatrix}$$

$$B = \begin{bmatrix} \frac{1-D}{L} \\ \frac{D}{R_i C_1} \\ 0 \end{bmatrix} \qquad C = (0 \quad 0 \quad 1) \quad (17)$$

Using Laplace transformation,

$$S\hat{x}(s) = A\hat{x}(s) + [(A_1 - A_2) \times +(B_1 - B_2)V]\hat{d}(s) \quad (18)$$

$$\hat{x}(s) = [SI - A]^{-1}[(A_1 - A_2) \times +(B_1 - B_2)V]\hat{d}(s) (19)$$

$$\frac{\hat{v}_0(s)}{\hat{d}(s)} = C[SI - A]^{-1}[(A_1 - A_2) \times +(B_1 - B_2)V_d] + (C_1 - C_2)X \quad (20)$$

$$SI - A = \begin{pmatrix} S & \frac{-1}{L} & \frac{(1-D)}{L} \\ -\frac{1}{C_1} & S + \frac{D}{R_i C_1} & 0 \\ \frac{(1-D)}{C_2} & 0 & S + \frac{1}{RC_2} \end{pmatrix} (21)$$

Removing Ri terms

$$\frac{\hat{v}_0}{\hat{d}} = V_g \left[\frac{\left(-SL\left(\frac{2-D}{(1-D)^2}\right)+R\right)}{S^2 LRC_2 + SL + R(1-D)^2} \right] (22)$$

IV. SIMULATION & RESULTS

The MATLab simulation of the above proposed model was performed and the outputs of the simulation were recorded.

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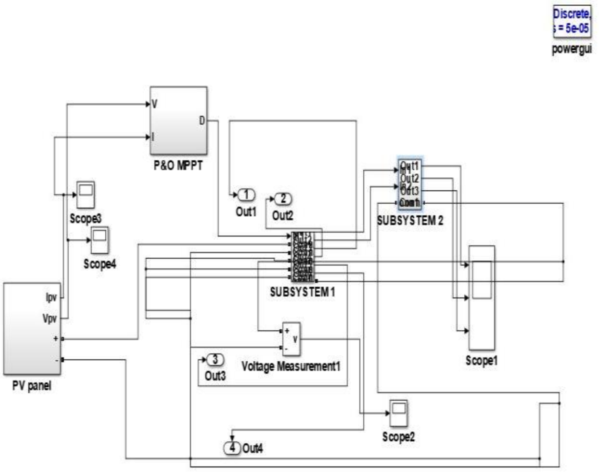

Fig.8: MATLab simulation model

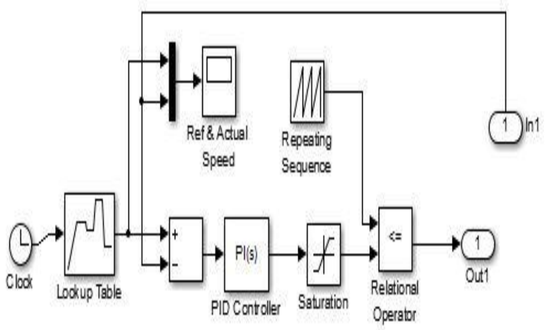

Fig.9: Controller simulation

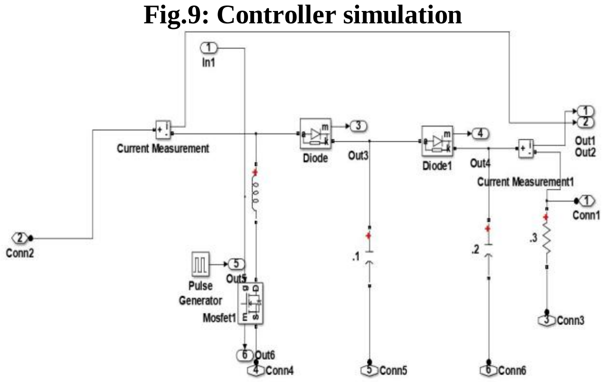

Fig.10: LUO simulation

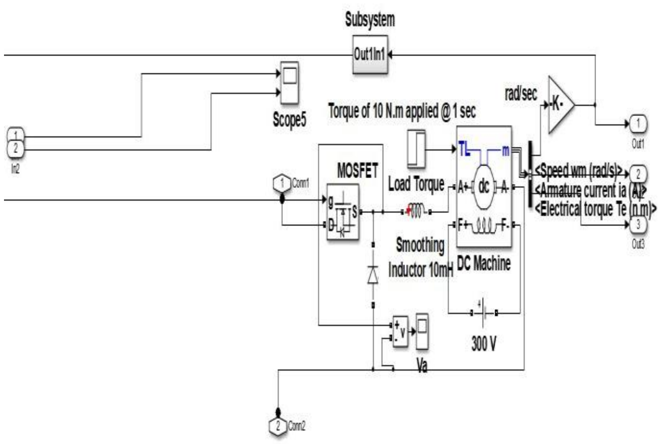

Fig.11: Simulation of motor

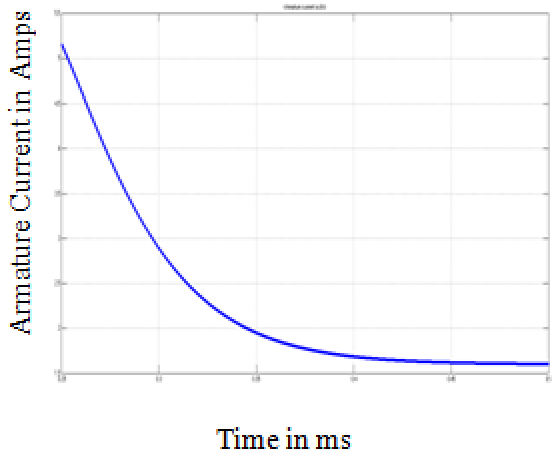

Fig. 12: Armature current

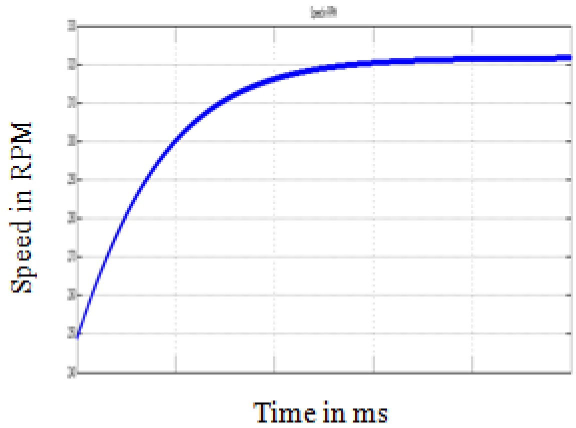

Fig. 13: Speed of the DC Motor

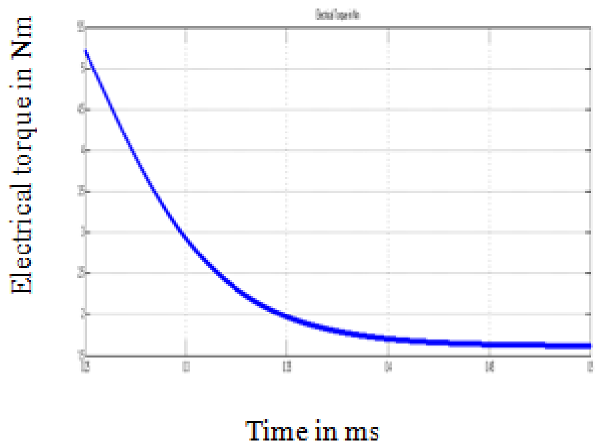

Fig. 14: Torque

The final output of the motor includes the characteristics of time with respect to Armature current, speed in RPM and Electrical torque which are shown in the Fig. 12, Fig. 13 and Fig. 14 respectively.

V. CONCLUSION

In this new era using renewable resources is important for our environment, so due to this increasing demand of these resources, we are using luo converter.

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Luo converters are series of DC-DC step up power conversion circuits. Luo converter has high efficiency and almost zero output voltage and current ripples and it gives very high voltage boost. The voltage captured by the PV panel is very low which by using luo converter is boosted to 3 to 4 times. The performance of the converter could further be improved by fast tracking MPPT algorithm.

Perturb and Observe technique is used which will always capture highest power possible. The high voltage supply is given to DC motor. The PV panel can also be referred to as a standalone system that is it is not connected to the grid it is self sufficient to produce power. This has a very big advantage in rural areas where sudden cutoff in power is major concerns to the local people. In this project MATlab simulation is used to simulate the hardware and high voltage power was generated. Finally, from simulation results, a comparative study of the performance of various luo converters for photovoltaic applications using MATlab simulation has been presented.

REFERENCES

1. K. Sangeetha, T. S. Babu, N. Sudhakar, N. Rajasekar, "Modeling analysis and design of efficient maximum power extraction method for solar pv system", *Sustainable Energy Technologies and Assessments*, vol. 15, pp. 60-70, 2016.
2. A. Gupta, Y. K. Chauhan, R. K. Pachauri, "A comparative investigation of maximum power point tracking methods for solar pv system", *Solar Energy*, vol. 136, pp. 236-253, 2016.
3. Jubaer Ahmed, Zainal Salam, "An improved perturb and observe (P&O) maximum power point tracking (MPPT) algorithm for higher efficiency", *Appl. Energy*, vol. 150, pp. 97-108, 2015.
4. M. Killi, S. Samanta, "Modified Perturb and Observe MPPT Algorithm for Drift Avoidance in Photovoltaic Systems", *IEEE Transactions on Industrial Electronics*, vol. 62, pp. 5549-5559, 2015.
5. X. Y. Zhang, H. G. Zhang, H. Q. Zhang, P. Q. Zhang, F. Wang, H. Jia, D. Y. Song, "A variable step-size P&O method in the application of MPPT control for a PV system", *IEEE*, pp. 978-1-4673-9613, 2016.
6. X. Y. Zhang, H. G. Zhang, H. Q. Zhang, P. Q. Zhang, F. Wang, H. Jia, D. Y. Song, "A variable step-size P&O method in the application of MPPT control for a PV system", *IEEE*, pp. 978-1-4673-9613, 2016.
7. M. Kaouane, A. Boukhelifa, A. Cheriti, "Design of a Synchronous Sepic DC-DC Converter for a Stand-alone Photovoltaic System", *Proc. Canadian Conference on Electrical and Computer Engineering at Halifax NS on*, pp. 870-874, 3-6 May 2015.
8. S. Dhamodharan, M. D. Pradeep, R. Vidhya, P. Yuvaraj, "An Improved Luo Converter for High Power Application", *International Journal of research in engineering and technology*, vol. 3 no. 11, pp. 360-365, Nov 2014.
9. Deepak, Rupendra Kumar Pachauri, Yogesh K. Chauhan, "Modeling and simulation analysis of PV fed CukSepic Zeta and Luo DC-DC converter", *International Conference on Power Electronics Intelligent Control and Energy Systems (ICPEICES)*, 2016.
10. Y. He ; F.L. Luo, "Analysis of Luo converters with voltage-lift circuit", IEE Proceedings - Electric Power Applications, vol. 152, issue: 5,pp. 1239 – 1252, 2005.
11. Mohammed A. Elgendy ; Bashar Zahawi ; David J. Atkinson, "Operating Characteristics of the P&O Algorithm at High Perturbation Frequencies for Standalone PV Systems", IEEE Transactions on Energy Conversion vol. 30 , pp.189 – 198, 2015.
12. MoustafaAdly ; Kai Strunz, "Irradiance-Adaptive PV Module Integrated Converter for High Efficiency and Power Quality in Standalone and DC Microgrid Applications", IEEE Transactions on Industrial Electronics, vol. 65 , Issue: 1, Page s: 436 – 446, 2018.
13. Mary HelnaMuttath,;PBaburaj, Interleaved Luo converter for the residential PV grid Connected systems, IEEE conference, pp. 1-6,2015.
14. Jubaer Ahmed ; Zainal Salam, "A Modified P&O Maximum Power Point Tracking Method With Reduced Steady-State Oscillation and Improved Tracking Efficiency", IEEE Transactions on Sustainable Energy, Volume: 7 , Issue: 4, pp. 1506 – 1515, 2016.
15. V. Bist, B. Singh, "Power Factor Correction In A Brushless DC Motor Drive Using An Isolated-Luo Converter", *Proc. 6th IEEE Power India International Conference at Delhi on*, pp. 1-6, 5-7 Dec. 2014.
16. P. Kumar et al., "Utilization of Energy Sources in Hybrid PV/FC Power Assisted Water Pumping System", *Pproc. IEEE Conference on Computational Intelligence & Communication Technology*, pp. 548-553, 2015.
17. Abhishek Kumar Gupta, Ravi Saxena, "Review on widely-used MPPT Techniques for PV Applications", *International Conference on Innovation and Challenges in Cyber Security (ICICCS-INBUSH)*, 2016.
18. YefinBerkovich, Boris Axelrod, RotemMadar, AvrahamTwima, "Improved Luo Converter Modifications with Increasing Voltage Ratio", *IET Power Electron*, vol. 8, no. 2, 2015.
19. D. Cheng, T. Zhang, D. Zhu, "Photovoltaic Power System Modeling and Simulation", *IEEE International Conference on Power and Renewable Energy*, 2016.
20. A. Rabeb, M. Ferdaous, D. Nabil, "Comparative study of the performances of the DC/DC luo-converter in photovoltaic applications", *International Conference on Smart Monitored and Controlled Cities*, 2017.
21. RabebAbid; FerdaousMasmoudi; Nabil Derbel, "Comparative study of the performances of DC-DC luo converter in photovoltaic applications", IEEE conferences, pp. 117-122, 2017.
22. A. Rabeb, M. Ferdaous and D. NabiL, "Comparative study of fundamental variable input converters used for PV conversion systems", 14th International Multi-conference on System, Signal and Devices (SSD), 2017.
23. F.L.Luo , "Positive output Luo converters: Voltage lift technique", IEEE Proc-Elec, Power Appl ,July 2014.
24. S. Sivakumar, M.J. Sathik, P.S. Manoj, G. Sundararajan, "An assessment on performance of DC/DC converters for renewable energy applications", Renewable and Sustainable Energy Reviews Elsivier, 2016.
25. MohammadrezaAghaei ; Francesco Grimaccia ; Carlo A. Gonano ; Sonia Leva, "Innovative Automated Control System for PV Fields Inspection and Remote Control" , IEEE Transactions on Industrial Electronics, vol.62 , Issue: 11, pp. 7287 – 7296, 2015.

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