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Direct Coupled PV Panel with ĆUK Converter for DC Load Applications

Fatima Unnisa, K.Jaiganesh, P.Arulkumar, S.Karunakaran

Abstract: The PV systems are becoming gradually more common in distribution and generation systems. The direct coupled CUK converter for DC load applications is connected with PV panel. The ĆUK converter convert DC- DC voltage, in which magnitude of voltage output is not more than or higher than the magnitude of voltage input also the input voltage polarity is reverse to that of output voltage.

The ĆUK converter is frequently customized for additional functions like simple transformer separation, high current protection, less ripple current and transfers the power regularly through capacitor. As per the research on the ĆUK converters has rigorous minor switching loss, capable to give unity power factor, decrease in element size, improving efficiency of the system, etc. Operation of ĆUK converter is relatively unusual with that of PWM converters. The effectiveness of proposed methods is to validate ĆUK converter in MATLAB/ SIMULINK.

Keywords: ĆUK Converter, Solar PV module, MATLAB / SIMULINK

I. INTRODUCTION

Several convenient electronic converters and inverters are designed with high frequency resource applications. This type of devices are applicable to interface with photovoltaic array and give low frequency sinusoidal output [1]. The equivalent circuit design for photovoltaic cell is also tried in different models with 3 diode, in this method the obtained output parameters from calculated value is matched with the real output of the PV circuit [3]. The thermal as well as electrical characteristic of PV panel are analyzed for a flat plate PV panel model and this will be applicable for different application [5]. In nonlinear current source consist of CC and CV properties, for this type of sources commercial solar simulators are designed with single and three phase dc-ac converters [7]. In PV inverters, the DC link plays a major role, the voltage value and the capacitor value used in the DC link is very important. This will make a control over the bandwidth of supply and input capacitance value [9].

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***** Correspondence Author

Fatima Unnisa, Assistant professor, EEE, Vardhaman College of Engineering. Email: fatimaunnisa7867@gmail.com.

Dr.K.Jaiganesh*, Professor, EEE, Vardhaman College of Engineering, jaiganesh@vardhaman.org

Dr.P.Arulkumar, Professor/EEE, Balaji Institute of Technology and Science, Telangana, India.

Dr. S.Karunakaran, Professor, ECE, Vardhaman college of Engineering,

PV module are dependent on variation in impedance, voltage and its frequency of operation, this parameters are validated by different frequency ranges [10]. It's well known that to have the maximum efficiency of solar panels, load must be linked to the solar panel through a DC-DC converter. The relationship between various DC-DC converters from dissimilar ideas is shown in Table 1.

II. SIMULATION OF THE PV ARRAY

Figure.1 shows a model which consist of current (I_m), series and parallel resistors (R_s and R_p). This model is implemented by simulator circuit.

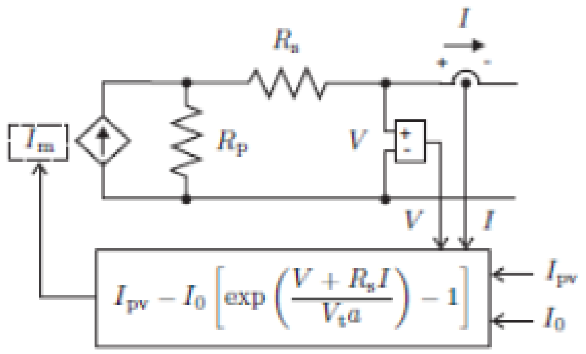

Fig 1. PV array model circuit

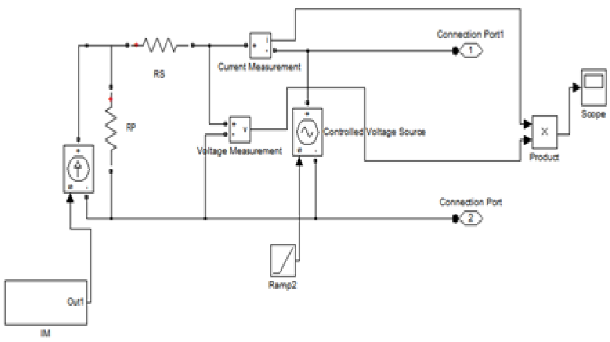

Fig 2. PV circuit model built through MATLAB/SIMULINK

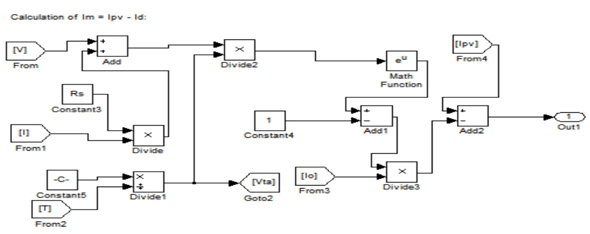

Fig .3 Calculation of $I_m = I_{pv} - I_d$

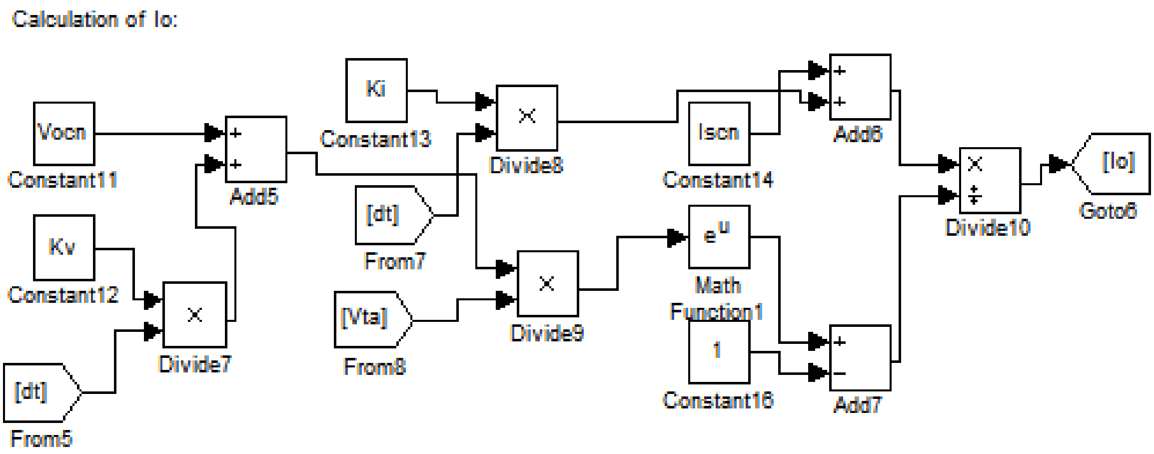

Fig .4 Calculation of I_o

Table 1 Assessment of different converters

Converter type / property	Buck and Boost	Ćuk	Positive Buck-Boost	SEPIC	Fly back
Output Voltage Polarity	Negative	Negative	Positive	Positive	Positive
Current I/P	Pulsating	Non-pulsating	Based on operating method	Non-pulsating	Pulsating
Drive switch	Floated	Floated	One floated One earth	Earth	Earth
η	Less	Normal	More	Normal	Less
Price	Normal with floating drive	Normal with extra block capacitor	More and complicated circuit	Normal with extra block capacitor	Less with earthed switch and no blocking capacitor

III. CIRCUIT CONFIGURATION OF ĆUK CONVERTER

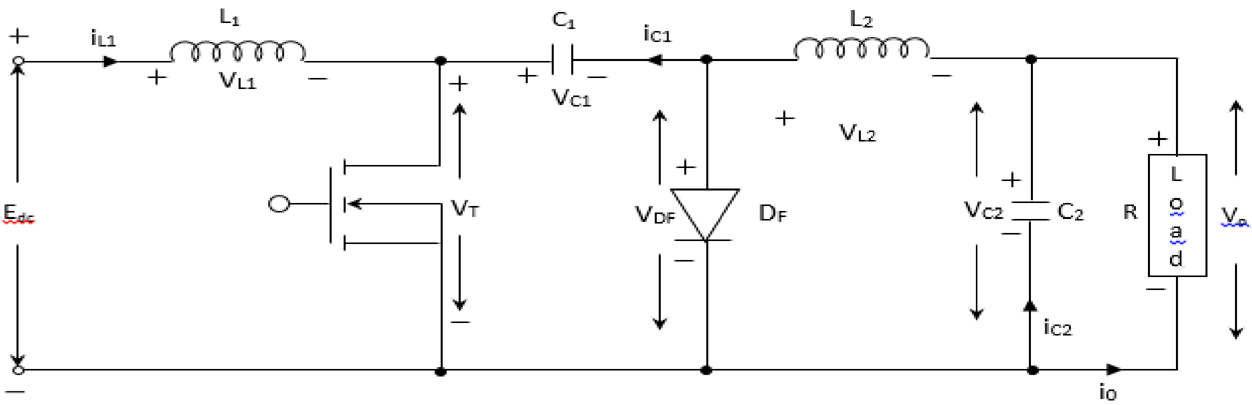

Fig .5 Circuit Diagram

When the supply voltage is given to the circuit and the MOSFET T_1 is switched-off, currents flowing through the inductors i_{L1} and i_{L2} flow through the diode D_F. An equivalent circuit is shown in Fig. 5 Hence, current through the capacitor C_1 is charged through L_1, D_F and the input supply E_{dc}. Current i_{L1} reduces, because $V_{C1} > E_{dc}$. Energy is stored in inductor L_2 supply the output and hence current i_{L2} also reduces.

When the switch is ON, capacitor voltage V_{C1} reverse the diode D_F and makes it turns OFF. The inductor currents i_{L_1} and i_{L_2} flow from the device as shown in Fig. 5. As $V_{C1}>E_{dc}$, C_1 discharges from the device, shift energy to the output and L_2, therefore i_{L1} boosted. The input provides energy to L_1 make i_{L_1} to boost. The waveforms for steady state voltages and currents are shown in Fig. 7 for continuous load current.

During time T_{on}, by assuming that the current of inductor L_1 rises linearly from $I_{L_{11}}$ to $I_{L_{12}}$. We can write

$$E_{dc} = L_1 \frac{I_{L_{12}} - I_{L_{11}}}{T_{on}} = L_1 \frac{\Delta I_1}{E_{dc}} \quad (3.1)$$

or

$$T_{on} = \frac{\Delta I_1 \cdot L_1}{E_{dc}} \quad (3.2)$$

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During time T_{off}, the current of inductor L_1 falls linearly from $I_{L_{12}}$ to $I_{L_{11}}$ due to the charged capacitor C_1.

$$E_{dc} - V_{C_1} = -L_1 \frac{\Delta I_1}{T_{off}} \qquad (3.3)$$

Or

$$T_{off} = \frac{-\Delta I_1 \cdot L_1}{E_{dc} - V_{C_1}} \qquad (3.4)$$

Where V_C is the average value of capacitor C_1 and

$$\Delta I_1 = I_{L_{12}} - I_{L_{11}}$$

From equations (3.1) and (3.3), we can write

$$\Delta I_1 = \frac{E_{dc} \cdot T_{on}}{L_1} = \frac{-(E_{dc} - V_{C_1})}{L_1} T_{off}$$

or

$$E_{dc} \cdot T_{on} = -E_{dc} T_{off} + V_{C_1} T_{off}$$
$$E_{dc}(T_{on} + T_{off}) = V_{C_1} T_{off}$$

or

$$V_{C_1} = \frac{E_{dc} \cdot T}{T_{off}} = \frac{E_{dc}}{1-\alpha} \qquad (3.5)$$

Also, during time T_{on}, suppose that the current through filter inductor L_2 rise up linearly from $I_{L_{21}}$ to $I_{L_{22}}$, we get

$$V_{C_1} + E_0 = L_2 \cdot \frac{I_{L_{22}} - I_{L_{21}}}{T_{on}} = L_2 \cdot \frac{\Delta I_2}{T_{on}} \qquad (3.6)$$

or

$$T_{on} = \frac{\Delta I_2 L_2}{V_{C_1} + E_0} \qquad (3.7)$$

Also, during time $T_{off,}$ current of inductor L_2 falls linearly from $I_{L_{22}}$ to $I_{L_{21}}$, therefore,

$$E_0 = -L_2 \frac{\Delta I_2}{T_{off}} \qquad (3.8)$$

or

$$T_{off} = -\frac{\Delta I_2 L_2}{E_0} \qquad (3.9)$$

Where $\Delta I_2 = I_{L_{22}} - I_{L_{21}}$

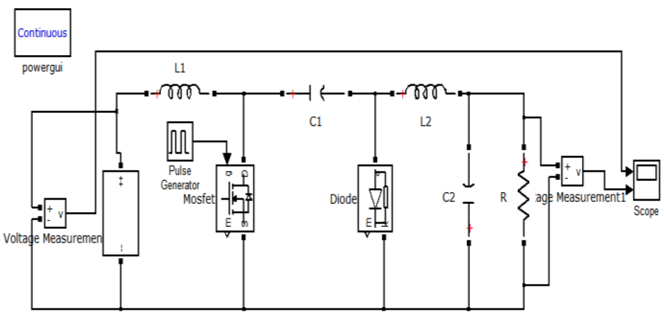

Fig . 6 The simulation circuit of Cuk converter

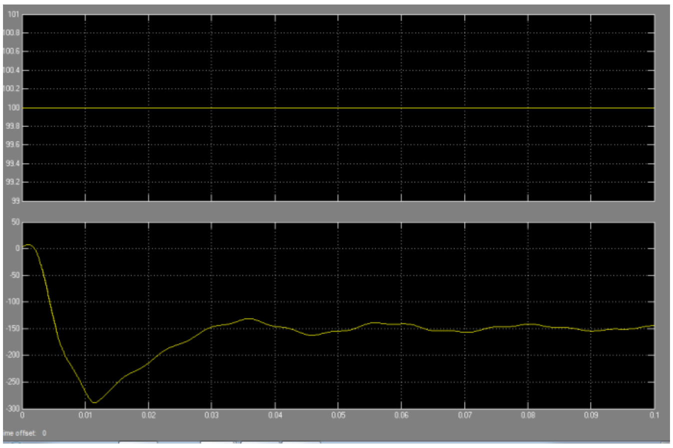

Fig .7 Output wave form

IV. RESULT AND DISCUSSION

In this paper, Depending on the operating point, PVG have a power and voltage-limit nonlinear current source internally, the dynamic resistance and capacitance decide the dynamic properties of the generator.

Key points form testing on design of PV converters study, summarized below:

i. Current/voltage need to control at input side or operate the converter at open loop, for high power transfer.

ii. The most practical scheme to control a Photovoltaic system is to control the feedback of I/P voltage.

iii. If the input is given from VCC, the converter should be fed by a current source.

iv. Since the deep effect on the converter interfacing dynamics, non-ideal PVG source impedance has to be considered.

Based on the study presented in this paper, the solar array simulator is suitably match with actual PV system, the main significant properties will be summarizing as follows:

i. The V-I curve and dynamic resistance must be matched as precisely as feasible.

ii. Dynamic capacitance must be emulate precisely. The PVG capacitance is slighter than the capacitance of the simulators.

iii. In real PVG explains the performance of the impedance at output must be in between the angle of +90˚ and -90˚.

This paper presents a Photovoltaic charger with the CUK converter. The system has exhibited to be efficient in power balance and MPPT control.

V. CONCLUSION

The above work was simulated successfully and this direct coupled CUK converter was very much suitable for different types of DC load applications with different magnitude and polarity.

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AUTHORS PROFILE

Fatima unnisa received PG In Power Electronics And Electric Drives,2014, Vardhaman College Of Engineering, UG In Electrical And Electronics Engineering, 2010, Shadan Women's College Of Engineering and Technology. Currently working as a Asst.Professor in EEE department at Vardhaman College of Engineering (Autonomous) Hyderabad.

Dr. K. Jaiganesh obtained his B.E from Periyar University, M.E and Ph.D from Anna University, Chennai in 2006 and 2015. He is currently working as a Professor in the Department of Electrical and Electronics Engineering at Vardhaman College of Engineering (Autonomous) Hyderabad.

Dr.P.Arulkumar, obtained his B.E degree from Periyar University in 2002, M.E from Anna University in 2004 and received his Ph.D in Power Electronics from PRIST University in 2017.

Dr.S.Karunakaran, Professor, Department of ECE in Vardhaman College of Engineering, (Autonomous) Hyderabad.