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Research Article

Design of Cuk Converter Powered by PV Array

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Abstract: This study presents PV power based cuk converter for dc load application. The maximum power from the sun radiation is obtained by sun tracking and Maximum Power Point Tracking (MPPT). The sun tracking is implemented by the stepper motor control and MPPT is implemented by the Cuk converter and the load voltage is maintained constant irrespective of the variation in solar power. This technique improves the dynamic and steady state characteristics of the system. The simulation was done in MATLAB simulink and the experiments are carried out and the results are presented.

Keywords: Cuk converter, inverter, PI controller, PV array, stepper motor

INTRODUCTION

Due to the demand of the fossil fuels, the photo voltaic technology was developed during the past two decades. Solar panel is the device used for the conversion of sun radiation to the electrical energy. It has the advantages of less maintenance, no wear problem and there is no noise pollution (Salameh and Taylor, 1990; Alghuwainem, 1992). Nowadays in smart grid, solar power system plays important role even though the initial cost of the solar power system is high. Generation of the solar power is depending upon the PV array. A single PV cell generates very low power. So a series of PV cell is connected in series which gives maximum power output. In order to reduce the number of PV cell intermediate dc -dc converter are used to obtain maximum utilization of PV power (Salameh and Taylor, 1990; Appelbaum *et al*., 1992). The solar power is increased by sun tracking, Maximum power tracking or both (Tse *et al*., 2002) Fundamental dc-dc converters are Buck and Boost converter. A converter which operating in both the mode by varying the duty cycle of the switch is the Cuk converter provides continuous input and output dc current. In recent years the MPPT technique is achieved by cuk converter (Jeremy *et al*., 2006). In this study, the sun tracking was implemented using stepper motor where step angle is controlled by the microcontroller chip. MPPT is achieved by power matching scheme (Applebaum, 1987). This is achieved by the PI controller, used for voltage control. The PV array is connected to the CUK converter and the maximum voltage is obtained by varying the duty cycle of the Mosfet switch.

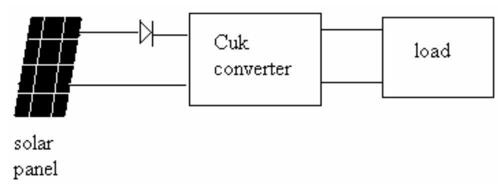

Fig. 1: Solar panel integrated Cuk converter

MODELING OF CUK CONVERTER

Figure 1 shows the PV powered cuk converter connected to the aload. The MPPT Technique used in this study for standalone PV generation system. The diode will reduce the ripple of the solar voltage. The PV array output is adjusted by the Cuk converter. The current equation for the solar cell is given by Athimulam and Subharensu (2010):

$$i = i_p - i_o(e^{qv/kT} - 1)$$
$$i = i_p - i_d$$

where,
i_p = The photo current
i_o = The reverse saturation current
q = The electron charge
k = The Boltzmann constant
i_d = The diode current
T = The solar cell operating temperature

The average voltage of the converter when it is operated in continuous mode of operation:

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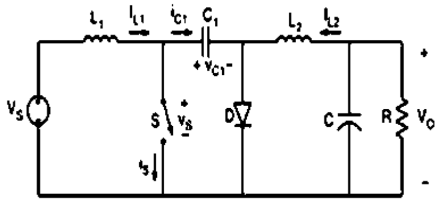

Fig. 2: Circuit diagram of Cuk converter powered by solar power

Table 1: Results of the output voltage of the converter for 10V input voltage

	Output voltage					
	Simulated output			Experimental output		
D	80	120	180	80	120	180
0.14	3.9	4.89	5.30	1.65	2.58	3.109
0.28	7.9	9.69	12.10	5.10	7.50	8.950
0.64	20	22.30	25.40	16.20	16.90	22.590
0.71	22	26.70	29.20	17.20	20.40	25.400
0.85	27	29.70	34.60	25.10	29.50	32.880

$$\frac{V_o}{V_i} = \frac{D}{1-D} = T_{vv}$$

where,
D = The duty cycle
V_o = The output voltage
V_i = The input voltage
T_{VV} = The voltage transfer ratio

Neglecting the converter losses, the input dc current is given by:

$$\frac{I_o}{I_s} = \frac{1-D}{D}$$

Peak stress voltage on the switch and the peak current through the switch is:

$$V_{SW\,max} = V_s + V_o$$

$$I_{SW\,max} = I_o + \frac{V_s T_s}{2L}$$

The mosfet switch is selected by Fig. 2 shows the overall circuit diagram of Cuk converter. Considering above peak voltage and peak current.

The inductor and capacitor value of the converter is calculated by considering 10% voltage ripple and current ripple. The following equations are used to design the Cuk converter:

$$\Delta I_1 = \frac{V_{dc} D}{L_1 f}$$

$$\Delta I_2 = \frac{V_{dc} D}{L_2 f}$$

$$\Delta V_{c1} = \frac{I_s (1-D)}{C_1 f}$$

$$\Delta V_{c2} = \frac{\Delta I_2}{8 C_2 f}$$

f is the switching frequency of the Mosfet Switch. The design values of the converter are in Table 1.

Solar power tracking:

Maximum power point tracking: The PI controller is used to maintain the power constant. The voltage control and inner current control loop helps the system to utilize the maximum solar power. Figure 3 shows the control scheme of the Cuk converter. Pulse width modulation techniques are implemented to control the output voltage of the converter. The saw tooth waveform was generated for 1 KHz and the PI controller is tuned to obtain a required output voltage.

Sun tracking: The maximum solar power is obtained by moving the panel using stepper motor. The steep angle for the stepper motor is given by ATMEL 89C54

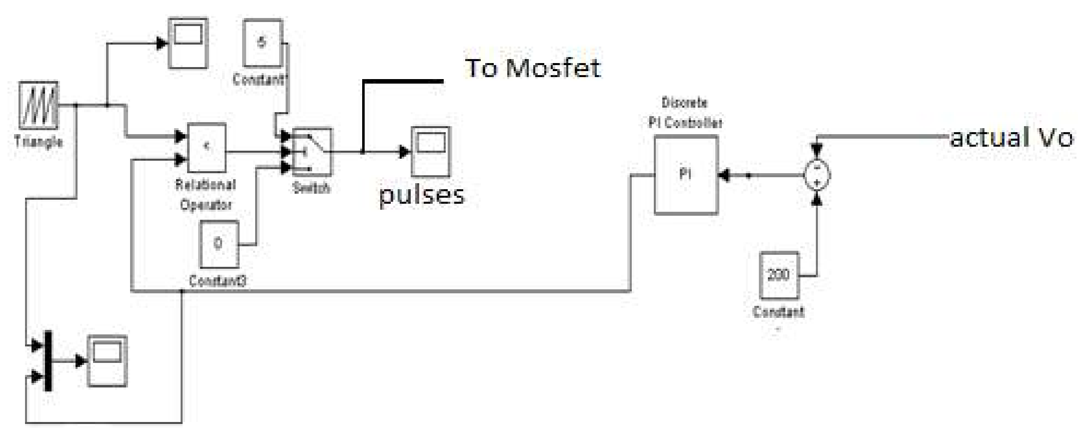

Fig. 3: Control scheme for Cuk converter

Fig. 4: Experimental set up of solar power tracking

microcontroller chip. Figure 4 shows the experimental setup of the sun tracking system.

MATLAB SIMULATION

The solar cell voltage is measured and that dc voltage is given as input to the Cuk converter for simulation. Sim power system block set are used to design the cuk converter. Figure 5 shows the closed loop control of the Cuk converter. The Simulation results show that the converter will maintain the voltage for the set value even the input voltage and load are changing.

Experimental setup: Simulation results show the performance of the PI controlled Cuk converter. Figure 5 shows the experimental set up was made to supply power to the load by PV powered Cuk converter. The sawtooth wave was generated for 1kHz and PI controller was designed to obtain the required gain. For the variation in input solar power, the output voltage is maintained constant by varying the duty cycle. Table 1 shows the duty cycle variation of the Cuk converter with variable load for constant input voltage. Table 2 shows the output voltage for the Variable input voltage with the variable load. The output voltage is maintained constant using the PI controller.

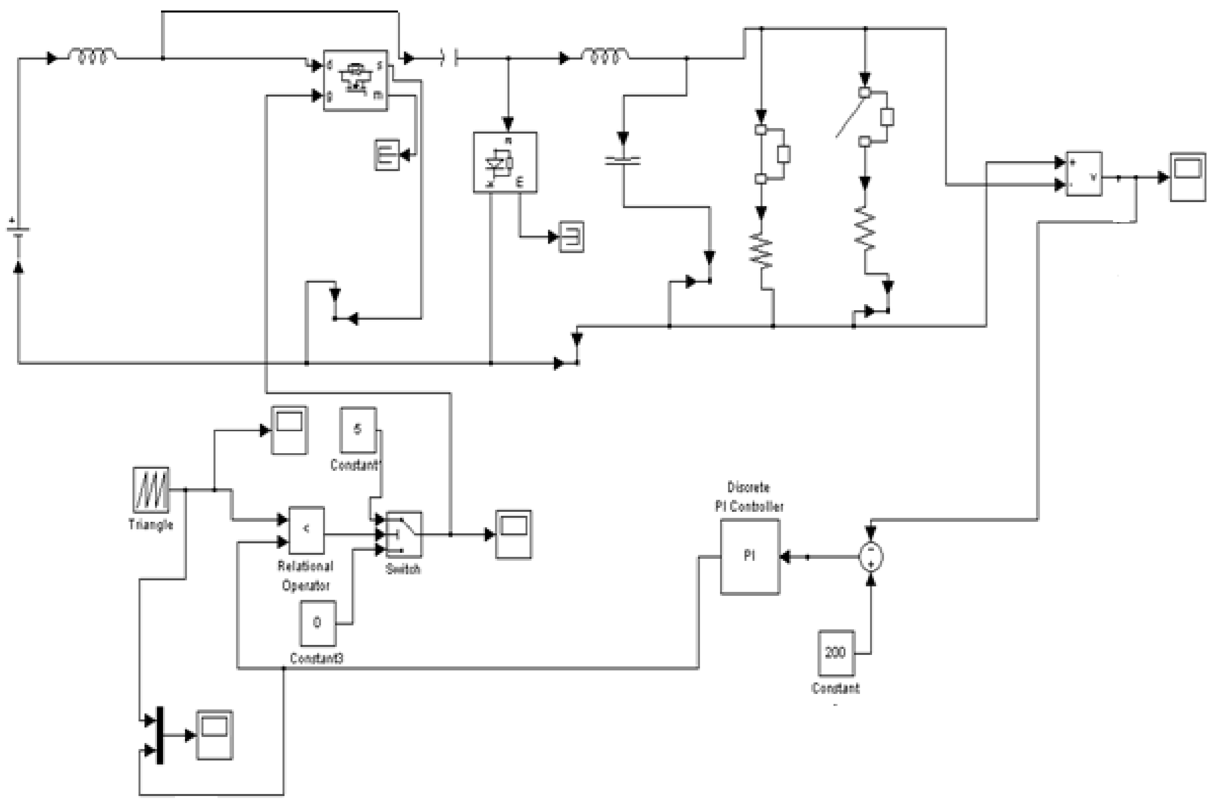

Fig. 5: Cuk converter

Table 2: Output voltage for variable load and variable input

S. No	Load	I_i	I_o	V_i	V_{ref}	V_o
1	100	6.146	0.20	10	20	20.0
3	100	4.668	0.20	08	20	20.0
4	100	7.565	0.20	12	20	20.0
5	120	6.239	0.17	10	20	20.0
6	80	6.002	0.25	10	20	20.0

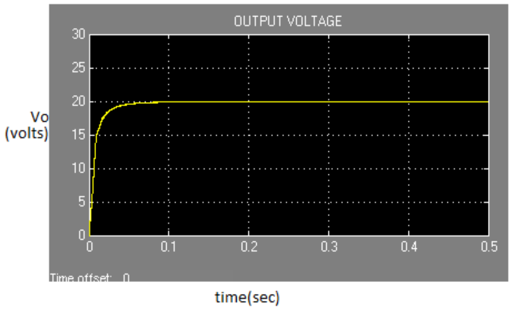

Fig. 6: Output voltage waveform
V_{in}: 8V; V_{out}: 20V; V_{ref}: 20V; Load resistance: 100 ohms

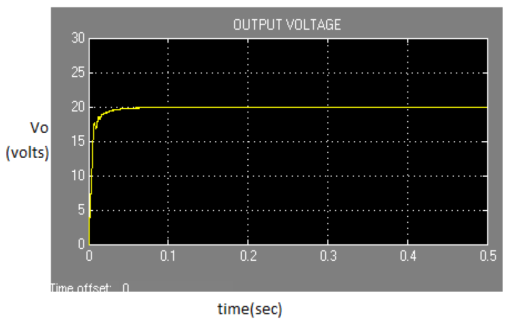

Fig. 7: Output voltage waveform
V_{in}: 40V; V_{out}: 20V; V_{ref}: 20V; Load resistance: 100 ohms

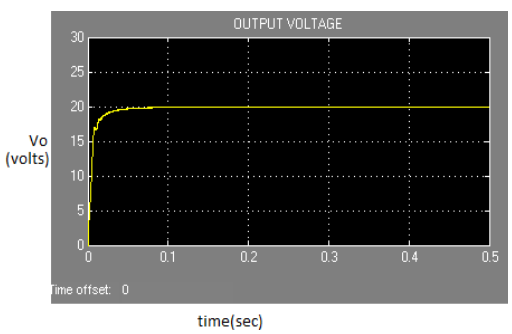

Fig. 8: Output voltage waveform
V_{in}: 10V; V_{out}: 20V; V_{ref}: 20V; Load resistance: 80 ohms

Figure 6, 7 and 8 shows the output voltage waveform of the Cuk converter with load variation and input voltage variation. This converter operates in both Buck and Boost mode when the input voltage is varied above and below the reference voltage.

CONCLUSION

Thus the Sun tracking and MPPT system wer maintained the load voltage constant irrespective of the variation in the input voltage and load resistances. Very simple control scheme is implemented to achieve the required output.

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