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A Comparative Analysis of PV Balancer with Buck, Flyback and SEPIC Converters

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ABSTRACT

Photovoltaic Balancer (PVB) is a basic module integrated converter (MIC) which is designed to reduce the mismatching voltages between PV panels and to perform the individual maximum power point tracking at a time. Several converters can be used as PVB, to realize the PVB the output terminal of a traditional converter should be the positive grounded with DC bus. In this paper the comparative study on PVB with three types of DC to DC converters (Buck, Flyback, Sepic) are presented. The simulation results suggested that the buck converter is a best candidate in terms of output stability, weight and lower initial cost.

Keywords*; module integrated converter, mppt, Flipkart buck converter, PV Balancer.*

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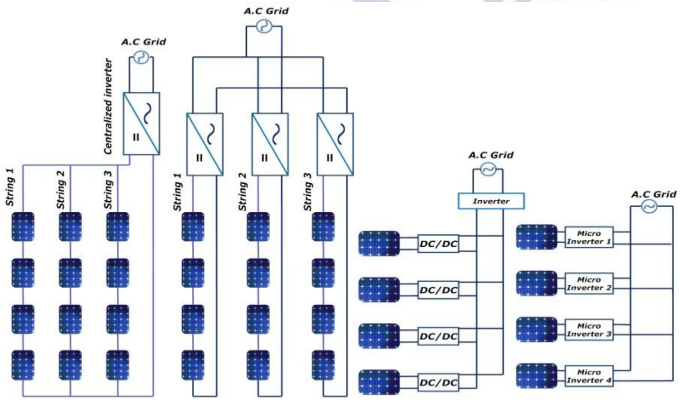
I. INTRODUCTION

In recent years the energy yield from photovoltaic systems has been increased drastically [1]. The researchers addressed different serious issues recording lower efficiencies of photovoltaic's. The variation in solar irradiation leads to reduce the efficiency of PV panel. The output power from PV panels can be maximized by adopting the different Technologies which is shown in figure 1[2][3].



Fig;1Different technologies of PV generation (a) centralized inverter technology (b) string technology (c) integrated converters (d) micro inverters

Among this micro inverter achieve higher efficiency but its application is limited to small scale PV generations due to higher initial cost and voltage transformation ratio [4]. Extensive research has been done to find the alternative solutions. In recent years advanced DC to DC Converter evolved with higher efficiencies and lower cost [5]. The module integrated converter shows promising future for researchers. The converters like buck, boost, buck- boost, flyback and resonant converters can be used as module integrated converters. By observing the actual operating V-I characteristics of PV panel the operating current changes drastically by changing its input solar irradiation which is shown in figure 2.

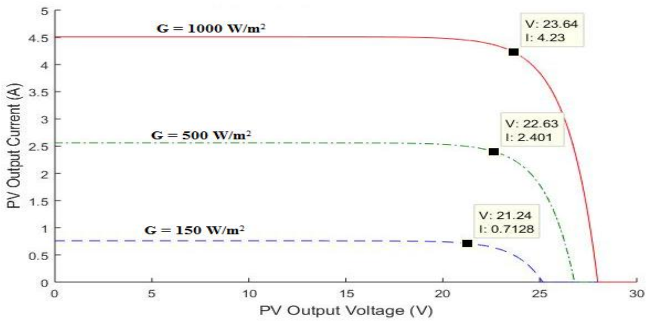


Fig: 2 Operating V-I characteristics of PV Panel

The output power of any converter will depends on its current handling capability and output voltage. The conventional module integrated converters power rating is designed according to PV panel output power [6]. Generally higher output rating devices demand more cost. So to provide the solution for higher power ratings, partial power flow converters are used as module integrated converter which will gives higher efficiency with lower power ratings [7].The PV balances are also working on partial powerful technique as its name suggested that it is used for balancing the voltages between PV panels. Under greatest mismatching input conditions the output voltage of PV panels is changed which can affect the healthy PV panel output so that the inverter input voltage reach to its critical value, finally it leads to shutdown of PV plants [8]. The unbalancing voltages can be regulated by connecting the PV Balancer output to the common DC bus. The inverter input voltage is fed from the common DC bus. So that the DC bus voltage should be in proper limits. The author proposed two different architectures to maintain the constant DC bus voltage irrespective of atmospheric conditions [9]. The comparative analysis has been done on architecture II since the architecture II shows the better results compared with architecture I.

II. CONVERTER ANALYSIS

The author proposed architectures of PVB are shown in figure 3 and figure 4. The front end converter output is connected to the input of PVB which is connected in series with the PV module. The PVB compensates the differential voltages between PV module and DC bus. The DC bus voltage is maintaining 28 volts and the input of PVB step down by the front end converter that is flyback converter which is about 12 volts. If the PV panel output voltage is 24 volts the differential 4 volts is supplied by the PV Balancer so that we can achieve required potential level corresponding to DC bus value [10].

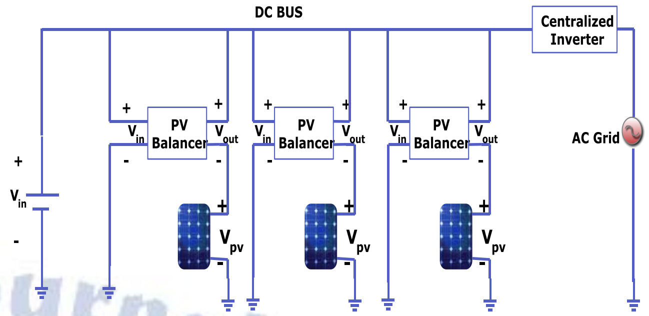


Fig: 3 Architecture-I

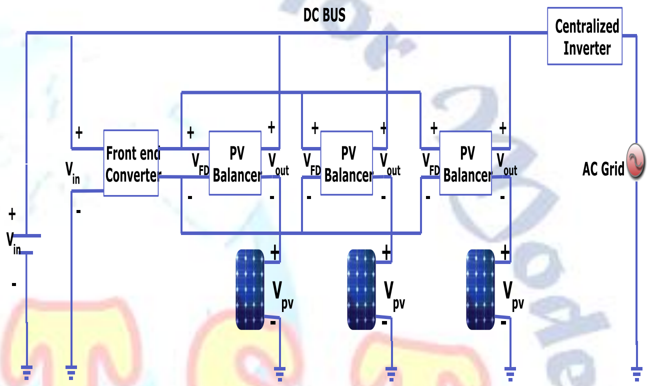


Fig: 4 Architecture-II

The fundamental performance metrics are presented and mathematically expressed below.

PV Balancer output voltage $V_{OUT} = V_{DC} - V_{MPP}$

PV Balancer output power $P_{OUT} = V_{OUT} \times I_{OUT} = (V_{DC} - V_{MPP}) \times I_{MPP}$

Since PVB is in series with PV panel $I_{OUT} = I_{MPP}$

Equivalent efficiency of PV Balancer $\eta_E = 1 - \frac{P_{LOSS}}{P_{MPP}} = 1 - R_{POWER}\frac{P_{LOSS}}{P_{OUT}}$

The ratio of output power $R_{POWER} = \frac{P_{OUT}}{P_{MPP}} = \frac{V_{OUT}}{V_{MPP}} = \frac{V_{DC}}{V_{MPP}} - 1$

If any fault conditions occurred in PVB the PV module is automatically connected to the DC bus by short circuiting the PVB. If fault persists at PV panel the balancer will disconnect PV panel from DC bus

(a) Buck converter

To realize the buck converter as PVB the output should be positive grounded with common DC bus, so the buck converter is flipped from the conventional topology which is shown in figure 5.

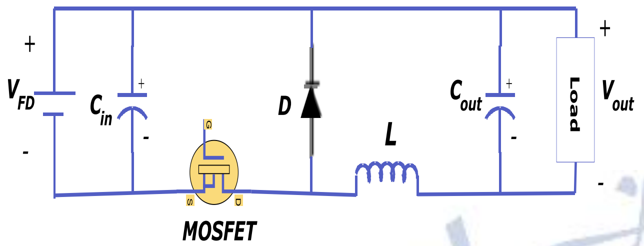


Fig: 5 Flipped buck converter

The output voltage of buck converter is represented as $V_O = D \times V$

Where D is duty ratio, V_o is output voltage and V_{in} is input voltage.

The inductor and capacitor values can be calculated as

$$L = \frac{(1-D)R_L}{2 \times f_S}$$

$$C = \frac{\Delta I}{8 \times f_S \times \Delta V}$$

where R_L is load resistance, f_s is switching frequency, ΔI is ripple current, ΔV is ripple voltage.

(b) Flyback converter

The design parameters for flyback converter are given below. In flyback converter high frequency Transformer is used instead of basic Transformer. The Basic circuit configuration is shown in figure 6.

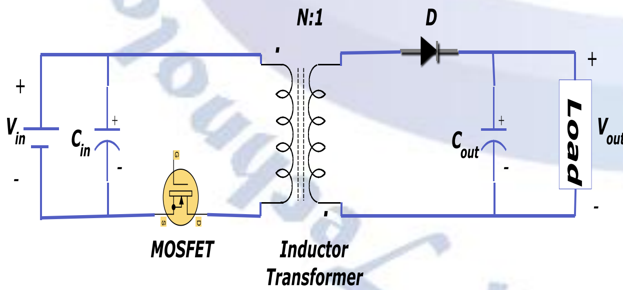


Fig: 6 Flyback converter

The output voltage of flyback converter is

$$V_O = V_{in} \times \frac{N_2}{N_1}$$

Where N1& N2 is primary and secondary turns of flyback transformer.

Primary and secondary inductance of transformer is calculated by following equations

Primary inductance $L_P = \dfrac{V_{in} \times D}{f_S \times I_{P_{peak}}}$

Where $I_{P_{peak}}$ is primary peak current

Secondary inductance $L_S = \dfrac{L_P}{\left(\dfrac{V_1}{V_2} \times \dfrac{N_2}{N_1} \right)^2}$

(c) SEPIC converter

Single end primary inductance converter is a DC-DC Converter which is shown in figure 7.

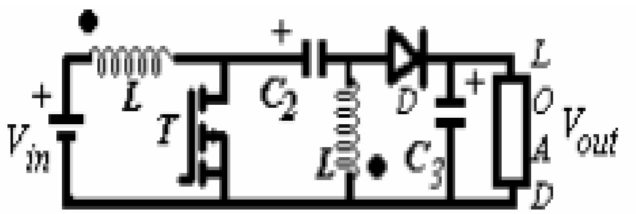


Fig: 7 SEPIC Converter

The output voltage of sepic converter is represented as

$$V_o = \left(\frac{D}{1-D} \right) V_{in}$$

Inductor and capacitor values are calculated with

$$L_1 = L_2 = \frac{V_{in} V_{out}}{\Delta I_L f \left(V_{in} + V_{out} \right)}$$

$$C_1 = \frac{V_{in} I_{in}}{\left(V_{out} + V_{in} \right) f \Delta V_c}$$

$$C_2 = \frac{V_{in} V_{out}}{8 f^2 L_2 \left(V_{out} + V_{in} \right) \Delta V_C}$$

Where ΔI_c is ripple current I in is input current ΔV_c is ripple voltage

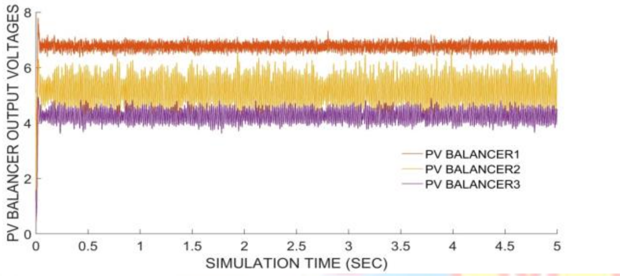
III. SIMULATION RESULTS

The simulation works are implemented on matlab. The comparative analysis of PV balancers with three different converters is presented in table 1. From table 1 it is cleared that the output performance of sepic converter is low compared to remaining converters due to its high oscillating output behavior.

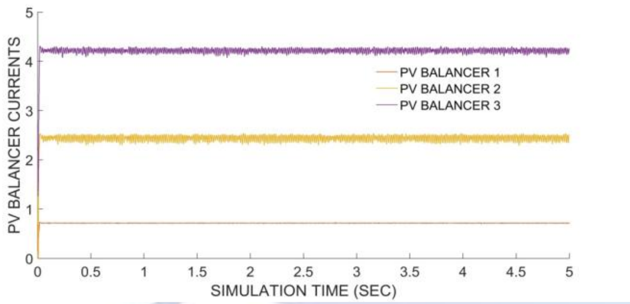
Table I. Comparison between buck converter, SEPIC converter and Flyback converter

PVB	Input voltage (Volts)	Output voltage (Volts)	Output current (Amps)	Output Power (Watts)	**Irradiation (W/m²)**
Buck converter	12	4.29	4.23	18.14	1000
		5.39	2.47	13.31	500
		6.79	0.71	4.82	150
SEPIC converter	12	4.00	4.168	16.672	1000
		4.65	2.105	9.788	500
		5.71	0. 6289	3.591	150
Flyback converter	12	4.29	4.23	18.14	1000
		5.39	2.47	13.31	500
		6.79	0.71	4.82	150

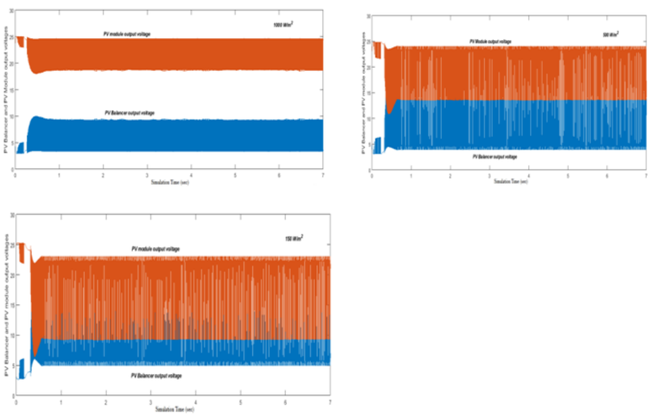
The output voltages and currents of flipped buck converter used as PVB shown in figure 8 and figure 9. The output voltage and output current of sepic converter is shown in figure 10 and figure 11 the deviation in output voltage and current leads to poor performance as PVB.



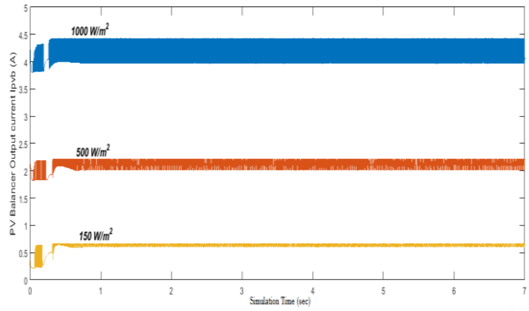
Fig; 8 Flipped buck Converter output voltages



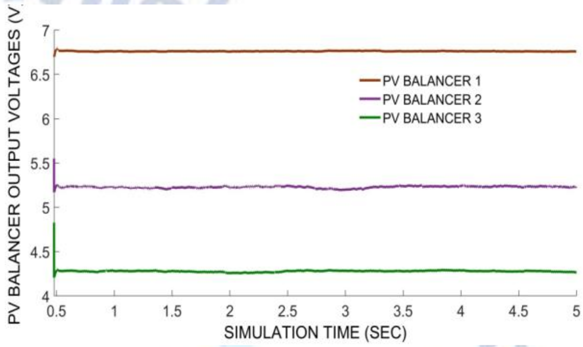
Fig; 9 Flipped buck Converter output currents



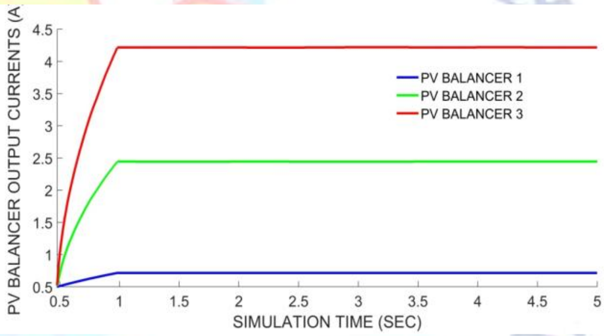
Fig; 10 SEPIC Converter output Voltages



Fig; 11 SEPIC Converter output Currents



Fig; 12 FLYBACK Converter output Voltages



Fig; 13 FLYBACK Converter output Currents

The output voltage and output current of flyback converter is shown in figure 12 and figure 13. The output values of buck and flyback converter are seemed to be same. In practical the weight and cost of flyback converter is more.

IV. CONCLUSION

In this paper three different converters (buck, flyback,Sepic) has been successfully realized as PV Balancer. The performance analysis of three converters is well demonstrated and compared qualitatively. The investigation shows that the buck converter has better output voltage, lower weight and cost solutions. So it is possible to integrate a buck converter in the junction box of a PV pane. This work is further extended to develop the special inverter for PV balancer and DC bus voltage control.

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