Modified Cascaded Boost Converter with High Voltage Gain for standalone PV system for high power application

MARIMUTHU.M., AP/EEE
Department of EEE
Saranathan college of Engineering
(Research scholar)
marimuthuphd@rediffmail.com

PARANTHAGAN. B., AP/EEE
Department of EEE
Saranathan college of Engineering

RAMADEVI. S., AP/EEE
Department of EEE
Idhaya Engineering College for Women
devinvyl90@gmail.com

***I. Abstract – In this paper* an attempt is made to implement modified cascaded boost converter for photovoltaic system Normally the output voltage of PV system is low which has to be stepped up to higher voltages. A normal boost converter provides low voltage gain while Cascaded boost converter provides high voltage gain. As cascaded boost converter ensures high voltage gain, the input inductor current and switching stress increases, which restrict the usage of cascaded boost topology to photovoltaic system for high power standalone applications . Modified cascaded boost topology ensures low switching stress and low input current. Simulations are carried out in Psim sowtware. simulation result proves MCBC decreases input current and switching stress while delivering high voltage gain for high power PV applications..**

I. INTRODUCTION

For applications like UPS, fuel cell, renewable energy systems and various other industrial applications the usage of dc –dc is inevitable. Buck, boost, buck-boost, cuk, flyback, forward, cascaded, half bridge and full bridge converters are the various topology used for step up or step down the output voltage. boost converter are widely used for boosting input voltage to higher values in the case of renewable energy systems. A boost converter is a dc to dc power converter that provides an output voltage greater than the input voltage. It is a class of SMPS which provides low voltage gain. For high voltage dc application boost converter cannot be used as it provides low voltage gain. For high voltage gains cascaded boost converter are employed. Cascaded boost converter consists of two basic dc to dc boost converter connected in cascade and the output voltage of cascaded boost converter is having high voltage gain and high power. For example if a 12V input voltage is boosted to 110V with a voltage gain fairly around 10, the input current also increases 10 times and this high current flows through the input inductor and the switch. The proposed converter topology involves splitting of the input inductors so that the high input current as a result of boosting the input voltage can be effectively handled. So this proposed converter can be used for fuel cell application. [1][2][3].

Fuel Cell Power is widely used for transportation applications and standalone power supplies. As fuel cell voltage is of low voltage cascaded boost converter is used as an interface for high voltage applications. Theoretically, conventional boost converters are able to achieve low voltage gain. Modified cascaded boost converter offer significant advantages, including simplicity, size, reduction, especially in high-powered applications

II. CONVENTIONAL CASCADED BOOST CONVERTER

The circuit diagram of the conventional dc to dc cascaded boost converter [5],[6] is shown in fig.1. It has two operating modes. The equivalent circuits of the converter operating in the two modes are shown in fig.2 and fig.3 respectively.

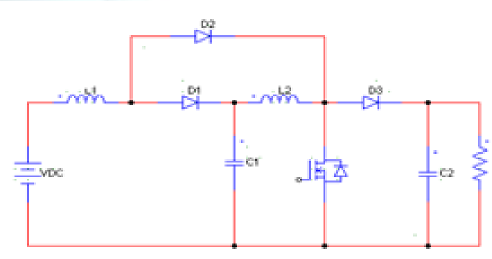

Fig.1 Conventional cascaded boost converter

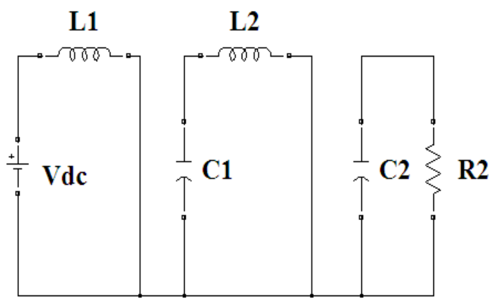

Fig.2 Equivalent circuit when Switch S is ON

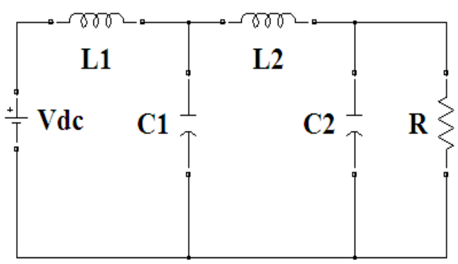

Fig.3 Equivalent circuit when Switch S is OFF

III. MODIFIED CASCADED BOOST CONVERTER

In the proposed converter topology the input inductor is split up into two parallel inductors and an additional switch is employed [6]. By doing so the magnitude of input current is reduced effectively. The input current is the sum of two inductor currents. The circuit of the proposed converter is shown in fig.4. and the operating modes of the converter are shown by equivalent circuits in fig.5 and fig.6

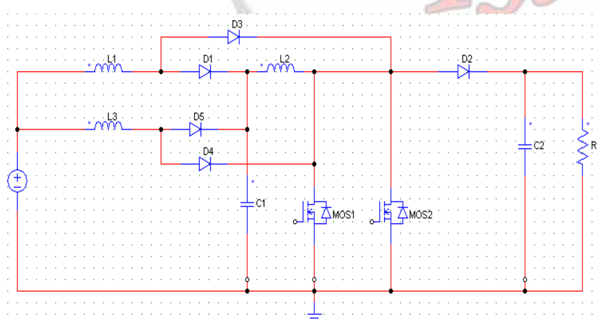

Fig.4 Proposed converter topology

Circuit parameters are calculated using the design equations described below. A switching frequency of 15 KHz and a duty cycle of 65% are chosen for a 110V, 40W application [7],[8],[9]. The output voltage is given by the expression

$$V_0 = V_{in}/(1-D)^2 \qquad (1)$$

The load value is calculated using the following expression.

$$R = V^2/P \qquad (2)$$

Current values are given by

$$I_0 = V_0/R \qquad (3)$$

$$I_{L1} = I_0/2(1-D)^2 \qquad (4)$$

$$I_{L3} = I_0/2(1-D)^2 \qquad (5)$$

$$I_{L2} = I_0/(1-D) \qquad (6)$$

A. Operating modes of proposed converter.

1) Mode 1: Switches S1 and S2 turned ON

The converter operates in two modes. In mode 1 both the switches are turned ON by giving gate pulses at the same instant. When the Switches S1 and S2 are turned ON the input voltage charges the inductors L1 and L3. The charge in inductor L2 is increased by the capacitor C1 and the output voltage V0 is given by the capacitor C2.

Applying Kirchhoff's laws we get the following equations for Mode 1.

$$L_1 \frac{d}{dt}(i_{L1}) = V_{in}/2 \qquad (7)$$

$$L_3 \frac{d}{dt}(i_{L3}) = V_{in}/2 \qquad (8)$$

$$L_2 \frac{d}{dt}(i_{L2}) = V_{C1} \qquad (9)$$

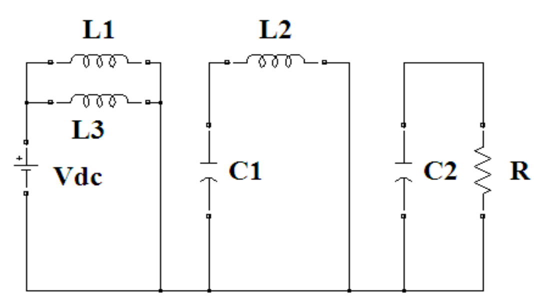

Fig.5 Equivalent circuit of proposed converter when Switch S is ON

$$C_1 \frac{d}{dt}(V_{C1}) = -i_{L2} \qquad (10)$$

$$C_2 \frac{d}{dt}(V_0) = -V_0/R \qquad (11)$$

2) Mode 2: Switches S1 and S2 turned OFF

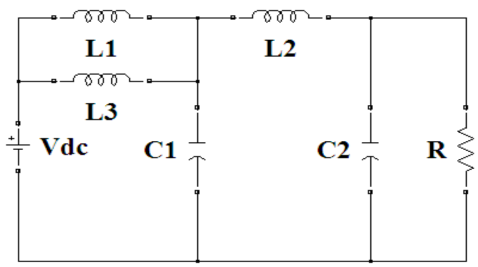

Fig.6 Equivalent circuit of proposed converter when Switch S is OFF

In mode 2 when switches are turned OFF the charges in the inductors L1, L2 and L3 are discharged to the load along with input voltage.

Applying Kirchhoff's laws to the above circuit we get the following equations for Mode 2.

$$L_1 \frac{d}{dt}(i_{L1}) = (V_{in} - V_{C1})/2 \qquad (12)$$

$$L_3 \frac{d}{dt}(i_{L3}) = (V_{in} - V_{C1})/2 \qquad (13)$$

$$L_2 \frac{d}{dt}(i_{L2}) = V_{C1} - V_0 \qquad (14)$$

$$C_1 \frac{d}{dt}(V_{C1}) = (i_{L1} + i_{L3}) - i_{L2} \qquad (15)$$

$$C_2 \frac{d}{dt}(V_0) = i_{L2} - (\frac{V_0}{R}) \qquad (16)$$

Based on the theoretical analysis the circuit parameters are calculated and tabulated in table.I.

TABLE.I

CALCULATED CIRCUIT PARAMETERS

PARAMETER	EXISTING CONVERTER	PROPOSED CONVERTER
Vin(V)	24	24
V0(V)	105	106.5
L1(mH)	1.619	3.238
L3(mH)	-	3.238
L2(mH)	14.78	14.78
C1(uF)	2.1	2.1
C2(uF)	100	100

IV. CIRCUIT SIMULATION

The proposed MCBC circuit topology and the conventional cascaded boost converter circuit are simulated using MATLAB software to validate the proposed results. Simulation is carried out based on the circuit parameters tabulated in table.I. Simulated input current values and switch currents are listed in table.II. The circuit is designed for a 110V, 40W application. The simulated circuit of MCBC is shown in fig.8 and fig.9 to fig.11 illustrate simulated results showing input currents, switch currents, output currents, output voltages and output power for different duty cycles and different load settings.

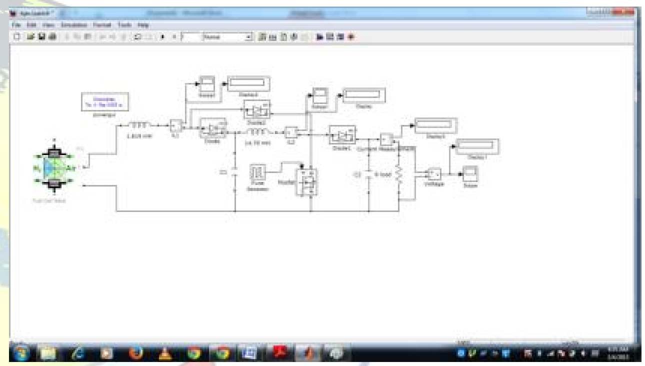

Fig.7 Conventional cascaded boost converter with fuel cell as input power.

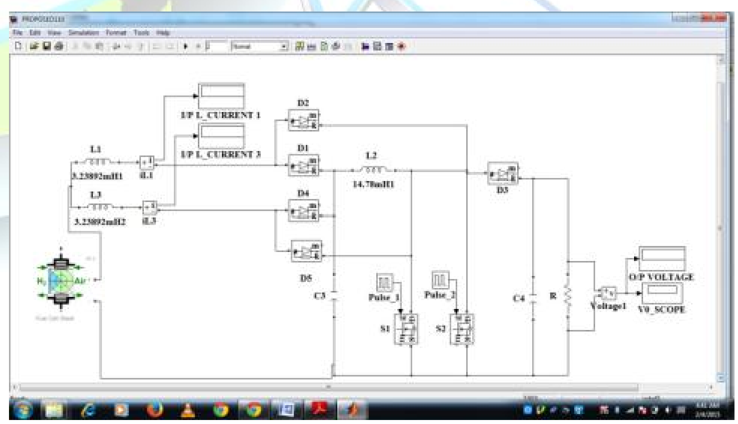

Fig.8 Modified cascaded boost converter (MCBC) with fuel cell power as input.

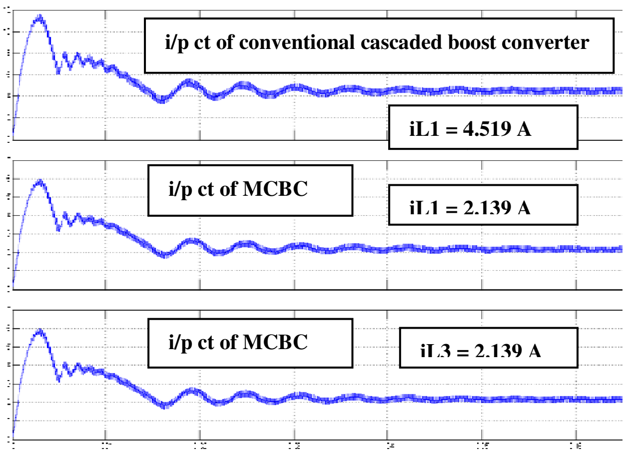

Fig.9 Comparison of input inductor currents of conventional cascaded boost converter and MCBC.

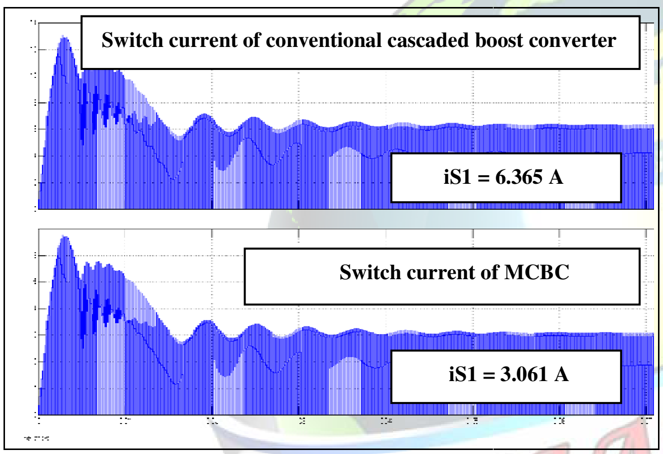

Fig.10 Comparison of switch currents of conventional cascaded boost converter and MCBC

TABLE.II

I/P CURRENT AND O/P VOLTAGE OF CONVENTIONAL CASCADED BOOST CONVERTER AND MCBC

D	CONV. CASCADED BOOST CONVERTER	MCBC		OUTPUT VOLTAGE CASCADED BOOST CONVERTER	OUTPUT VOLT MCBC
	iL1	iL1	iL3	V0	V0
0.3	0.45	0.24	0.24	42.21	42.01
0.4	0.80	0.41	0.41	42.12	41.92
0.55	4.51	2.14	2.14	110.8	106.5
0.65	4.51	2.14	2.14	110.8	106.5
0.7	4.51	2.14	2.14	110.8	106.5

From the above comparison it is shown that in the proposed MCBC the input current is effectively reduced to half while delivering the expected high voltage gain high power output.

IV. COMPARITIVE ANALYSIS OF PERFORMANCE

The load (R) and duty cycle D are varied and the corresponding output voltage and output power of both the conventional cascaded boost converter and MCBC are simulated and the simulated values are tabulated in table.III.

TABLE.III

OUTPUT POWER FOR DIFFERENT LOAD SETTINGS

LOAD R	CONVENTIONAL CASCADED BOOST CONVERTER			MCBC		
	i0	V0	P0	i0	V0	P0
50	1.546	77.28	119.48	1.651	82.54	136.27
100	0.828	82.75	68.52	0.856	85.59	73.27
150	0.565	84.76	47.89	0.578	86.65	50.08
200	0.429	85.79	36.80	0.436	87.19	38.01
250	0.383	95.76	36.68	0.372	92.95	34.58
300	0.366	110.8	40.55	0.352	106.5	37.49

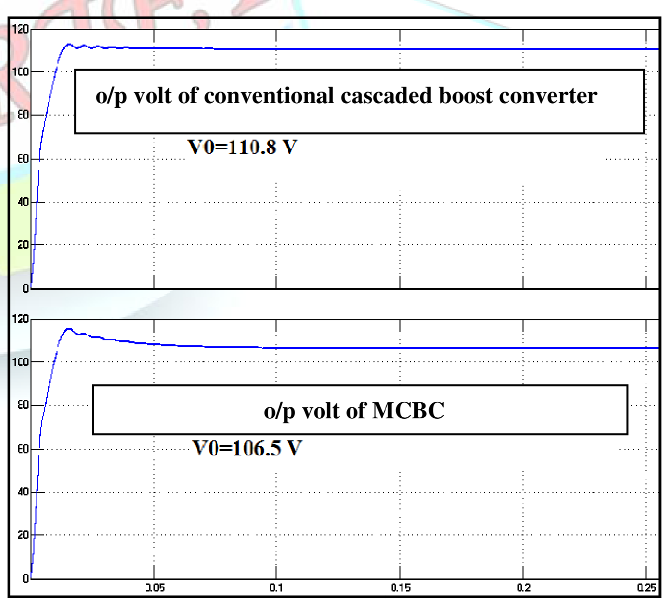

Fig.11 Comparison of output voltages of conventional cascaded boost converter and proposed MCBC.

The duty cycle D is varied and the corresponding input current and output voltage of both the converters are calculated and compared in the plots illustrated in fig.12 and fig.14. It shows that the input current of MCBC is reduced to half the value of input current of the conventional cascaded boost converter, but the output voltage of both the converters are almost equal. The obtained results are tabulated in table.IV.

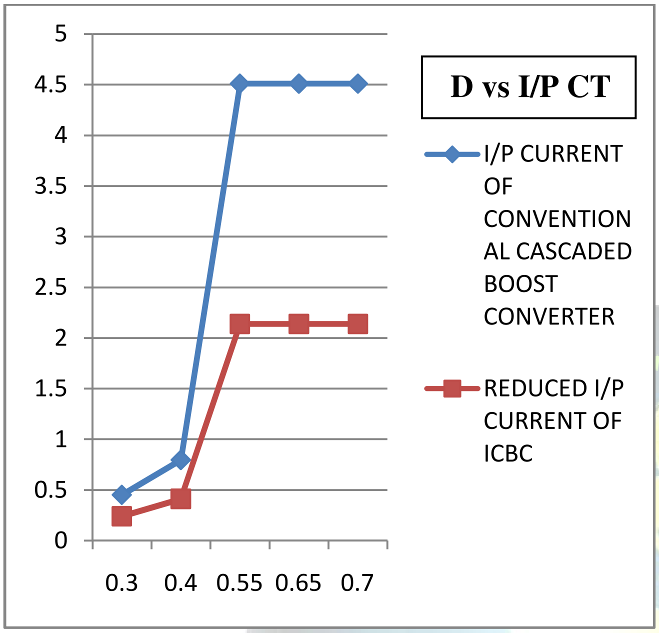

Fig.12 Plot showing comparison of input currents of conventional boost converter and modified /improved CBC for different duty cycles.

For a constant voltage gain, as output power increases, output current increases along with that the input current increases in conventional cascaded boost converter but for the same voltage gain and output power, the input current is reduced to half in proposed MCBC and it is shown in fig.13.

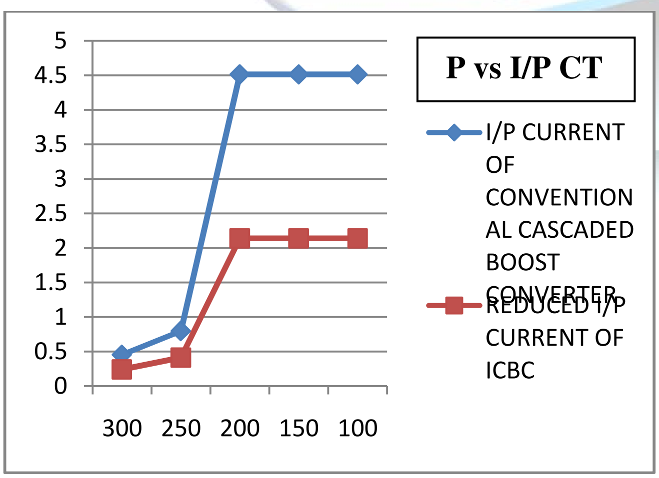

Fig.13 Plot showing input current of converters for different load setting

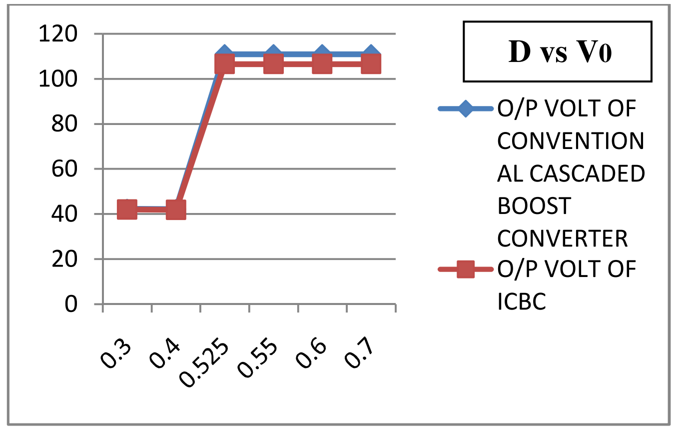

Fig.14 Plot showing comparison of output voltages of conventional boost converter and modified / improved CBC for different duty cycles.

TABLE IV

COMPARISON OF INPUT AND OUTPUT CURRENTS FOR DIFFERENT DUTY CYCLES

D	I/P CT		O/P CT	
	CONV. CASCADED BOOST CONVERTER	MCBC	CONV. CASCADED BOOST CONVERTER	MCBC
	iL1	iL1, iL3	i0	i0
0.3	0.454	0.241	0.139	0.138
0.4	0.797	0.413	0.139	0.138
0.55	4.51	2.138	0.366	0.352
0.65	4.51	2.138	0.366	0.352
0.7	4.51	2.138	0.366	0.352

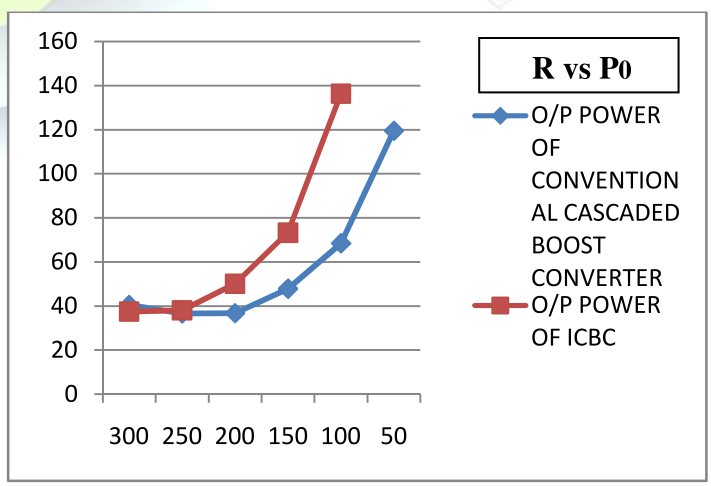

Fig.15 Plot showing comparison of output power of conventional cascaded boost converter and modified /improved CBC for various load(R) settings

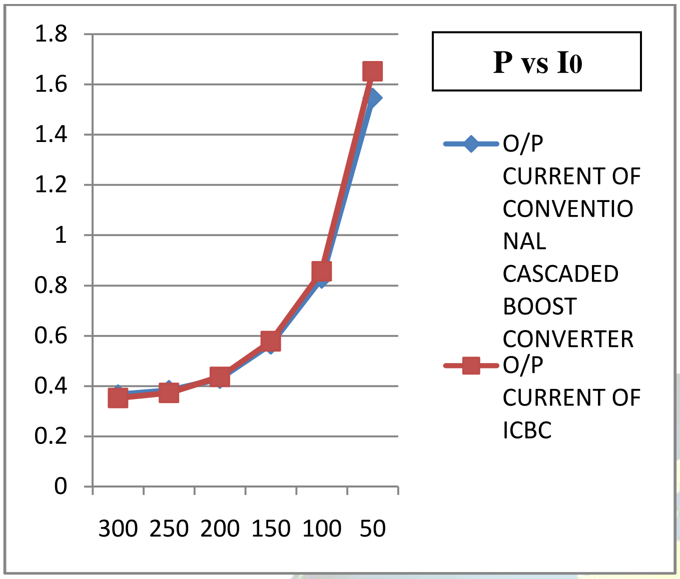

Fig.16 Plot showing comparison of output current of conventional cascaded boost converter and improved CBC for various load (R) settings

In the plots given fig.13 the input current for different load settings and in fig.15 and fig.16 the output power and output current for various load (R) settings are compared for conventional and modified cascaded boost converters, where the proposed MCBC has better performance. The plots given in fig.16 and fig.17 make it evident that the input current of the MCBC is reduced which in turn reduces high switching stress and makes this converter topology more suitable for photovoltaic and fuel cell based dc water pumping applications. To confirm the effective operation of the proposed MCBC a prototype is built and its performance under various operating condition is being experimented.

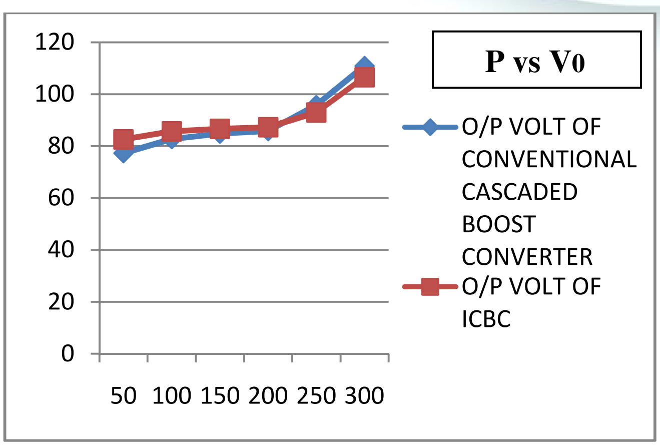

Fig.17 Plot showing output power of converters for various load (R) settings

V. CONCLUSION

.This paper presents the design and simulation of modified cascaded boost converter (MCBC). The proposed MCBC and conventional converters are simulated using Psim software and the results are compared for more than one duty cycle and output power setting. To validate the simulation results and theoretical analysis a prototype of the conventional cascaded boost converter and the proposed MCBC is fabricated and the experimentation is under process. This MCBC gives a high output gain while reducing the input current and the switching stress which makes it suitable for high power PV applications.

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