High Voltage Gain Hybrid Boost Converter for Photovoltaic Generation

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***Abstract*— In a parallel connected PV arrays, if there is any damage in one of the arrays the overall output voltage will get effected .In traditional system, converters used to overcome voltage difference, would have to be operated at higher duty cycle Hence a three level hybrid boost DC-DC converter is designed to overcome the voltage level difference across the low voltage photovoltaic(PV) arrays and the grid which are running along side. The converter is called as three level converter since the output produced has three different level of voltage. The system can be easily designed with transformerless high voltage gain by integrating inductor, two capacitors, power switches and diodes. The pulse width modulation control method is achieved from the switching functions of the output pulse voltages of both half bridges. Hence the designed converter gets the duty cycle of the power switch near to 0.5 and can also operate with voltage gain at higher level. the modeling and simulation is done using MATLAB/simulink**.

Index Terms*— *Photovoltaic generation, hybrid boost converter High voltage gain, high efficiency

I. INTRODUCTION

Due to increase in power demand renewable energy has gained a lot of importance. Solar and wind energy both are important part of renewable energy sources as they are environmental friendly and does not use fossil fuels [1] , [2].

In a grid connected system, higher level of voltage is in demand. A stand alone PV array is able to provide a low level DC voltage. To overcome the above problem, series connected PV arrays were introduced to decrease the difference of level in voltages within DC bus and grid system. But PV cells with lower voltages have to deal with dust, clouds , shadows etc. which in turn decreases the output voltage of series system [3],[4], thus reduces the efficiency of the system.

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The level of power generation is improvised by connecting the PV arrays in parallel flexibly. With high voltage gain the DC bus has to be steeped up for such configuration of PV system. Hence for low voltage PV arrays parallel connected in parallel high step up dc dc converter are used to get voltage conversion[5]. The converters works with high step up gain, the power switches in traditional two level boost converters tolerate extreme voltage at output but usual three level boost converters decrease 50% of the stress[6], but due to lower turn off time, the voltage gain and switching frequency is restricted by higher duty cycle. To extend the voltage gain and duty cycle series connected boost converters are also utilized [7]. But demand for higher number of separated Inductors and the output voltage stress of the power switches of the last power stage cannot be avoided.

In our proposed work the three level hybrid DC DC boost converter are used without a transformer or coupled inductors so as to obtain higher level of voltage gain and efficiency and also it avoids extreme duty cycles.

II. SYSTEM TOPOLOGY

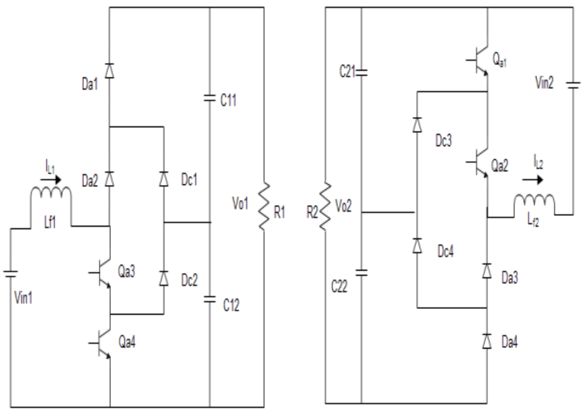

Fig. 1 Two derived three level boostl dc-dc coverters.

In our present work so as to improvise the overall voltage at dc bus and level of power of pv generation systems, and in addition to obtain thin pulse voltages a three level hybrid boost converter has been derived by the three level boost converters I and II in fig 1. For converters I and II, vin1 and vin2 are given as input dc voltages and lf1 and lf2 as filtering inductors respectively. In the hybrid converters the input power level is improved by series connection of input and parallel connection of output as shown in fig2.

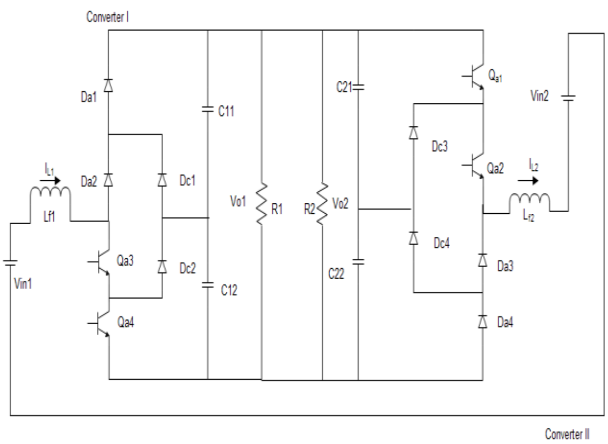

FIG 2: synthesized three level hybrid boost converter .

The simplified three level hybrid boost l converter is shown in fig3. The DC voltage vin and the inductor lf are the equivalent input sides of converter 1 and converter 2 in sequence. The parallel connected capacitors and load resistors in fig2 are replaced by equivalent capacitors and load resistors respectively as presents in fig 3.

III. OPERATION PRINCIPLE

A. *Modes of operation:*

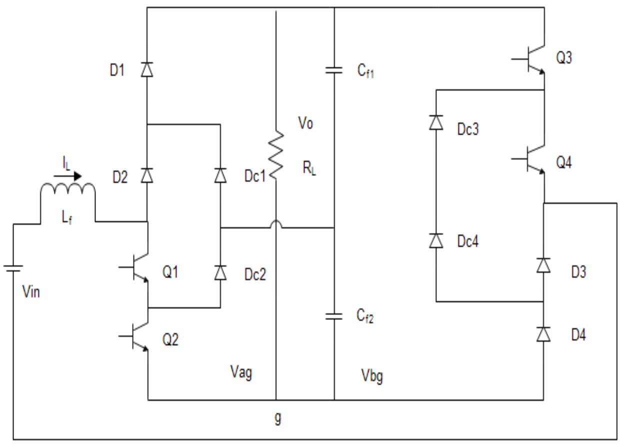

Fig 3: Designed hybrid three level DC DCboost converter.

In fig3 the output voltages of two converter are Vag and Vbg. The output voltage Vo is obtained by filtering capacitors The equation for pulse voltage of output of the hybrid converter is given by

$$Vab = Vag - Vbg \qquad (1)$$

TABLE I
Modes of operation of the power components of the hybrid converter

Vag	Vbg	Vab	Q1-Q4	D1-D4	Lf	DC1-DC4
$V_{cf1}+V_{cf2}$	0	V_0	0000	1111	tr	0000
$V_{cf1}+V_{cf2}$	V_{cf2}	$V_0/2$	0001	1100	tr	0010
V_{cf2}	0	$V_0/2$	1000	0011	tr	0100
0	0	0	1100	0011	st	0000
V_{cf2}	V_{cf2}	0	1001	0000	St	0110
$V_{cf1}+V_{cf2}$	$V_{cf1}+V_{cf2}$	0	0011	1100	st	0000

Table 1 presents the modes of operation of the power components of the hybrid converter. The voltage across capacitor cgf1 and cf2 are vcf1 and vcf2 respectively which are equal. When Q1-Q4 are switched off, the capacitors in series charge together by both dc voltage source and inductor through diodes D1-D4. The output of the hybrid converter is Vo. When cf1 is charged by input dc voltage as well as inductor through diodes D2, D1 and Dc3 and only Q4 is switched on. Simultaneously cf2 is discharged and output is Vo/2. For V0/2 the cf2 is charged by input dc voltage and inductor through diodes Dc2, D4 and D3 when only Q1 is turned on and cf1 is discharged. The energy in the inductor increases when Q1 and Q2 are switched on by diodes D4 and D3, the capacitors are discharged together then Vab = 0

B.*PWM Control:*

The gating signal produced for turning on and off the owner switches is done by comparing a reference signal with a carrier wave. The frequency of the reference signal determine the output frequency fo and carrier frequency fc finds the number of pulse per 50% of cycle P. the modulation index control the output voltage. The pulses per 50% of cycle is given by

$$P = (f_c)/(f_o) = (m_f)/2 \qquad (2)$$

Where, $m_f = f_c/f_o$ is defined as the frequency modulation ratio.

The switching function Vag and Vbg for both converters is given by

$$Vag = (1-S_1S_2)*(V_{cf1}+V_{cf2}) - (S_1-S_2)*(V_{cf1}) \qquad (3)$$

$$Vbg = S_{3*} V_{cf1} + S_{4*} V_{cf2} \qquad (4)$$

The switching action is done between two adjacent switches. Considering m_a and m_b to be modulation index of converter I and II respectively, which are designed to have a phase shift π due to the structure of hybrid converter. According to voltage level required the gating signals can be obtained by PWM control. When Vab is 0, the energy in inductor Lf is either increased or decreased.

C. *High voltage gain operation :*

In hybrid converter when Vab is 0, the energy Wst is stocked in inductor Lf, otherwise energy Wtr is transferred. The inductor current i_L is assumed to be continuous and IL is its average current. Wst and Wtr is given by

$$Wst = Vin * I_L * ton_2 * 2 \qquad (5)$$

$$Wtr = (Vo - Vin)\, I_L * \left(\frac{I}{2} - ton_1 \right) * 2 + \left(\frac{Vo}{2} - Vin \right) * I_L - (t_1 + t_2) * 2 \qquad (6)$$

$$Wst = Wtr \qquad (7)$$

Where $ton_1 - ton_2$ are turn on time of Q1 to Q4 where t= T/4 or t = 3T/4

$$t_1 = t_2 = (ton_1 - ton_2)/2$$

$$t_3 = t_4 = (ton_4 - ton_3)/2$$

$$ton_1 = ton_4$$

$$ton_2 = ton_3$$

$$t_1 + t_2 = t_3 + t_4$$

Hence the output voltage is given by

$$Vo = \frac{T}{T-(t_{on1}+t_{on2})} = \frac{V_{in}}{1-(d1+d2)} \qquad (8)$$

Where the duty cycle of transistor Q1 and Q2 are d1 and d2

IV. SIMULATION RESULTS

The simulink model of the designed system is as presented in fig 4. The boosted voltage obtained from the input dc voltage is as presented in fig 5. As explained in the operation principle the voltage Vag , Vbg and Vab is obtained by the simulation as presented in fig 6. The voltage across the capacitor Cf1 and Cf2 and the current across the inductor obtained is as shown in fig 7. From the obtained results the designed converter is appropriate for the high step up dc dc to interference of voltage of PV generation systems. For input of 12V the output obtained is 23V as shown in figure 5. The output current is too low (0.5A). The duty cycle for the switch is 0.3.If there is any error in the voltage of PV connected array which are in turn connected in parallel, the Hybrid boost converter boost the voltage error at very low duty cycle so as to keep the overall voltage of the system constant. Unlike the traditional one switch converters, hybrid boost converter has 4 switches in turn reducing the switching time of each switch hence switching losses are reduced.

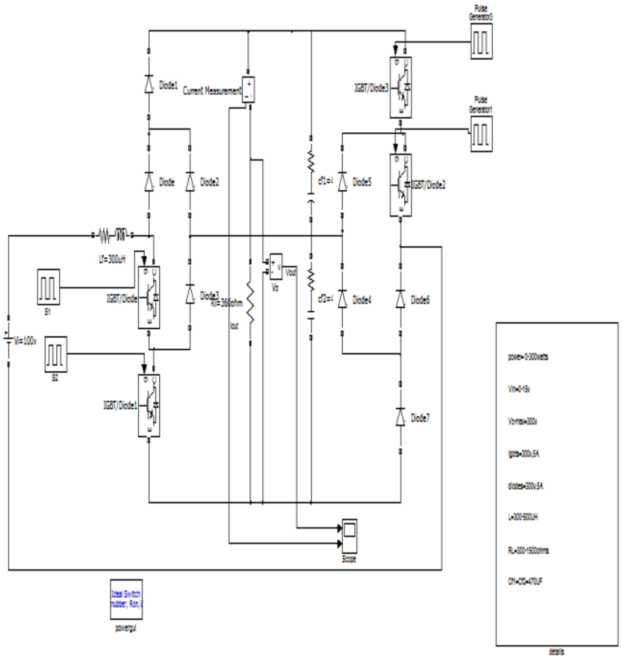

Fig.4 Simulink model of hybrid boost converter

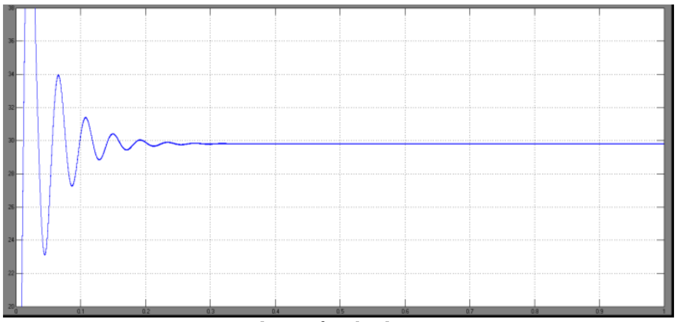

Fig 5 Output voltage of Hybrid Boost converter

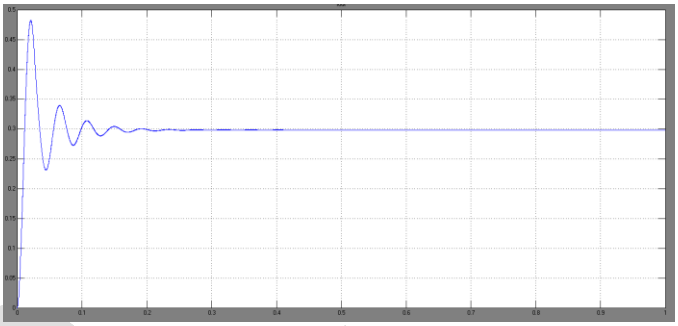

Fig 6 output current of Hybrid converter

CONCLUSION

In our proposed work the three level hybrid boost dc-dc converter can function with voltage gain at higher level without transformer and also gets the duty cycle of power switch near to 0.5 without higher duty cycle but with increasing voltage gain. The PWM method used can keep the capacitor voltage stable. The designed system is apropriate for PV system which is connected to grid with parrallel connected low voltage PV arrays and simulation work is carried out in this paper.

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