A Modified High Gain Boost Converter for PV in DC Microgrid for AC and DC Application

Rajalakshmi Menon
M.Tech Student, EEE Dept
ASIET
rajalakshmimenon94@gmail.com

Gomathy S
HOD. EEE Department
ASIET

Dr. Jeno Paul
Prof , EEE Dept
ASIET

Rajalakshy S
Sr. Asst. Prof, EEE Dept.
ASIET

Lakshmipriya K J
EEE Dept, ASIET

Abstract—**This paper presents a novel boost converter for PV in a dc micro-grid for both ac and dc application. The main aim is to improve the voltage gain capacity of conventional boost converter used in PV for a DC micro-grid. Boost converters are dc to dc converter used to increase the input voltage. Conventional boost converters have low voltage gain capacity with high duty ratio. To eliminate this problem a new three level boost converter which improves the voltage gain capacity with low duty ratio is proposed. Through this modified converter the voltage gain capacity is increased. The circuit is designed in MATLAB/SIMULINK and results are verified**

Keywords— DC micro-grid, low gain, Three level boost converter

I.INTRODUCTION

There are many remote locations in the world, which don't have access to electricity. There are also many places, which are connected to the grid, however, they don't receive electricity for up to 10-12 hours in the day. Many of such places are rich in renewable energy (RE) sources such as wind, solar and bio-mass. Nowadays electrical distribution system is experimenting the use of these DERs and thus forming power clusters [1]. This power cluster is called as Micro-grid. It has two types – Alternating Current Micro-grid (ACMG), and Direct Current Micro-grid (DCMG). If the micro-grid has two type of sources then it is called a hybrid micro-grid. Basically the DERs such as solar PV systems, fuel cells operate at DC. Using power electronics circuits, a DC link can be formed to feed DC loads. For AC loads it can use an inverter at each section to convert DC power to AC power and this type of grid is AC micro-grid.

In AC micro-grid most of the DERs supply power to AC mains network and require costly and inefficient power inverters, even where the power may ultimately have delivered to a DC device. [3,5]. Whereas in DC micro-grid all the sources will be DC. In modern world electrical loads in buildings such as computers, light emitting diodes (LEDs), etc. are supplied by DC power. Also most of the renewable energy sources produce DC power. Aside from reducing financial costs, a major advantage of DC micro-grid is that the low risk of dangerous electric shocks from low voltage DC makes plug-and-play grids a possibility [8]. This also reduces the cost of installations of micro-grid, and will encourage end users to take responsibility to understand and control their own energy usage. By implementing intelligence and internet facility to DC micro-grid controllers it will further enables consumer involvement with AC devices - through smart metering and in result with dynamic demand management.

And therefore it will help to reduce costs in association with schedule of high and low power consumption. [10]

The problem with DC micro-grid is that the renewable energy sources produces only a small amount of power therefore it is must use a converter to boost this power to integrate to grid only a small amount of power therefore it is must use a converter to boost this power to integrate to grid.

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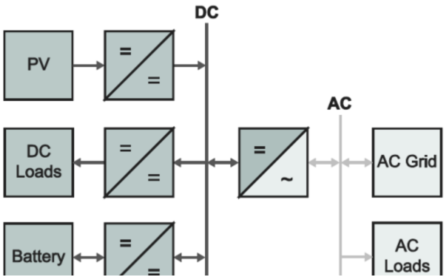

Fig 1. General DC Micro-grid

Conventionally use boost converters but these have low voltage gain, hence it is necessary to increase the number of boost converters. Also the efficiency of boost converter will be less for high gain i.e. for very large duty cycle. Therefore, in this converter it cannot achieve high gain operation. Efficiency will be as poor as 60% for a duty cycle of 0.7[12]. Whereas it will have a highest efficiency for duty cycle of 0.5. To achieve low ripple of ripple free current the use of the Cuk and Sepic converters has been proposed [7]. However, the Cuk and Sepic converters have higher switch voltage and current stresses than the Boost converter, which may result in a low efficiency. Therefore, boost topology may still be preferable.

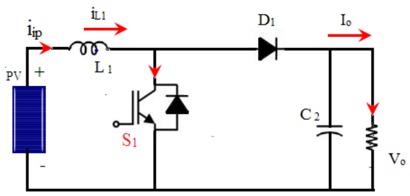

Fig 2. Conventional Boost Converter

Therefore, to overcome these disadvantages of conventional boost converter a modified boost converter is proposed [13]. In this a three level boost converter whose main features includes low devices voltages stress requirement is for high voltage application, small inductor size that leads to the decrease of cost and it is compact and can be operated with a large range of input voltage.

II.PROPOSED SYSTEM

Circuit Daigram

This paper proposes a three level boost converter which has a high gain. This boost converter has the ability to convert low voltage of PV solar system to high voltage without the use of multiple boost converter.

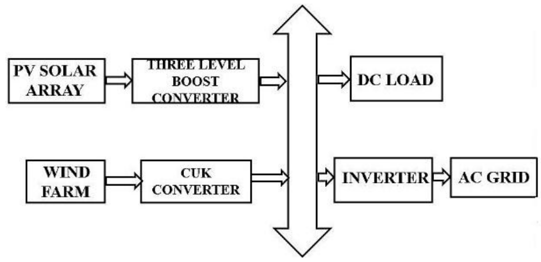

Fig 3. Block Diagram of Proposed System

The proposed system consists of a Solar PV array which is designed to give an output of 60V. In this each solar cell is designed with 4.75A short circuit current, 1V open circuit voltage, 25deg Celsius system temperature, 1000 W/m^2 irradiance. Wind turbine is also designed to have an output of 60V. The output of solar is boosted using the modified three level boost converter.

III.WORKING OF MODIFIED CONVERTER

Fig 4 shows the proposed circuit. It consists of 4 switches S_1 to S_4, two inductors (L_{in}, L_s) and two output capacitors (C_{01}, C_{02}). Output of solar is given to this converter which boost the voltage to required level of the grid. In this paper, the output of the converter is coupled with output of CUK converter of wind. Then from this coupled output DC loads are directly fed and also an inverter is connected to convert it into AC to feed AC loads.

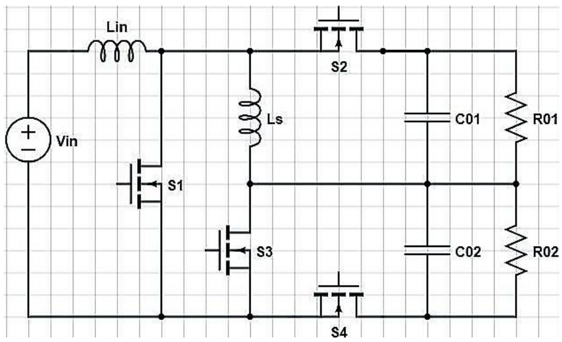

Fig 4. Proposed Converter

Mode 1 : Fig 4 (a) shows mode 1. In this mode the current flows through inductor L_{in} , S_1, L_s , S_3. Therefore, the active switches are S_1 and S_3. Output is taken across R_{01} and R_{02}.

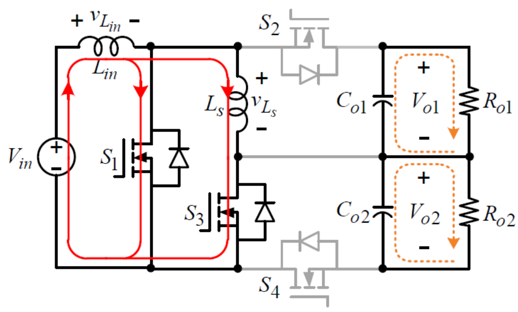

Fig 4 (a). Mode 1

Mode 2 : Fig 4(b) shows mode 2. In this mode there are two current paths. One is through inductor L_{in} , S_1 and V_{in}. Other one is through L_{in}, L_s, S_4 and V_{in}. Therefore switch S_1 remains in on state S_3 is turned off and S_4 is turned on.

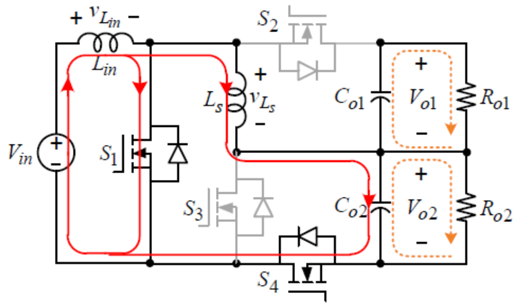

Fig. 4(b). Mode 2

Mode 3 : In this mode S_4 is turned off and S_3 is turned on again therefore it is same as that of mode 1.

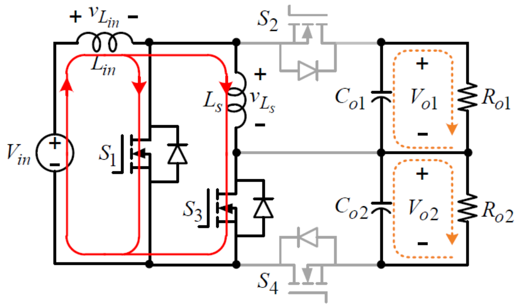

Fig 4 (c). Mode 3

Mode 4 : Fig 4 (d) shows mode 4. In this mode S_1 is turned off and S_2 is turned on. S_3 remains on. Current flows through V_{in} ,L_{in} , L_s and S_3. Another path is through V_{in} L_{in} , C_{o1} and S_3.

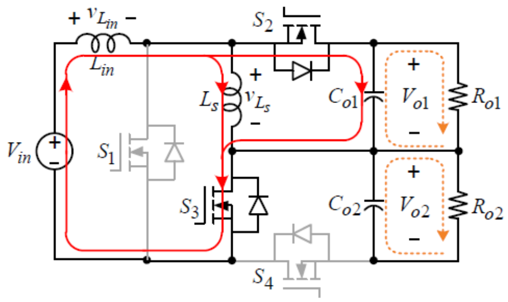

Fig 4 (d) Mode 4

IV.DESIGN EQUATION

In the proposed converter the voltage gain is given by

$$V_{in}(1+D)T_s/2 = (V_{01} - V_{in})(1-D)T_s/2 \quad (1)$$

$$V_{01}(1+D)T_s/2 = V_{02}(1-D)T_s/2 \quad (2)$$

Where (D) is the duty ratio defined as the time interval when S_1 , S_3 are both turned-on during half switching period ($T_s/2$).

$$\frac{V_0}{V_{in}} = \frac{2}{1-D} \quad (3)$$

D=0.2

From equation (3) it is clear that the gain is twice than that of conventional boost converter.

With minimum input voltage V_{in} , maximum current I_{Lin} flows through the inductor for a fixed output P_o. The inductor value to maintain the ripple is

$$L_{in} \geq \frac{(1-D)DV_0}{4*x\%I_{Lin\ max}} * \frac{1}{2f_s} \quad (4)$$

L_{in}= 280 micro Henry

$$L_s \geq \frac{(1-D)V_0}{z\%*I_{Lin\ max}} * \frac{1}{2f_s} \quad (5)$$

L_s = 960micro henry

In this paper 30% of current ripple of the corresponding average current is given to all the inductors in the circuit.

The current relation between the two inductors is found as

$$I_{Ls} = \frac{R_{01}}{R_{01}+R_{02}} * I_{Lin} \quad (6)$$

Efficiency can be calculated by

$$\frac{Output\ power}{Input\ power} = Efficiency \quad (7)$$

V. CONTROL SYSTEM

Figure 5 shows the control system of the proposed system. During time interval 0 to $DT_s/2$ switches S_1 and S_3 are in on condition. During time interval $DT_s/2$ to $T_s/2$ switch S_1 remain in on condition while S_3 is turned off and S_4 is turned on. In the next interval first situation is repeated. After that uptoT$_s$ S_1 and S_4 are off. S_2 and S_3 are in on condition. To obtain this condition it must give same pulse to S_1 and S_3. By giving a delay of half the time period and give it to S_2 and S_4.

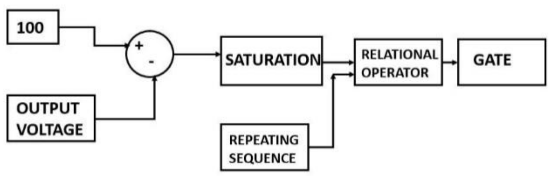

Fig. 5. Control system for switch

A 50% delay is given to switches S_1 and S_2. Delay cane be obtained by adding a delay block, or by giving a phase shift of half the time that of the actual

VI. SIMULATION RESULTS

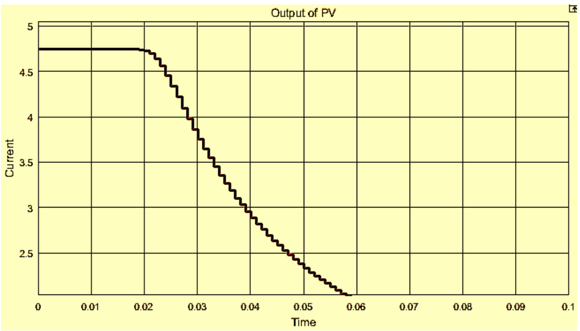

Fig 6. PV current

Fig.6. shows the current of solar PV. The value of current is 4.7. In these each of these solar cell was designed with 4.75A short circuit current.

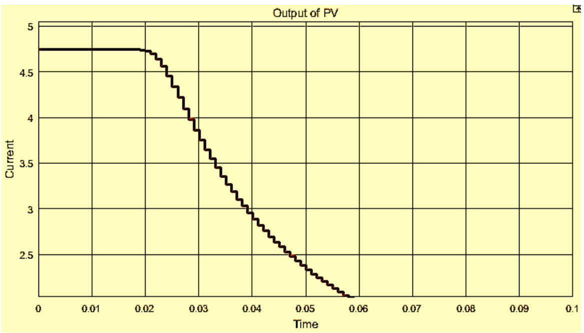

Fig. 7. Voltage graph of solar

Fig.7. shows the voltage verses time graph of solar panel. Output voltage is 60V. Voltage increases from zero to 60V. From time 0 to 0.025 voltage is increasing. After that the voltage becomes steady.

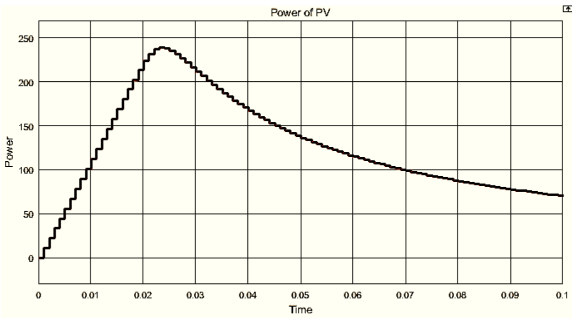

Fig. 8 Power of PV

Fig.8 shows the power of PV. It is 250W. The output voltage is 60 volt and output current is 4.7A. Maximum power is obtained at .025s.

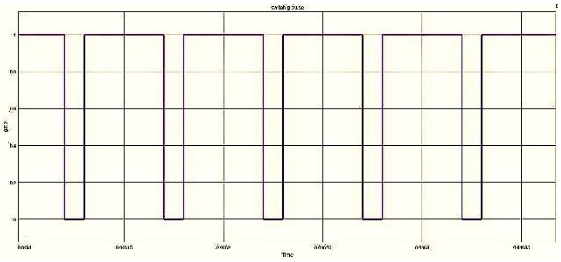

Fig 9 Switching pulse of existing boost converter.

Fig. 9 shows the switching pulse of existing system that is the conventional boost converter. It is almost 0.6. this is a higher duty ratio which will decrease the efficiency of the system.

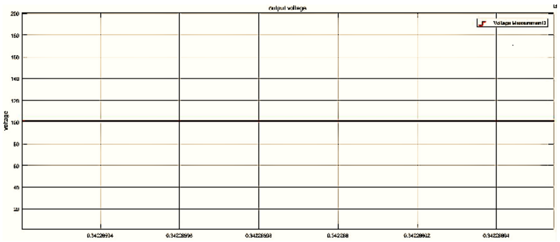

Fig 10. DC output voltage of existing boost converter

Fig 10. shows the DC output voltage of micro-grid. Input is 60V, the boost converter increased the voltage to 100V with a duty ratio 0.64. With this higher duty ratio only small amount of voltage is increased. Therefore it need a higher version of this boost converter.

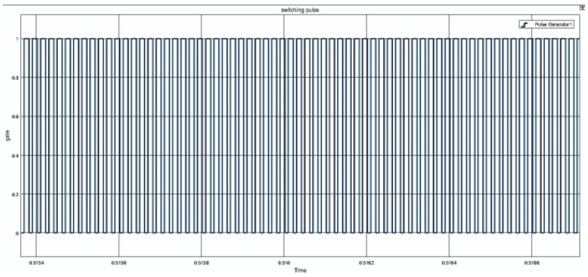

Fig 11. Switching pulse of proposed system

Fig. 11 shows the switching pulse of proposed three level boost converter. From the figure it is clear that it has a small duty ratio of 0.2, also with this small duty ration the out voltage has increased from 100V to 150V as compared to conventional boost converter.

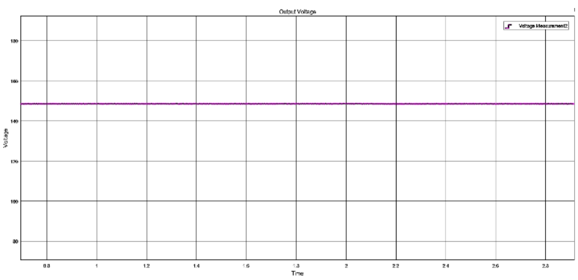

Fig. 12. Output of proposed system

Figure.12 shows the output voltage of three level boost converter. The output has been increased to 150V with a small duty ratio of 0.2

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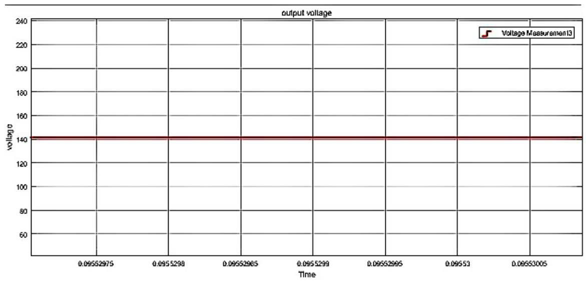

Fig. 13. DC load voltage

Fig .13. shows the output voltage of DC load. Output voltage is 141V for an input of 60V.

VII. CONCLUSION

This paper proposes a novel high gain boost converter for solar PV system in a DC micro-grid. Boost converter is a DC-DC converter used to increase the output voltage. Efficiency of boost converter decreases with increase in duty ratio. This paper showed a high gain boost converter with low duty ratio. Thus it can improve the efficiency of the system. Also the conduction losses are reduced by using three level boost instead of three individual boost converter. Matlab/imulink based results proved the effectiveness of proposed configuration.

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