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# ANALYSIS OF BOOST CONVERTERS FOR PV AND WIND IN A HYBRID MICROGRID

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ABSTRACT:

This paper presents the analysis of two types of boost converter for PV and Wind in a hybrid Micro-grid. The main aim is to improve the voltage gain capacity of conventional boost converter used in PV and Wind sources for a Hybrid 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 for PV and a new coupled inductor based boost converter is used for Wind, this also has a high voltage gain capacity. Through this modified converter the voltage gain capacity is increased. The circuit is designed in MATLAB/SIMULINK and results are verified.

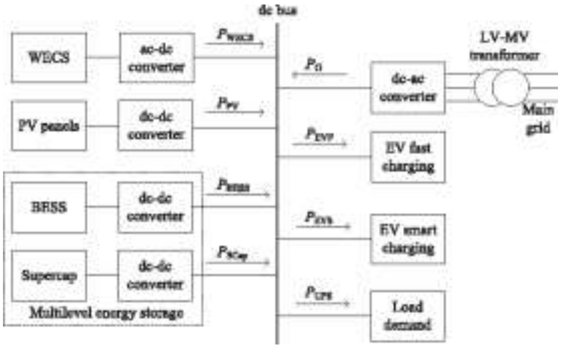
Keywords: Renewable Energy, Boost Converters, DC Micro-Grid

## INTRODUCTION

There are many isolated locations in the world, which don't have approach to electricity. There are also many places, which are connected to the grid, but, they don't obtain 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.

Contemporary distribution system is experimenting the use of these DERs and thus forming power clusters [1]. This power cluster is called as Micro-grid. Micro-grid is of 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 cell operates at DC. Using power electronics circuits, a DC link capacitor can be formed to feed DC loads. For AC loads we 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 current 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. Apart from decreasing financial costs, a main 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 embolden end users to take responsibility to understand and control their own energy usage. By executing intelligence and internet facility to DC micro-grid controllers it will further enhance consumer involvement with AC devices – through smart metering and in result with dynamic
demand management. In association with schedule of high and low power consumption, therefore it will help to reduce costs. [10] The problem with DC micro-grid is that the renewable energy sources produce only a small amount of power therefore we must use a converter to boost this power to integrate to grid only a small amount of power therefore we must use a converter to boost this power to integrate to grid.




Fig,1. General Micro-grid

Traditionally use of boost converters but these have low voltage gain, hence it should be necessary to increase the number of boost converters. But the efficiency of boost converter is less for high gain i.e. for
very large duty cycle. Therefore, for conventional boost converter we 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.

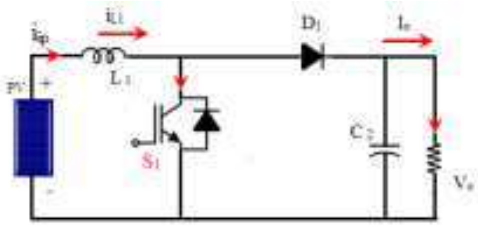


Fig.2. Conventional Converter

Therefore, to overcome these disadvantages of conventional boost converter a modified boost converter is proposed. In this a three level boost converter whose feature includes low devices voltages stress requirement for high voltage application, small inductor size that leads to the reduction of cost and size and can be operated with a wide range input voltage for Wind [13]. And for PV a high gain coupled inductor based interleaved boost converter is used, it has the following features, it improves the transfer characteristics, as well as system efficiency even for high power levels.

## PROPOSED SYSTEM

### A. Circuit Description

This paper proposes a three level boost converter and a coupled inductor based interleaved boost converter both has high gain. These boost converter has the ability to convert low voltage of PV solar system and wind farm to high voltage without the use of more number of boost converter.

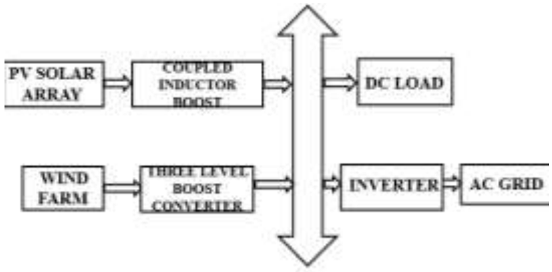



Fig3. Basic Block Diagram

The proposed system consists of a Solar PV array which is designed to give an output of 48V RMS and 67 V Peak. In this each solar cell is designed with 4.75A short circuit current, 1V open circuit voltage, 25deg Celsius system temperature, 1000 W/m2 irradiance. Wind turbine is also designed to have an output of 48V RMS and 67 V peak. The output of solar is boosted using the modified three level boost converter. And the output of wind is boosted using coupled inductor based interleaved boost converter. The output of both these converters are coupled and given to inverter to produce AC voltage for AC applications.

### B. Working of Modified converter 1

Fig 4 shows the proposed circuit. It consists of 4 switches S1 to S4, two inductors (L1, L2) and two output capacitors (C4, C5). Output of wind is given to this converter which is AC therefore, first it converted into DC by using diode bridge rectifier boost the voltage to required level of the grid. In this
paper, the output of the converter is coupled with output of coupled inductor boost converter of PV. 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.

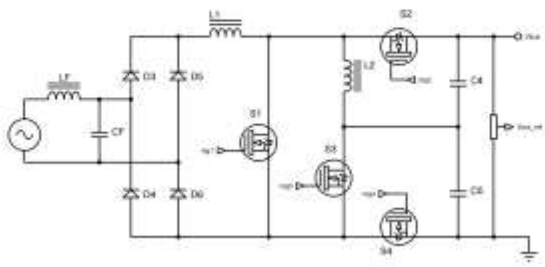


Fig.4. Three Level Boost Converter

Mode 1 : Fig 4 (a) shows mode 1. In this mode the current flows through inductor

L1 , S1, L2 , S3. Therefore, the active switches are S1 and S3. Output is taken across R.

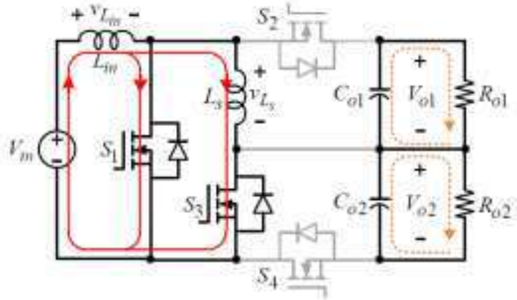



Fig 5. Mode 1

Mode 2 : Fig 4(b) shows mode 2. In this mode there are two current paths. One is through inductor L1 , S1 and Vin. Other one is through L1, L2, S4 and Vin. Therefore switch S1 remains in on state S3 is turned off and S4 is turned on.

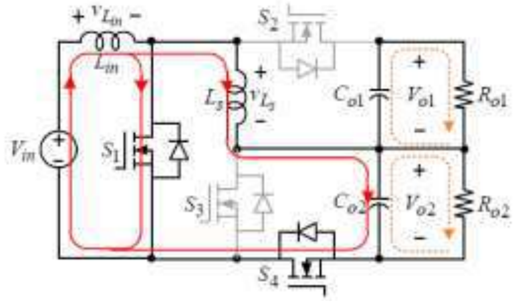



Fig. 6. Mode 2

Mode 3 : In this mode S4 is turned off and S3 is turned on again therefore it is same as that of mode 1.

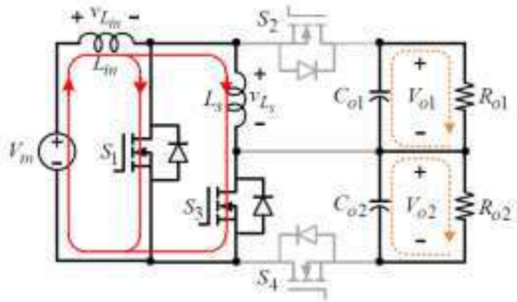



Fig 7. Mode 3

Mode 4 : Fig 4 (d) shows mode 4. In this mode S1 is turned off and S2 is turned on. S3 remains on. Current flows through Vin , L1, L2 and S3. Another path is through Vin L1 , C4 and S3.

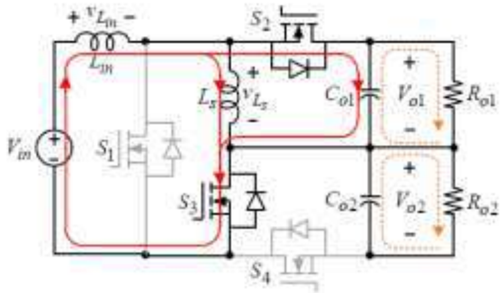



Fig 8 Mode 4

C. Working of Modified converter 2

Fig9. Shows the circuit diagram of coupled inductor based interleaved boost converter. It consists of 2 switches $S_1$ and $S_2$, a inductors ($L_{in}$), coupled inductors($L_1$ and $L_2$) and a output capacitors ($C_f$) Output of solar is given to this converter which boost the voltage to required level of the grid. The output of the converter is coupled with output of TLB converter of wind.

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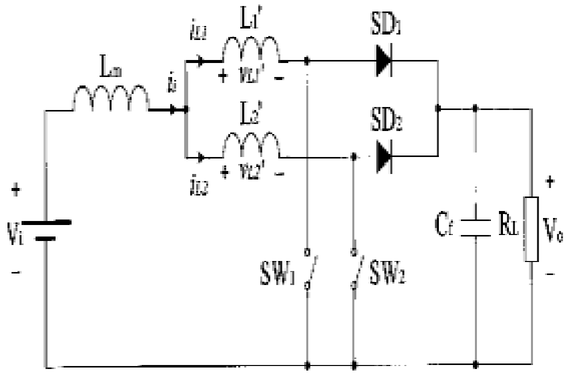


Fig. 9. Coupled Inductor Based Interleaved Boost Converter

Mode 1: Switch $S_1$ is ON Current flows through inductor $L_{in}$ and $L_2$ .Both gets charged. Since $L_2$ is coupled inductor $L_1$ also get charged due to mutual inductance. Diode $SD_1$ turns ON and capacitor is charged.

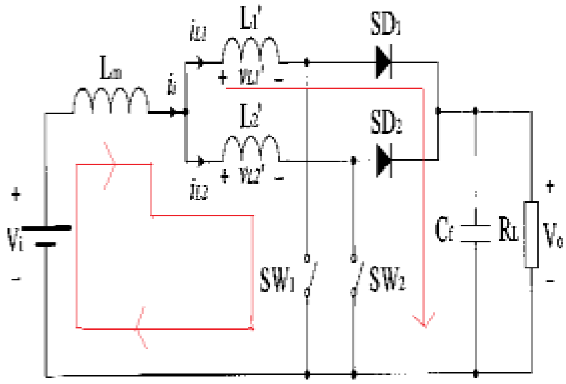


Fig.10 . Mode 1

Mode 2: Switch $S_1$ and $S_2$ is ON. All the inductors get charged by the paths of current. Output is supplied from the capacitors.

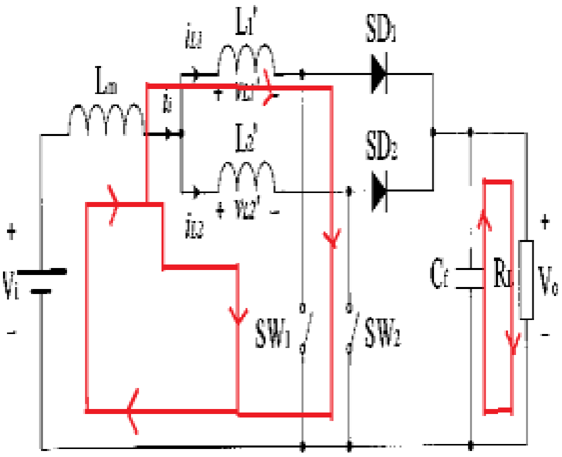


Fig.11. Mode 2

Mode 3: Switch $S_2$ is turned ON. Current flows through $L_{in}$ and $L_1$. Since $L_1$ and $L_2$ are coupled inductors $L_2$ also get charged. Diode $D_2$ is forward biased and capacitor is charged.

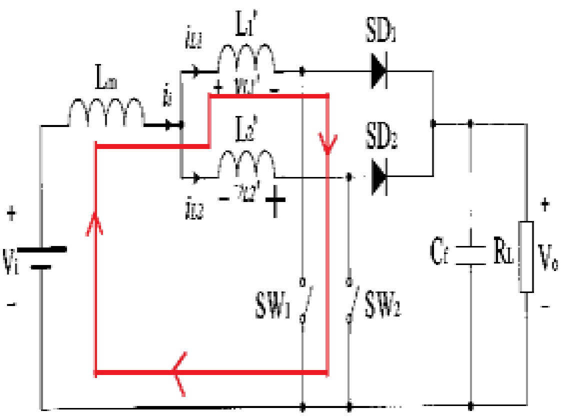


Fig.12. Mode 3

## D. 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 S1 , S3 are both turned on during half switching period (Ts/2).

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

From equation (3) it is clear that the gain is twice than that of conventional boost converter.With minimum input voltage Vin ,maximum current ILin flows through the inductor for a fixed output Po.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

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

## E. 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 upto $T_s$ $S_1$ 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 $S_4$.

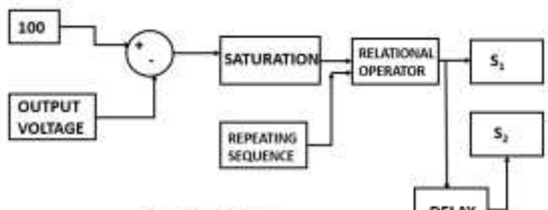


Fig. 13. Control System

## SIMULATION RESULTS

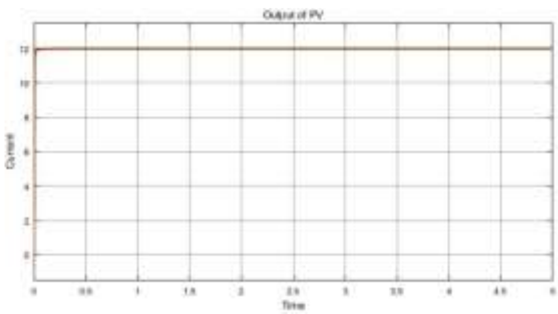

Fig.14. PV Voltage

Fig.14 shows the voltage verses time graph of solar panel. Output voltage is 12V. Voltage increases from zero to 60V. From time 0 to 0.025 voltage is increasing. After that the voltage becomes steady

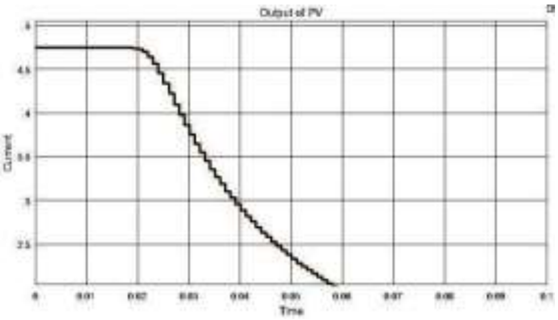


Fig.15. PV Current

Fig.15 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.

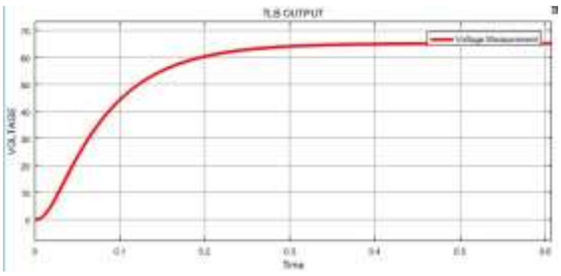


Fig. 16 Output Voltage of Three Level Boost Converter

Figure 16 shows the output voltage of three level boost converter. It is the converter of Wind. It boosts 12V of Wind to 68V after being rectified by the diode bridge rectifier at the front end. It shows a steady increase in voltage. As the PV charges the voltage also increases.

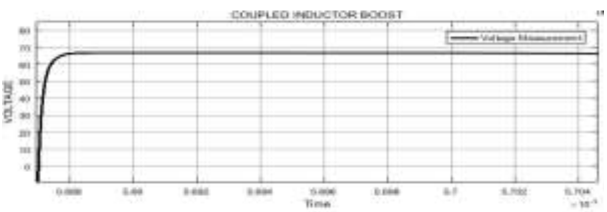


Fig.17. Output Voltage of Coupled Inductor Boost Converter

Figure 17 shows the output voltage of three level boost converter. It is the converter of PV. It boosts 12V of PV to 68V. It shows a steady increase in voltage. As the PV charges the voltage also increases

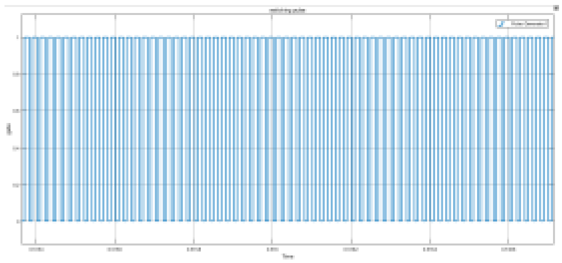

Fig 18. Switching Pulse

Figure 18 shows the switching pulse of the converters. From this it is clear that with this much small duty ration we could boost the voltage 5 times. Therefore, these converters increases the efficiency of the system.

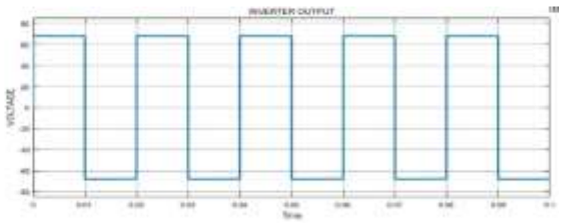


Fig.19. Inverter Output

Figure 19 shows the output voltage of the inverter. The output of both the converters are coupled and given to the inverter. It will produce the AC output for AC applications. It produces 68V AC.

## CONCLUSION

This paper proposes two novel high gain boost converter for solar PV system and Wind 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 two high gain boost converter with low duty ratio. Thus we can improve the efficiency of the system. Also the conduction losses are reduced by using three level boost instead of three individual boost converter. Also by using coupled inductor boost the current ripple is reduced. High power. Power sharing. Component rating is reduced and hence cost is reduced. Matlab/simulink based results proved the effectiveness of proposed configuration.

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