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NON-ISOLATED HIGH VOLTAGE GAIN DC–DC CONVERTERS USING INDUCTORS FOR PV APPLICATION

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***Abstract*- This paper presents, Non-isolated High Voltage Gain DC-DC Converter for PV application. The suggested structure includes two non-isolated inductors to obtain high voltage gain for PV application. In addition, the different two duty ratios are used for three switches. The proposed DC-DC converter can reach a gain of 15 without using switched capacitor techniques and voltage multiplier cell. DC Micro-grids are famous due to coalition of distributed energy storage devices, energy resources and distributed load that operate in co-ordination. Also the steady state analysis is discussed in detail. The MATLAB simulation results for $V_{in} = 20$ V and $V_{out} = 300$ V has been developed with result.**

Keyword- Continuous conduction mode (CCM), High Voltage gain, DC-DC Converter.

I. INTRODUCTION

With increased understanding of energy storage and renewable energy sources, high voltage gain DC-DC converters come up with increase utilization in green energy system. Photovoltaic (PV), Batteries and fuel cell are used to interface with green energy system to the 300V in DC Microgrid system [1]. Presently, DC-DC converters are utilized for several applications in different types of electronic equipment like X-ray power generators, battery backup system for UPS (Uninterrupted Power supply), Electric Traction, HID (High Intensity Discharge) Lamps and servo motor drive [2].

High voltage gain DC-DC converters are suitable explanation for the aforementioned problem. A particular high gain converter can be connected to an each PV panel. Hence, independently control each panel. These converters boost (24-40V) low input voltages to (300-400) high output voltages [3]. Large conversion ratio, small size and high efficiency are the main advantages of high voltage DC-DC converter [4]. Theoretically, extremely large duty ratio is required for achieving high voltage gain from conventional boost converter. Voltage stress on aswitch increases as the output voltage of the converter increases. Therefore, high rating switch is required and result in extreme conduction loss [5]. Coupled inductor, voltage multiplier cell and high frequency transformer are used to obtain desired high voltage gain [6].

Few transformer-based converters such as flyback or push-pull, by regulating turn ratio of the transformer forward converters can obtain high voltage gain. Problem like high power dissipation and voltage spike on power electronic switches are caused due to leakage inductance of transformer [7]. For obtaining high voltage gain and to improve the efficiency, several converter topologies have been granted [8]-[10]. Switched capacitor, voltage lift and coupled inductor topologies are widely used to obtain high voltage gain. After all, in these techniques, in the main switches high charging current is flowing and result in increase conduction loss.

Several Isolated DC-DC converter techniques are suggested by several researches to obtain a high voltage gain. However, transformer core saturation problem consort with these type of converter. Consequently, non-isolated DC-DC converters are utilized to obtain a high voltage gain with reduction in cost and size, in which isolation is not required. Few of non-isolated high voltage gain converters are voltage lift, conventional boost converter, the quadratic boost, cascaded boost and capacitor-diode voltage multiplier technique converter combined with switched capacitor topology. The composition of switched- inductor or switched capacitor stage increase the difficulty of the circuit and cost [11].

Coupled inductor structure based DC-DC converters gives low voltage stress on power electronic switch located on elected duty ratio and high voltage gain. Periodically, coupled inductor turns ratio is increased to achieve a desired adaptation ratio, arising high input ripple current. Thus, the input filter is required to overcome the ripple current [12].

This paper introduces a new technique of high voltage gain DC-DC converter. The suggested structure consist of a two inductor, two diodes and three switches for obtaining high voltage gain. Proposed converter has following attributes,

1) The energy stored in inductor is provided without using active or passive circuit.
2) As compared to traditional boost converters, voltage gain obtained by this converter is more.
3) To obtain the desired high voltage gain the three power electronic switches are used with the two different duty ratios.
4) Without using voltage multiplier cell (VCM) or switched capacitor this converter topology gives high voltage gain.
5) Depreciate voltage on the switches is based on the percentage of output voltage.

Section II describes the proposed DC-DC converter circuit configuration. In section III, the steady state analysis of the high voltage converter described. Simulation results of this converter granted in section IV. Voltage stress on the power electronic switches and High voltage gain is concluded in section V.

II. CIRCUIT CONFIGURATION

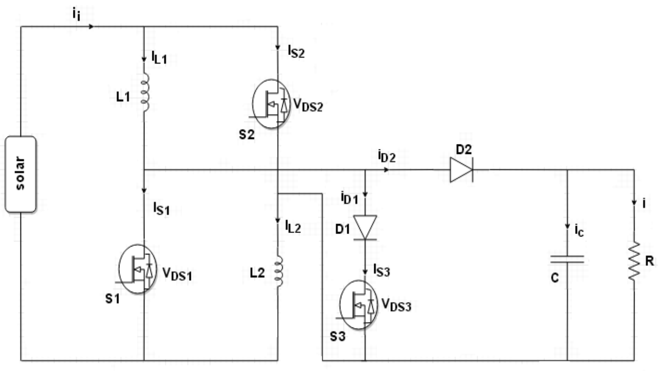

Fig.1. Non-isolated high voltage gain DC-DC converter configuration

Fig.1. shows the proposed topology of Non-isolated high voltage gain DC-DC Converter using Inductors. It consist of two inductors L_1 and L_2, capacitor C, three active switches s_1, s_2, s_3 and two diodes i.e. D_1 and D_2. The switches s_1, s_2 and s_3 are operated at the switching frequency F_s. The switches S_1 and S_2 duty ratio is D_1 and switch S_3 is D_2.

Following assumptions are made for the steady state operation of the proposed DC-DC converter. 1] In this circuit all the components are ideal. Therefore the effect of ON state resistance of switches, equivalent series resistance forward i.e. ESR of the capacitor and inductors, voltage drop of diodesare not considered. 2] For maintaining the constant output voltage the capacitance C is sufficiently large. Consider the inductors with equal number of turn.

$$L_1 = L_2 = L \tag{1}$$

Hence, the voltage across the inductors V_{L1} and V_{L2} are,

$$V_{L1} = L_1 \frac{di_{L1}}{dt} = L\frac{di_{L1}}{dt} \tag{2}$$

$$V_{L2} = L_2 \frac{di_{L2}}{dt} = L\frac{di_{L2}}{dt} \tag{3}$$

III. STEADY STATE ANALYSIS

In this section, the Continuous Conduction Modes are discussed.

Mode I:- Switch s_1 and s_2 are turned ON at the time interval of $[t_0, t_1]$ and the remaining switch s_3 remains OFF. Path of current flowingin the circuit is shown in the fig.2. The source energy is transfer through the inductors L_1 and L_2 and the stored energy is discharge to the load. Diode D_1 and D_2 are reverse biased in this mode. However, the internal Diode of s_3 is in forward bias condition. When switch s_3 is turn OFF, conduction voltage across the diode is appearing across the switch.

In this mode of operation, the inductors are connected in parallel to source. Therefore the voltages across inductors are,

$$V_{L1} = V_{L2} = V_i \tag{4}$$

In (4) Substituting (2) and (3), then equation become

$$L_1 \frac{di_{L1}}{dt} = L\frac{di_{L1}}{dt} = L\frac{di_L}{dt} = V_i,\ \ t_0 \le t \le t_1 \tag{5}$$

$$\frac{di_{L1}}{dt} = \frac{di_{L1}}{dt} = \frac{di_L}{dt} = \frac{V_i}{L} \tag{6}$$

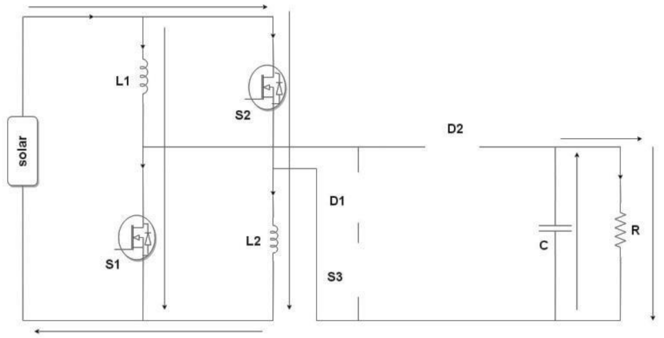

Fig.2. Mode I

Mode II:- Switch s_3 is turned ON at the time interval $[t_1, t_2]$ and the switch s_1 and s_2 are turned OFF. Fig.3. Shows the path of current flowing in the circuit. Source energy is dissipated in inductors L_1 and L_2 .Voltage appears across the switch s_1 and s_2 is the half as compared to the input voltage. As the diode is in reverse bias condition the stored energy in the capacitor c is given to the load. As the inductor is connected in series to the source, the two switches are OFF. The voltage across the inductor and current through it is shown in (7) and (8).

$$i_{L1} = i_{L2} = i_L \tag{7}$$

$$V_{L1} + V_{L2} = V_i \tag{8}$$

Where, i_L is current flowing through the inductors L_1 and L_2 Substituting (2) and (3) in (8) then

$$\frac{di_L}{dt} = \frac{V_i - V_0}{2L},\ \ t_2 \le t \le t_3 \tag{9}$$

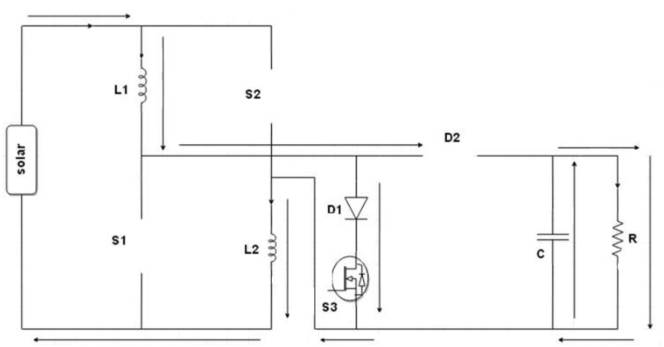

Fig.3. Mode 2

Mode III:- During this mode the time Interval $[t_2, t_3]$, the all switches S_1, S_2 and S_3 are turned OFF. Fig.4. shows the current flowing path in this time period. The inductors and the source both supply to the load. In this mode, diode D_1 is reverse biased and diode D_2 is forward biased, capacitor C is in charging mode. The average of voltage V_i

and V_o will be the voltage across the switch S_1 and S_2. Sum of voltage V_i and V_o is equal to the voltage across switch S_3. In this mode there is series connection of inductor to the source. The voltage across the inductor and current through it is shown inbelow equations,

$$i_{L1} = i_{L2} = i_L \qquad (10)$$

$$V_{L1} + V_{L2} = V_i - V_0 \qquad (11)$$

Substituting equation (2) and (3) in (11), then equation becomes

$$\frac{di_L}{dt} = \frac{V_i - V_0}{2L}, \; t_3 \geq t \geq t_2 \qquad (12)$$

Using state space average method, from equation (6), (9) and (12) equation (13) is obtained

$$\int_0^{D_1T_s} \left(\frac{di_L}{dt}\right)^I dt + \int_0^{D_2T_s} \left(\frac{di_L}{dt}\right)^{II} dt + \int_0^{(1-D_1-D_2)T_s} \left(\frac{di_L}{dt}\right)^{III} dt \qquad (13)$$

By solving equation (13), the voltage gain of the converter is obtained as

$$\frac{V_0}{V_i} = \frac{(1 + D_1)}{(1 - D_1 - D_2)} \qquad (14)$$

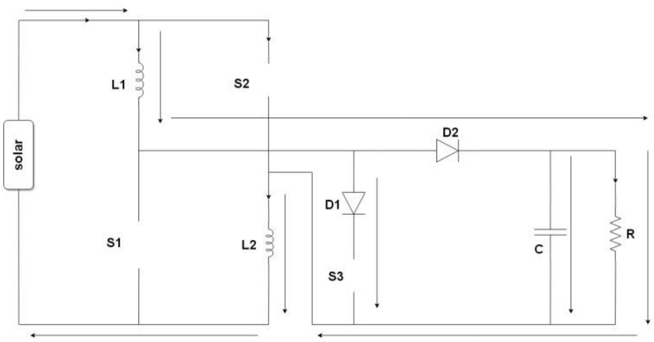

Fig.4. Mode 3

IV. SIMULATION RESULTS

MATLAB Simulation for the Non-isolated high voltage gain DC-DC converter has been simulated. The input voltage V_i is 20V and output voltage V_0 is 300V. The output power of the converter is 200W. The overall gain of the converter is 15. Two different duty ratios D_1 and D_2 are used in this converter. Fig.5. illustrates the simulation model of the converter. The input voltage of the solar is showing in Fig.6. The inductor current of the proposed converter is continuous which is illustrated in Fig.7. Fig.8. shows the switching voltages. The gate pulse voltages of switch V_{GS1} and V_{GS2} are same and V_{GS3} is 180^0 phase shifted. The voltage stresses across the switches are illustrated in Fig.9. The voltage stress on the switches is average of the output and input voltages. The result of output voltage and currentis shown in Fig.10. The output voltage is 300V and output current is 0.67A.

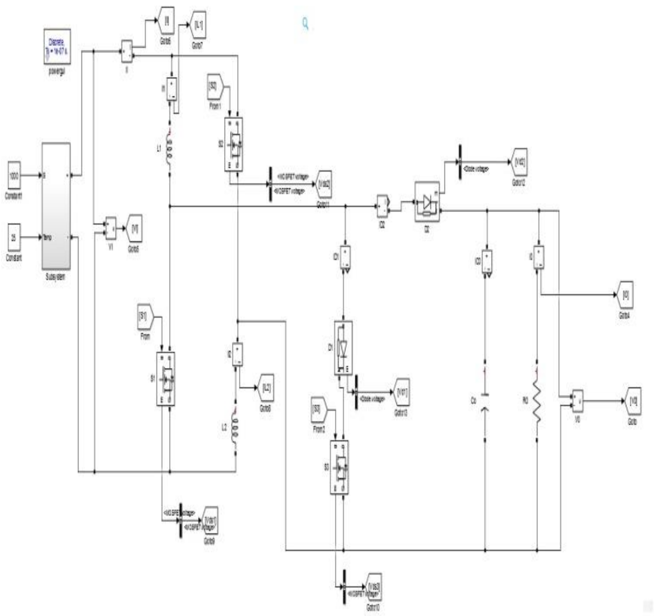

Fig.5. Simulation model of proposed converter

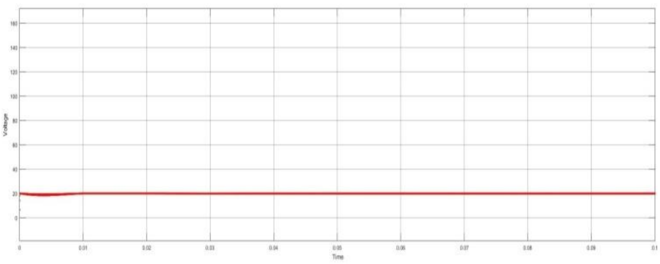

Fig.6. Output voltage of PV system

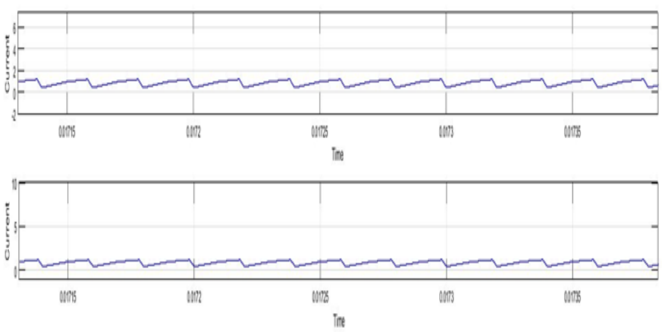

Fig.7. Inductor current

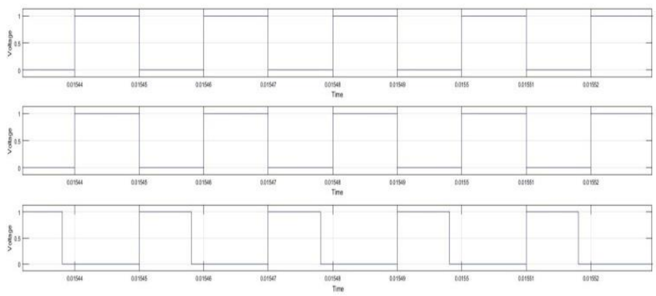

Fig.8. Gate pulse switches

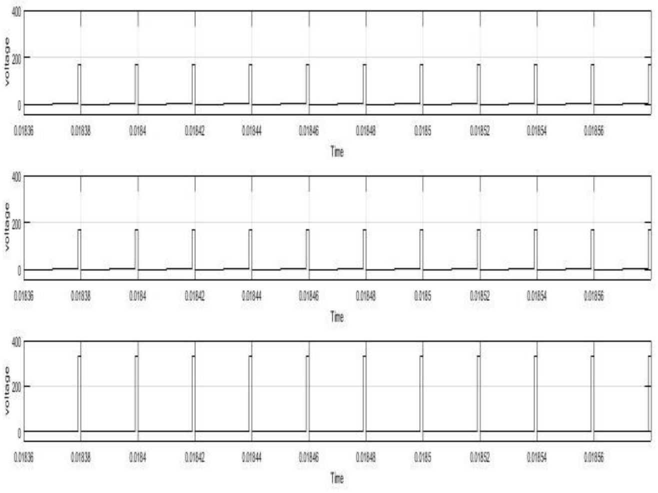

Fig.9. Voltage across the switches

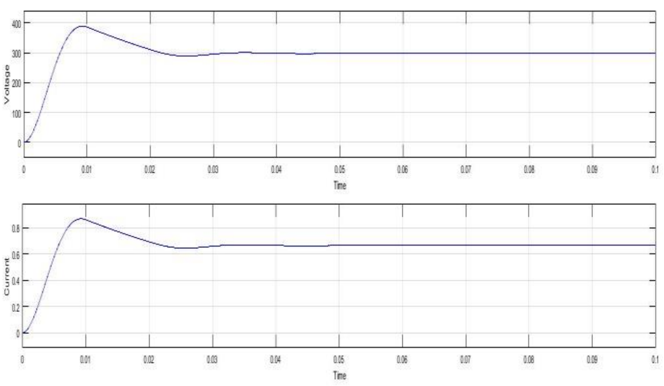

Fig.10. Output Voltages of Converter

TABLE I

SPECIFICATION OF CONVERTER

Components	Parameters
Output Power	200W
Input Voltage V_i	20V
Output Voltage V_0	300V
Capacitor C	100μF
Switching frequency	50kHz

V. CONCLUSION

This paper presents new topology of Non-isolated high voltage DC-DC converter using inductors for PV application. The proposed structure is suitable for obtaining high voltage gain. It gives an extensive voltage gain of 15 without using the switch inductor or capacitor technique or Voltage multiplier cell. In addition, the continuous input current and voltage stress on the switches is reduced. Therefore, the efficiency of the converter has been increased. The proposed topology has been tested through MATLAB simulation results.

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