An Efficient Step-Up DC-DC Converter for DC Grid Applications

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ABSTRACT

In recently days using distributed power generation systems constructed with boost type dc-dc converters is being extremely popularized because of the rising need of environment friendly energy generation power systems. In this paper a new constructed An efficient Step-Up DC-DC Converter for DC Grid Applications is proposed to boost a low level DC voltage (36-80V) to high DC bus (380V) level. When comparing to other step-up converters, the proposed topology has a reduced number of switching devices, can make high quality power with lower input current ripple and has wider input DC voltage range. Finally, the performance of the proposed topology is presented by simulation results with 350W hardware prototype.

1. INTRODUCTION

The increasing energy crisis due to fossil fuel sources for power generation has resulted in an increased demand on renewable sources of energy. A solar based power generations could play the most important role in solving the energy crisis but requires some solutions that can work in weak sun conditions.

The method for harvesting solar energy is to connect solar panels in series or parallel to get required voltage and power levels[1-2]. This method has some limitations in terms of efficiency and reliability. DC-AC grid-tied inverter which is connected to PV panels require at least 320V DC to inject solar harvested power to AC grid. If there is a sun-rich conditions, PV panel arrays can produce high DC voltages, but in the worst climate conditions PV panel arrays cannot make the required DC voltage. Thus there is a need a some power converter which lifts PV voltage to meet the optimum voltage level. Fig. 1 shows a typical solar power generation system connecting PV panel with DC Grid. Many PV panels employing step-up DC-DC converters have included the switched-inductor and switched-capacitor type boost topologies [3-4]. These types of converters are able to produce high voltage output without using any isolated transformers. However, the large number of components, especially power semiconductors, can reduce the efficiency and reliability of the system.

In this paper an efficient solar power optimizer for single phase grid-tied PV modules is proposed to make a high gain DC voltage level. The proposed topology has many advantages, such as decreased stress voltage for active and passive elements, wider input voltage range, continuous input current and simple control method. Comparing to another step-up converters, the proposed topology can create high voltage gain in lowered duty cycle with low power losses.

Fig. 1 A typical voltage step-up converter connection circuit.

Fig. 2. Circuit configuration of the proposed topology.
2. THE CIRCUIT CONFIGURATION

The proposed topology circuit configuration is presented in Fig. 2. As seen, two switches, three diodes, two inductors and five capacitors are used to make the hardware structure. Two switches operate in the same duty value, but their PWM signals have 180° phase shifting. Output DC voltage can be made by summing two output capacitors voltage.

3. OPERATING PRINCIPLES OF THE PROPOSED TOPOLOGY

The proposed topology operation can be divided into three modes under CCM operation as shown in Fig. 3(a), 3(b) and 3(c). In \( DT_{st} \) mode \( L_1 \) and \( L_2 \) inductors, \( C_2 \) and \( C_3 \) capacitors are charged. The other capacitors are discharged. In mode \( S_1S_2 = 00 \) both the switches are switched off. In this mode \( C_3 \) capacitor is charged through \( L_2 \) inductor. Output load voltage is formed by summing \( V_{\text{source}} \), \( V_{L_2} \) and \( C_3 \) capacitors voltages. In the next \( DT_{st} \) mode \( C_3 \) capacitor voltage divided through \( C_2 \), \( C_2 \) and \( C_4 \) capacitors. The load is supplied by summing \( C_4 \) and \( C_5 \) capacitors voltages. Applying KVL at all three switching modes the following equations can be obtained:

\[
V_s = L_1 \frac{dI_{L_1}}{dT} \quad (1)
\]

\[
V_s = L_2 \frac{dI_{L_2}}{dT} \quad (2)
\]

\[
V_{out} = V_{C_1} + V_{C_2} \quad (3)
\]

\[
G = \frac{3 - (4 \times D)}{(1 - (2 \times D))^2 \times (1 - D)} \quad (4)
\]

where \( G \) is voltage gain and \( V_{out} \) is output voltage of the proposed topology.
(4) equation shows that \( D \) duty value of the proposed topology should be in \([0 < D < 0.5]\) interval.

4. SIMULATION RESULTS

In order to verify the performance of the proposed topology the simulation was carried out using PSIM 9.1 software tool. Simulation parameters are that: \( V_{\text{source}} = 36 \) V, \( V_{\text{out}} = 380 \) V, \( P_{\text{out}} = 350 \) W, \( f_{\text{sw}} = 30 \) kHz, all the capacitors have \( 320 \mu \)F capacitance and \( L_1 = L_2 = 800 \mu \)H.

Fig. 3 shows the simulation results when input DC voltage is 36 V. It is obvious that drain-source voltage of switches have been decreased and input current ripple in desirable range. It can be noticed that the output voltage is formed by summing output \( C_4 \) and \( C_5 \) capacitors voltages as seen from Fig. 3(a). Fig. 5 shows the measured efficiency plot of the proposed topology when \( P_{\text{out}} = 350 \) W at different input condition.

5. CONCLUSIONS

A new topology of an efficient step-up DC-DC converter for DC Grid applications is proposed in this paper for renewable power sources. All the elements stress voltages are decreased to optimum value and operating dut value is limited in desirable value, so the efficiency of the proposed topology is increased. And also control method of the proposed topology is simple. It has been verified from the simulation experiments that the proposed topology can obtain the theoretical voltage gain.

REFERENCES