

Voltage Gain Enhancement of Step-Up Dc/Dc Converter by Switched-Capacitor and Coupled Inductor Techniques for Distributed Generation

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ABSTRACT:

A new high step-up dc/dc converter is presented for renewable energy applications. The construction implementation of a dual inductor and more than one voltage multiplier cells, to obtain large step-up voltage gain, two capacitors has been placed charged during the switch-off period, energy accumulated in the dual inductor which increases the voltage gain. The MMF energy in the leakage inductance is use by a passive clamp circuit. The voltage pressure on the power switch is reduced in effective manner in the proposed topology. A main power switch with less resistance can be used to reduce the conduction losses. The working principle and the analyses converter are discussed. The simulation of the high step up DC/DC converter design in MATLAB /SIMULINK and verify through the wave forms.

Index Terms- Coupled inductor, Dc/dc converters, High step-up, switched capacitor,

INTRODUCTION:

Demand for clean and sustainable energy sources has dramatically increased during the past few years with growing population and industrial development. For a long time, fossil fuels have been used as the major source of generating electrical energy. Environmental consequences of these resources have made it necessary to benefit from clean energy sources such as wind and solar. Therefore, distributed generation (DG) systems based on renewable energy sources have attracted the researchers' attention. The DG systems

include photovoltaic (PV) cells, fuel cells and wind power. High step-up converters are a suitable solution for the aforementioned problem. Each PV panel can be connected to a particular high step-up converter.

Exciting concept:

A typical fuel cell power supply system containing a high step-up converter generates voltage of the fuel cell stack is rather low. In practice, the step-up voltage gain is limited by effects of the power switch, rectifier diode, and the resistances of the inductors and capacitors. In addition, the extreme duty cycle may result in a serious reverse-recovery problem and conduction losses. This problem can be solved by passive lossless clamped technology.

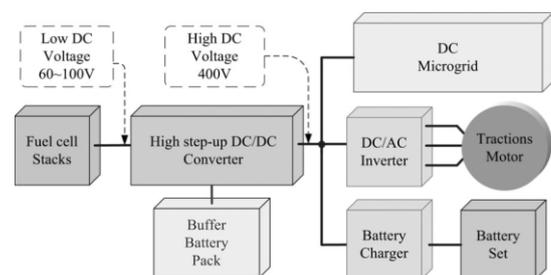


Fig 1 Fuel cell power supply system with high step-up converter.

However, the energy stored in the leakage inductor causes a voltage spike on the main switch and deteriorates the conversion efficiency. In order to increase the conversion efficiency and voltage gain, many technologies such as zero-voltage switching (ZVS), zero-current switching (ZCS), coupled-inductor-based converters with an active-clamp circuit

have been presented in. Some high step-up converters with two-switch and single-switch are introduced in the recent published literatures. However, the conversion ratio is not large enough.

Proposed concept:

This paper presents a novel high step-up dc/dc converter for renewable energy applications. The suggested structure consists of a coupled inductor and two voltage multiplier cells in order to obtain high-step-up voltage gain [1]-[3]. In addition, a capacitor is charged during the switch-off period using the energy stored in the coupled inductor, which increases the voltage transfer gain. The energy stored in the leakage inductance is recycled with the use of a passive clamp circuit. The voltage stress on the main power switch is also reduced in the proposed topology. Therefore, a main power switch with low resistance $R_{DS(ON)}$ can be used to reduce the conduction losses[4]. The operation principle and the steady-state analyses are discussed thoroughly. To verify the performance of the presented converter, a 300-W laboratory prototype circuit is implemented. The results validate the theoretical analyses and the practicability of the presented high-step-up converter [5].

Operation Principle:

The circuit configuration of the proposed converter is shown in Fig. 2. The proposed converter comprises a dc input voltage (V_i), active power switch (S), coupled inductor, four diodes, and four capacitors. Capacitor C_1 and diode D_1 are employed as clamp circuit respectively. The capacitor C_3 is employed as the capacitor of the extended voltage multiplier cell. The capacitor C_2 and diode D_2 are the circuit elements of the voltage multiplier which increase the voltage of clamping capacitor C_1 . The coupled inductor is modeled as an ideal transformer with a turn ratio N (N_p/N_s), a magnetizing inductor L_m and leakage inductor L_k . In order to simplify the circuit analysis of the converter, some assumptions are considered as follows:

Modes of operation:

1) Mode I [$t_0 < t < t_1$]:

In this mode, switch S is turned ON. Also, diodes D_2 and D_4 are turned ON and diodes D_1 and D_3 are turned OFF. The dc source (V_i) magnetizes L_m through S. The secondary-side of the coupled inductor is in parallel with capacitor C_2 using diode D_2 . As the current of the leakage inductor L_k increases linearly, the secondary-side current of the coupled inductor (i_s) decreases linearly. The required energy of load (R_L) is supplied by the output capacitor C_O .

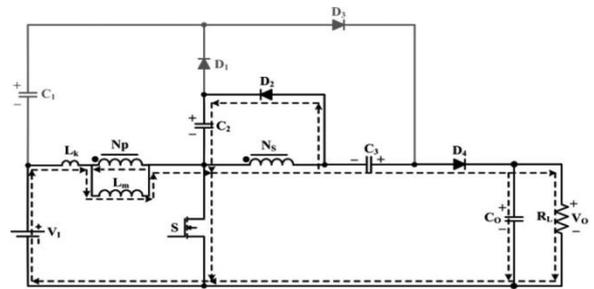


Fig. 2(a) Period (I) [$t_0 < t < t_1$]

Fig 2: proposed High Step-up DC/DC Converter.

2) Mode II [$t_1 < t < t_2$]:

In this mode, switch S and diode D_3 are turned ON and diodes D_1 , D_2 , and D_4 are turned OFF. The dc source V_i magnetizes L_m through switch S. So, the current of the leakage inductor L_k and magnetizing inductor L_m increase linearly. The capacitor C_3 is charged by dc source V_i , clamp capacitor and the secondary-side of the coupled inductor. Output capacitor C_O supplies the demanded energy of the load R_L .

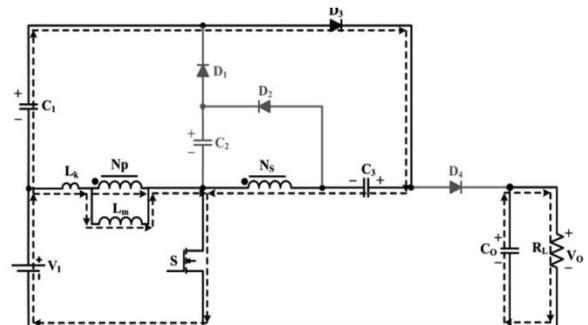


Fig. 2(b) Period (II) [$t_1 < t < t_2$]

3) Mode III [$t_2 < t < t_3$]:

In this stage, switch S is turned OFF. Diodes D1 and D3 are turned ON and diodes D2 and D4 are turned OFF. The clamp capacitor C1 is charged by the stored energy in capacitor C2 and the energies of leakage inductor Lk and magnetizing inductor Lm. The currents of the secondary-side of the coupled inductor (i_s) and the leakage inductor are increased and decreased, respectively. The capacitor C3 is still charged through D3. Output capacitor C0 supplies the energy to load RL. This interval ends when i_{Lk} is equal to i_{Lm} at $t = t_3$.

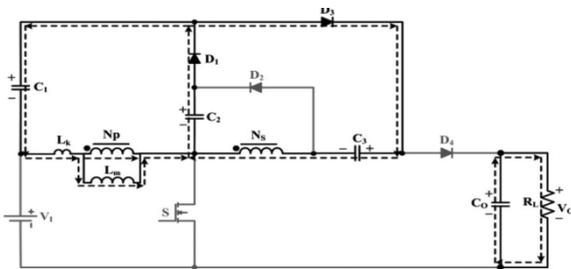


Fig. 2(c) Period (III) [$t_2 < t < t_3$]

4) Mode IV [$t_3 < t < t_4$]:

In this stage, S is turned OFF. Diodes D1 and D4 are turned ON and diodes D2 and D3 are turned OFF. The clamp capacitor C1 is charged by the capacitor C2 and the energies of leakage inductor Lk and magnetizing inductor Lm. The currents of the leakage inductor Lk and magnetizing inductor Lm decrease linearly. Also, a part of the energy stored in Lm is transferred to the secondary side of the coupled inductor. The dc source VI, capacitor C3 and both sides of the coupled inductor charge output capacitor and provide energy to the load RL. This interval ends when diode D1 is turned OFF at $t = t_4$.

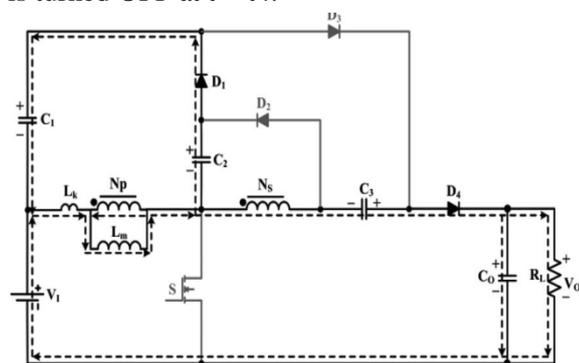


Fig. 2(d) Period (IV) [$t_3 < t < t_4$]

5) Mode V [$t_4 < t < t_5$]:

In this stage, S is turned OFF. Diodes D2 and D4 are turned ON and diodes D1 and D3 are turned OFF. The currents of the leakage inductor Lk and magnetizing inductor Lm decrease linearly. Apart of stored energy in Lm is transferred to the secondary side of the coupled inductor in order to charge the capacitor C2 through diode D2. In this interval the dc input voltage VI and stored energy in the capacitor C3 and inductances of both sides of the coupled inductor charge the output capacitor C0 and provide the demand energy of the load RL. This interval ends when switch S is turned ON at $t = t_5$.

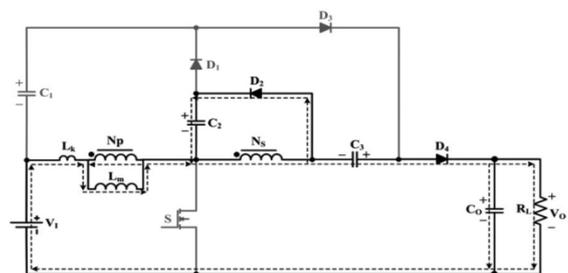


Fig. 2(d) Period (IV) [$t_3 < t < t_4$]

Analysis:

Continuous Conductions Mode:

To simplify the steady-state analysis, only stages II, IV, and V are considered since these stages are sufficiently large in comparison with stages I and III.

During stage II, Lk and Lm are charged by dc source VI. Therefore, the following equation can be written according to Fig. 2(b):

$$V_{Lm} = kV_I \quad (1)$$

Where k is the coupling coefficient of coupled inductor, which equals to $L_m / (L_m + L_k)$. Capacitor C3 is charged by clamp capacitor C1, dc source (VI), and the secondary-side of the coupled inductor. The voltage across the capacitor C3 can be expressed by

$$V_{C3} = V_{C1} + (kn + 1)V_I \quad (2)$$

Where; n is the turn ratio of coupled inductor which is equal to N_s / N_p .

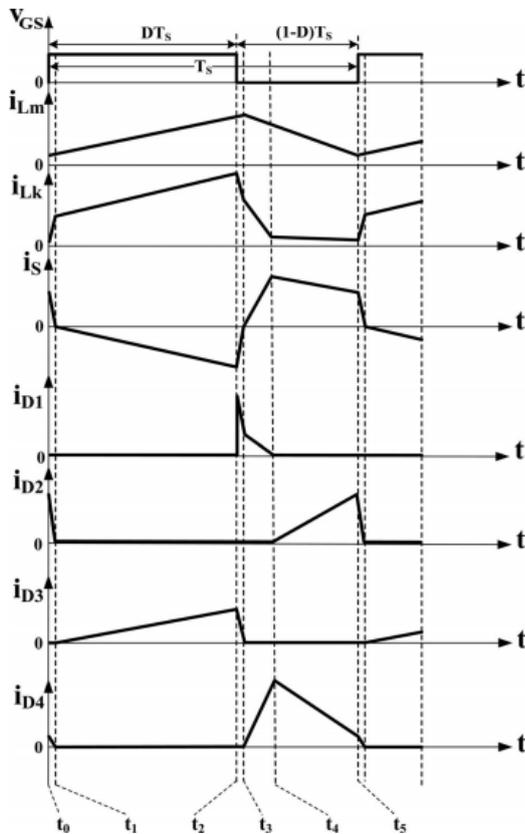


Fig:3 waveforms of the proposed converter at CCM operation.

EXPERIMENTAL SIMULINK MODEL

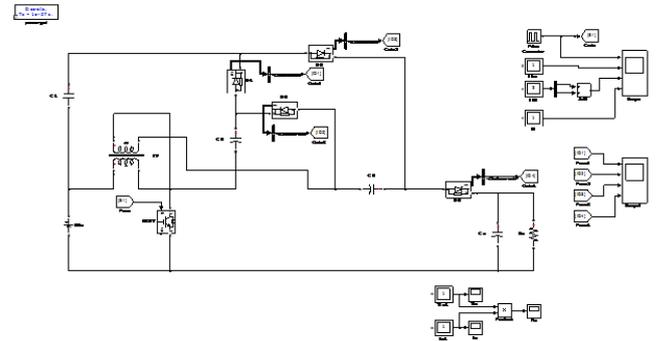


Fig.5 Experimental simulink model

Waveforms of Proposed Simulink Module

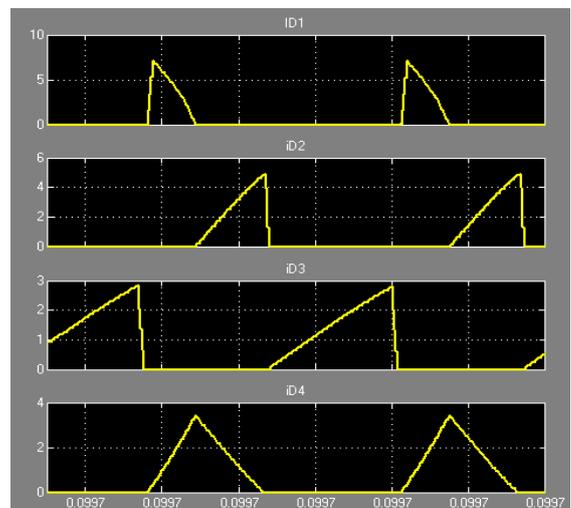
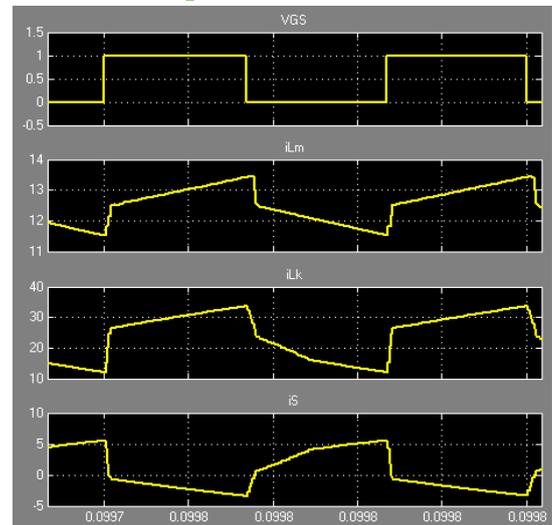


Fig.5 Typical waveform of the proposed converter

EXPERIMENTAL RESULTS AND SIMULATION:

Experimental results: The experimental results are shown in the waveforms.

Specifications	VALUES
Input dc voltage	$V_{in} = 40 \text{ V}$
Output dc voltage	$V_{out} = 400 \text{ V}$
Switching frequency	$F = 60 \text{ kHz}$
Fast Diodes	$D1, D2, D3, D4$
Coupled inductor	$LK : 1 \mu\text{H}, Lm : 300 \mu\text{H}$
Capacitors	$C1, C2, C3, Co$ 47, 47, 100, 220 μF
Load	300 W
Power Switch (MOSFET)	

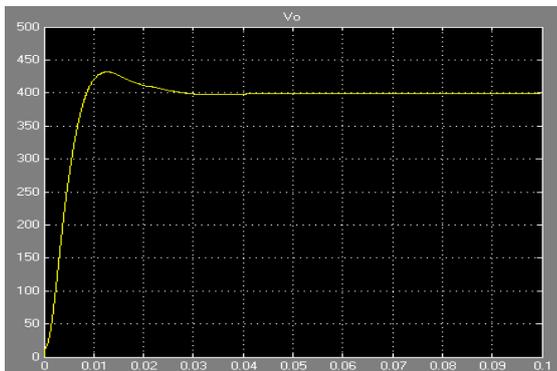


Fig.6 Converter output voltage

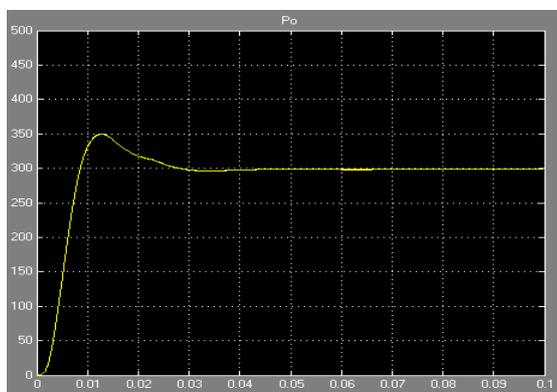


Fig.7 Converter output power

Features of Proposed System:

- 1) Through adjusting the turns ratio of coupled inductor, the proposed converter achieves high step-up gain that renewable energy systems require;
- 2) Leakage energy is recycled to the output terminal, which improves the efficiency and alleviates large voltage spikes across the main switch;
- 3) Due to the passive lossless clamped performance, the voltage stress across main switch is substantially lower than the output voltage;
- 4) Low cost and high efficiency are achieved by adopting low-voltage-rated power switch with low R_{DS-ON} ;
- 5) Using three-winding coupled inductor; the proposed converter possesses more flexible adjustment of voltage conversion ratio and voltage stress on each diode.

CONCLUSION

This project presents a new high-step-up dc/dc converter for renewable energy applications. The suggested converter is suitable for DG systems based on renewable energy sources, which require high-step-up voltage transfer gain. The energy stored in the leakage inductance is recycled to improve the performance of the presented converter. Furthermore, voltage stress on the main power switch is reduced. Therefore, a switch with a low on-state resistance can be chosen. The steady-state operation of the converter has been analyzed in detail. Also, the boundary condition has been obtained. The results prove the feasibility of the presented converter.

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