Integrating Coupled Inductor and Switched-Capacitor based high gain DC-DC converter for PMDC drive

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Abstract -The transformer less DC-DC converters, such as the cascade boost type, the quadratic boost type, the switched-inductor type , the voltage-lift type , the voltage doubler technique , the capacitor-diode voltage multiplier type , and the boost type that is integrated using a switched-capacitor technique . These converters can provide higher voltage gain than the conventional DC-DC boost converter. However, the voltage gain of these converters is only moderately high. 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. Finally, a hardware prototype is implemented which converts the 40-V input voltage into 400-V output voltage.

I. Introduction

The DC-DC converter with high step-up voltage gain is widely used for many applications, such as fuel-cell energy-conversion systems, solar-cell energy-conversion systems and high-intensity-discharge lamp ballasts for automobile headlamps. Conventionally, the DC-DC boost converter is used for voltage step-up applications, and in this case this converter will be operated at extremely high duty ratio to achieve high step-up voltage gain. However, the voltage gain and the efficiency are limited due to the constraining effect of power switches, diodes, and the equivalent series resistance (ESR) of inductors and capacitors. Moreover, the extremely high duty-ratio operation will result in a serious reverse-recovery problem.

Some literatures have researched the high step-up DC-DC converters that do not incur an extremely high duty ratio. The transformer less DC-DC converters, such as the cascade boost type, the quadratic boost type, the switched-inductor type , the voltage-lift type , the voltage doubler technique , the capacitor-diode voltage multiplier type , and the boost type that is integrated using a switched-capacitor technique . These converters can provide higher voltage gain than the conventional DC-DC boost converter. However, the voltage gain of these converters is only moderately high. If higher voltage gain is required, these converters must cascade more power stages, which will result in low efficiency. The DC-DC flyback converter is adopted to achieve high step-up voltage gain by adjusting the turn's ratio of the transformer.

II. LITERATURE SURVEY

Proposed High Step Up converter

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. 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. The operation principle and the steady-state analyses are discussed thoroughly.

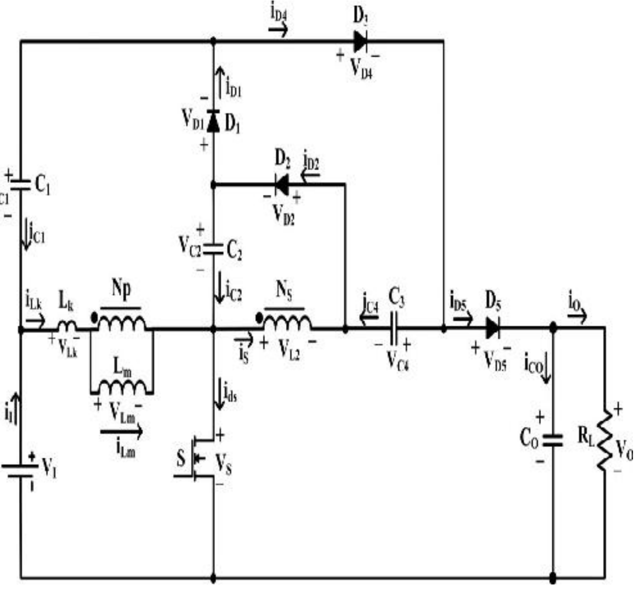

Fig.2.1 Circuit configuration of the presented high-step-up converter

2.2 Features of this converter

A conventional high step-up DC-DC converter with coupled-inductor technique. The structure of this converter is very simple and the leakage-inductor energy of the coupled inductor can be recycled to the output. However, the voltage stresses on switch S1 and diode D1, which are equal to the output voltage, are high. This paper presents a novel high step-up DC-DC converter. The coupled-inductor and voltage-doubler techniques are integrated in the proposed converter to achieve high step-up voltage gain.

The features of this converter are as follows:

1. The leakage-inductor energy of the coupled inductor can be recycled.
2. The voltage stresses on the switches are half the level of the output voltage. Thus, the switches with low voltage rating and low ON-state resistance RDS (ON) can be selected.
3. The voltage gain achieved by the proposed converter is double that of the conventional high step-up converter. Under the same voltage gain and duty ratio, the turns ratio of the coupled inductor for the proposed converter can be designed to be less than the conventional high step-up converter.
4. The frequency of the magnetizing-inductor current for the proposed converter is double of the switching frequency.

III. PROPOSED METHOD

A Novel high step-up dc/dc converter

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. 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 RDS(ON) can be used to reduce the conduction losses. The operation principle and the steady-state analyses are discussed thoroughly. Therefore, a main power switch with low resistance RDS(ON) can be used to reduce the conduction losses. The operation principle and the steady-state analyses are discussed thoroughly.

Some transformer-based converters like forward, push–pull, or fly back converters can achieve high step-up voltage gain by adjusting the turn ratio of the transformer. However, the leakage inductor of the transformer will cause serious problems such as voltage spike on the main switch and high power dissipation . In order to improve the conversion efficiency and obtain high step-up voltage gain, many converter structures have been presented. Switched capacitor and voltage lift techniques have been used widely to achieve high step-up voltage gain. However, in these structures, high charging currents will flow through the main switch and increase the conduction losses.

Coupled-inductor-based converters can also achieve high step-up voltage gain by adjusting the turn ratios. However, the energy stored in the leakage inductor causes a voltage spike on the main switch and deteriorates the conversion efficiency. To overcome this problem, 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.

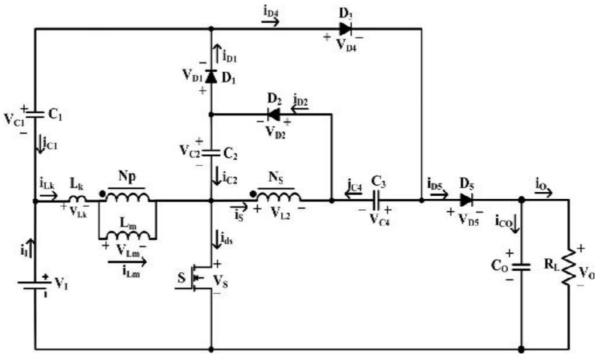

Fig 3.1 A novel high step up dc/dc converter

3.2 OPERATING PRINCIPLE OF THE PROPOSED CONVERTER

The circuit configuration of the proposed converter. The proposed converter comprises a dc input voltage (VI), active power switch (S), coupled inductor, four diodes, and four capacitors. Capacitor $C1$ and diode $D1$ are employed as clamp circuit respectively. The capacitor $C3$ is employed as the capacitor of the extended voltage multiplier cell. The capacitor $C2$ and diode $D2$ are the circuit elements of the voltage multiplier which increase the voltage ofclamping capacitor C .

The coupled inductor is modeled as an ideal transformer with a turn ratio N (NP/NS), a magnetizing inductor Lm and leakage inductor Lk . In order to simplify the circuit analysis of the converter, some assumptions are considered as follows:

1) All Capacitors are sufficiently large; therefore $VC1$, $VC2$, $VC3$, and VO are considered to be constant during one switching period;

2) All components are ideal but the leakage inductance of the coupled inductor is considered.

According to the aforementioned assumptions, the continuous conduction mode (CCM) operation of the proposed converter includes five intervals in one switching period. The current-flow path of the proposed converter for each stage is depicted in Fig. 2. Some typical waveforms under CCM operation are illustrated in Fig. 3. The operating stages are explained as follows:

Stage I [t0 < t < t1 see Fig. 2(a)]:

In this stage, switch S is turned ON. Also, diodes $D2$ and $D4$ are turned ON and diodes $D1$ and $D3$ are turned OFF. The dc source (VI) magnetizes Lm through S. The secondary-side of the coupled inductor is in parallel with capacitor $C2$ using diode $D2$. As the current of the leakage inductor Lk increases linearly, the secondaryside current of the coupled inductor (iS) decreases linearly. The required energy of load (RL) is supplied by the output capacitor CO. This interval ends when the secondary-side current of the coupled inductor becomes zero at $t = t1$

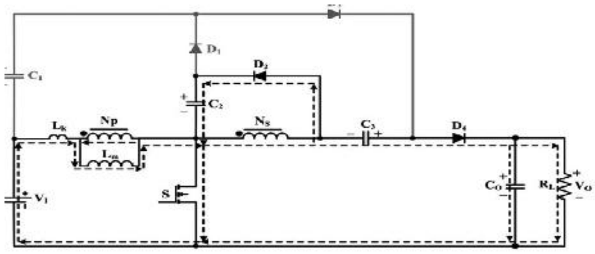

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Fig 3.2(a) mode I operation

Stage II [t1 < t < t2 see Fig. 2(b)]:

In this stage, switch S and diode $D3$ are turned ON and diodes $D1$, $D2$, and $D4$ are turned OFF. The dc source VI magnetizes Lm through switch S. So, the current of the leakage inductor Lk and magnetizing inductor Lm increase linearly. The capacitor $C3$ is charged by dc source VI , clamp capacitor and the secondary-side of the coupled inductor. Output capacitor CO supplies the demanded energy of the load RL . This interval ends when switch (S) is turned OFF at $t = t2$.

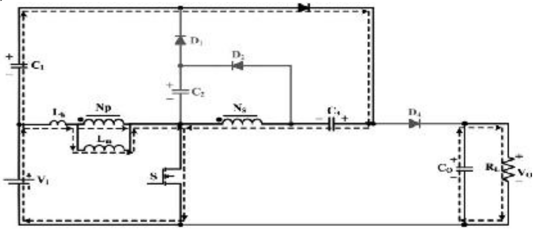

Fig 3.2(b) mode II operation

Stage III [t2 < t < t3 see Fig. 2(c)]:

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 (iS) and the leakage inductor are increased and decreased, respectively. The capacitor $C3$ is still charged through $D3$. Output capacitor CO supplies the energy to load RL. This interval ends when iLk is equal to iLm at $t = t3$.

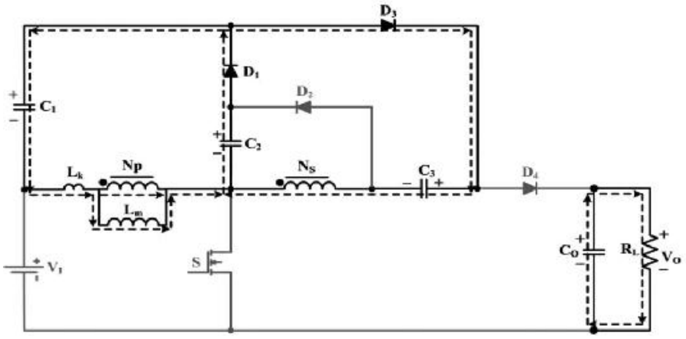

Fig 3.2(c) Mode III operation

Stage IV [t3 < t < t4 see Fig. 2(d)]:

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 $t = t4$.

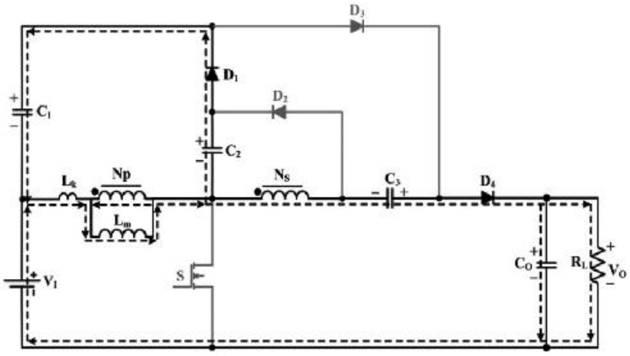

fig 3.2(d) Mode IV operation

Stage V [t4 < t < t5 see Fig. 2(e)]:

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 Co and provide the demand energy of the load RL . This interval ends when switch S is turned ON at $t = t5$.

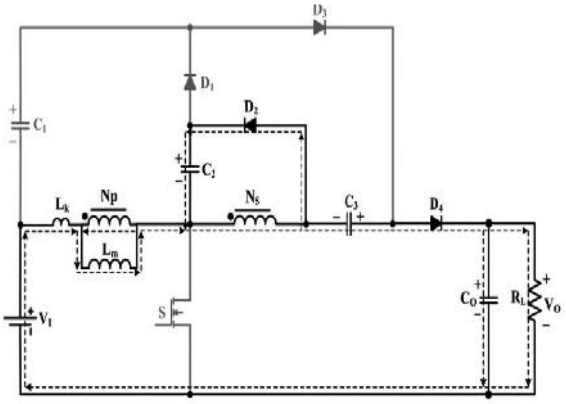

fig 3.2(e) Mode V operation

IV.Simulation Results

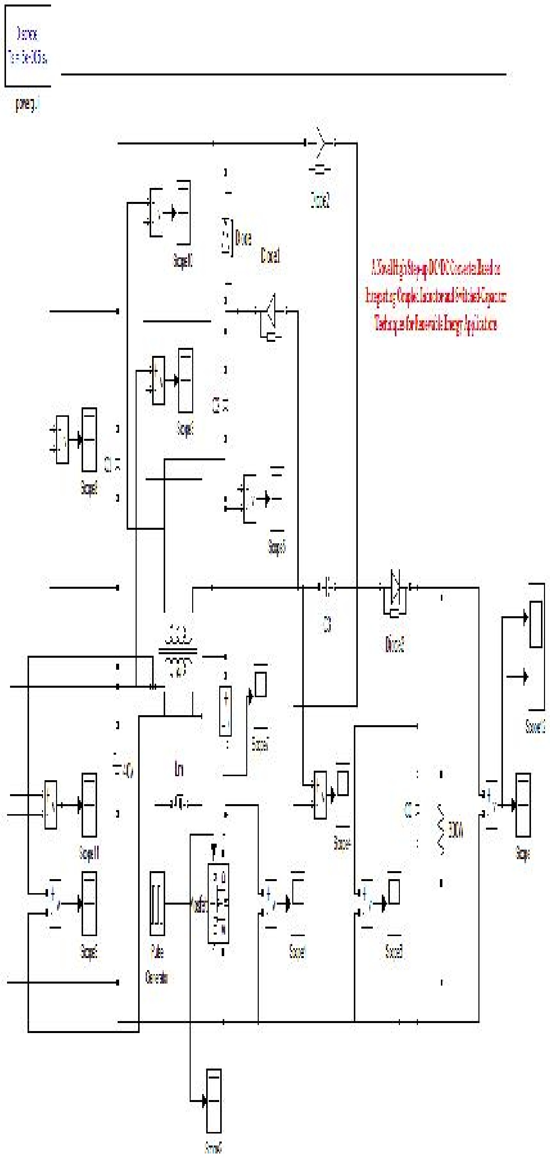

Fig 4.1 Simulation circuit diagram of novel step up dc/dc converter

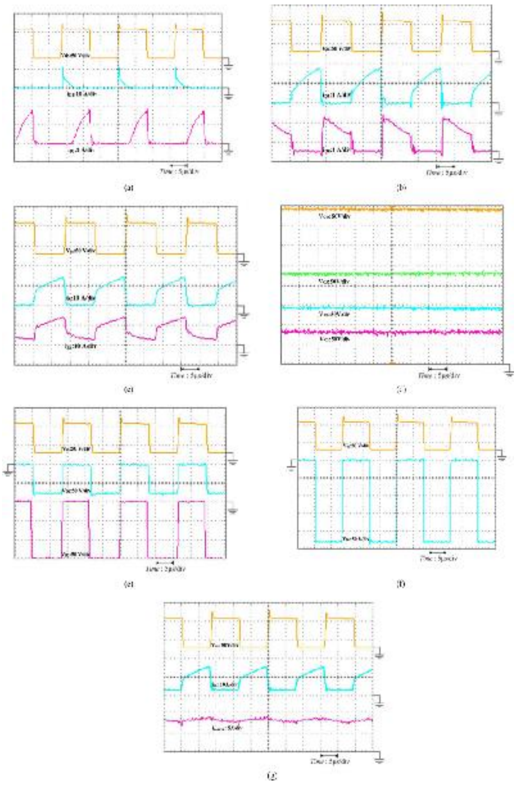

fig 4.2 simulation waveforms

4.3 input and output voltage waveforms

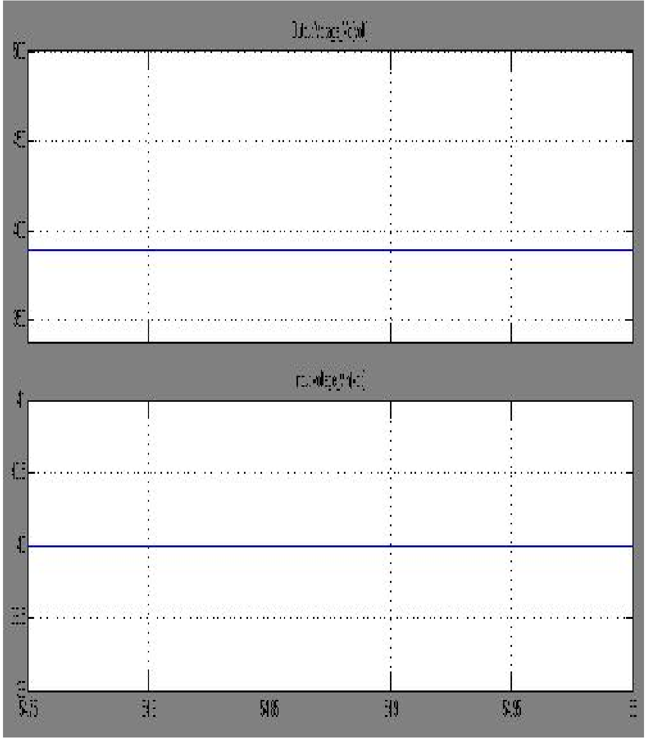

Fig 4.3 Input and output voltage of proposed system

4.4 Extension system

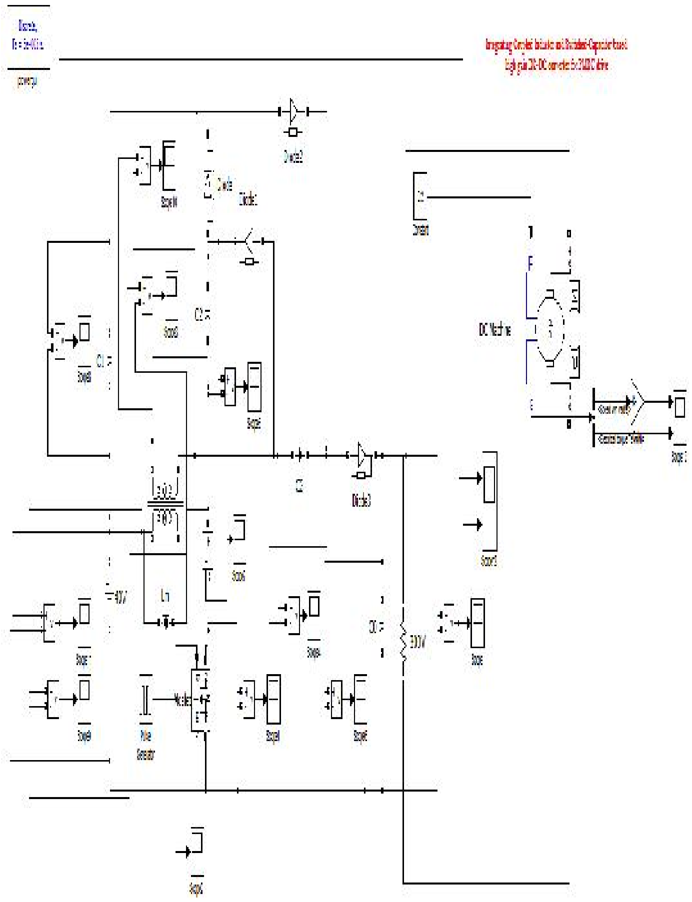

fig 4.4 Extension simulation circuit

CONCLUSION

This paper 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. Finally, a hardware prototype is implemented which converts the 40-V input voltage into 400-V output voltage. The results prove the feasibility of the presented converter.

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