International Journal of Innovative Technologies

WWW.IJITECH.ORG

ISSN 2321-8665
Volume.06, Issue.01,
January-June, 2018,
Pages:0045-0048

# High-Efficiency Single-Input Multiple-Output DC–DC Converter

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**Abstract:** A soft-switching dc/dc converter with high voltage gain is proposed in this paper. It provides a continuous input current and high voltage gain. Moreover, soft-switching characteristic of the proposed converter reduces switching loss of active power switches and raises the conversion efficiency. The reverse-recovery problem of output rectifiers is also alleviated by controlling the current changing rates of diodes with the use of the leakage inductance of a coupled inductor. Hybrid power system consists of a combination of renewable energy sources such as: photovoltaic (PV), wind generators, hydro, etc., to charge batteries and provide power to meet the energy demand. Finally, a simplified design procedure is proposed in hybrid system by using stand-alone application.

**Keywords:** Active Clamp, DC-DC Converter, High Step Up, Switched Capacitor, Voltage Doubler Circuit.

## I. INTRODUCTION

Recently, the demand for dc/dc converters with high voltage gain has increased. The energy shortage and the atmosphere pollution have led to more researches on the renewable and green energy sources such as the solar arrays and the fuel cells. Moreover, the power systems based on battery sources and super capacitors have been increased. Unfortunately, the output voltages of these sources are relatively low. Therefore, the step-up power conversion is required in these systems. Besides the step-up function, the demands such as low current ripple, high efficiency, fast dynamics, light weight, and high power density have also increased for various applications. Input current ripple is an important factor in a high step-up dc/dc converter. Especially in the fuel cell systems, reducing the input current ripple is very important because the large current ripple shortens fuel cell's lifetime as well as decreases performances. Therefore, current fed converters are commonly used due to their ability to reduce the current ripple. In applications that require a voltage step-up function and a continuous input current, a continuous-conduction-mode (CCM) boost converter is often used due to its advantages such as continuous input current and simple structure. However, it has a limited voltage gain due to its parasitic components. The reverse-recovery problem of the output diodes is another important factor in dc/dc converters with high voltage gain.

## II. PROPOSED SYSTEM PROJECT DESCRIPTION

A non isolated converter using voltage multiplier cell is introduced. It can achieve high voltage gain without large duty ratio operation. However, to obtain high conversion ratio multiple of such cell has to be used. Switched capacitor or switched inductor based converters are given in literatures. Switched capacitor converter proposed have advantage of lack of magnetic components and good line regulation. For high gain applications, these converters require more number of switched capacitor and switched inductor cells. This increases the component counts.

### A. Active clamp

Forward converters with active-clamp reset offer multiple benefits to designers and are presently finding wide use. Power converters based on the forward topology are an excellent choice for applications where high efficiency and good power handling capability is required in the 50 to 500W power range. While the popularity of forward topology is based upon many factors, designers have been primarily drawn to it's simplicity, performance, and efficiency. The forward converter is derived from the buck topology. The main difference between the two topologies is that the transformer employed in the forward topology provides input-output ground isolation as well as a step-down or step-up function. The transformer in a forward topology does not inherently reset each switching cycle as do symmetrical topologies (push-pull, halfbridge, and full-bridge). A number of different reset mechanisms have been employed in forward power converters, each method has its own benefits and challenges. Forward converters with active-clamp reset offer multiple benefits to designers and are presently finding wide use.

### B. DC-DC Converter

The buck–boost converter is a type of DC-to-DC converter that has an output voltage magnitude that is either greater than or less than the input voltage magnitude. It is equivalent to a flyback converter using a single inductor instead of a transformer.[1] Two different topologies are called buck–boost converter. Both of them can produce a range of output voltages, from an output voltage much larger (in absolute magnitude) than the input voltage, down to almost zero. The inverting topology The output voltage is of the opposite polarity than the input. This is a switched-mode power supply with a similar circuit topology to the boost converter and the buck converter. The output voltage is adjustable based on the duty cycle of the switching transistor. One possible drawback of this converter is that the switch does not have a terminal at ground; this complicates the driving circuitry. Neither drawback is of any consequence if the power supply is isolated from the load circuit (if, for example, the supply is a battery) because the supply and diode polarity can simply be reversed. The switch can be on either the ground side or the supply side. A buck (step-down) converter combined with a boost (step-up) converterThe output voltage is typically of the same polarity of the input, and can be lower or higher than the input. Such a non-inverting buck-boost converter may use a single inductor which is used for both the buck inductor and the boost inductor,[2][3][4] sometimes called a "four-switch buck-boost converter",it may use multiple inductors but only a single switch as in the SEPIC and Ćuk topologies.

**B. Switched capacitor**

A switched capacitor is an electronic circuit element used for discrete time signal processing. It works by moving charges into and out of capacitors when switches are opened and closed. Usually, non-overlapping signals are used to control the switches,sothat not all switches are closed simultaneously. Filters implemented with these elements are termed "switched-capacitor filters," and depend only on the ratios between capacitances. This makes them much more suitable for use within integrated circuits, where accurately specified resistors and capacitors are not economical to construct.

**C. Voltage doubler circuit**

A voltage doubler is an electronic circuit which charges capacitors from the input voltage and switches these charges in such a way that, in the ideal case, exactly twice the voltage is produced at the output as at its input. The simplest of these circuits are a form of rectifier which take an AC voltage as input and outputs a doubled DC voltage. The switching elements are simple diodes and they are driven to switch state merely by the alternating voltage of the input. DC-to-DC voltage doublers cannot switch in this way and require a driving circuit to control the switching. They frequently also require a switching element that can be controlled directly, such as a transistor, rather than relying on the voltage across the switch as in the simple AC-to-DC case. Voltage doublers are a variety of voltage multiplier circuit. Many, but not all, voltage doubler circuits can be viewed as a single stage of a higher order multiplier: cascading identical stages together achieves a greater voltage multiplication.

## III. MODULES DESCRIPTION

Proposed converter is shown in Fig1 along with normal direction of currents through the elements. It consists of a coupled inductor and switched capacitor voltage extension cells. Voltage extension cell comprise of two switched capacitorsC1 and C2 and charging diodes D1 and D2 respectively. Output diode Do have similar function of an output diode of a normal boost converter. In Fig1, coupled inductor is represented by its equivalent transformer model, where Lm and Lk represents the magnetizing and leakage inductance of the coupled inductor referred to the primary. Auxiliary switch SAUX and clamp capacitor Cc forms the active clamp circuit. For the analysis of the converter, all the switches and other elements are considered to be ideal except leakage inductance of the coupled inductor and parasitic drain to source capacitance of the MOSFET switches (Cr) .Key waveforms of the converter are given in Fig2. Inthe key waveforms Vg1 and Vgaux are the gate signals forthe main and auxiliary switches. Steady state operation of the proposed converter can be divided into eight modes. Simplified equivalent circuit for each modes are given.

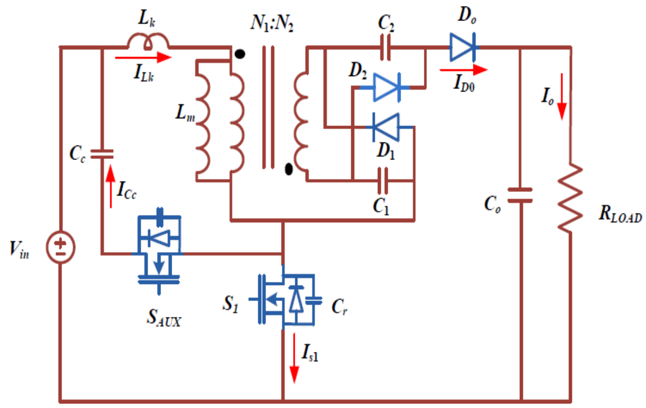


**Fig1. Proposed high step up soft switched converter.**

**A. Operation Modes**

**Mode1(to-t1):** In this mode, the main switch S1is conducting, auxiliary switch SAUX is turned OFF. The magnetizing current iLm and leakage current iLk increase linearly. The switched capacitors C1 and C2 charge in parallel through the secondary of the coupled inductor and diodes D1and D2 respectively. The output capacitor (Co) supplies energy to the load.

**Mode 2 (t1 - t2):** This mode starts at t = t1, when the main switch S1 is turned off. Leakage inductor current start to charge the parallel capacitor (Cr) of the main switch S1.Voltage across Cr increases from 0 to Vin + VCc. reflected voltage from the primary side.

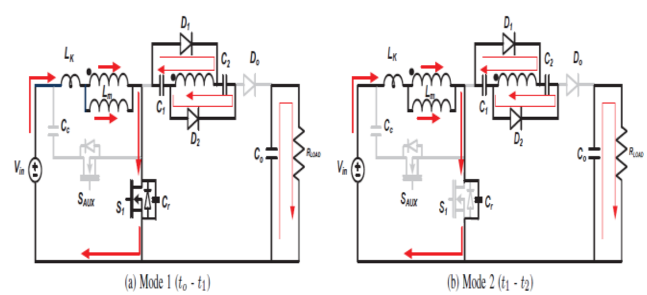


**Fig2.**

**Mode 3 (t2 - t3):** This mode starts at t = t2, when thevoltage across the main switch S1 equal to Vin+VCc. Now thebody diode of the auxiliary switch SAUX start to conduct andthus limit the voltage spike on the main switch S1.

Leakageinductor and clamp capacitor forms a resonant circuit and theclamp capacitor start to charge So the magnetizing and leakage inductance current start todecrease. Rate of decrease of the secondary current is limitedby the presence of secondary leakage inductance. This causesthe secondary current to decrease slowly and finally becomezero at time t = t3. Thus presence of leakage inductancereduces the reverse recovery problem of the diodes D1 andD2.

**Mode 4 (t3 - t4):**

At t3, current through the charging diodesD1 and D2 become zero and thus stop conducting. Prior tothis, output capacitor Co was delivering energy to the load. This causes the output diode Do to forward biases and startto conduct. Input voltage Vin, magnetizing inductance Lm,switch capacitors C1 and C2 supplies their energy to theload in series. Leakage inductance Lk and clamp capacitorCc continue to resonate. In order to get ZVS for auxiliaryswitch, it should be turned on before the resonating currentiCc(t) reverse its direction.

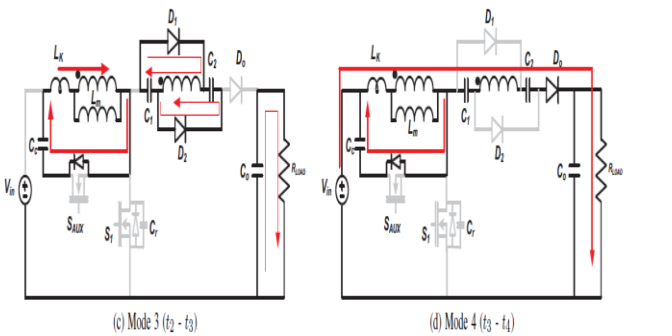


**Fig3.**

**Mode 5 (t4 - t5):** At t = t4, gate signal for SAUX is applied. Prior to the application of gate signal, body diode of theauxiliary switch was in conduction. So auxiliary switch turnedon with ZVS. Input voltage Vin, magnetizing inductance Lm,switch capacitors C1 and C2 continue to supplies their energyto the load. Resonant current iLk(t) reverse its direction andflow through the auxiliary switch

**Mode 6 (t5-t6):** This mode starts at t5, when the auxiliary switch is turned off. Now leakage inductance Lk and parasitic capacitor of the main switch Cr forms new resonating circuitand start to discharge the parasitic capacitor voltage VCr(t).Since Cr is small, voltage across the main switch decrease srapidly.

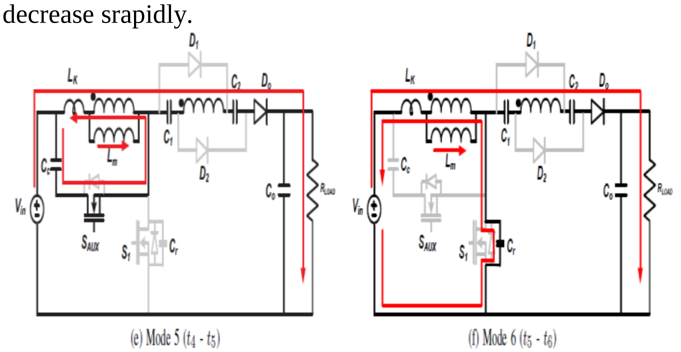


**Fig4.**

**Mode 7 (t6 - t7):** This mode starts at t6, when the parasitic capacitor is fully discharged. Now body diode of the main switch S1 starts to conduct the current iLk. To achieve ZVSfor the main switch, gate signal (Vg1) should be applied duringthis period.

**Mode 8 (t7 - t8):** At t7, main switch turned on with ZVS. Leakage inductor current and magnetizing current start toincrease linearly. Output diode current starts to decrease. Thismode end at t8, when the output diode Do stop conductingand reverse bias. At this instant, the switch capacitors C1 andC2 start to charges in parallel through the secondary of thecoupled inductor. Here after, the cycle repeats.

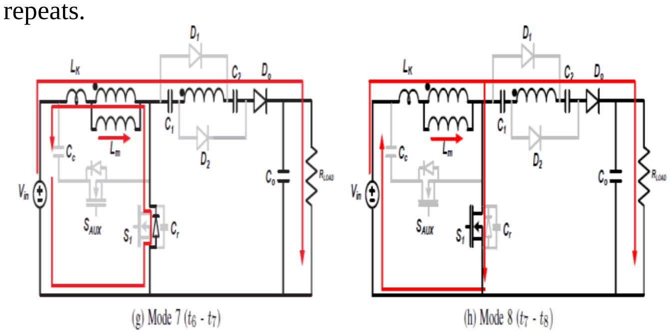


**Fig5.**

## IV. SIMULATION RESULTS

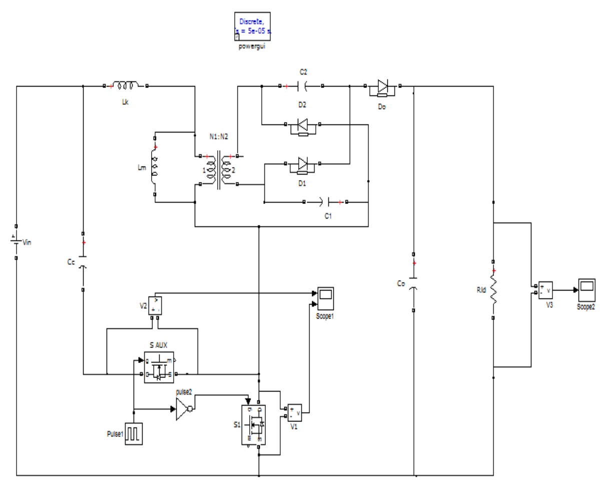

**Fig6. Proposed System Simulink Model.**

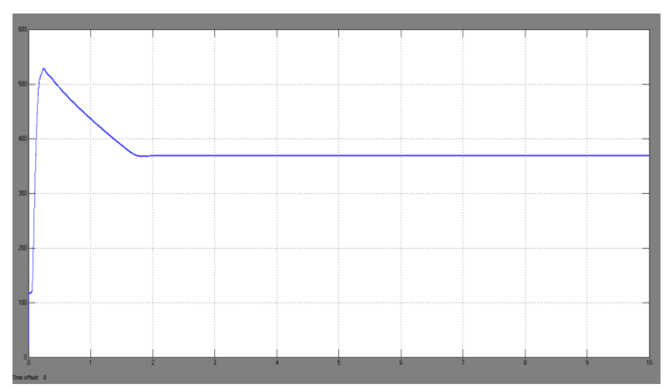

**Fig7. Output Voltage Waveform.**

## V. CONCLUSION

A soft-switching dc/dc converter with high voltage gain has been proposed in this paper. The proposed converter can minimize the voltage stresses of the switching devices and lower the turn ratio of the coupled inductor. It provides a continuous input current, and the ripple components of the input current can be controlled by using the inductance of the CCM boost cell. Finally the proposed converter is applied in standalone renewable application. A Matlab/Simulink model is developed and simulation results are presented.

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