Over Current Protection for High Voltage Gain DC-DC Converter

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Abstract

This paper introduces a single-switch high voltage gain non isolated dc–dc converter containing coupled inductor and diode–capacitor techniques. The proposed converter produces extremely large voltage conversion ratio. The energy stored in leakage inductance of coupled inductor is efficiently recycled to the output. The voltage stress on the power devices is reduced. The high-pulsed input current in the converter is decreased. This paper proposes an overcurrent protection for high voltage gain dc–dc converter with coupled inductor.

Keywords: Coupled Inductor, Diode-Capacitor, Voltage Stress, High Voltage Gain, Over Current Protection

I. INTRODUCTION

The high voltage gain dc–dc boost converters is used in industry applications such as uninterrupted power supplies, electric traction, photovoltaic generation systems, fuel cell energy conversion systems, automobile HID headlamps, and some medical equipments[1]. A classical boost converter can be used for these applications, but the voltage stress of the switch is equal to the high output voltage. So a high-voltage rating switch with high on-resistance should be used, which results high conduction losses. As a result, the classical boost converter is not acceptable for realizing high step-up voltage gain along with high efficiency.

Many nonisolated topologies have been studied to achieve a high conversion ratio and to avoid operating at high-duty cycle. These converters are switched-capacitor types, switched-inductor types, the voltage-doubler circuits, and the capacitor diode voltage multiplier. All of them can provide higher voltage gain than the conventional boost converter. But, more switched capacitor or switched-inductor stages will be required for an extremely large conversion ratio, results in higher cost and complex circuit. In quadratic boost converter [2] using a single active switch, the voltage conversion ratio is given as a quadratic function of the duty ratio. But, the voltage gain of this converter is moderate since the output voltage level depends on the duty cycle. The voltage stress across the active switch is equal to the output voltage. Some converters based on transformers or coupled inductors or tapped inductors [3],[4] have been researched to provide a high conversion ratio without operating at high duty ratio. The conventional flyback converter can provide high voltage gain by adjusting the turn’s ratio of the transformer. The leakage inductor of the transformer not only cause high voltage spikes on the power device, but also induce energy losses. The active clamped techniques [5] can release high voltage spikes and reduce switching losses, but an additional active switch leads to complex structures and control. Many boost converters based on a coupled inductor can provide high voltage gain, and low voltage stress on the active switch without the penalty of high duty ratio. However, the input current is not continuous.

The main features of the converter are the voltage gain is increased by a coupled inductor and the secondary winding of the coupled inductor is inserted into a diode-capacitor for further increasing the voltage gain, a passive clamped circuit is connected to the primary winding of the coupled inductor to clamp the voltage across the active switch to lower voltage level. As a result, the power devices with low voltage rating and low on-state resistance can be selected, the leakage inductance energy of coupled inductor can be recycled, improving the efficiency and the potential resonance between the leakage inductance and the junction capacitor of output diode may be cancelled. This paper shows the operational analysis and simulation results of the proposed converter. In section II the structure and the principle of operations are explained. In section III over current protection of converter was explained. In section IV the simulation results of overcurrent protection are presented and the conclusion is presented in section V.

II. HIGH VOLTAGE GAIN DC-DC CONVERTER

A. Circuit Structure and Principle of Operation

The circuit structure of the proposed converter contains a switch Q, an input inductor L₁, and a coupled inductor T₁, diodes D₁, D₂ and D₀, a storage energy capacitor C₁ and a output capacitor C₀, a clamped circuit including diode D₃ and capacitor C₂, an extended voltage doubler cell comprising regeneration diode D₄, and capacitor C₃, and the secondary side of the coupled
The dual-winding coupled inductor has a turn ratio $N (n_2 / n_1)$, a parallel magnetizing inductance $L_m$, and primary and secondary leakage inductance $L_{k1}$ and $L_{k2}$.

![Proposed high voltage gain dc-dc converter](image)

The operating modes are described as follows:

1) **Mode 1:**
   - The switch $Q$ starts conducting at $t = t_0$. Diodes $D_1$ is reverse biased by $V_{C1}$. Diodes $D_3$ is reverse biased by $V_{C1} + V_{C2}$. Diodes $D_0$ is reverse biased by $V_0 - V_{C1} - V_{C2}$. Diodes $D_2$ and $D_4$ are turned ON. The dc source energy is transferred to the inductor $L_1$ through $D_2$ and $Q$. The primary voltage of the coupled inductor including magnetizing inductor $L_m$ and leakage $L_{k1}$ is $V_{C1}$ and the capacitor $C_1$ is discharging its energy to the magnetizing inductor $L_m$ and primary leakage inductor $L_{k1}$ through the switch. The energy stored in $C_2$ and $C_1$ is released to $C_3$ through $D_4$. The load $R$ is supplied by the output capacitor $C_0$. This stage ends at $t = t_1$.

2) **Mode 2:**
   - The switch $Q$ is turned OFF at $t = t_1$, the current through $Q$ flow through $D_3$. The energy stored in inductor $L_1$ flows through diode $D_3$ to charge capacitor $C_4$ and the current $i_{L1}$ declines linearly. The diode $D_2$ is reverse biased by $V_{C2}$. The diode $D_0$ is reverse biased by $V_0 - V_{C1} - V_{C2}$. The energy stored in inductor $L_{k1}$ flows through diode $D_4$ to charge capacitor $C_2$. The energy stored in $L_{k1}$ is recycled to $C_2$. The voltage stress across $Q$ is the summation of $V_{C1}$ and $V_{C2}$. The load energy is supplied by the output capacitors $C_0$.

3) **Mode 3:**
   - During this transition interval, switch $Q$ remains OFF. $V_{C2}$ is reflected to the secondary side of coupled inductor thus, regeneration-diode $D_4$ is reverse biased by $V_{C3} + NV_{C2}$. Meanwhile, the diode $D_0$ starts to conduct. The inductance $L_1$ is still releasing its energy to the capacitor $C_4$. Thus, the current $i_{L1}$ still declines linearly. The energy stored in $L_{k1}$ and $L_m$ is given.

![Mode 1](image)

![Mode 2](image)

![Mode 3](image)
An overcurrent is a situation when a current flowing through the load is greater than the rated load current. This can cause damage to the diode, MOSFET and also the inductor. Possible causes for overcurrent include short circuits, excessive load, and incorrect design. When current in the load goes above the rated value of load current, a protection circuit is provided which will isolate the converter from the supply. A current sensing element such as relays can be used to sense the output current of the converter. The output current of the converter will be compared with a reference current set in the comparator. The reference...
current set in the comparator will be equal to the rated load current of the converter. When the output from the current sensing element exceeds the reference current in the comparator, pulses will be generated from the comparator which will be given to the trip circuit.

Depending upon the load converter can be isolated from the supply in two ways. If the load current exceeds the rated load current, converter can be permanently isolated from the supply. This method of isolation is used for the load which requires desired voltage and current. Another method is when the load current exceeds the rated load current converter can be isolated from the supply and converter is reconnected to the supply whenever the load current is below the rated load current.

![Block diagram of over current protection.](image)

**IV. SIMULATION RESULTS**

The designing of high voltage gain dc-dc converter has done and circuitry are simulated using Matlab/Simulink software. The input to the converter is 36 V and the output obtained is 380 V. The gating signal is obtained using PWM block and it is given to the gate of switch. Simulation diagram of the converter with over current protection having permanent isolation is shown in fig 4.

![Simulation diagram with permanent isolation.](image)

The output voltage waveform of the converter with permanent isolation is shown in Figure. In simulation reference current is kept as 1A, that is when output current exceeds 1A tripping occur. The tripping is done through a switch. Whenever load current exceeds rated load current gate signal to the switch is maintained at the zero level. The output voltage of the converter will be zero when tripping occurs. The gating signal to the switch is shown in Figure below.
Simulation diagram of the converter with over current protection having temporary isolation is shown in Fig.7. The isolation of converter from the supply is not permanent and the output voltage waveform is shown in figure. The reference current is kept as 1A. Whenever load current exceeds rated load current gate signal to the switch is at low level otherwise gate signal is kept at high level, when output current exceeds 1A tripping occur. The output voltage of the converter is reduced from the desired voltage level when overcurrent occurs. The tripping is done through a switch. The gating signal to the switch is shown below.
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A high voltage gain dc–dc converter with over current protection has been proposed in this paper. When the load current exceeds the rated load current, the converter will be disconnected from the supply. A high voltage gain dc–dc converter with coupled inductor and diode clamped technique will increase the voltage gain and reduce the voltage stress across the switch. The energy in the leakage inductor can be recycled and the turned off voltage spikes on the main switch are suppressed. In addition, one MOSFET is required to simplify the circuit configuration and improve the system reliability, and the proposed converter maintains the advantage of continuous input current.

V. CONCLUSION

REFERENCES


