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NOVEL TRANSFORMER LESS ADAPTABLE VOLTAGE QUADRUPLER DC CONVERTER WITH CLOSED LOOP CONTROL

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ABSTRACT: *In this paper, a novel transformer-less adjustable voltage quadrupler dc–dc converter with high voltage transfer gain and reduced semiconductor voltage stress was analyzed. The proposed topology utilizes input-parallel output-series configuration and is derived from a two-phase interleaved boost converter for providing a much higher voltage gain without adopting an extreme large duty cycle. The proposed converter cannot only achieve high step-up voltage gain but also reduce the voltage stress of both active switches and diodes. This will allow one to choose lower voltage rating MOSFETs and diodes to reduce both switching and conduction losses. In addition, due to the charge balance of the blocking capacitor, the converter features automatic uniform current sharing characteristic of the two interleaved phases for voltage boosting mode without adding any extra circuitry or complex control methods.*

KEYWORDS: Automatic Uniform Current Sharing, High Step-Up Converter, Low Voltage Stress, Transformer-Less, Voltage Quadrupler.

INTRODUCTION

With global energy shortage and strong environmental movements, renewable or clean energy sources such as solar cells and fuel cells are increasingly value worldwide. However, due to the inherent low voltage characteristic of these sources, a high stepup dc converter is essential as a prestage of the corresponding power conditioner. The conventional boost and buck–boost converters, due to the degradation in the overall efficiency as the duty ratio approaches unity, obviously cannot fulfill the application need. Besides, the extreme duty ratio not only induces very large voltage spikes and increases conduction losses but also induces severe diode reverserecovery problem. Many topologies have been presented to provide a high step-up voltage gain without an extremely high duty ratio.

A dc–dc fly back converter is a very simple isolated structure with a high step-up voltage gain, but the active switch of this converter will suffer a high voltage stress due to the can realize high efficiency and high step-up conversion. However, the start-up operation of these converters must be considered separately. Moreover, the cost is increased because many extra power components and isolated sensors or feedback controllers are required. In order to reduce system cost and to improve system efficiency, a non isolated dc/dc converter is, in fact, a more suitable solution. The switched capacitor-based converters proposed in provide solutions to improve the conversion efficiency and achieve large voltage conversion ratio. achieve large voltage conversion ratio.

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Unfortunately, the conventional switched capacitor technique makes the switch suffer high transient current and large conduction losses. Furthermore, many switched capacitor cells are required to obtain extremely high step-up conversion, which increases the circuit complexity. The coupled inductor-based converters are another solution to implement high step-up gain because the turns ratio of the coupled inductor can be employed as another control freedom to extend the voltage gain. However, the input current ripple is relatively larger by employing single stage single-phase-coupled inductor-based converters, which may shorten the usage life of the input electrolytic capacitor. As such, a family of interleaved high step-up boost converters with winding-cross-coupled inductors is proposed .

To achieve higher voltage conversion ratio and further reduce voltage stress on the switch and diode, the high step-up ratio converter and the ultra high step-up converter have been proposed. These converters can provide large step-up voltage conversion ratios. Unfortunately, the voltage stress of diodes in those converters remains rather high. In this project, a novel transformer-less adjustable voltage quadrupler topology is proposed. It integrates two-phase interleaved boost converter to realize a high voltage gain and maintain the advantage of an automatic current sharing capability simultaneously. Furthermore, the voltage stress of active switches and diodes in the proposed converter can be greatly reduced to enhance overall conversion efficiency.

Proposed System

Here the uncoupled interleaved boost converter voltage gain is twice that of the basic two phase boost converter. Also, the voltage stress of both the active switches and diodes are much lower than the latter.

The modified converter possesses automatic uniform current sharing capability without adding extra circuitry or complex control methods.This proposed system will produce an output voltage 16 times that of the input. If a 12v DC input voltage is applied to an quadrupler boost converter .The quadrupler, it receives and produce an output as16 times of that input voltage, ie 200V. This output voltage is fed to a motor load . An closed loop feedback Is provided to get desired and constant output during varying load. A PI controller is provided in the feedback.

Block diagram of Proposed System:

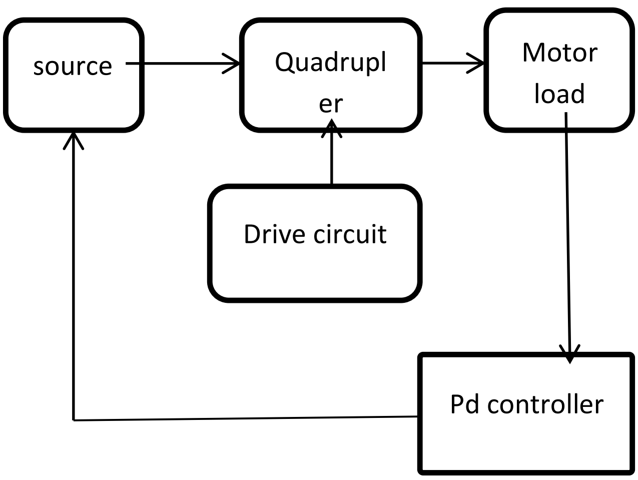

Fig 1. Block diagram of the proposed system

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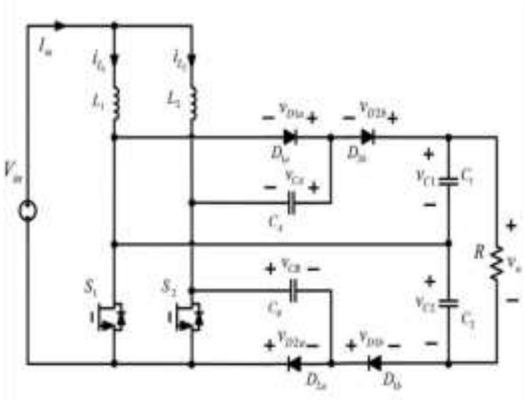
Topology of the transformer -less voltage quadrupler



The modified converter topology is basically derived from a two phase interleaved boost converter. In this topology consist of two boost inductors which is represented as L1 and L2 which is connected in parallel from the interleaved structure. Two active switches such as MOSFET S1 and S2 are placed in the two phases. Four power diodes D1a, D2a, D1b, D2b. the capacitor Ca and Cb constitute the blocking capacitor and C1, C2 be the output capacitors.

During the energy transfer period partial inductor stored energy is stored in one capacitor and the other partial inductor stored energy together with the other capacitor store energy is transferred to the output to achieve much higher voltage gain.

Analysis of Operating Principle

Based on the waveforms of the inductor currents, one switching period is divided in to four intervals. The equivalent circuits for each interval are also required where the red and blue dotted lines denoted the actual current directions of each inductor in each mode. The different modes of operations are as follows,

Mode 1

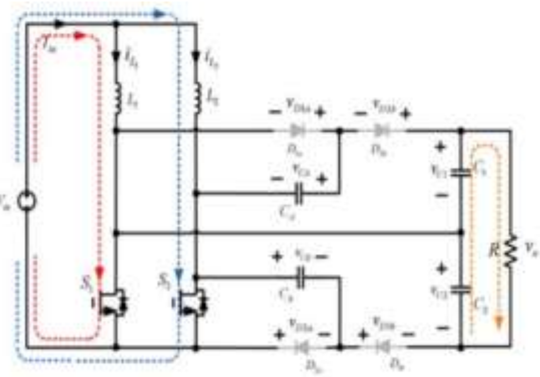


Fig 2 Equivalent circuit of mode 1

Mode 1 ($t0 \leq t < t1$): For mode 1, switches S1 and S2 are turned ON, D1a, D1b, D2a, and D2b are all OFF. From Fig.5.3, it is seen that both iL1 and iL_2 are increasing to store energy in L1 and L2, respectively. The voltages across diodes D1a and D2a are clamped to capacitor voltage

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VCA and VCB, respectively, and the voltages across the diodes D1b and D2b are clamped to VC2 minus VCB and VC1 minus VCA, respectively.

Mode 2

Mode 2 ($t_1 \leq t < t_2$): For this operation mode, switch S1 remains conducting and S2 is turned OFF. Diodes D2a and D2b become conducting. The corresponding equivalent circuit is shown in Fig.5.4. It is seen from that part of stored energy in inductor L2 as well as the stored energy of CA is now released to output capacitor C1 and load. Meanwhile, part of stored energy in inductor L2 is stored in CB. In this mode, capacitor voltage VC1 is equal to VCB plus VCA. Thus, iL1 still increases continuously and iL2 decreases linearly.

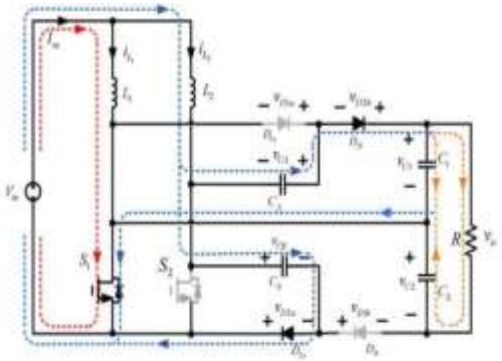

Fig 3 Equivalent circuit of mode 2 Mode 3

Mode 3 ($t2 \leq t < t3$): For this operation mode, as can be observed from Fig.5.5 both

S1 and S2 are turned ON. The corresponding equivalent circuit turns out to be the same as mode 1

Mode 4

Mode 4 ($t3 \leq t < t4$): For this operation mode, switch S2 remains conducting and S1 is turned OFF. Diodes D1a and D1b become conducting. It is seen from that the part of stored energy in inductor L1 as well as the stored energy of CB is now released to output capacitor C2 and load. Meanwhile, part of stored energy in inductor L1 is stored in CA. In this mode, the output capacitor voltage VC2 is equal to VCB plus VCA. Thus, iL2 still increases continuously and iL1 decreases linearly. The corresponding equivalent circuit is shown in Fig 5.6

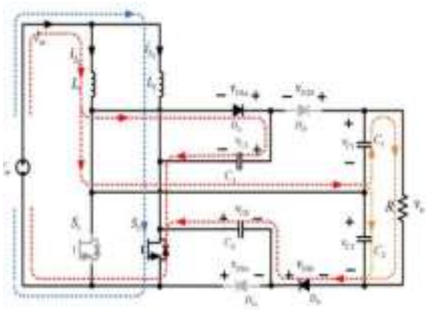

Fig 4 Equivalent circuit of mode 4

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The main objective is to obtain high voltage gain and such characteristic can only be achieved when the duty cycle is greater than 0.5 and in continuous conduction mode (CCM); hence, the steady-state analysis is made only for this case. However, with duty cycle lower than 0.5 or in DCM, as there is no enough energy transfer from the inductors to the blocking capacitors, output capacitors, and load side, and Consequently, it is not possible to get the high voltage gain as that for duty ratio greater than 0.5. In addition, only with duty cycle larger than 0.5, due to the charge balance of the blocking capacitor, the converter can feature the automatic current sharing characteristic that can obviate any extra current-sharing control circuit. In order to simplify the circuit analysis of the proposed converter, some assumptions are made as follows.

1) All components are ideal components.
2) The capacitors are sufficiently large, such that the voltages across them can be considered as constant approximately.
3) The system is under steady state and is operating in CCM and with duty ratio being greater than 0.5 for high step-up voltage purpose.

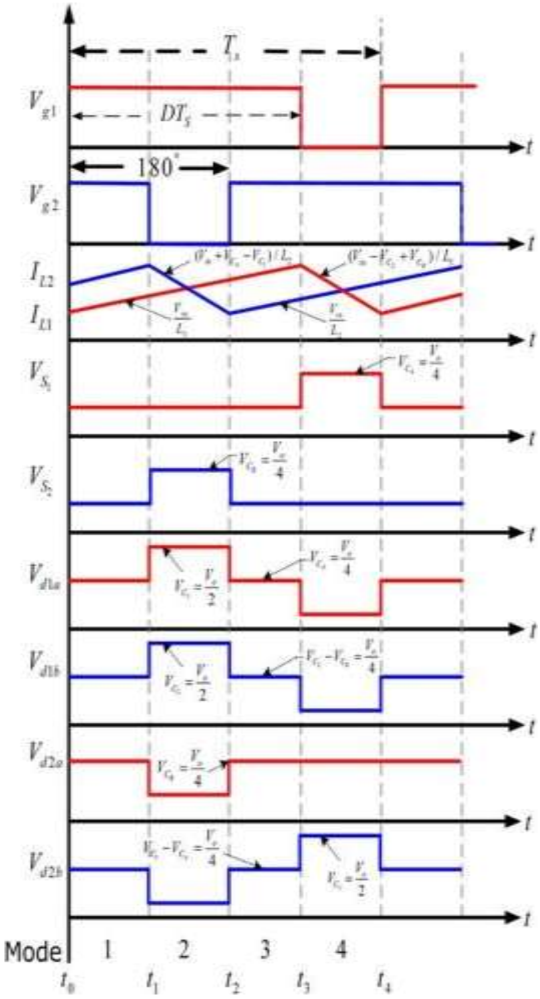


Fig 5 operating waveforms of the proposed converter at CCM with a 180° phase shift

SIMULATION RESULTS:

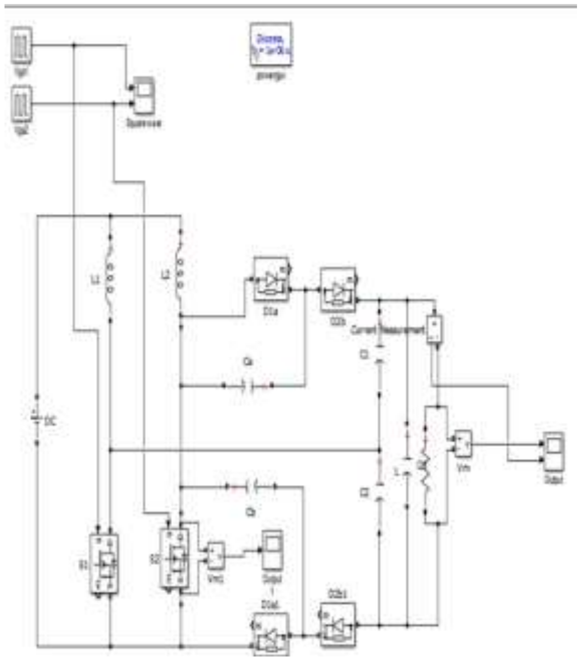


Fig 6 The above figure shows the Simulink model of the proposed concept in open loop

Fig 7 The above figure shows the Simulink model of the proposed system with closed loop control

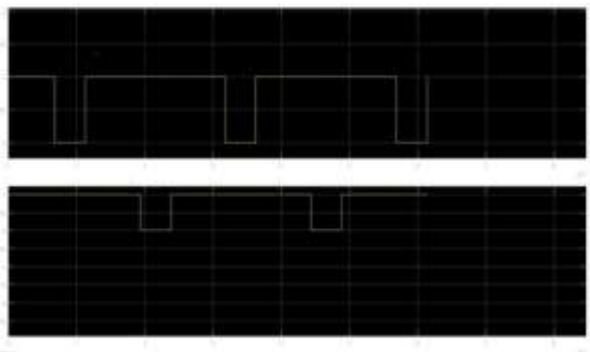


Fig 8 The above figure shows the simulation result of input voltage waveform of the proposed system.

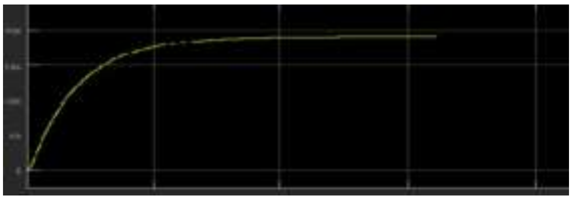
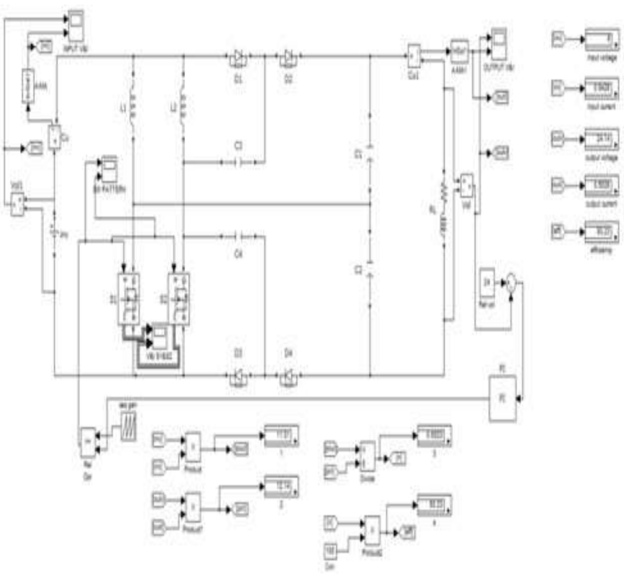


Fig 9 The above figure shows the simulation result of output voltage waveform of the proposed system.



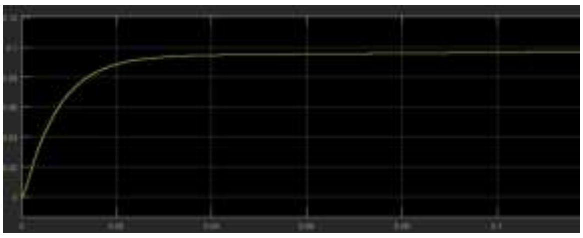


Fig 10 The above figure shows the simulation result of output current waveform of the proposed system

CONCLUSION

This paper discussed a transformer - less DC Boost converter with PI Controller to enhance efficiency with high voltage transfer gain and reduced semiconductor voltage stress is proposed. The proposed topology utilizes input-parallel output-series configuration and is derived from a twophase interleaved boost converter for providing a much higher voltage gain without adopting an extreme large duty cycle. The proposed converter cannot only achieve high step-up voltage gain but also reduce the voltage stress of both active switches and diodes. This will allow one to choose lower voltage rating MOSFETs and diodes to reduce both switching and conduction losses. In addition, due to the charge balance of the blocking capacitor, the converter features automatic uniform current sharing characteristic of the two interleaved phases for voltage boosting mode without adding any well as a comparison with other recent existing high step-up topologies are presented. Finally, a 100-W rating prototype with 12-V input and 200-V output is constructed for verifying the validity of the proposed converter. It is seen that the resulting experimental results indeed agree very close and show

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great agreement with the simulation results. Therefore, the proposed converter is very suitable for applications requiring high step-up voltage gain.

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