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WIDE INPUT WIDE OUTPUT DC–DC CONVERTER

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Abstract

Wide Input Wide Output (WIWO) DC-DC converter is a combination of buck and boost converters through a coupled inductor. It has an output voltage that is either greater than or less than the input voltage. Step down and step up mode is switched by a proper control scheme. The WIWO will minimize the input voltage 48 Vdc to 19 Vdc also maximize the input voltage 48 Vdc to 230 Vdc with the switching frequency 67 kHz for buck and 2 kHz for boost. The simulation software used for simulation of WIWO converter is MATLAB SIMULINK.

Introduction

The buck, boost, buck–boost and CUK converters are the four basic dc–dc non isolating converters that have found wide applications in industry. The buck converter is used for step down the dc voltage, whereas the boost converter is used as step-up dc voltage. In applications where both step-down and step-up conversion ratios are required, the buck–boost converter and CUK converters can be used. Robustness and Simplicity are among the advantages of the buck–boost converter. However, the pulsating input and output currents cause high conduction losses, and thus, impair the efficiency of buck–boost. Furthermore, the buck–boost converter uses the inductor to hold the energy from the input source, and then leaves the stored energy to the output. For this cause, the magnetic components of wide input wide output converters are subjected to a significant stress. These are the drawbacks that limit the applications of the wide input wide output converter mainly to low power level. The separated version of buck–boost, referred to as the fly-back converter, can obtain greater step-down or step-up conversion ratio using a transformer, probably, with multiple outputs. As matched up with the buck–boost converter, the CUK converter has greater efficiency and smaller ripples in input and output currents. A significant improvement of the CUK converter performance can be achieved by using the zero ripple concepts. The CUK converter can be found in many high-performance power applications.In theory boost and buck converters can generate almost any voltage, in reality the output voltage range is limited by component stresses that increase at the extreme duty cycle. Consequently, step down converter losses mount at low duty cycle, whereas step up converter efficiency deteriorates when the duty cycle goes to unity. Accordingly, voltage conversion range of the step down converter below 0.1–0.15 turns impractical whereas that of the step up converters' is limited to below 8–10. Some other problems associated with narrow duty cycle are caused by MOSFET drivers rise and fall times as well as pulse width-modulated (PWM) controllers that have maximum pulse width limitations. These challenges become even more severe at high voltages and high frequencies.

I. WIWO DC–DC CONVERTER

A. Proposed WIWO DC–DC Converter Topology

The proposed WIWO dc–dc converter is illustrated in Fig 1. The converter is comprised of two active switches S1 and S2,tapped inductors L1 and L2 with turns ratio n = n2 : n1 , diodeD, and capacitive output filter C. Being Equivalent configuration is beneficial from practical point of view. In Fig 15, S1 and S2 are connected to a common junction or midpoint. The midpoint is periodically switched by S1 to ground, which allows recharging the bootstrap power supply and reliable operation of the flying driver of the top switch S2. Consequently, a standard half-bridge driver chip can be used with the low-side driver operating the bottom switch S1 and the bootstrap high-side driver activating the top switch S2.WIWO can operate either in the step-down or the buck mode or in the step-up or the boost mode. To operate the WIWO in the buck mode, the switch S1 is assigned a high-frequency switching signal with a predetermined duty cycle D, whereas S2 is switched complementarily to S1. The diode D is kept ON by the inductor L2 current, which is assumed to be continuous. To operate WIWO in the boost mode, the controller keeps S2 switch continuously ON and issues the required duty cycle signal for the S1 switch. Thus, the diode D is forced to switch on and off complementarily to S1. In both modes, the capacitor C filters the pulsating current and provides a smoothed output voltage for the load R.

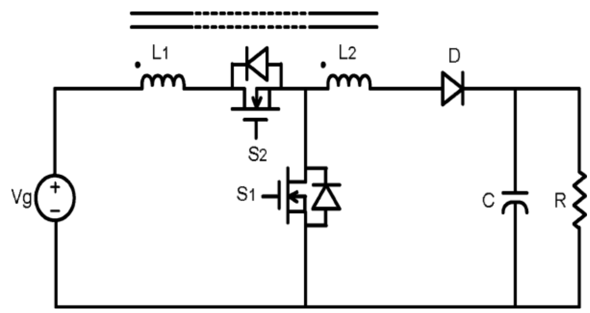


Fig 1. WIWO dc–dc converter topology

B. Control Scheme

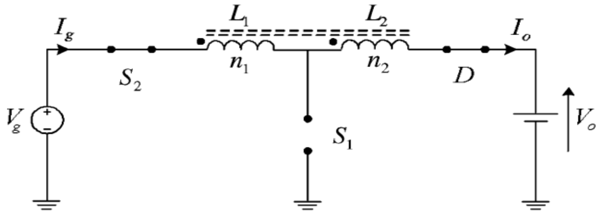
For the proper operation of WIWO, a changed PWM control circuitry is required. This PWM is originated from a microcontroller and the process for generating switching pulses for the MOSFET switches are defined in the microcontroller. The microcontroller produces a PWM signal in the form of pulses whose voltage is low compared to the switching pulses of the switch. There the signal generated is not directly given to the switch since there is no use. It needs an intermediate circuit to drive the pulses and amplify the pulses. This process is done by means of driver circuit. The generated pulse from the controller is boosted up and given to the switches.

II. Operating Principle of the WIWO Converter

In the following, the steady-state operation of the proposed WIWO converter is described. The analysis is performed assuming that the circuit is comprised of ideal components. The coupling coefficient of the tapped inductor is assumed to be unity. Under continuous inductor current (CCM) condition, the proposed WIWO converter exhibits four topological states, as shown in Fig 1(a), Fig 2(b), Fig 3(c), Fig 4(d) here the large output filter capacitor is replaced by an ideal voltage source. The waveforms and timing of WIWO for both buck and boost modes are illustrated in Fig 8.

I. Buck Mode:

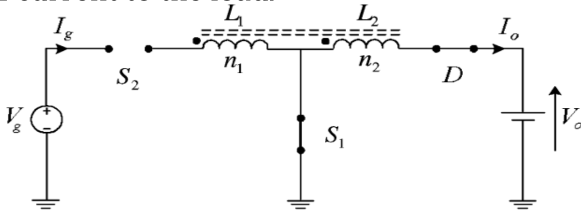
State 1 (t0 ≤ t < t1) is the buck-mode charging state [see Figs. 1(a)]. Here, the switch S2 is turned on and S1 is turned off. The diode D conducts and the coupled inductors L1 and L2 are charged. The energy is also transferred from dc source to load.



(a)

Fig 1 (a) Buck mode charging state

State 2 (t1 ≤ t ≤ t2) is the buck-mode discharging state [see Figs. 1(b)]. Here, the switch S2 is turned off also cutting off the current in the L1 winding, whereas S1 is turned on and the diode D conducts L2 current to the load.

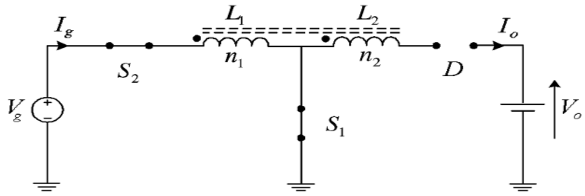


(b)

Fig 2 (b) Buck-mode discharging state

II. Boost Mode:

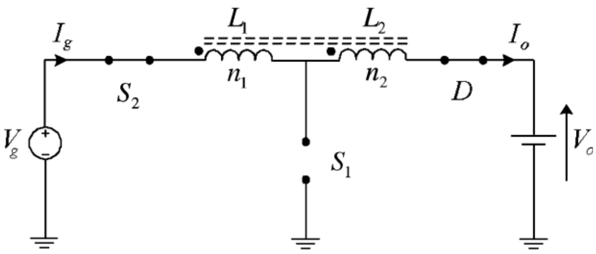
State 1 (t0 ≤ t < t1) is the boost-mode charging state [see Figs. 3(c)]. Here, the switches S1 and S2 are turned on charging the L1 inductor. The diode D is cut off by the negative voltage induced in L2 winding. The output voltage is supported by the capacitor C.



(c)

Fig 3 (c) Boost-mode charging state

State 2 (t1 ≤ t ≤ t2) is the boost-mode discharging state [see Figs. 4(d)]. Here, the switch S2 is still ON whereas S1 is turned off. Both windings L1 and L2 conduct through the diode D and discharge the stored energy to the output.



(d)

Fig 4 (d) Boost-mode discharging state

III. Simulation Results

Proposed WIWO converter is designed for input Voltage range of 12–48 Vdc and two constant output voltages of 6.6 Vdc & 230 Vdc. The turn ratio of the tapped inductor was set to n =1 with a total inductance of 10 mH. The switching frequency of 2 kHz for boost & 67 kHz was chosen.

1) PROPOSED METHOD – WIWO OPEN LOOP SYSTEM:

The Simulation circuit of the proposed coupled inductor WIWO converter open loop is shown in the Fig 5.

2) Output Voltage waveforms in buck & boost mode

The output voltage in buck mode is shown in the Fig 6.

By performing simulation with the help of MATLAB 13 it is cleared that the output is 6.6 V for input voltage of 48 V.

The output voltage in boost mode is shown in the Fig 7

3) Waveforms and timing of WIWO

Waveforms and timing of WIWO for buck mode are illustrated in Fig 8.

Waveforms and timing of WIWO for boost mode are illustrated in Fig 9.

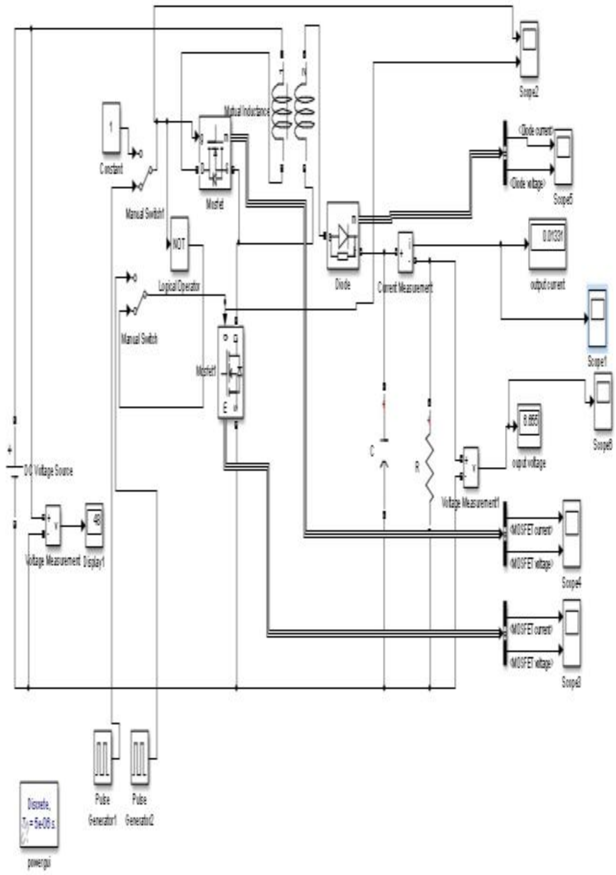


Fig 5. Simulation circuit of coupled inductor WIWO converter- Open Loop

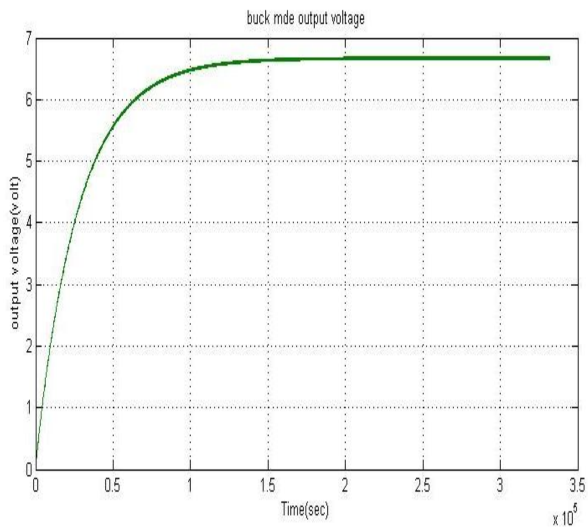


Fig 6 Output voltage in buck mode

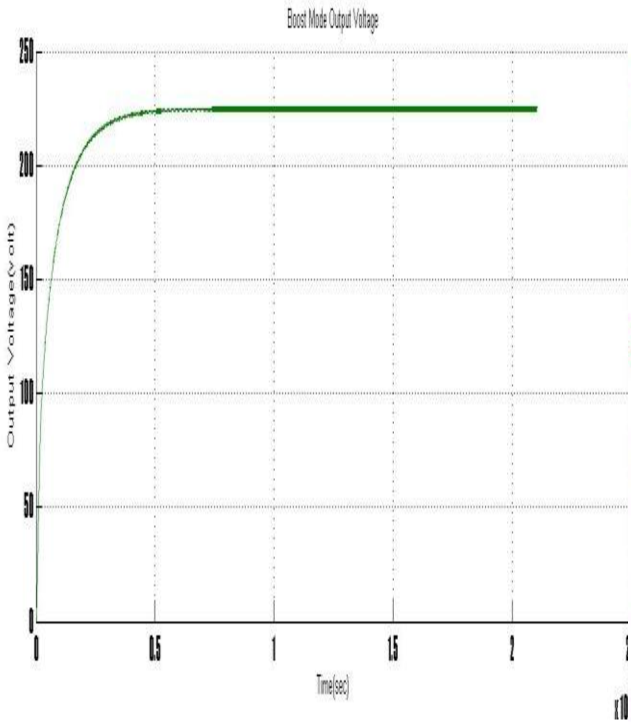


Fig 7Output voltage in boost mode

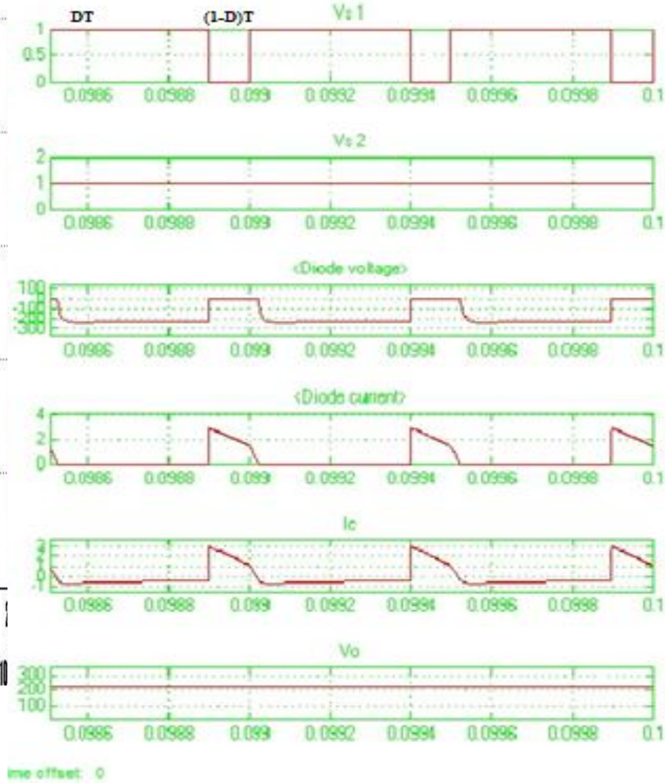


Fig 9 Waveforms and timing of WIWO for boost mode

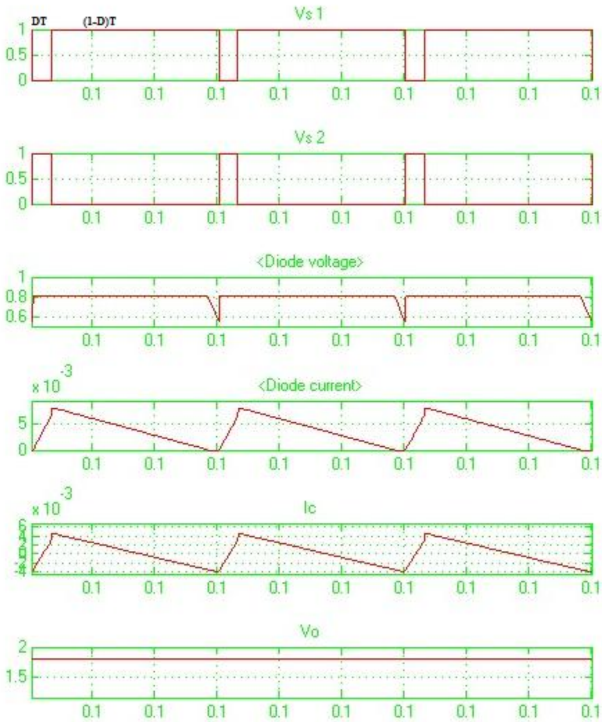


Fig 8 Waveforms and timing of WIWO for buck mode

CONCLUSION

A new WIWO dc-dc converter, which is an integration of buck and boost converters with coupled inductors. The new converter topology has several advantages. The WIWO retains the features of both the buck and the boost converters however it achieves wider step-up and wider step-down dc-dc conversion range. By replacing the inductor with coupled inductors, the new converter not only retains the functions of both converters, but also extends the conversion range. Therefore, wide-step-up and wide-step-down dc-dc conversions can be achieved and it yield an output voltage of 2-230V for an input voltage of 48V.

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