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POWER ELECTRONICS

ASSIGNMENT

CITATION : L.-S. Yang and T.-J. Liang, "Analysis and Implementation of a Novel Bidirectional DC-DC Converter," in IEEE Transactions on Industrial Electronics, vol. 59, no. 1, pp 422-434, Jan 2012 doi: 10.1109/TIE.2011.2134060

ABSTRACT

A novel bidirectional dc-dc converter is presented in this paper. The circuit configuration of the proposed converted is not much different. The proposed converter employs a coupled inductor with same winding turns in primary and secondary sides. In step-up mode, the primary and secondary windings of the coupled inductor are operated in parallel charge and series discharge to achieve high step-up voltage gain. Thus, the proposed converter has higher step-up and step-down

voltage gains than the conventional bidirectional dc-dc boost/buck converter. Under same electric specifications for the proposed converter and the conventiel bidirectional boost/buck converter, the average value of the switch current in the proposed converter is less than the conventional bidirectional boost/buck converter. The operating principle and steady-state analysis are discussed in detail. Finally, a 14/42V prototype circuit is implemented to verify the performance for the automobile dual-battery system i.e. we check the input & output for these values.

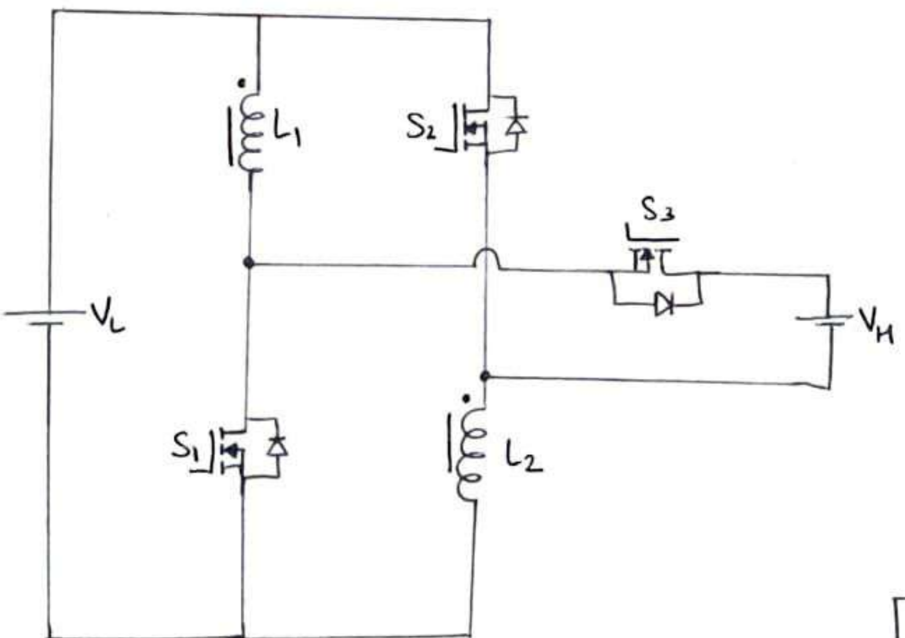


Fig1. Proposed bidirectional dc-dc converter

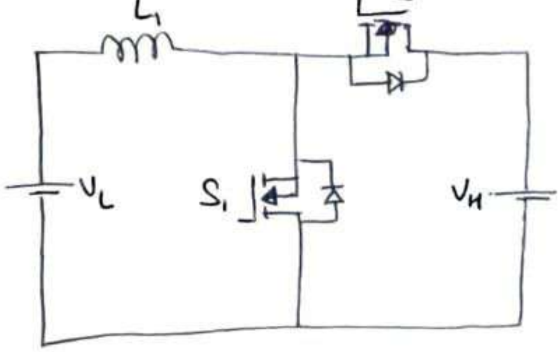
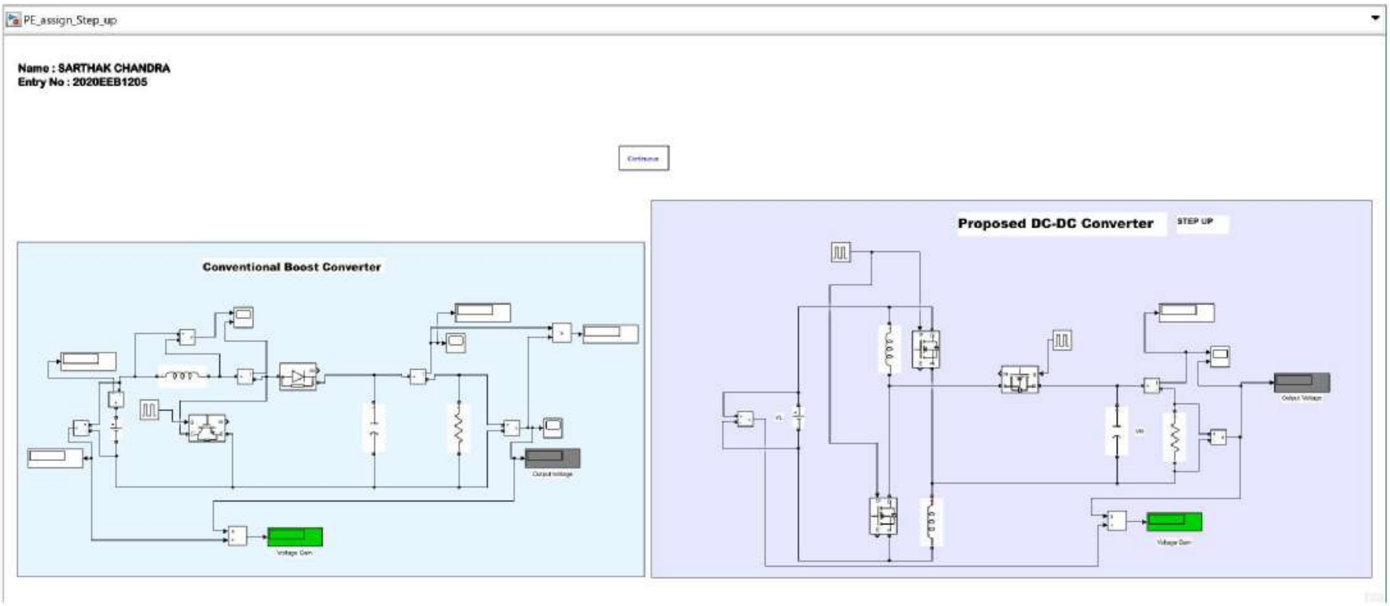
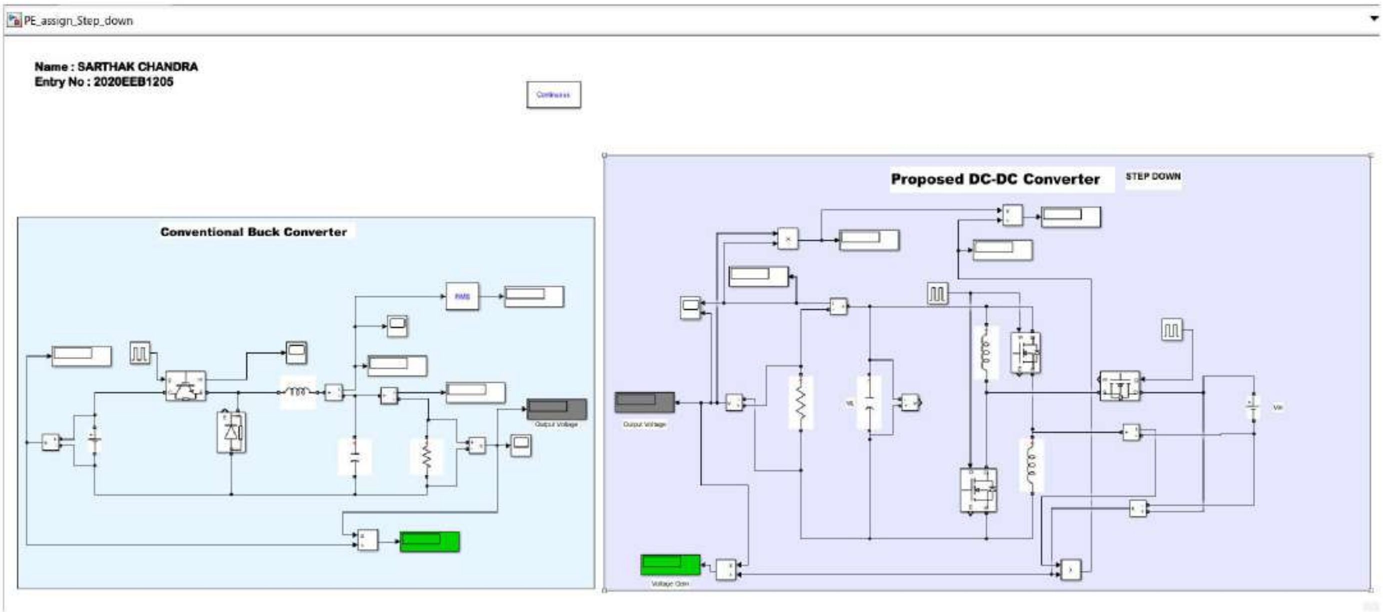


Fig2. Conventional bidirectional dc-dc boost/buck converter

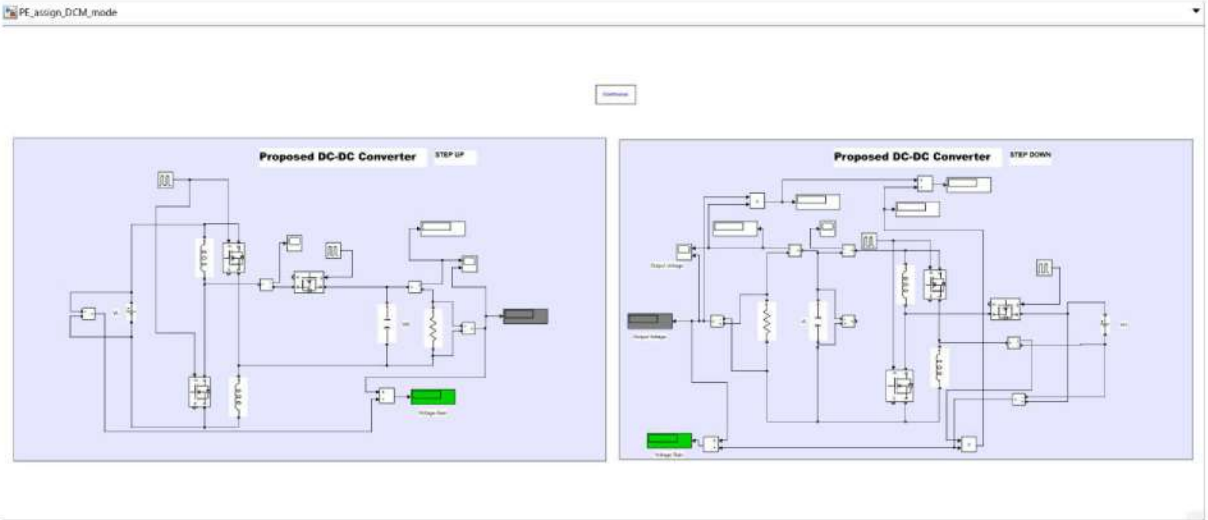
Simulation in MATLAB



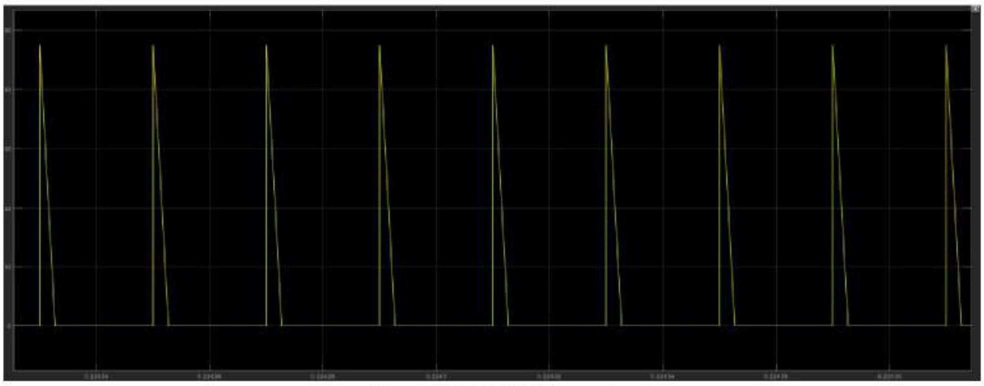


Proposed Converter Step up

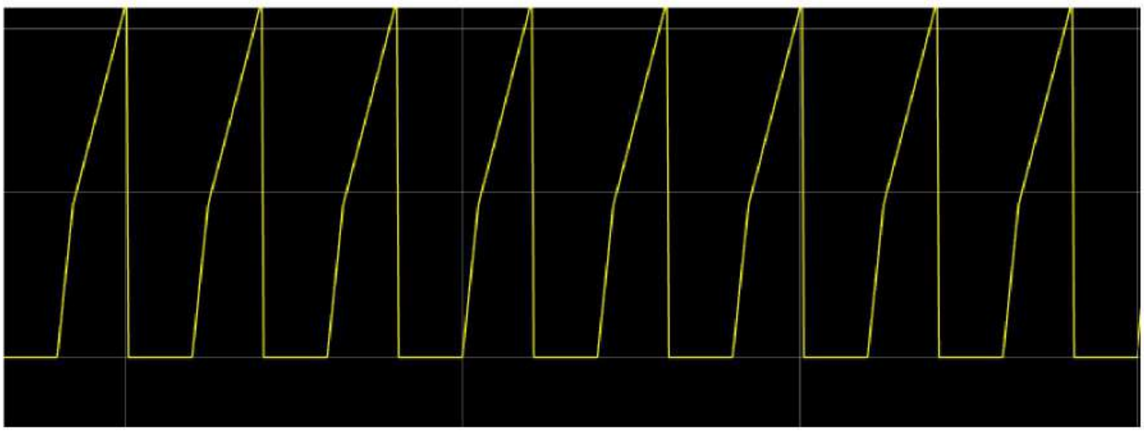
Proposed Converter Step down



<u>Proposed Converter DCM modes</u>



Step Up DCM mode



Inference Of Paper

Since the primary and secondary winding turns of the coupled inductor is same

$$L_1 = L_2 = L$$

hence,

$$V_{L1} = L_1 \frac{di_{L1}}{dt} + M \frac{di_{L2}}{dt} = L \frac{di_{L1}}{dt} + kL \frac{di_{L2}}{dt}$$

$$V_{L2} = kL \frac{di_{L1}}{dt} + L \frac{di_{L2}}{dt}$$

1. Step-Up Mode

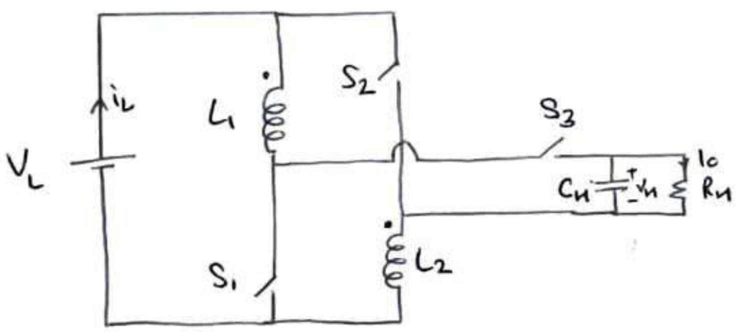


Fig Proposed Converter in Step-up mode

The pulse width modulation technique is used to control the switches S_1 and S_2 simultaneously

During the time interval $[t_0, t_1]$ S_1 and S_2 are turned ON and S_3 is OFF. The energy of low-voltage side V_L is transferred to coupled inductor. The energy stored in capacitor C_H is discharged to load

$$\frac{di_{L1}(t)}{dt} = \frac{di_{L2}(t)}{dt} = \frac{V_L}{(1+k)L} \qquad t_0 \le t \le t_1 \qquad (1)$$

After t_1 from $[t_1, t_2]$ $S_1 S_2$ are turned OFF and S_3 is turned ON. The low voltage side V_L and coupled inductor transfer their energies to capacitor C_H and the load.

$$i_{L1} = i_{L2}$$

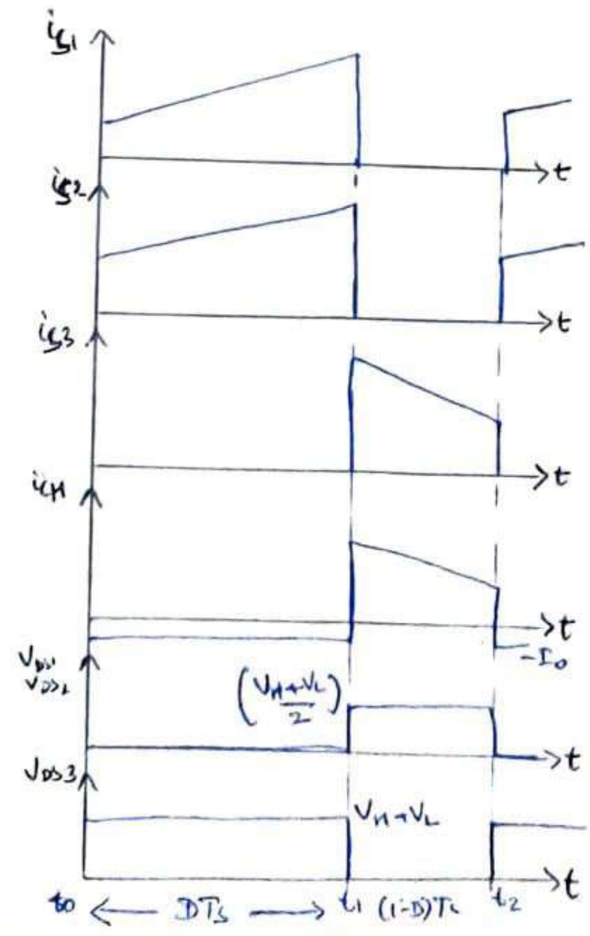
$$V_{L1} + V_{L2} = V_L - V_H$$

$$\frac{di_{L1}(t)}{dt} = \frac{di_{L2}(t)}{dt} = \frac{V_L - V_H}{2(1+K)L} \qquad t_1 \le t \le 2t_2 \quad \text{—— (2)}$$

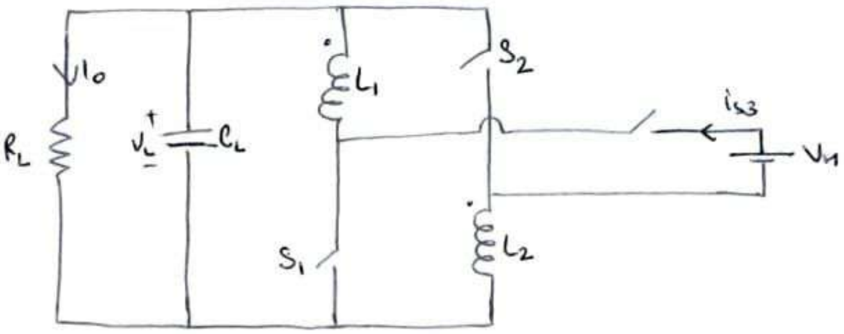
from eq^n (1) and (2)

$$\frac{DV_L}{(1+K)L} + \frac{(1-D)(V_L - V_H)}{2(1+K)L} = 0$$

$$\Rightarrow \quad \boxed{G_{(step-up)} = \frac{V_H}{V_L} = \frac{1+D}{1-D}}$$



2. Step - Down Mode



Propsed Converter in step-down mode

The PWM technique is used to control switch. S_3.

During the time interval $[t_0, t_1]$ S_3 is turned on and S_1/S_3 are turned off. The energy of high voltage side V_H is transferred to the coupled inductor, the capacitor C_L and the load

$$i_{L1} = i_{L2}$$

$$V_{L1} + V_{L2} = V_H - V_L$$

$$\frac{di_{L1}(t)}{dt} = \frac{di_{L2}(t)}{dt} = \frac{V_H - V_L}{2(1+k)L} \qquad t_0 \leq t \leq t_1 \tag{3}$$

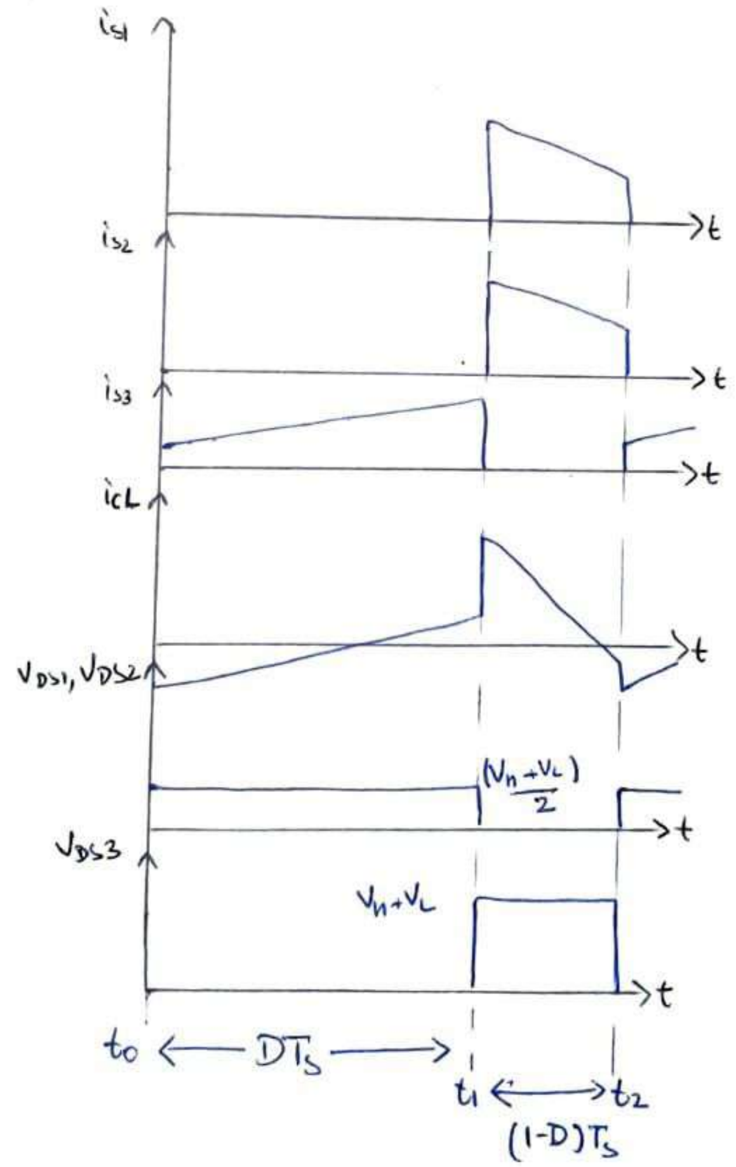
After t_1 from $[t_1, t_2]$, S_3 is turned OFF and S_1/S_2 are turned ON. The energy stored in coupled inductor is released to the capacitor C_L and the load.

$$\frac{di_{L1}(t)}{dt} = \frac{di_{L2}(t)}{dt} = -\frac{V_L}{(1+k)L} \qquad t_1 \leq t \leq t_2 \tag{4}$$

from eq^n (3) and (4)

$$\frac{D(V_H - V_L)}{2(1+k)L} - \frac{(1-D)V_L}{(1+k)L} = 0$$

$$\boxed{G_{(step\text{-}down)} = \frac{V_L}{V_H} = \frac{D}{2-D}}$$



Step Down DCM mode

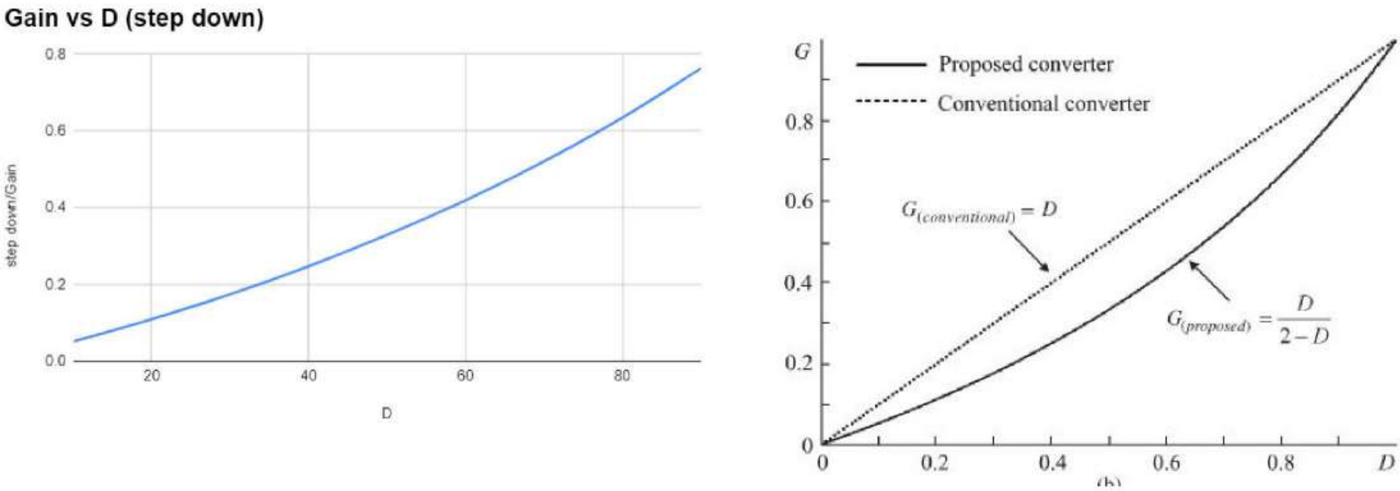


Fig. Step Down Voltage Gain vs D Proposed Converter (left) Conventional Converter (right)

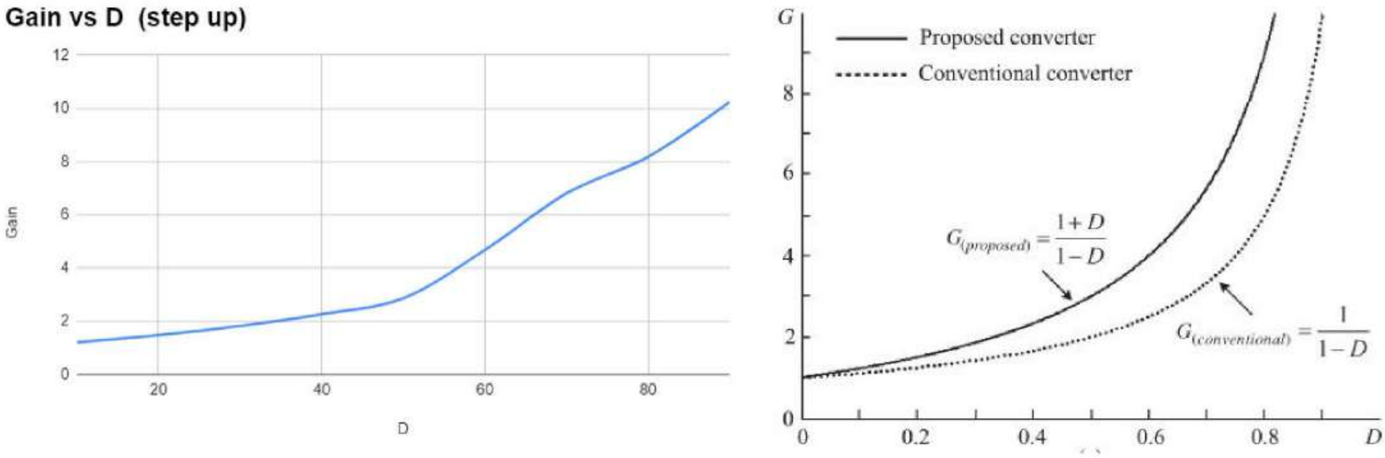


Fig. Step Up Voltage Gain vs D Proposed Converter (left) Conventional Converter (right)

APPLICATION

The novel bidirectional DC-DC converter has a range of potential applications in various fields. For instances, it can be used in hybrid electric vehicle energy system to transfer power between DC sources in either direction. The converter is also suitable for uninterrupted power supplies, fuel-cell hybrid power system, photovoltaic hybrid power system, and battery chargers. Additionally, the converter's simple structure and ease of control make it an attractive option in these applications. The converter's ability to control make it an attractive option in these applications.
The converter's ability to achieve higher step-up and step-down voltage gains while reducing voltages stress on power devices and improving conversion efficiency further enhance its suitability for these applications. Overall, the novel ~~di~~ bidirectional DC-DC converter has significant potential to enchance energy transfer system's efficiency and reliability in various fields.

RESULTS JUSTIFICATION ALONG APPLICATION

Bidirectional DC-DC converters are widely used in various applications such as electric vehicles, uninterrupted power supplies and battery charges. The bidirectional flyback converter is popular choice but it suffers from high voltage stress on power devices. The conventional bidectional boost/buck converter has simple structure but low step-up and step-down voltage gains.

The voltage gain of this converter is higher than the conventional dc-dc boost converter. Compared to other converter it has following advantages which are verified through simulink model

- Higher step-up and step-down voltage gains
- Lower average value of switch current under same electric specifications.

Its simple structure and ease of control it an attractive option in these applications reducing complexity and cost. The converter's ability to achieve higher step-up and step-down voltage gains makes it ideal for applications where voltage regulation is critical. Reducing voltage stress on power devices improves reliability and extends their lifespan, reducing maintenance costs. Finally, the converter's improved conversion efficiency results in lower operating costs and reduced environmental impact, making it a promising solution for various energy trasfer system.

SIMULATION ANALYSIS

The electric specifications for the simulink are

$V_L = 14\ V$

$V_H = 42\ V$

$f_s = 50\ kHz$

$C_L = C_H = 330\ \mu F$

$L_1 = L_2 = 15.5\ \mu H$

$R_L = 0.98\ \Omega$

$R_H = 8.82\ \Omega$

MOSFet for switches S1, S2, S3

CONCLUSION

This research aims to explore a newly proposed bidirectional DC-DC converter featuring a simple circuit configuration. The proposed converter demonstrates superior performance with regards to step-up and step-down voltage gains, as well as a reduced average switch current when compared to conventional bidirectional boost/buck converter. Experimental results have been analyzed to validate the converter's operation according to its design and steady-state analysis. The study of this novel converter contributes to development of efficient and effective energy transfer systems for applications such as electric vehicles, fuel-cell hybrid power system and photovoltaic hybrid power system. The advancement of such technologies is crucial for achieving sustainable energy systems and reducing carbon emissions. Overall, the proposed converter has significant potential to enhance the efficiency and reliablity of energy transfer systems in a range of applications.