A novel single switch controlled efficient coupled inductor-based DC-DC boost converter

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ABSTRACT

Pollution is one of the most hazard facing in the world. Day by day pollutions has been increased in the society due to population growth, industries, constructions, and transportation. As per the world health organization (WHO) survey, 45% of the air pollution is due to transportation because they lay on internal combustion engine (ICE) based engines. To avoid carbon footprints, green transportation should be encouraged for further generations. In recent days many electric vehicles (EV's) are found in the market but facing some issues like battery blasts, storage limitations and lack of charging infrastructure. Out of these issues, mainly my focus is on developing a compact, efficient, simple, medium gain coupled inductor-based DC-DC boost converter is proposed which is helpful for fast charging system. In this paper, coupled inductor (CI) and switched coupled inductor (SCI) based converters are designed and analysed with mathematical approach. The outputs of both CI and SCI converters are verified and compared with simulation results and as well CI based converter is developed with hardware prototype and verified hardware and simulation results in terms of gain, elements and efficient.

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1. INTRODUCTION

Now a days most of the countries are facing the problems due to pollution. The reasons for increment of pollution in world are due transportation and industries especcially in modern cities. Industries are necessary to increase the employability of people for the development of nation. Transportaion is major cause of pollution, to prevent them internal combustion engine (ICE) vehicles need to be replaced with electric vehicles (EV's). The major problem with electric vehicles is stoarage capacity, time taken to charge a battery, charging system development, fire accidents. Out of these problems, my main focus is on fast charging system development to reduce charging time of battery [1]–[3]. To develop a fast-charging system, high rated constant current is required to charge a battery in less time. Constant current can be developed by using the resonant converter circuits. But the problem is generation of high rated current which is not possible with resonant converters, so it need to be cascaded with DC-DC converter.

DC-DC converters are preferable for voltage gain, but based on load the converter delivers the current to load. By increasing the load, the voltage as well as current for the load increases. Therefore proper choosing of DC-DC converter is most important task in fast charging system. One more advantage of DC-DC converter is integration of renewable energy source. Photo-voltaic energy can be used to generate DC power which can be integrated at the input of DC-DC converter [4]–[6]. DC-DC converters has many classifications like single stage (conventional boost, buck, and buck-boost), multi stage (switched inductor/capacitors), impedance networks (transformer/coupled inductor), multi-level and multi phase converters [7]–[9]. These many types of DC-DC converters are available in the market, but the main focus is on magnetically coupled based converters.

As per the literature, magnetic coupled based converters are preferred to boost the output voltage of the converter which can be attained through transformer or coupled inductor. Transformer based converter provides the isolation but cannot minimise of low leakage inductance and minimum ripple currents which can be achieved through coupled inductor [10]–[15]. A proposed novel coupled inductor (CI) based converter is used in this paper because of many advantages compared to other converters like;

- DC-DC boost converter for medium gain applications which uses three switching elements wherein one is controlled the other two are uncontrolled elements.
- Low loss power conversion due to least number of semiconductor switches and conduction losses.
- Coupled inductor overcomes leakage inductance and can have better regulation on output due to low harmonics.
- Compact in size due to low conduction loss and simple thermal management.
- Simple gate driver with minimum protection features is sufficient to drive controlled switch.
- Least weight, size and minimum maintenance due to simple circuitry and thermal management.

Because of above said benefits, CI based DC-DC converter is used in fast charging technology. Many coupled inductor based topologies [16]–[25] are available like switched coupled inductor (SCI) but the proposed novel topology has unique construction. The block diagram of coupled inductor-based DC-DC converter circuit is shown in Figure 1.

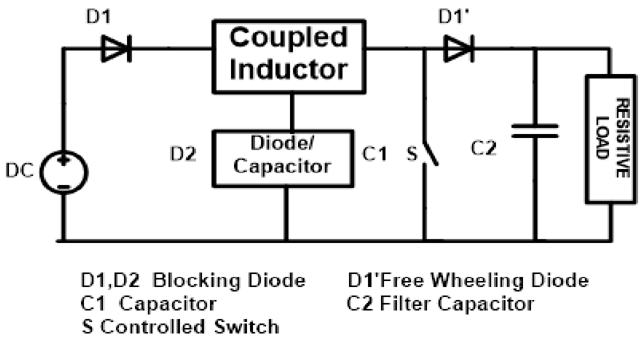


Figure 1. Block diagram of proposed novel CI and SCI based DC-DC converter

In the block diagram diode (D2) or capacitor (C1) is placed at same point. If the converter is placed with C1 then that is the proposed novel converter. In place of capacitor (C1) replaces with diode (D2) then it is said to be SCI. In this paper SCI based DC-DC converter is also designed, analyzed and simulated. After the results both the converters are compared. The outline of the paper is organized as section 1 with introduction, design and analysis of proposed novel CI based converter in section 2, simulation results and of CI based converter in developed a prototype which was discussed in section 3, SCI based converter analysis design and simulation in section 4, finally comparison of both CI and SCI based converter in section 5.

2. DESIGN AND ANALYSIS OF PROPOSED NOVEL CI BASED DC-DC CONVERTER

A novel CI based DC-DC boost converter is proposed for medium power applications, whose schematic is presented in Figure 2. Basically, the conversion ratio depends on the following parameters such as transformation ratio of coupled inductor, co-efficient of coupling, on time of switch. The main components used in the converter are two winding coupled inductor, metal oxide silicon field effect transistor (MOSFET) switch, two diodes-D1 is acts as blocking diode and D1'acts as free wheeling diode, two capacitors-C1 capacitor used to charge and discharge during ON and OFF time of switch and C2 which is a filter capacitor and resistive load (R_L). The couple inductor is manufactured with ferro magnetic material with high coupling factor i.e., coefficient of coupling (K=1). The specifications of proposed novel CI based boost converter is tabulated in Table 1.

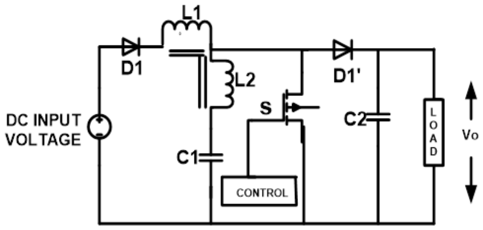


Figure 2. Schematic circuit of a proposed novel CI based converter

The above said converter will operates in two states, switch-ON state, and switch-OFF state. In one state, the circuit behaves as shown in Figure 3. In this state the switch is open (OFF state) and the diode (D1) will become ON then the coupled inductor (CI) and a capacitor (C1) stores the energy from input source. For the circuit shown in Figure 3(a). is analysed with voltage law then the voltage across the inductor (V_L) is expressed in 1.

In next state, the switch is closed (ON state) in such state both the legs get shorted which calls as shoot through state. In this state along with switch, remaining devices like diode (D1) and (D1') get reversed bias i.e., OFF state because of high potential at switch compared to source as per the circuit shown in Figure 3(b). By applying Kirchhoff's voltage law in this state, the voltage across the inductor is expressed as (2).

$$V_{c1} + \frac{V_L}{N_{12}} = 0 \Rightarrow V_L = -N_{12}V_{c1} \quad (1)$$

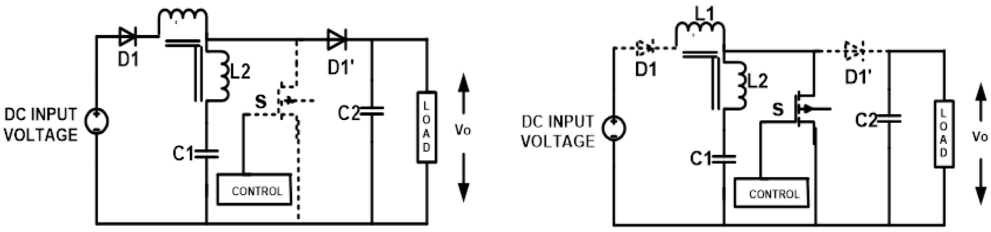


Figure 3. Modes of operation states on proposed novel CI based converter; (a) Switch-OFF state and (b) Switch-ON state

$$V_{dc} = V_L + \frac{V_L}{N_{12}} + V_{C1} \Rightarrow V_L = \frac{N_{12}}{N_{12}+1}(V_{dc} - V_{c1}) \quad (2)$$

State averging technique is implemented for the circuit in both the states of switch then it is expressed as (3) and (4). By computing above said equations, the voltage across the capacitor C1 is derived w.r.t to input which is expressed as per (5).

$$V_L(during\ ON\ time) + V_L(during\ OFF\ time) = 0 \quad (3)$$

$$V_L D + V_L(1 - D) = 0 \quad (4)$$

$$V_{c1} = V_{dc}\frac{(1-D)}{(N_{12}D+1)} \quad (5)$$

By referring above said equations during ON and OFF states, the output voltage (V_o) is determined. The maximum value of the converter's output voltage during OFF time of the switch is calculated and expressed in (6):

$$V_o = V_{dc}(1 - \frac{N_{12}D}{N_{12}D+1}) \quad (6)$$

the Table 1 says about the specifications of the proposed novel CI based converter which are used in simulation work.

Table 1. Design specifications of proposed novel CI based converter

S.No.	Specifications for the coupled inductor based DC-DC converter
1	DC Input of the converter is Vdc is 5 V
2	Turn's ratio of coupled Inductor (CI) is N1:N2=1:2
3	operating frequency of the converter is 10 KHz
4	Self-inductances of coupled inductor are L1=3µH and L2=6 µH
5	Mutual inductance of converter(L_M)=4.2e-4H
6	capacitors (C1) and (C2) =470 µF
7	Resistive load (RL)=200 Ω
8	Output voltage of the converter (VO) is Gain*Vdc

3. SIMULATION AND HARDWARE RESULTS OF PROPOSED COUPLED INDUCTOR BASED DC-DC CONVERTER

3.1. Simulation of proposed CI based DC-DC converter

The specifications which are mentioned in Table.1 are implemented in MATLAB/SIMLINK as per the Figure 4. The simulation circuit of proposed converter is shown in Figure 4(a). Simulated circuit is tested with two conditions such as:

- Change in load resistance (R_L).
- Change in duty ratio (D).

After testing simulation circuit, output voltages of the proposed converter are observed and measured with different loads @ dutyratio of 10% with input voltage of 5 volts which is shown in Figure 4(b). Similarlly the output voltages of converter are observed and measured with different dutyratio's @ load resistance of 200 Ω with same 5 volts input voltage which are shown in Figure 4(c).

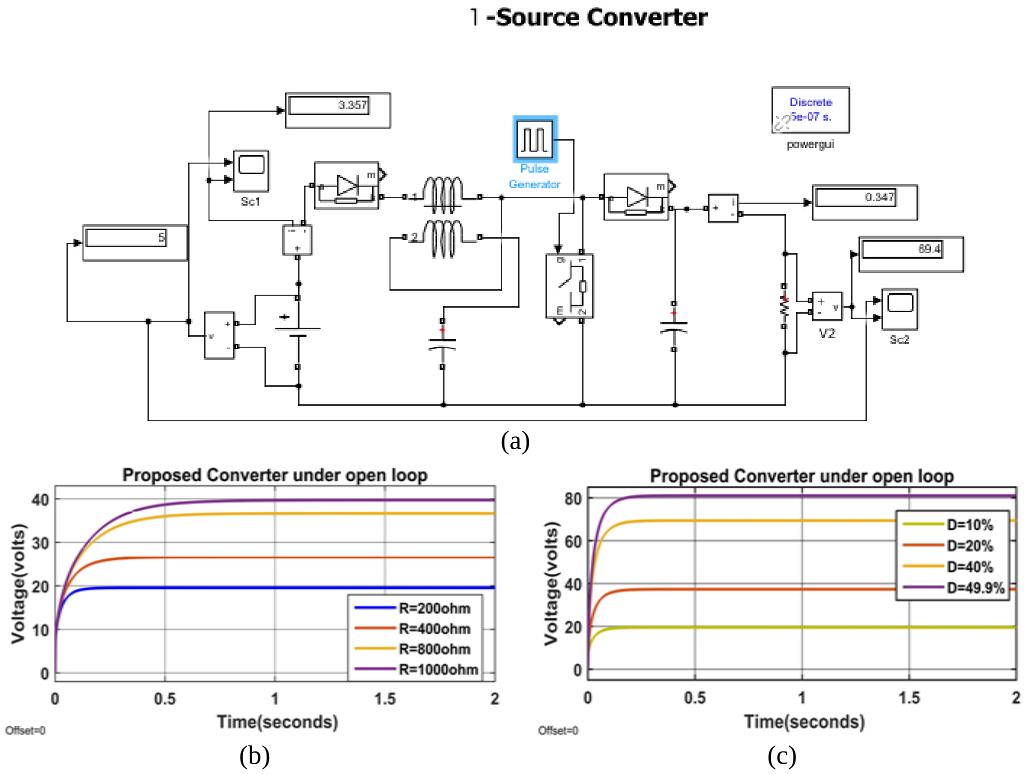


Figure 4. Implementation in MATLAB/SIMULINK (a) MATLAB/SIMULINK circuit of CI based DC-DC converter; output voltages of the CI based converter, (b) different resistive loads @Duty ratio (D)=10% and V_{dc} with 5 volts, and (c) different dutyratio's@ load resistance of 200 Ω and V_{dc} with 5 volts

3.2. Development of hardware prototype

From the simulation results, it is observed that the output voltages are dependent on resistive load (R_L) and duty ratio (D). To observe the same a hardware prototype is developed as shown in Figure 5. The components used to develop the hardware prototype are listed in the Table 2. The coupled inductor (CI) was designed in-house, and manufacturing was done by 3rd party. An Arduino is used as a controller to generate gate pulse to trigger the MOSFET switch. To toggle the switch the current required will be high so a gate driver is used, the Arduino supplies the gate pulses to the gate driver which will supply to the MOSFET the required level of current to toggle the ON state of the switch. The gate driver is separately powered by 18 V using a step-down transformer. The ouput voltage of CI based converter @300 Ω is shown in Figure 6 and components used list is tabulated in Table 2.

Table 2. Hardware components to develop prototype

S.No.	Components/Description	Value/Part number
1	Input voltage (V_{dc})	5 V
2	Capacitances C_1 and C_2	470 µF, 400 V, Kemet
3	Turns ratio N_1:N_2	20:42 on
4	Switching frequency fs	10 KHz
5	Switch	MOSFET, IRFP2907 PbF
6	Diodes D_1, D_1'	IRF

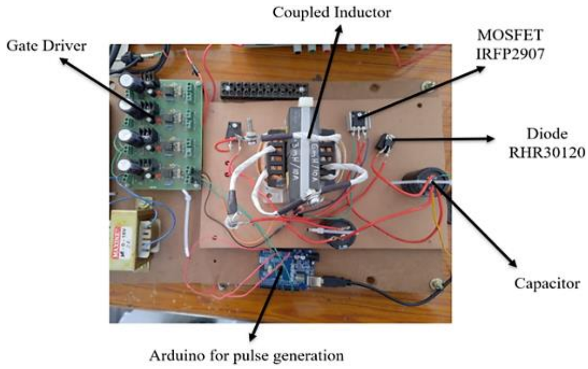


Figure 5. Hardware implementation of proposed novel CI based DC-DC converter

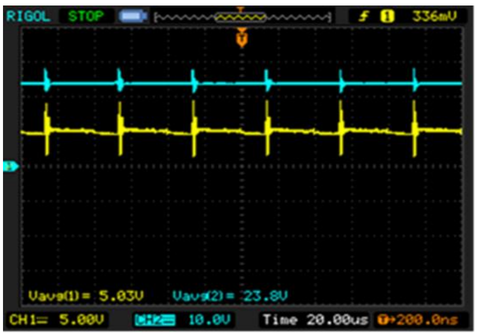


Figure 6. Output voltage (V_o) of the proposed CI based converter @ D=10% and R_L=300Ω

3.3. Comparison of hardware and simulation of proposed converter

By validating the simulation and hardware results of proposed CI based converter in section 4. A comparative analysis on results is declared in Table 3. And other results in Table 4.

Table 3. Output voltages with different loads

S.No.		Duty ratio @ 10%	
	Load (R) in Ω	Output voltages (Vo) in volts (simulation)	Output voltages (Vo) in volts (hardware)
1	100	14.45	13.45
2	200	19.55	18.35
3	300	24.95	23.80
4	400	26.63	25.33
5	500	29.86	28.16

Table 4. Output voltages with different duty ratio

S.No.	Constant load resistance @200 Ω		
	Duty ratio (D) in %	Output voltages (Vo) in volts (simulation)	output voltages (Vo) in volts (hardware)
1	10	19.55	18.35
2	20	37.34	36.12
3	30	54.26	52.65
4	40	69.40	67.38
5	49.9	81.03	79.98

4. SWITCHED COUPLED INDUCTOR BASED DC-DC CONVERTER

A SCI based DC-DC converter which is also a boost converter which is shown in Figure 7. In this converter, the no. of turns of N_1 is lesser than N_2 ($N_1 < N_2$). Compared to CI based converter, in this SCI converter capacitor (C1) is replaced with a diode (D2) as per the circuit [18]. The design specifications of SCI based converter is tabulated in Table 5.

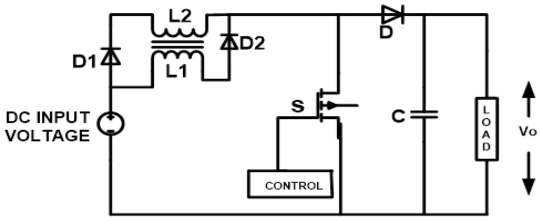


Figure 7. Schematic diagram of switched-coupled inductor converter

4.1. Operation and analysis of converter

This switched-coupled inductor-based converter is also operates in two states as shown in Figure 8. In state: 1 the switch and diode (D2) is ON state as well the D get reverse biased because of zero potential at switch and high potential at capacitance as shown in Figure 8(a). Therefore, the same voltage will exist across the capacitor and load. By obeying Kirchhoff's Voltage law, the circuit is operated as per (7) to (10).

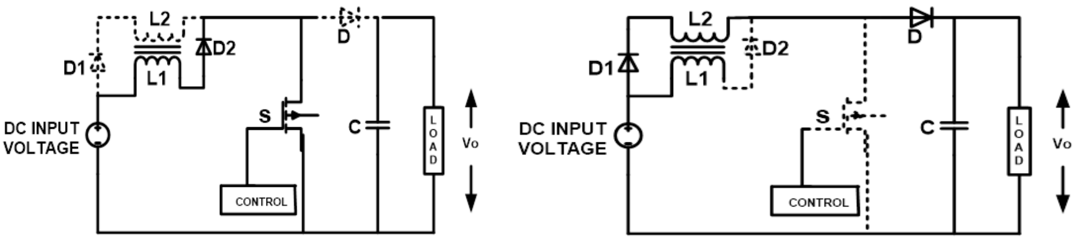
$$V_{L1} = V_{dc} \tag{7}$$

$$V_{L2} = N_{12} V_{dc} \tag{8}$$

$$V_{D2} = (1 - N_{12}) V_{dc} \tag{9}$$

$$V_o = -V_c \tag{10}$$

In state: 2, the circuit switch is in OFF state, so that the diode (D2) is also will get reversed. So that the current flows through the diode (D1) which is forward bias as per circuit shown in Figure 8(b). By implementing voltage law to the below circuit following (11) to (14) are obtained.



(a) (b)

Figure 8. Modes of operation; (a) state 1: switch-ON state and (b) state 2: switch-OFF state

$$V_{L2} = V_{dc} - V_o \quad (11)$$

$$V_{L1} = N_{12}(V_{dc} - V_o) \quad (12)$$

$$V_{switch} = V_o \quad (13)$$

$$V_{D1} = (1 - N_{12})(V_{dc} - V_o) \quad (14)$$

By implementing state averaging technique during ON and OFF time of controlled switch used in the converter. The average voltage obtained under steady state condition are expressed in equations. The output voltage w.r.t to couple inductor and input voltage is expressed in (15) to (17);

$$V_L(during\ ON\ time) + V_L(during\ OFF\ time) = 0 \quad (15)$$

$$V_{dc}D + \frac{N_1}{N_2}(V_{dc} - V_o)(1 - D) = 0 \quad (16)$$

$$\frac{V_o}{V_{dc}} = \frac{N_1}{N_2} * \frac{1}{(1-D)} \quad (17)$$

the Table 5 is representing the specifications used in SCI base converter. These specifications are used in simulations.

Table 5. Design specifications of converter

S.No.	Specifications for the coupled inductor based DC-DC converter
1	DC Input of the converter is Vdc is 5 V
2	Turn's ratio of CI is N1:N2=1:5
3	operating frequency of the converter is 10 KHz
4	Self-inductances of coupled inductor are L1=3µH and L2=3µH
5	Mutual inductance of converter(L_M)=44.2µH
6	capacitors ©=470µF
7	Resistive load (RL)=200Ω
8	Output voltage of the converter (VO) is Gain*Vdc

4.2. Simulation of SCI-based converter

The SCI based DC-DC boost converter is simulated in MATLAB/Simulink environment as shown in Figure 9. In this simulation, the converter is applied with 5 volts input voltage. The converter is operated with pulse generator under open loop, the circuit is tested with different loads and different duty-ratio's. The results with different load resistances with 10% of duty ratio is tabulated in Table 6 along with output voltage waveforms of the converter are shown in Figure 10. Similarly, converter output voltage results with different duty ratios with 200 Ω load resistance are tabulated in Table 7 along with volt waveforms shown in Figure 10.

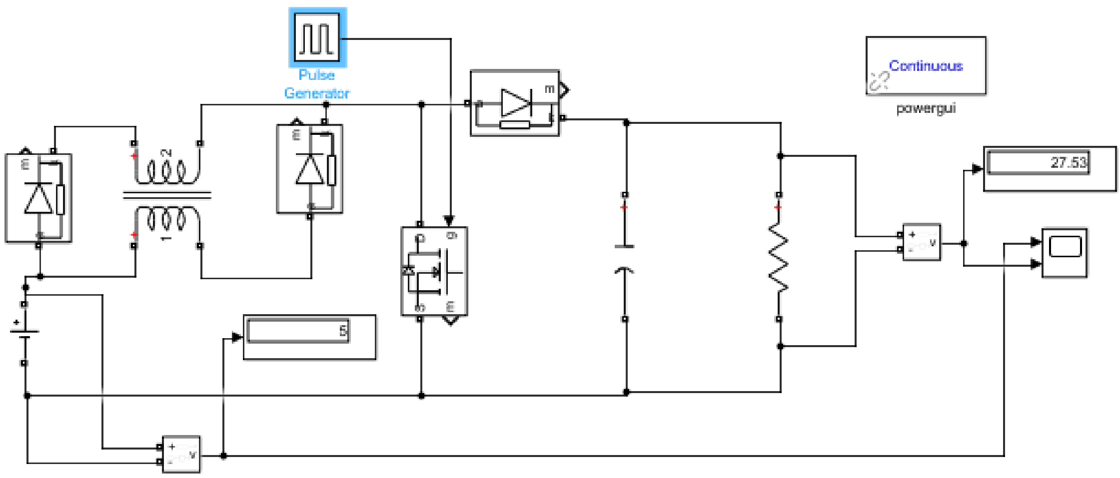
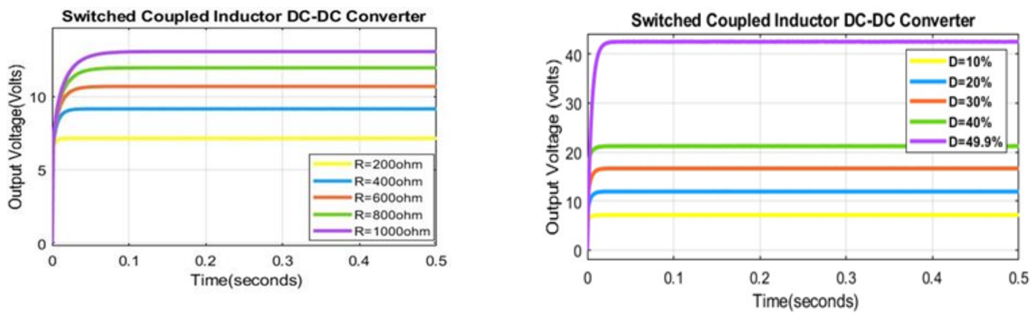


Figure 9. MATLAB/Simulink circuit of SCI-based DC-DC converter



(a) (b)

Figure 10. Output voltages of the SCI based converter; (a) different resistive loads@ Duty ratio of 10% and Vin=5 volts and (b) different dutyratio's@load resistance of 200 Ω and Vin=5 volts

Table 6. Output voltages with different loads

S.No.		Duty ratio @ 10%
	Load R_L in Ω	Output voltages (vo) in volts (simulation)
1	200	7.15
2	400	8.42
3	600	11.38
4	800	12.45
5	1000	13.62

Table 7. Output voltages with different duty ratio

S.No.		Constant load resistance @200 Ω
	Duty ratio (D) in %	Output voltages (Vo) in volts (simulation)
1	10	7.15
2	20	13.22
3	30	17.78
4	40	24.30
5	49.9	43.10

5. COMPARISION OF CI AND SCI BASED CONVERTERS

After design and simulation of the both (CI and SCI) the converters are compared in two aspects. Comparison tables are listed below in Table 8 and Table 9: i) comparison of components and devices, and ii) gain of the converter. After the comparison of both the Tables 8 and 9, a proposed novel CI based converter has less no. of turns in CI, less duty ratio, less no. of devices and more gain compared to SCI.

Table 8. Comparison of elements in CI and SCI converter

Components	Proposed CI converter	Switched CI converter
Coupled inductor	1	1
Diodes	2	3
Capacitors	2	1
MOSFET switch	1	1

Table 9. Comparison of voltage gain

Components	Proposed CI converter	Switched CI converter
Turns ratio	1:2	1:5
Voltage gain @ D=10% and R_L=200 Ω	3.91	1.43

6. CONCLUSION

A proposed novel CI based converter is a boost converter which is required for battery charging system. The novel converter is designed and analyzed under steady state. The converter is simulated in MATLAB and developed a prototype to validate results of them. After validation, the gain of the proposed converter is 3.91 (near to 4) @ 10% of duty ratio. This converter more efficient because of less duty ratio, low conduction loss and high gain. Similar type of another converter i.e., SCI based converter is also analyzed, designed and simulated. SCI converter is also a boost converter which gives gain of 1.43 @ same 10% duty ratio. By comparing both the converters but the proposed novel converter has less No of turns in coupled inductor, more voltage gain @ same duty ratio. Finally, the proposed novel CI based high-gain converter is preferreable for compact fast charging system in EV's.

REFERENCES

[1] M. Brenna, F. Foiadelli, C. Leone, and M. Longo, "Electric vehicles charging technology review and optimal size estimation," *Journal of Electrical Engineering and Technology*, vol. 15, no. 6, pp. 2539–2552, 2020, doi: 10.1007/s42835-020-00547-x.

[2] H. S. Das, M. M. Rahman, S. Li, and C. W. Tan, "Electric vehicles standards, charging infrastructure, and impact on grid integration: A technological review," *Renewable and Sustainable Energy Reviews*, vol. 120, p. 109618, Mar. 2020, doi: 10.1016/j.rser.2019.109618.

[3] A. Ahmad, Z. A. Khan, M. S. Alam, and S. Khateeb, "A review of the electric vehicle charging techniques, standards, progression and evolution of EV technologies in Germany," *Smart Science*, vol. 6, no. 1, pp. 36–53, Jan. 2018, doi: 10.1080/23080477.2017.1420132.

[4] S. K. Biradar, R. A. Patil, and M. Ullegaddi, "Energy storage system in electric vehicle," in *Proceedings of 1998 Power Quality Conference, PQ 1998*, 1998, vol. 1998-June, pp. 247–255, doi: 10.1109/PQ.1998.710382.

[5] S. Sharma, A. K. Panwar, and M. M. Tripathi, "Storage technologies for electric vehicles," *Journal of Traffic and Transportation Engineering (English Edition)*, vol. 7, no. 3, pp. 340–361, 2020, doi: 10.1016/j.jtte.2020.04.004.

[6] F. Nadeem, S. M. S. Hussain, P. K. Tiwari, A. K. Goswami, and T. S. Ustun, "Comparative review of energy storage systems, their roles, and impacts on future power systems," *IEEE Access*, vol. 7, pp. 4555–4585, 2019, doi: 10.1109/ACCESS.2018.2888497.

[7] M. S. Bhaskar *et al.*, "Survey of DC-DC non-isolated topologies for unidirectional power flow in fuel cell vehicles," *IEEE Access*, vol. 8, pp. 178130–178166, 2020, doi: 10.1109/ACCESS.2020.3027041.

[8] M. A. Chewale, R. A. Wanjari, V. B. Savakhande, and P. R. Sonawane, "A review on isolated and non-isolated DC-DC converter for PV application," in *2018 International Conference on Control, Power, Communication and Computing Technologies, ICCPCCT 2018*, Mar. 2018, pp. 399–404, doi: 10.1109/ICCPCCT.2018.8574312.

[9] M. H. Taghvaee, M. A. M. Radzi, S. M. Moosavain, H. Hizam, and M. H. Marhaban, "A current and future study on non-isolated DC-DC converters for photovoltaic applications," *Renewable and Sustainable Energy Reviews*, vol. 17, pp. 216–227, 2013, doi: 10.1016/j.rser.2012.09.023.

[10] A. F. Witulski, "Introduction to modeling of transformers and coupled inductors," *IEEE Transactions on Power Electronics*, vol. 10, no. 3, pp. 349–357, May 1995, doi: 10.1109/63.388001.

[11] L. Albiol-Tendillo, E. Vidal-Idiarte, J. Maixé-Altés, J. M. Bosque-Moncusí, and H. Valderrama-Blaví, "Design and control of a bidirectional DC/DC converter for an electric vehicle," in *15th International Power Electronics and Motion Control Conference and Exposition, EPE-PEMC 2012 ECCE Europe*, Sep. 2012, p. LS4d.2-1-LS4d.2-5, doi: 10.1109/EPEPEMC.2012.6397462.

[12] R. G. Kumari, N. Pasula, and A. Ezhilarasi, "Design and validation of high gain z-source fed LCL-T resonant charger for constant current application," in *2021 6th International Conference for Convergence in Technology, I2CT 2021*, Apr. 2021, pp. 1–8, doi: 10.1109/I2CT51068.2021.9418069.

[13] D. M. Bellur and M. K. Kazimierczuk, "DC-DC converters for electric vehicle applications," in *2007 Electrical Insulation Conference and Electrical Manufacturing Expo, EEIC 2007*, Oct. 2007, pp. 286–293, doi: 10.1109/EEIC.2007.4562633.

[14] G. Pandeswara and N. Pasula, "Investigation through analytical studies and experimental validation of ladder type resonant converter based constant current charger (>20 kW) for charging applications," *Journal of Instrumentation*, vol. 16, no. 2, 2021, doi: 10.1088/1748-0221/16/02/P02032.

[15] O. Husev, T. Shults, D. Vinnikov, C. Roncero-Clemente, E. Romero-Cadaval, and A. Chub, "Comprehensive comparative analysis of impedance-source networks for DC and AC application," *Electronics (Switzerland)*, vol. 8, no. 4, p. 405, Apr. 2019, doi: 10.3390/electronics8040405.

[16] P. Naresh, A. Patel, and A. Sharma, "Conducted noise analysis and protection of 45 kJ/s, ±50 kV capacitor charging power supply when interfaced with repetitive Marx based pulse power system," *Review of Scientific Instruments*, vol. 86, no. 9. 2015, doi: 10.1063/1.4929515.

[17] I. Laird, D. D. C. Lu, and V. G. Agelidis, "High-gain switched-coupled-inductor boost converter," in *Proceedings of the International Conference on Power Electronics and Drive Systems*, Nov. 2009, pp. 423–428, doi: 10.1109/PEDS.2009.5385890.

[18] P. C. Loh, "Z-Source DC-DC Converters," in *Impedance Source Power Electronic Converters*, 2016, pp. 138–147, doi: 10.1002/9781119037088.ch9.

[19] Y. P. Siwakoti, F. Z. Peng, F. Blaabjerg, P. C. Loh, and G. E. Town, "Impedance-source networks for electric power conversion Part I: A topological review," *IEEE Transactions on Power Electronics*, vol. 30, no. 2, pp. 699–716, Feb. 2015, doi: 10.1109/TPEL.2014.2313746.

[20] M. Forouzesh, Y. P. Siwakoti, S. A. Gorji, F. Blaabjerg, and B. Lehman, "Step-Up DC-DC converters: a comprehensive review of voltage-boosting techniques, topologies, and applications," *IEEE Transactions on Power Electronics*, vol. 32, no. 12, pp. 9143–9178, Dec. 2017, doi: 10.1109/TPEL.2017.2652318.

[21] Y. P. Siwakoti and G. E. Town, "Performance of distributed DC power system using quasi Z-Source Inverter based DC/DC converters," in *Conference Proceedings - IEEE Applied Power Electronics Conference and Exposition - APEC*, Mar. 2013, pp. 1946–1953, doi: 10.1109/APEC.2013.6520561.

[22] F. Guo, L. Fu, C. H. Lin, C. Li, W. Choi, and J. Wang, "Development of an 85-kW bidirectional quasi-Z-source inverter with DC-link feed-forward compensation for electric vehicle applications," *IEEE Transactions on Power Electronics*, vol. 28, no. 12, pp. 5477–5488, Dec. 2013, doi: 10.1109/TPEL.2012.2237523.

[23] P. C. Loh, D. Li, and F. Blaabjerg, "Γ-Z-source inverters," *IEEE Transactions on Power Electronics*, vol. 28, no. 11, pp. 4880–4884, Nov. 2013, doi: 10.1109/TPEL.2013.2243755.

[24] R. G. Kumari, A. Ezhilarasi, and N. Pasula, "A novel low loss, medium gain CI based DC-DC boost converter," in *2022 International Conference on Recent Trends in Microelectronics, Automation, Computing and Communications Systems (ICMACC)*, 2022, pp. 489-493, doi: 10.1109/ICMACC54824.2022.1009347.

[25] G. Pandeswara and N. Pasula, "A comprehensive study of capacitive loaded resonant converter topologies for charging applications," *Indonesian Journal of Electrical Engineering and Informatics (IJEEI)*, vol. 9, no. 4, pp. 973–982, 2021, doi: 10.52549/ijeei.v9i4.3521.

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