International Journal of Engineering Research and Science & Technology

www.ijerst.org

ISSN : 2319-5991

Vol. 21 No. 3 (1) 2025



ijerst.editor@gmail.com

editor@ijerst.com

International Journal of Engineering Research and Science & Technology

ISSN 2319-5991 www.ijerst.com
Vol. 21, No. 3(1), 2025
© 2025 IJERST. All Rights Reserved

Research Paper

AN ENHANCED DC-DC MULTI PORT CONVERTER FOR ELECTRIC VEHICLE APPLICATIONS

Vallepi Laxmi[1] P. Purna chander Rao[2]

[1]M. Tech Student, Department of Electrical and Electronics Engineering, Vaagdevi College of Engineering, Khammam - Warangal Hwy, Road, Bollikunta, Telangana 506005

[2]Associate Professor, Department of Electrical and Electronics Engineering, Vaagdevi College of Engineering, Khammam - Warangal Hwy, Road, Bollikunta, Telangana 506005

Abstract *Multiport converters play a significant role in portable electronic and electric vehicle (EV) applications. In literature, different configurations of single-input multi-output (SIMO) converters are presented. Most of the SIMO converters generate the outputs with operating constraints on the duty ratio and charging of inductors. The cross-regulation problem is still a challenge in SIMO converters design. A SIMO topology is proposed in this study to overcome the limitations mentioned earlier. It can generate three different output voltages without constraint on the duty cycle and inductor currents (like iL1 > iL2 > iL3 or iL1 < iL2 < iL3). Cross regulation problems do not exist in the proposed topology, so the load voltage V01 (V02) (V03) is not affected by the variation of output current i03 (i02) (i01). The loads are isolated from each other during control. In the laboratory, a 200 W prototype circuit is developed; simulation and experimental results are validated.*

Received: 29-07-2025 Accepted: 03-09-2025 Published: 10-09-2025

1. Introduction

Electric vehicles (EVs) are being seen as a crucial technology for lowering pollution levels in the transportation industry. In addition, initiatives aimed at promoting the use of EVs across the globe are leading to an exponential growth in the percentage of EVs. Due to their short driving range, electric vehicles require regular recharging while on the road, making this a major worry. Moreover, one of the major concerns about EV use is the accompanying high cost and the limitation in terms of battery life. Therefore, in order to establish sufficient charging stations for electric vehicles, there is a great deal of study into the use of renewable energy for this purpose. Here, electric vehicle charging stations are making use of sources such as solar photovoltaic arrays, wind turbines, and fuel cell stacks. Consequently, it is crucial to use dispersed energy resources in a hybrid manner that complements the unpredictability of each in order to meet the power demand while also improving environmental circumstances. Additionally, a big issue presently is the charging of electric vehicles using appropriate control algorithms.

Furthermore, a concentrate by the EU observed that street transportation was liable for over 70% of CO2 discharges in the transportation area, and that the business in general was liable for roughly 28% of all emanations. To relieve the development of CO2 and other ozone harming substances in the air, authorities in most of industrialized countries are pushing for the reception of EVs. Specifically, they advocate for proficient and harmless to the ecosystem transportation by means of different projects, generally as tax cuts, purchasing appropriations, or other interesting arrangements, such free open stopping or roadway utilization.

2. Electrical vehicles

On a worldwide scale, the vehicle business has developed into a force to be reckoned with as far as both financial result and Research and development spending. To an ever increasing extent, cars are equipped with innovation includes that intend to improve the security of the two people on foot and travelers. Even better, we can go in relative solace and speed since there are more vehicles out and about.

Tragically, this has brought about a huge ascent in degrees of air toxins in metropolitan regions,

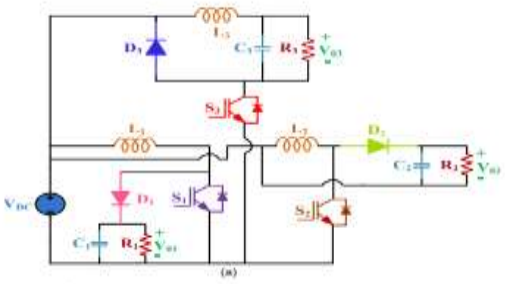
including particulate matter (PM), sulfur dioxide (SO2), nitrogen oxides (NOx), and carbon monoxide (CO). Besides, more than 70% of CO2 emanations from transportation are owing to street transport, and the area in general is liable for around 28% of all discharges, as per an EU examination.

To mitigate the buildup of CO2 and other greenhouse gases in the air, officials in the majority of industrialized nations are pushing for the adoption of EVs. In particular, they advocate for efficient and environmentally friendly transportation via a variety of programs, mostly in the form of tax breaks, buying subsidies, or other unique policies, such free public parking or highway usage.

3. PROPOSED SIMO CONFIGURATION AND MODES OF OPERATION

The proposed single input three-output DC-DC configuration is depicted in Figure 2(a). In this configuration the components are as follows, input voltage VDC, switches (S1-S3), diodes (D1-D3), and passive elements (L1-C1, L2-C2, and L3-C3). It can generate three different output voltages, i.e., boost (V01), buck-boost (V02) with positive voltage polarity, and buck (V03). The proposed converter is suitable for independently regulating the output voltages by the duty cycles D1, D2, and D3, respectively. The theoretical waveforms of circuit elements are depicted in Figure 2(b).

The proposed configuration is different from the conventional parallel combination of buck, boost, and buck-boost configuration. In the proposed circuit configuration, the loads are isolated during the simultaneous control. From the following figures, one may observe that during mode-1operation, load R3 alone through S3 is connected to the input power supply, but the other loads are isolated, as shown in Figure 3(a). Similarly, during mode-2 only load R1 alone through D1 is connected to the input supply, but other loads are isolated, as depicted in Figure 3(b). In the proposed control strategy, all the loads are isolated from each other during their control in any mode of operation. However, this feature is impossible in the conventional parallel combination of buck, boost, and buck-boost converters. This circuit configuration looks very simple, but it is novel and valuable. A comparison in terms of the number of components, modes of operation, and working conditions between the conventional and proposed SIMO converter is presented in Table 1, as given below



Proposed configuration: (a) SIMO configuration

Table 1: Parameter specification comparison between the conventional and proposed SIMO converter

Comparison different aspects	Conventional	Proposed
Number of components	6	6
Output voltage	Buck, Boost, and Buck-Boost (Negative output voltage)	Buck, Boost, and Buck-Boost (Positive output voltage)
Inverting circuit is required for the positive output voltage	Yes	No
Loads are isolated to each other during control	No	Yes

In the conventional approach shown in Figure1, the main drawback is the cross-regulation problem, and the loads are not isolated from each other during their operation. Further, the circuit complexity will increase to convert the negative polarity of output voltages in the buck-boost mode of operation.

The proposed structure has the following advantages:

a) It is a simple structure and no assumptions on operating duty ratio (D1 > D2 > D3 or D3 < D2 < D1 or D1 = D2 = D3)

b) It can generate three different output voltages, i.e., boost, buck, buck-boost()

c) No constraints on inductor currents (like iL1 > iL2 > iL3 or iL1 < iL2 < iL3 or iL1 = iL2 = iL3)

d) Loads are isolated from each other during control and the cross-regulation problem is successfully eliminated e) It gives the positive buck-boost output voltage.

A. MODES OF OPERATION

1) SWITCHING STATE 1

Switches S1, S2, and S3 are turned ON. The current flow path is depicted in Figure 3(a), and the energy port VDC magnetizes L1, L2, and L3. Consequently, the C1 and C2 are discharged to the loads (R1) and (R2), respectively, whereas (C3) is charged. The inductor currents and capacitor voltages are represented in Eq. (1)-(4).

$$i_{L_1}(t) = \frac{V_{DC}}{L_1}t + i_{L_1(0)}, \quad v_{C_1}(t) = v_{C_1(0)}e^{\frac{-1}{R_1C_1}t} \tag{1}$$

$$i_{L_2}(t) = \frac{V_{DC}}{L_2}t + i_{L_2(0)}, \quad v_{C_2}(t) = v_{C_2(0)}e^{\frac{-1}{R_2C_2}t} \tag{2}$$

$$i_{L_3}(t) = \frac{V_{DC}}{R_3} + e^{-\alpha t}\left[c_1 \cos\omega_d t + c_2 \sin\omega_d t\right] \tag{3}$$

$$v_{C_3}(t) = V_{DC} - \frac{L_3}{2C_3}e^{-\alpha t}\left[\begin{array}{l}\cos\omega_d t\left(\frac{\alpha c_1}{R_3} + \omega_d c_2\right) \\ + \sin\omega_d t\left(-\alpha c_2 + \frac{\omega_d c_1}{R_3}\right)\end{array}\right] \tag{4}$$

2) SWITCHING STATE 2 In this state, L1, L2, and L3 are de-magnetized and deliver their energy to the load through D1, D2, and D3, respectively.

It is observed that during switching state-1operation, load (R3) alone through S4 is connected to the ground but the other loads are isolated even when the ground is involved during charging the battery, as shown in Figure 3(a). Similarly, during switching state-2 only load (R1) alone through D1 is connected to the ground, but other loads are isolated from the ground and the load (R1) as well as depicted in Figure 3(b). In the proposed control strategy, all the loads are isolated from each other during their control during any mode of operation. Moreover, the configuration of the circuit is such that energy stored in the inductor is confined to one output only and is not shared with the other outputs during the control and also, which allows controlling the output voltages with independent duty-cycles. As a result, the load voltage V01 (V02) (V03) is not influenced by the variation of load current i03 (i02) (i01). Hence the proposed configuration with this control approach avoids all the issues about crossregulation problems even when the ground is involved during battery charging. More importantly, the configuration is simple and it can generate three independent outputs without any assumptions on inductor currents (iL1 > iL2 > iL3 or iL1 < iL2 < iL3 or iL1 = iL2 = iL3) and/or operating duty cycle.

B. SEMICONDUCTOR STRESS ANALYSIS

Semiconductor stresses of the proposed configuration are presented Eq.

1) VOLTAGE STRESSES

$$V_{S_1} = V_{01}, \quad V_{D_1} = V_{01}, \; V_{S_2} = \left(\frac{V_{02} + V_{DC}}{2}\right)$$
$$V_{D_2} = (V_{02} + V_{DC}), \quad s_3 = V_{D_3} = V_{DC} \tag{13}$$

2) CURRENT STRESSES

a: MODE 1

$$i_{S_1} = i_{L_1}, \quad i_{D_1} = 0, \; i_{S_2} = i_{L_2},$$
$$i_{D_2} = 0, \quad i_{S_3} = i_{L_3}, \; i_{D_3} = 0 \tag{14}$$

b: MODE 2

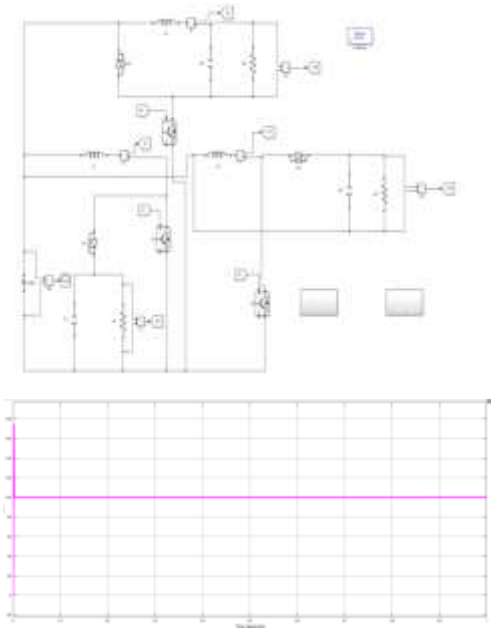
$$i_{S_1} = i_{D_1} = i_{L_1}, \quad i_{S_2} = i_{S_3} = 0,$$
$$i_{D_2} = i_{L_1}, \quad i_{D_3} = i_{L_3} \tag{15}$$

III. SMALL-SIGNAL MODELING

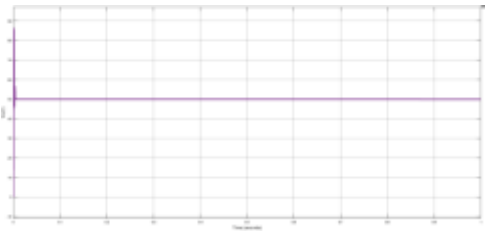
The transfer function of the proposed topology is derived from small signal analysis as [26]. The state-space equations (16)-(25) are as follows

4. Simulation model and results

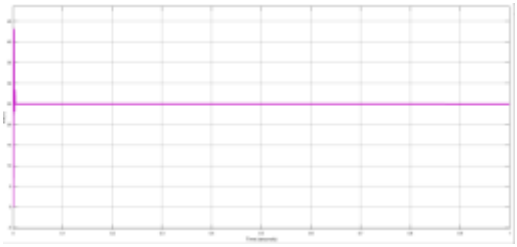
Simulation results



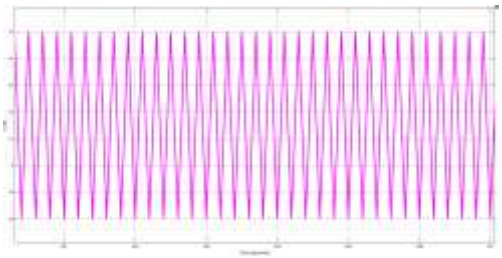
VB1



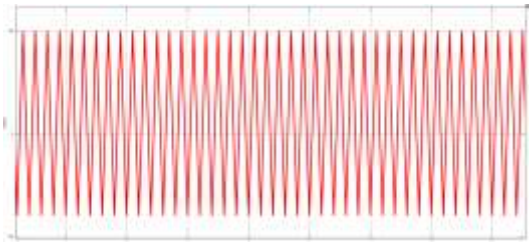
VB2



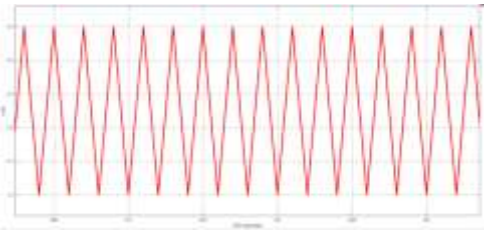
VB3



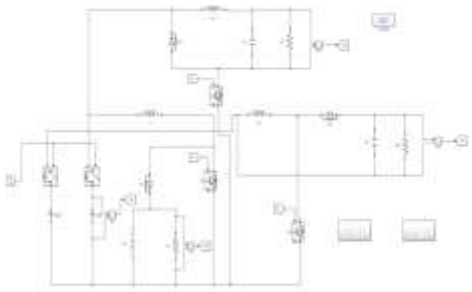
IL1

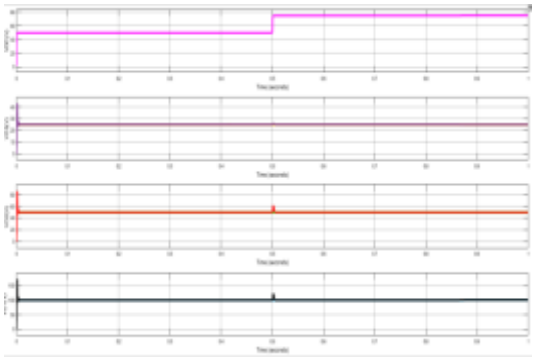


IL2



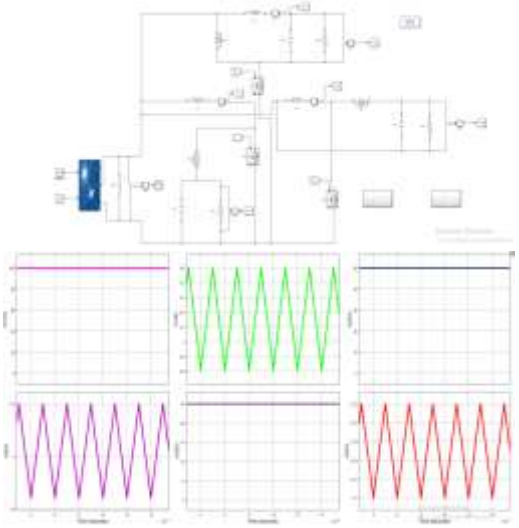
IL3



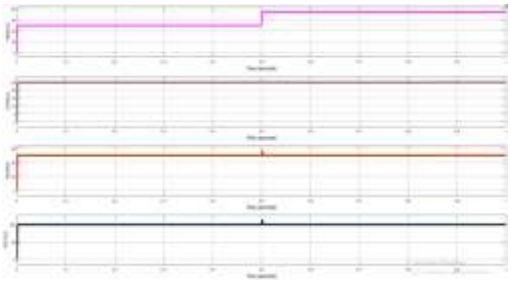


Performance of closed-loop control for a sudden variation in input voltage (VDC) at 0.5 sec.

Extenction simulation model



VO1, IL2, IL2,VO3, VO2,IL3



Performance of closed-loop control for a sudden variation in input voltage (VDC) at 0.5 sec.

5. Conclusion

The structure of the SIMO converter is proposed in this paper. The operating principle and modes of operation have been explained in detail. The proposed configuration is simple and without assumptions on the charging of inductors and operating duty cycle. It can generate the buck, boost, and buck-boost output voltages with independent regulated voltages. Cross regulation problems do not

exist in the proposed topology, so the sudden change in inductor and load currents does not affect the output voltages. Finally, simulation and experimental results validate the proposed converter operation and performance.

References

[1] P. C. Heris, Z. Saadatizadeh, and E. Babaei, ‘‘A new two input-single output high voltage gain converter with ripple-free input currents and reduced voltage on semiconductors,’’ IEEE Trans. Power Electron., vol. 34, no. 8, pp. 7693–7702, Aug. 2019, doi: 10.1109/TPEL.2018.2880493.

[2] A. Farakhor, M. Abapour, and M. Sabahi, ‘‘Design, analysis, and implementation of a multiport DC–DC converter for renewable energy applications,’’ IET Power Electron., vol. 12, no. 3, pp. 465–475, Mar. 2019.

[3] S. K. Mishra, K. K. Nayak, M. S. Rana, and V. Dharmarajan, ‘‘Switchedboost action based multiport converter,’’ IEEE Trans. Ind. Appl., vol. 55, no. 1, pp. 964–975, Jan./Feb. 2019

[4] X. Lu, K. L. V. Iyer, C. Lai, K. Mukherjee, and N. C. Kar, ‘‘Design and testing of a multi-port sustainable DC fast-charging system for electric vehicles,’’ Electr. Power Compon. Syst., vol. 44, no. 14, pp. 1576–1587, Aug. 2016.

[5] E. Babaei and O. Abbasi, ‘‘A new topology for bidirectional multi-input multi-output buck direct current–direct current converter,’’ Int. Trans. Electr. Energ. Syst., vol. 27, no. 2, pp. 1–15, Feb. 2017.

[6] Z. Rehman, I. Al-Bahadly, and S. Mukhopadhyay, ‘‘Multiinput DC–DC converters in renewable energy applications—An overview,’’ Renew. Sustain. Energy Rev., vol. 41, pp. 521–539, Jan. 2015.

[7] G. Chen, Y. Liu, X. Qing, and F. Wang, ‘‘Synthesis of integrated multi-port DC–DC converters with reduced switches,’’ IEEE Trans. Ind. Electron., vol. 67, no. 6, pp. 4536–4546, Jun. 2019.

[8] P. Patra, A. Patra, and N. Misra, ‘‘A single-inductor multiple-output switcher with simultaneous buck, boost, and inverted outputs,’’ IEEE Trans. Power Electron., vol. 27, no. 4, pp. 1936–1951, Apr. 2012.

[9] M. Abbasi, A. Afifi, and M. R. A. Pahlavani, ‘‘Comments on ‘a singleinductor multiple-output switcher with simultaneous buck, boost, and inverted outputs,’’’ IEEE Trans. Power Electron., vol. 34, no. 2, pp. 1980–1984, Feb. 2019.

[10] Y.-C. Hsu, J.-Y. Lin, C.-H. Wang, and S.-W. Chou, ‘‘An SIMO stepdown converter with coupled inductor,’’ in Proc. Int. Symp. VLSI Design, Autom. Test (VLSI-DAT), Hsinchu, Taiwan, Aug. 2020, pp. 1–4, doi: 10.1109/VLSI-DAT49148.2020.9196435.

[11] G. Nayak and S. Nath, ‘‘Comparing performances of SIDO buck converters,’’ in Proc. IEEE Int. Conf. Power Electron., Drives Energy Syst. (PEDES), Chennai, India, Dec. 2018, pp. 1–6.

[12] Y. Zheng, J. Guo, and K. N. Leung, ‘‘A single-inductor multiple-output buck/boost DC–DC converter with duty-cycle and control-current predictor,’’ IEEE Trans. Power Electron., vol. 35, no. 11, pp. 12022–12039, Nov. 2020.

[13] X. Zhang, B. Wang, X. Tan, H. B. Gooi, H. H.-C. Iu, and T. Fernando, ‘‘Deadbeat control for single-inductor multiple-output DC–DC converter with effectively reduced cross regulation,’’ IEEE J. Emerg. Sel. Topics Power Electron., vol. 8, no. 4, pp. 3372–3381, Dec. 2020.

[14] J. D. Dasika, B. Bahrani, M. Saeedifard, A. Karimi, and A. Rufer, ‘‘Multivariable control of single-inductor dual-output buck converters,’’ IEEE Trans. Power Electron., vol. 29, no. 4, pp. 2061–2070, Apr. 2014.

[15] E. Durán, S. P. Litrán, and M. B. Ferrera, ‘‘Configurations of DC–DC converters of one input and multiple outputs without transformer,’’ IET Power Electron., vol. 13, no. 12, pp. 2658–2670, Sep. 2020.

[16] B. Faridpak, M. Farrokhifar, M. Nasiri, A. Alahyari, and N. Sadoogi, ‘‘Developing a super-lift Luo-converter with integration of buck converters for electric vehicle applications,’’ CSEE J. Power Energy Syst., vol. 7, no. 4, pp. 811–820, Jul. 2021, doi: 10.17775/CSEEJPES.2020.01880.

[17] O. Ray, A. Josyula, S. Mishra, and A. Joshi, ‘‘Integrated dual-output converter,’’ IEEE Trans. Ind. Electron., vol. 62, no. 1, pp. 371–382, Jan. 2015.

[18] G. Chen, Y. Deng, J. Dong, Y. Hu, L. Jiang, and X. He, ‘‘Integrated multiple-output synchronous buck converter for electric vehicle power supply,’’ IEEE Trans. Veh. Technol., vol. 66, no. 7, pp. 5752–5761, Jul. 2017