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NEURAL NETWORK BASED MULTI-OUTPUT DC-DC CONVERTER FOR ELECTRIC VEHICLE APPLICATION

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ABSTRACT
This research implements a Single Input Multi Output (SIMO) converter system that generates multiple outputs by using Neural Network (NN) for Electric Vehicle (EV) Application. SIMO converter is one of the Multiport Converters that provides three distinct output voltages by using a neural network controller. Neural networks improve the efficiency, flexibility, and also reduce the complexity of the system. To reduce voltage ripples, prevent cross-regulation issues, and manage output voltages, the configuration SIMO converter is suggested. The proposed configuration eliminates cross-regulation issues, and the load voltage is unaffected. Further, the loads are isolated from one another during control by using the neural network controller. MATLAB/Simulink software Simulation results are used to confirm the effectiveness of the proposed converter and control method.
Keywords: Cross-Regulation, Electric vehicle, Multiport converters, Neural Network Controller, Single Input Multi Output Converter.

I. INTRODUCTION
Concerns over global warming and the depletion of fossil fuels are driving up the demand for electric vehicles (EVs), multiport DC-DC converters, and various battery chargers. Several dc–dc converters are typically needed in the auxiliary power supply system of EVs in order to meet various load circumstances [1], [2]. Multiport dc to dc converters attracted a lot more attention from researchers in recent years; this is due to the development of power electronic systems or the growing need for energy from non-conventional sources, and the growing application of micro grids. Multiport DC-DC converters offer a compact design with fewer components and a reduced cost as compared to multiple independent converters [3], [4].
Various control strategies are placed in the review of the literature to address the cross-regulation problem in a single inductor-based SIMO converter; in [5] the Predictor controller as of the now is provided as an alternative to the traditional charge balance strategy. A challenge that has emerged is the generation of duty ratios for active switches. Likewise, [6] the presents the deadbeat-based control technique. Since it's dependent upon an output current monitor, noise and large parametric changes might affect it. A multivariable digital controller-based SIMO is suggested for reducing output voltage fluctuations, cross regulation issues, and control voltage ripples. On the other hand, complexity may rise as a result of controller design. Non-isolated SIMO converters, which independently regulate the output voltages and don't need a separate control circuit, are presented to address the issues with single inductor SIMO converters. A new SIDO converter topology can be seen in [7], [8], [9] to combine buck and super lift converters to produce step-up and step-down voltages at output are used in EV applications. Combining high gain step-up with SEPIC converter-based SIMO is advised for solar powered applications.
By including capacitors and diodes, the output voltage in this configuration is increased to be higher than the supply voltage. Conduction losses and cost are nevertheless impacted by the quantity of diodes and capacitors used. In [10], a novel SIDO buck-boost architecture is created to provide both positive and negative outputs. With the fewer parts, a multi-output converter is recommended in [11]. Conduction losses are raised by the fact that it has more diodes. With the benefits of lowering low voltage stress and passive filter size, a SIMO configuration structure is presented [12].

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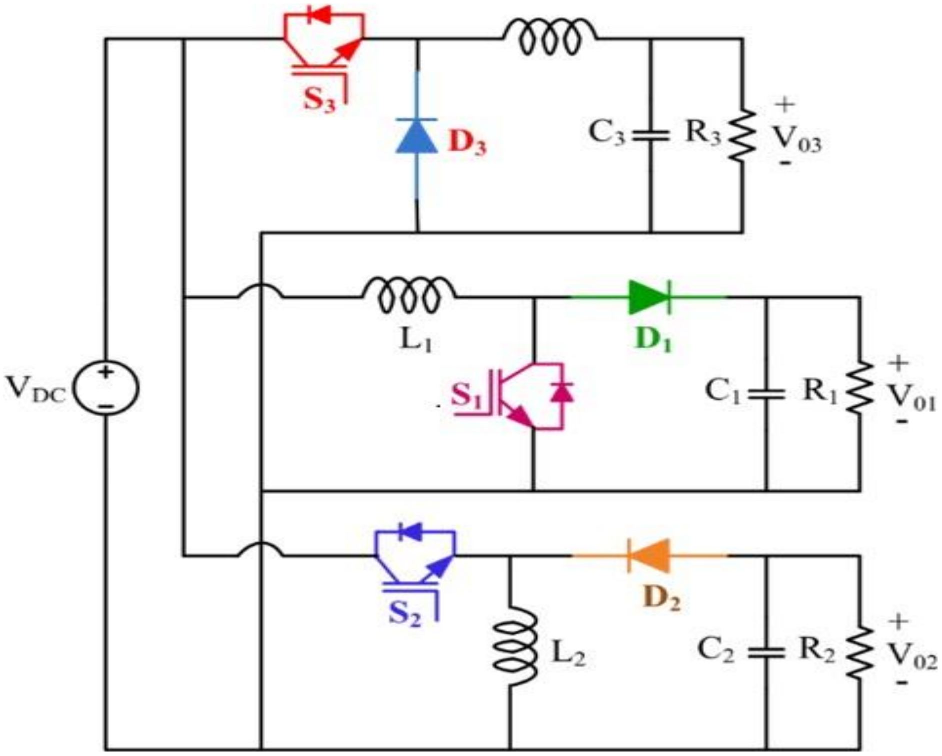

Fig 1: SIMO converter with cross regulation problem.

The updated SEPIC and a high step-up SIMO converter with interleaved base are provided in the [9]. It is made up of a voltage multiplier, an attached inductor, and switching capacitors that increase the output voltage in sustainable energy applications. But still, because there are more components, it is more complex. For SIMO applications, a four-phase interleaved converter based on the SEPIC-Cuk converter is recommended in [13]. Its benefits include small size, low ripple voltage, and fit to high power applications requiring quick response times. Fig 1. illustrates the auxiliary power supply system for EVs in the usual method of handling load requirements. Although this approach appears easy to understand its primary defect is that it has a cross-regulation issue, meaning that loads are not isolated from one another while they are operating. Additionally, if the ground is engaged or there are loads that are turned on concurrently when charging the battery, there is a potential of grounding problems [14].

It is possible to employ different duty ratios to control the output voltages in accordance with the circuit architecture shown in the circuit layout in Fig 2. This prevents the energy stored in the inductor from being shared with the other outputs during control and restricts it to a single output. Furthermore, the loads maintain their isolation against one another during control, thus overcoming the problem of cross-regulation

II. SIMO CONVERTER AND NUERAL NETWORK CONTROLLER

A. SIMO Converter

The proposed SIMO DC-DC Converter is shown in Fig 2. The components of this configuration are as follows: input voltage (VDC), switches (S1, S2, S3), diodes (D1, D2, D3), along with passive elements (L1, L2, L3 and C1, C2, C3). The proposed converter can produce three distinct output voltages: Boost (Vo1), Buck-Boost (Vo2) with positive voltage polarity, Buck (Vo3). The converter can be used to independently regulate the three output voltages, respectively.

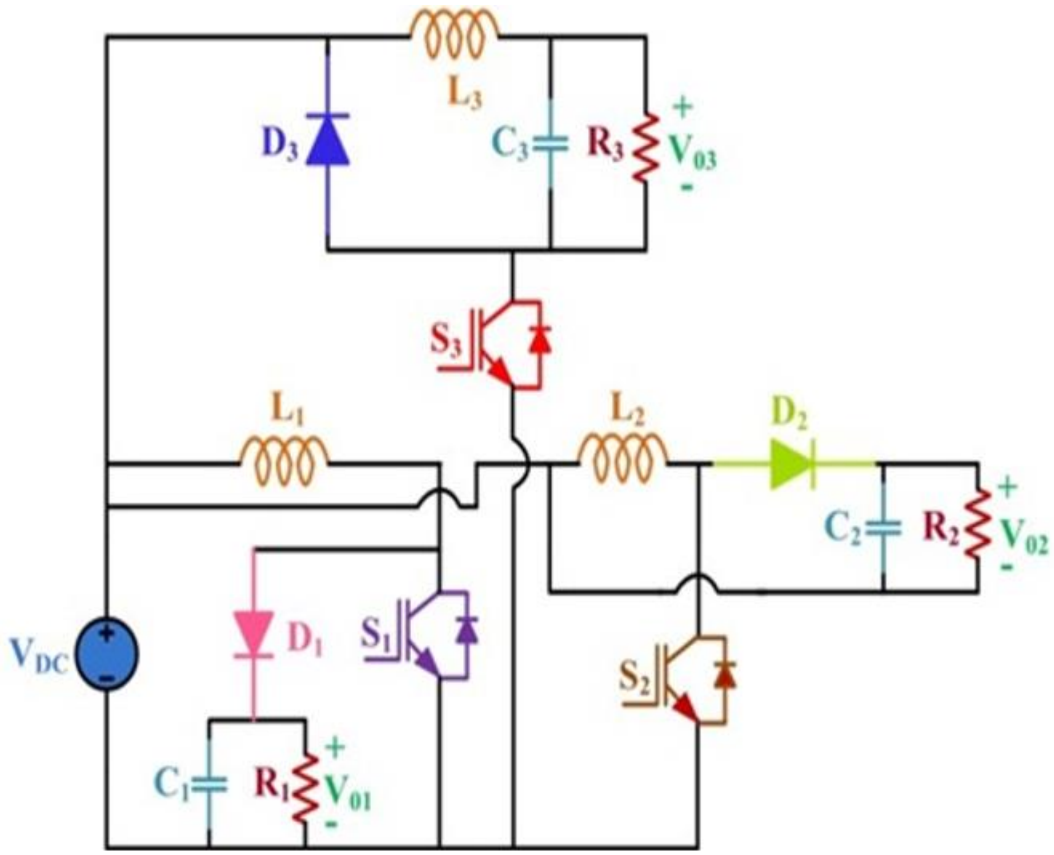

Fig 2: SIMO converter without cross regulation problem

In this recommended circuit design, the loads are scaling with concurrent operation. As can be seen from the accompanying pictures, load R3 through S3 alone is linked to the input power supply during mode-1 operation, while the remaining loads are separated, as Figure 3(a) illustrates.

Similarly, as shown in Figure 3(b), In mode-2, the input supply is connected to only load R1 through D1; all other loads are isolated. Every load in the suggested control strategy is kept apart from the others while it is being controlled in any mode of operation. Although this circuit layout appears to be relatively basic, it is unique and useful. The primary flaw in the traditional method depicted in Fig. 1. is the cross-regulation issue, which results in the loads not being separated from one another while they are operating. Furthermore, in the buck-boost mode of operation, to change the output voltages' inverse polarity, the system design will get more complex.

The proposed SIMO has the following benefits:

1. There are no operational duty ratio assumptions, and the structure is straightforward.
2. It has the ability to produce three distinct output voltages those are boost, buck, and buck-boost
3. During control, loads are separate from one another, and
4. The cross-regulation issue is satisfactorily resolved the output voltage is positive buck-boost.

1. OPERATION MODES OF SIMO

a) MODE-1

S1, S2, and S3 switches are in the ON position. Fig 3(a) shows the current flow path. L1, L2, and L3 are magnetized by the energy port VDC. As a result, (C3) is charged and the C1 and C2 are discharged to the loads (R1) and (R2), respectively. The voltages and currents of the capacitors and inductor are shown in Eq. (1)-(4).

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

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

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

$$v_{C_3}(t) = V_{DC} - \frac{L_3}{2C_3}e^{-\alpha t}\begin{bmatrix} \cos\omega_d t(\frac{\alpha c_1}{R_3} + \omega_d c_2) \\ + \sin\omega_d t(-\alpha c_2 + \frac{\omega_d c_1}{R_3}) \end{bmatrix} \qquad (4)$$

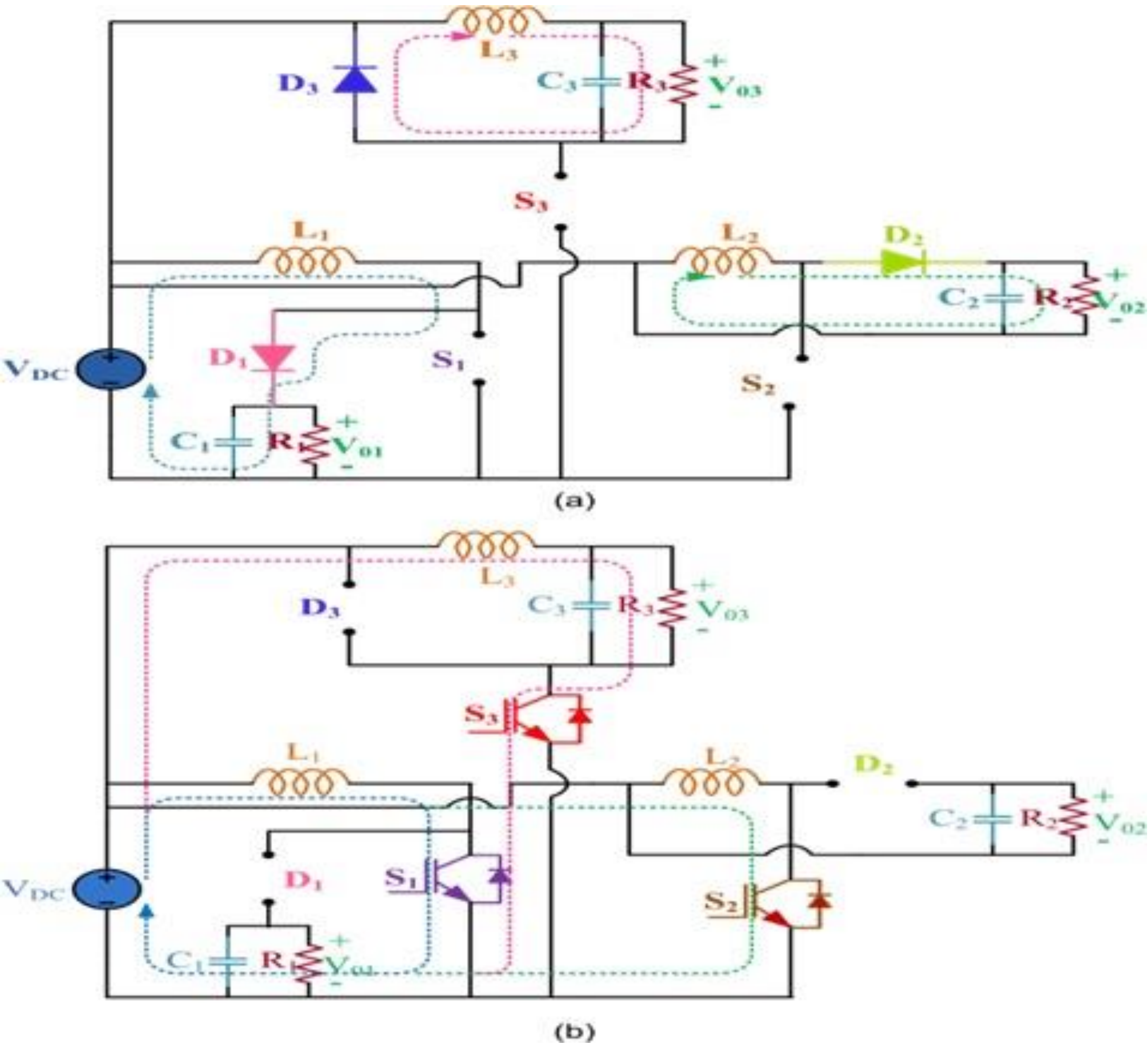

Fig 3: Operational Modes of SIMO: (a)Mode-1 and (b) Mode-2.

b) MODE-2

In this condition, L1, L2, and L3 lose their magnetic fields and send their energy through D1, D2, and D3, respectively, to the load. Fig 3(b) provides an illustration of it. The voltages of capacitors and currents of the inductors found in Equations (5) to (11) are as follows: where c1, c2, c3, c4, c5, and c6 are the initial values.

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$$i_{L_1}(t) = \frac{V_{DC}}{R_1} + e^{-\alpha_1 t}\left[c_1 \cos \omega_{d1} t + c_2 \sin \omega_{d1} t\right] \quad (5)$$

$$v_{C_1}(t) = V_{DC} - \frac{L_1}{2C_1} e^{-\alpha_1 t} \begin{bmatrix} \cos \omega_{d1} t (\frac{c_1}{R_1} - \omega_{d1} c_2) \\ + \sin \omega_{d1} t (\omega_{d1} c_1 + \frac{c_2}{R_1}) \end{bmatrix} \quad (6)$$

$$i_{L_2}(t) = e^{-\alpha_2 t}\left[c_3 \cos \omega_{d2} t + c_4 \sin \omega_{d2} t\right] \quad (7)$$

$$v_{C_2}(t) = -L_2 e^{-\alpha_2 t} \begin{bmatrix} (-\alpha_2 c_3 + \omega_{d2} c_4) \cos \omega_{d2} t \\ + (\omega_{d2} c_3 - \alpha_2 c_4) \sin \omega_{d2} t \end{bmatrix} \quad (8)$$

$$i_{L_3}(t) = e^{-\alpha t}\left[c_5 \cos \omega_d t + c_6 \sin \omega_d t\right] \quad (9)$$

$$v_{C_3}(t) = -L_3 e^{-\alpha t} \begin{bmatrix} (-\alpha c_5 + \omega_d c_6) \cos \omega_d t \\ + (\omega_d c_5 - \alpha c_6) \sin \omega_d t \end{bmatrix} \quad (10)$$

$$\alpha_1 = \frac{1}{2R_1C_1}, \quad \omega_{d1} = \frac{1}{2}\sqrt{\left(\frac{1}{R_1^2 C_1^2} - \frac{4}{L_1 C_1}\right)},$$

$$\alpha_2 = \frac{1}{2R_2C_2} \quad \text{and } \omega_{d2} = \frac{1}{2}\sqrt{\left(\frac{1}{R_2^2 C_2^2} - \frac{4}{L_2 C_2}\right)}$$

$$\alpha_3 = \frac{1}{2R_3C_3}, \quad \omega_{d_3} = \frac{1}{2}\sqrt{\left(\frac{1}{R_3^2 C_3^2} - \frac{4}{L_3 C_3}\right)}, \quad (11)$$

As seen in Fig-3(a), it is seen that load (R3) alone through S3 is linked to the ground during Mode-1 operation, when, during battery charging, even in the presence of the ground, the remaining loads are separate from one another. Similar to this, only load (R1) through D1 is linked to the ground during Mode2; other loads, like what is displayed above Figure-3 (b), are isolated from both the load (R1) and ground. Every load in the suggested control strategy is kept apart from the others while it is being controlled in any of the operational mode.

Furthermore, the circuit design guarantees that under control, the stored energy of the inductor is restricted to just a single output and doesn't interact with remaining outputs. This permits separate duty-cycle regulation of the output voltages. Thus, there is no impact in the Load Voltages (Vo1, Vo2, Vo3) by the variation in Load Currents (Io1, Io2, Io3) Because of this, the suggested setup using this control method eliminates all cross-regulation difficulties, even while the battery charging process is taking place on the ground. There are no assumptions needed because the arrangement is simple and can generate three different outputs.

B. Neural Network controller

To manage the intricate dynamics and control needs of the SIMO DC-DC converter, a neural network controller can be employed. For various subsystems (such as motor control, battery management, and auxiliary systems), the neural network controller gathers information on input and output voltages, load circumstances, and designed output voltages [15], [16]. And for this NN controller should be train by using its layers, they are input layer, hidden layer, and output layer. The EV system sends data to the input layer, including the intended output voltage, load current, and battery voltage. The input data is processed by hidden layers using a number of nonlinear functions. The intended system complexity and performance determine how many hidden layers there are and how complex they are. The output layer generates the control signals that are delivered to the DC-DC converter's switching components according to the data that has been received from the hidden layers. Fig 4. Displays the general view of NN Controller.

It also gains the ability to manage different interruptions and load circumstances [17]. To ensure optimal performance across all outputs, a neural network controller can be modify the converter's operation: When the load on the motor increases, the neural network can modify the converter's output to make sure that the motor receives enough voltage without burdening the other outputs and it can adjust the converter's settings so that that all outputs are steady in the case of a drop or sudden change in input voltage Enhancing the efficiency and adaptability of power management systems through the use of a neural network controller for a SIMO DC-DC converter in electric vehicle applications can improve the electrical system's overall performance.

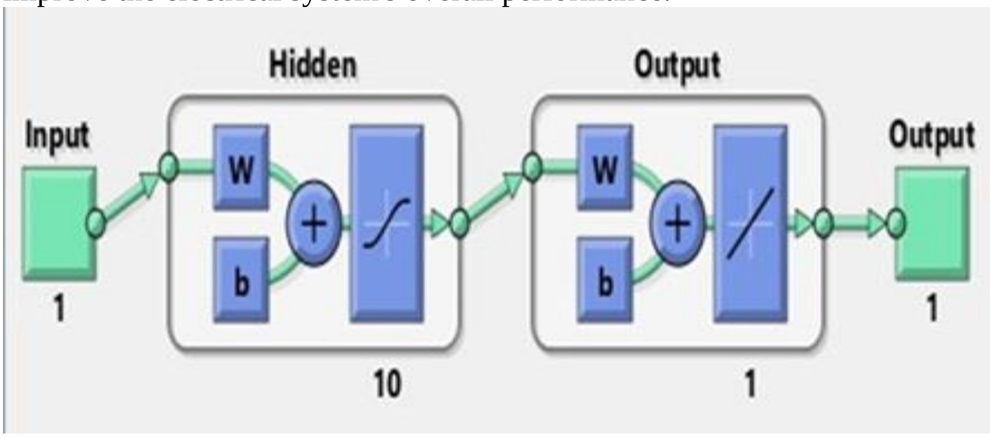

Fig 4: General view of NN controller

III. METHODOLOGY

The Single-Input Multi-Output (SIMO) converter system that has been suggested for use in electric vehicle (EV) applications must be implemented methodically in order to handle issues like voltage ripple and cross-regulation and guarantee effective power management. The first step in the process is designing the SIMO converter, which combines three separate DC-DC converters with one input source to create a single system that can produce three different output voltages shown in Fig 5. A sort of DC-to-DC converter that is employed to raise a lower input voltage to a greater output voltage is called a boost converter, commonly called as a step-up converter. In order to ensure that individual battery cells function under acceptable parameters and maximize their performance, battery management systems utilize buck-boost converters to regulate their voltage levels [18]. Step-down converters, or buck converters, are a kind of DC-to-DC converter that effectively converts a higher voltage to a lower voltage. The EV's motor drive, auxiliary systems, and battery management are just a few of the subsystems that are powered by these output voltages, which lowers the total number of components and system complexity. The operation of the converter is then controlled by a controller built using a neural network. This controller effectively prevents cross-regulation by guaranteeing that each output voltage is isolated from the others and stays stable. MATLAB/Simulink software is utilized to model and simulate the SIMO converter system.

To confirm that the system can reduce voltage ripples, maintain stable output voltages, and run effectively, the simulation results are examined. This will enable the neural network controller to be further improved and the performance of the converter to be optimized. After a thorough analysis of the system's performance, the implementation ends with recommendations for future work that will concentrate on further optimization and integration with other EV systems. This work highlights the benefits of the SIMO converter in lowering complexity, cost, and operational challenges in EV power management systems. By cleverly modifying the control settings, the neural network controller can isolate these outputs and reduce or completely eradicate cross- regulation problem.

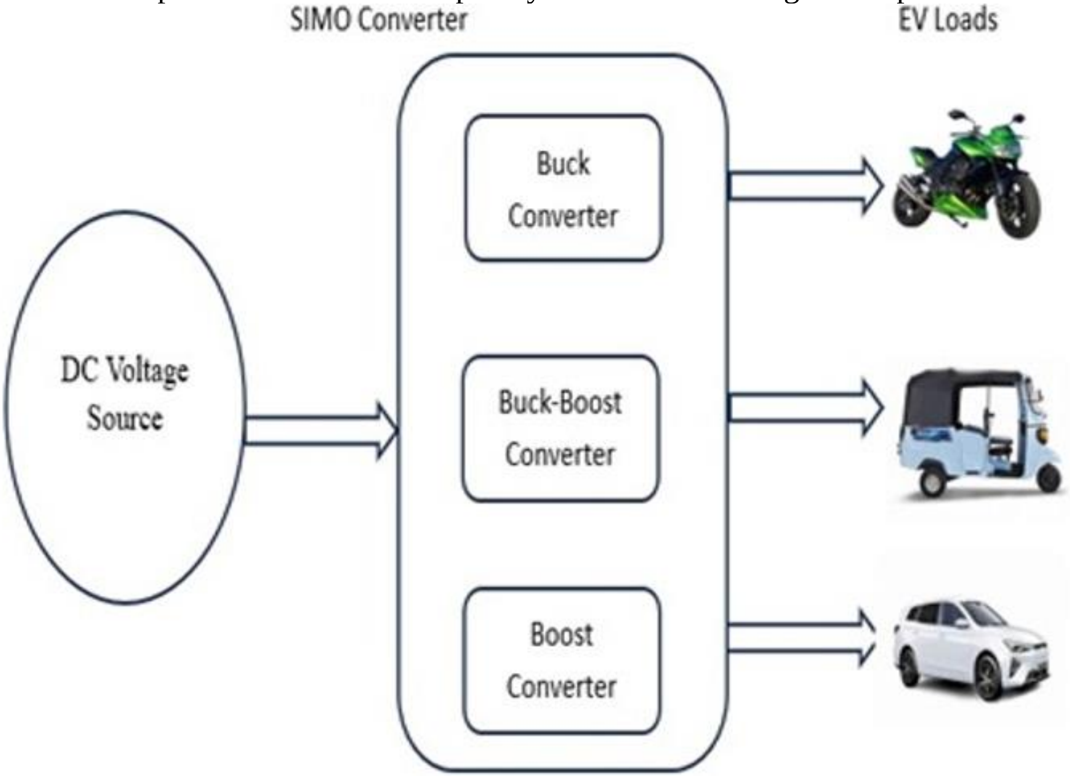

Fig 5: Block diagram of SIMO converter.

As a result, each EV subsystem receives power delivery that is more consistent and dependable. The neural network controller lessens voltage ripples. Because of their adaptability, they can be used for a variety of EV applications, ranging from tiny personal vehicles to bigger commercial or industrial EVs. Neural network optimization of the converter can improve system efficiency as a whole.

In this, there are two cases in which a SIMO converter can operate. In Case 1, there are three distinct outputs (Boost, Buck-Boost, and Buck Converters) with an input value of 50V from 0 to 1 sec. In Case 2, the input value is initially 50V, however after 0.5 seconds, the input value suddenly changes to 70V for each of the three outputs. Thus, by the A sudden change that causes distortions in the output waveforms at 0.5 seconds. However, the distortions are not as severe when using the NN controller, and these include can be resolved more quickly.

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TABLE-I. SPECIFICATIONS

S. No	Parameter Name	Parameter Value with Units		
		Boost Converter	**Buck-Boost Converter**	**Buck Converter**
1.	Output Voltage (Vo)	100 V	50 V	25 V
(2.	Output Current (Io)	2 A	2 A	2 A
3.	Capacitance (C)	200 µF	470 µF	360 µF
4.	Inductance (L)	0.6 mH	0.9 mH	1 mH
5.	Switching Frequency (f)	50 Hz	50 Hz	50 Hz

Above table-1 illustrates that the parameter specifications of SIMO converter.

IV. SIMULATION RESULTS

In order to verify the effectiveness of the proposed SIMO with neural network is implemented in MATLAB Orientation. Further, the proposed system is simulated with different cases: The case-1 simulation is presented with input voltage 50V and the case-2 simulated the input voltage changes 50V to 70V at 0.5sec.

Case 1: At 50V Input.

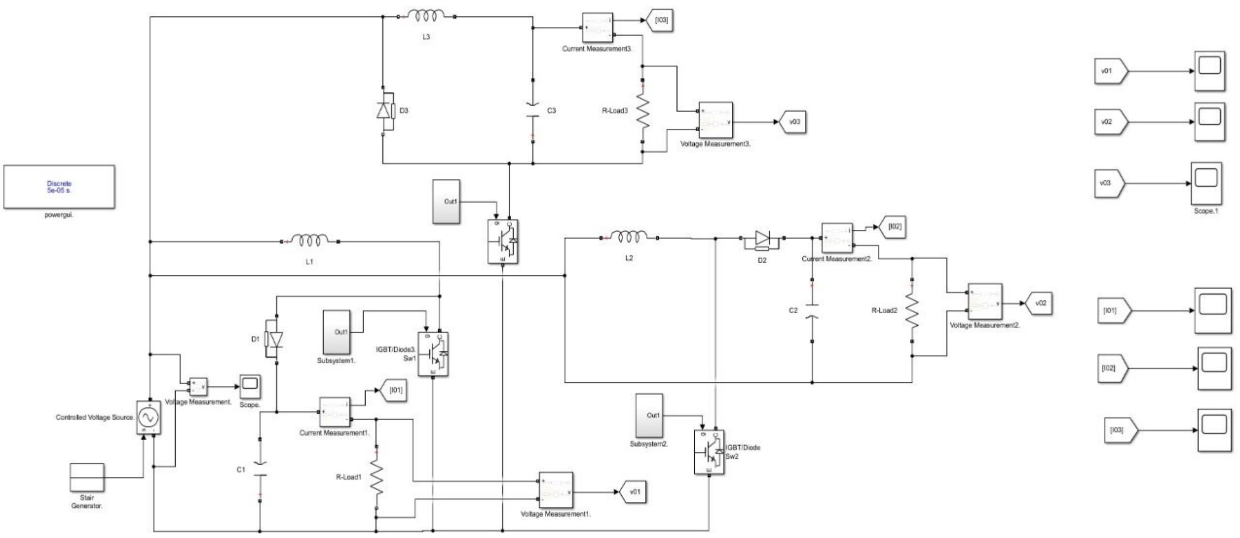

Fig 6: Simulation Diagram of case-1

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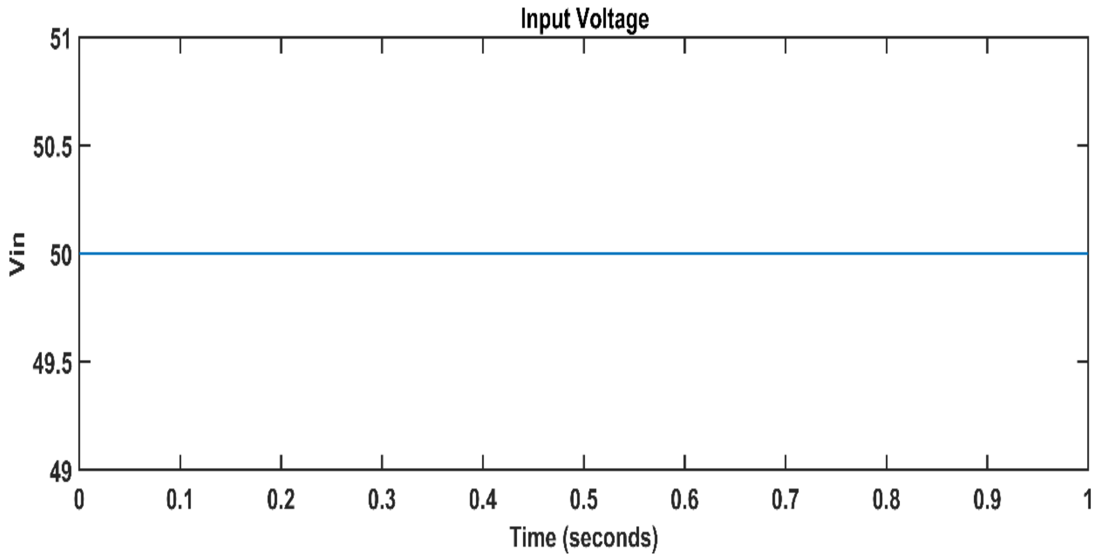

Fig 7: Input Voltage (Volts).

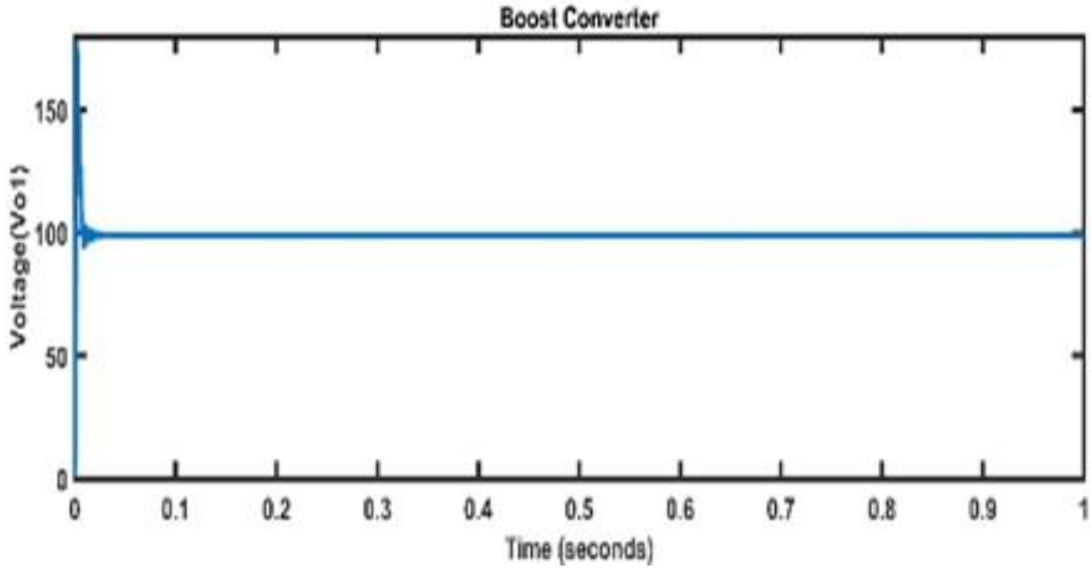

Fig 8 (a): Vo1

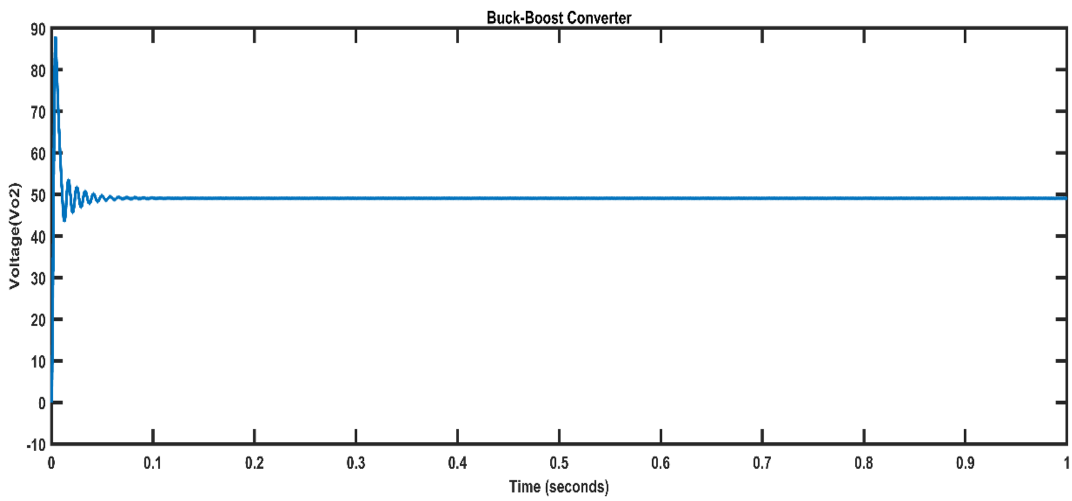

Fig 8 (b): Vo2

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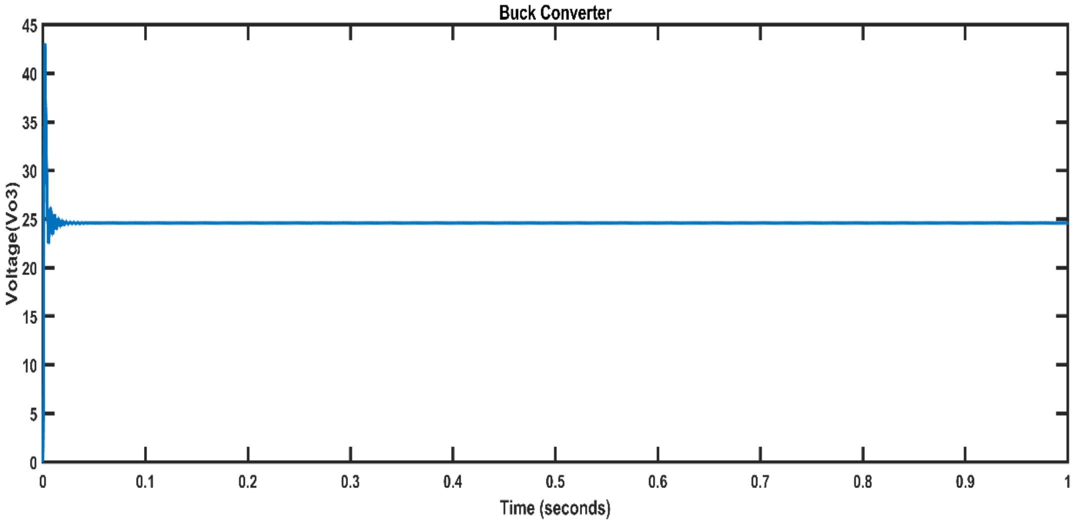

Fig 8 (c): Vo3

Fig 8 (a, b, c): Output Voltages (Volts).

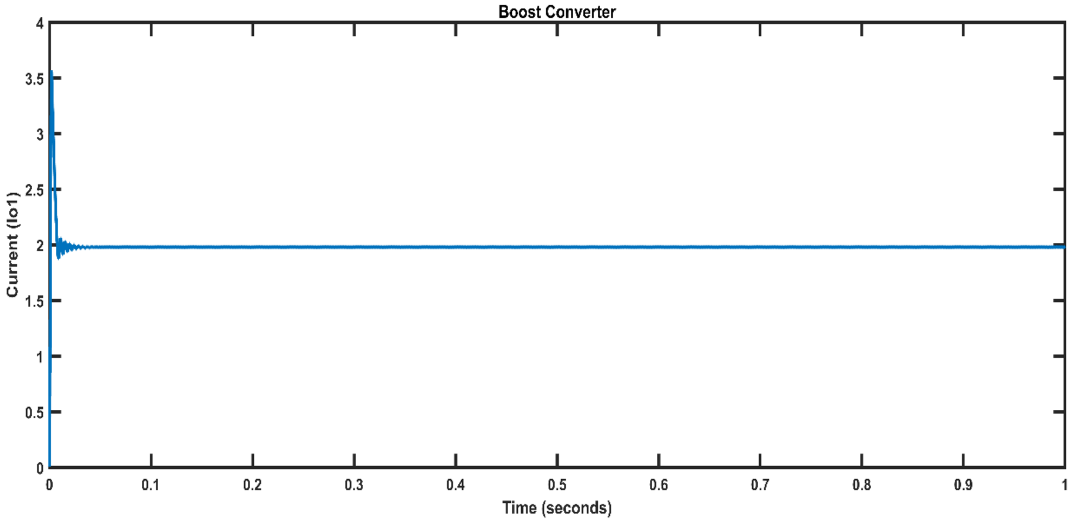

Fig 9 (a): Io1

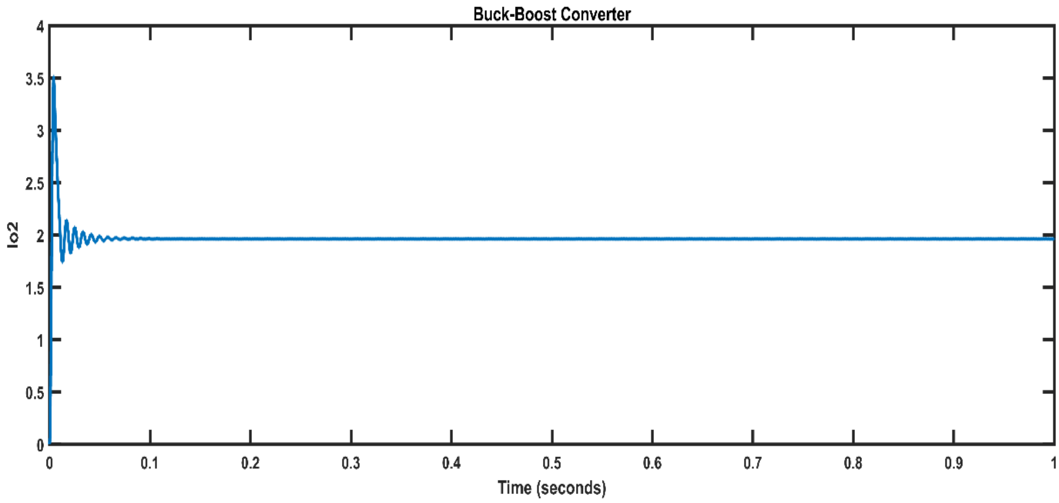

Fig 9 (b): Io2

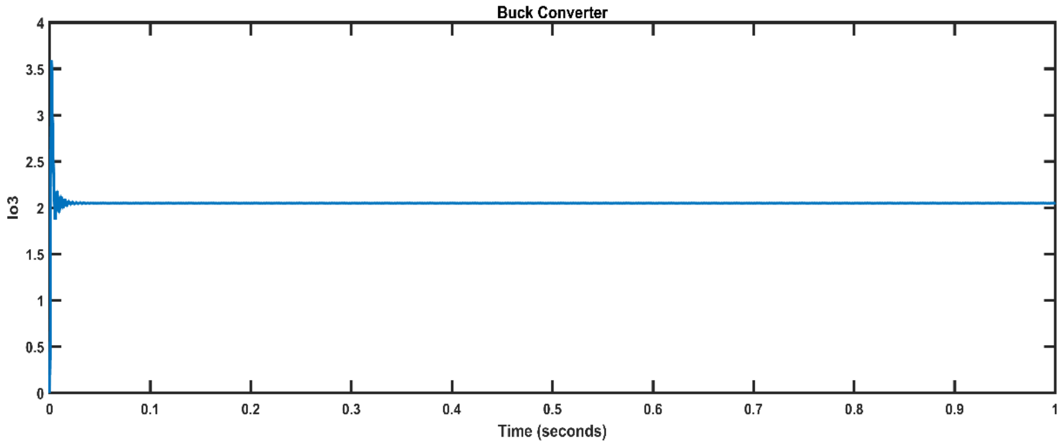

Fig 9 (c). Io3

Fig 9 (a, b, c): Output Currents (Amps).

Figs 8 and 9 show the simulated output voltages and currents respectively. The intelligent Neural Networks is maximumly reduce the ripple content of the proposed converter topology.

Case 2: At Input Changes 50V to 70V at 0.5sec.

The case-2 simulation is presented in Fig 10. And the input voltage shown in Fig 11. The system's performance can be evaluated in the event of a sudden input voltage shift. Figures 12 (a, b, c) and 13 (a, b, c) displays the simulation result over a sudden shift in the input voltage (VDC) for the Boost output from 50 V to 70 V at 0.5 seconds; the same thing applies for the Buck-Boost and Buck voltages and currents. The output voltages (Vo1, Vo2, Vo3) are displayed along with their reference voltage (Vref). The reference voltage for Vo1 is 100V, for Vo2 is 50V, for Vo3 is 25V are shown in Fig 11(a, b, c) and the Output Currents are shown in Fig 12 (a, b, c).

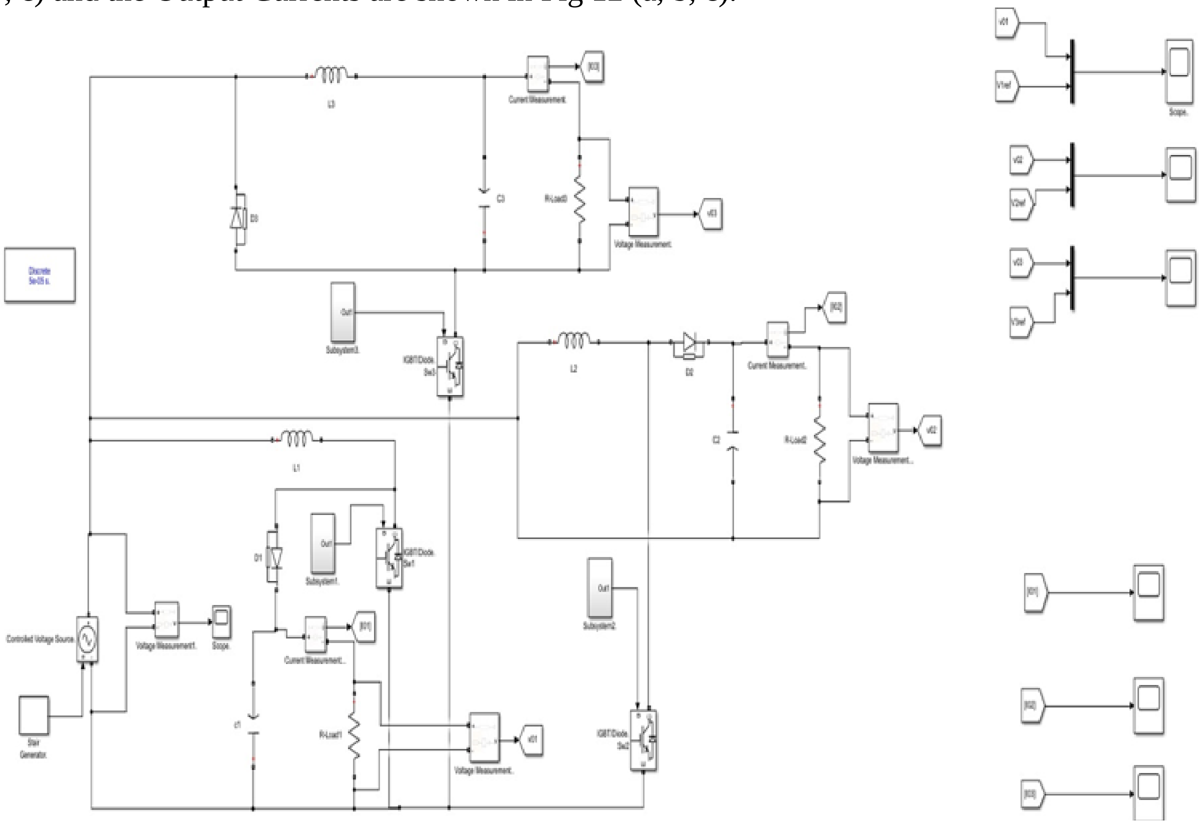

Fig 10: Simulation diagram of case-2

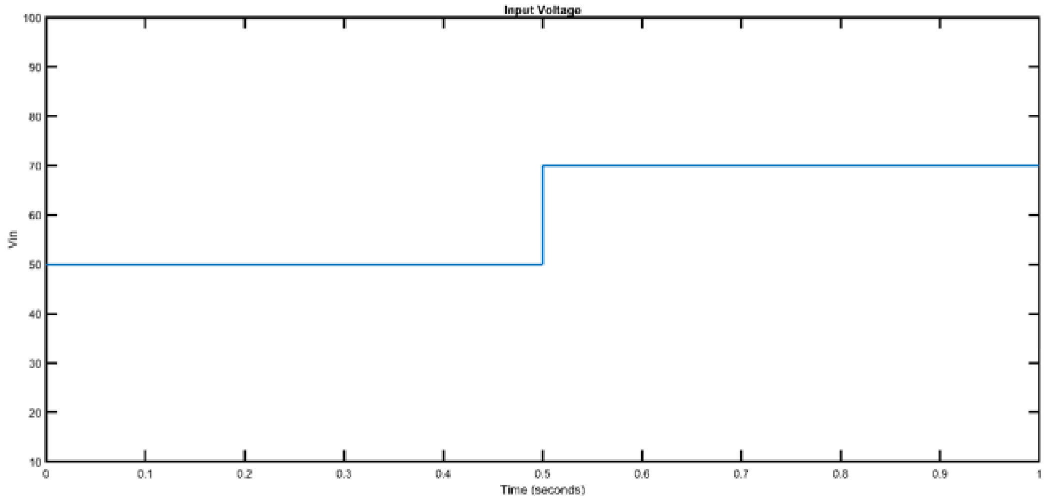

Fig 11: Input voltage (Volts).

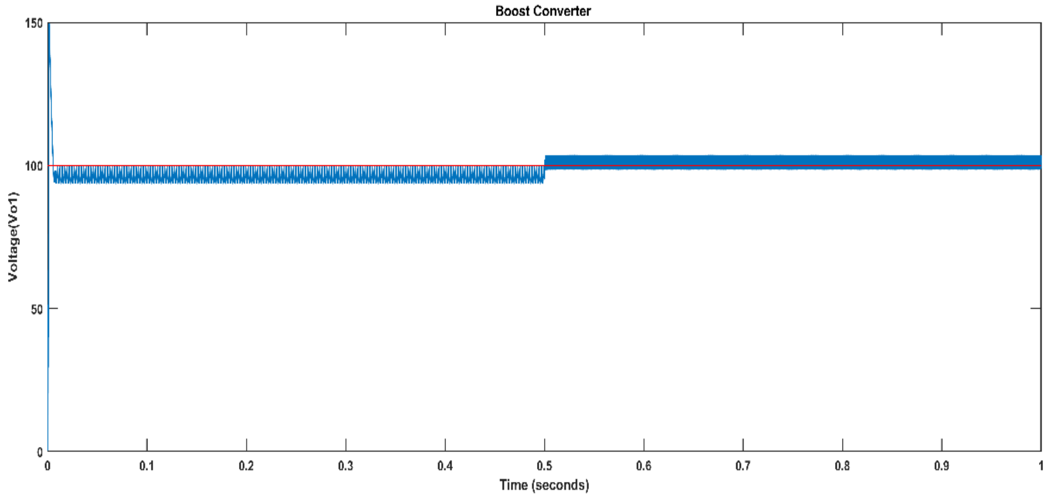

Fig 12 (a): Vo1

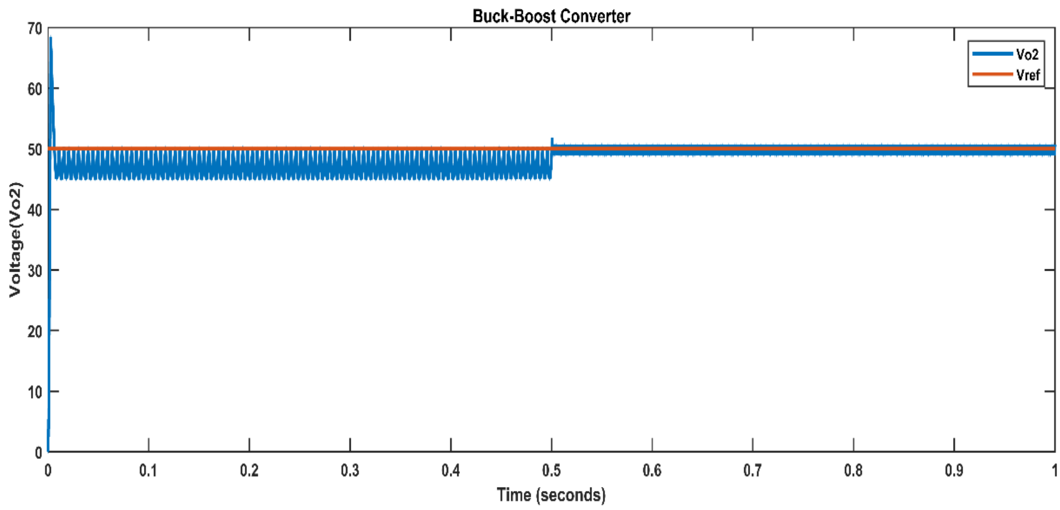

Fig 12 (b): Vo2

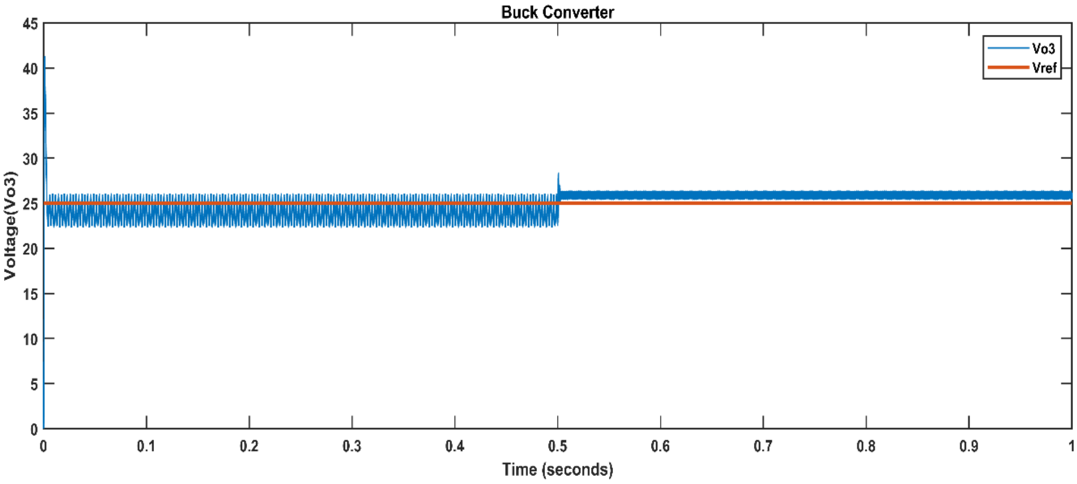

Fig 12 (c): Vo3
Fig 12 (a, b, c): Output Voltages (Volts).

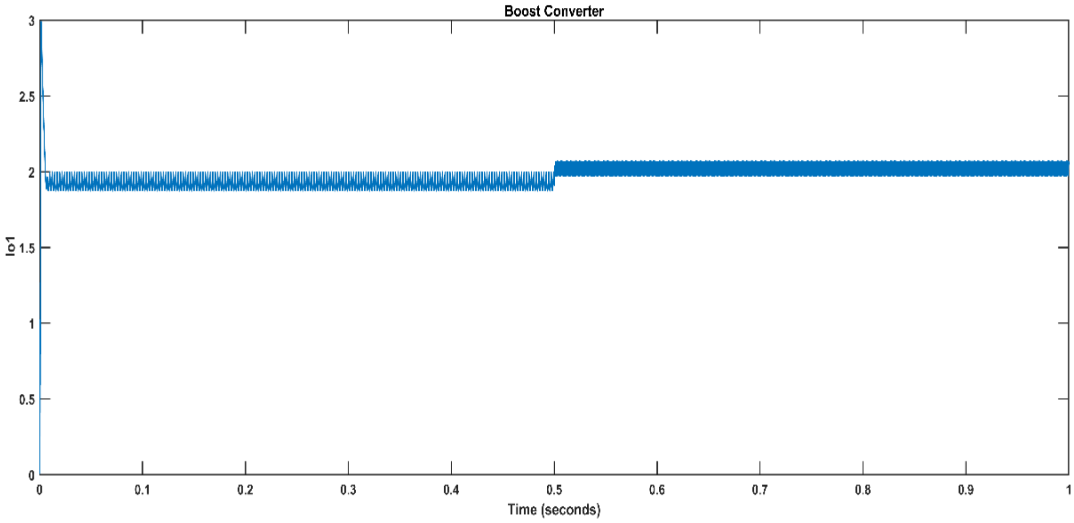

Fig 13 (a): Io1

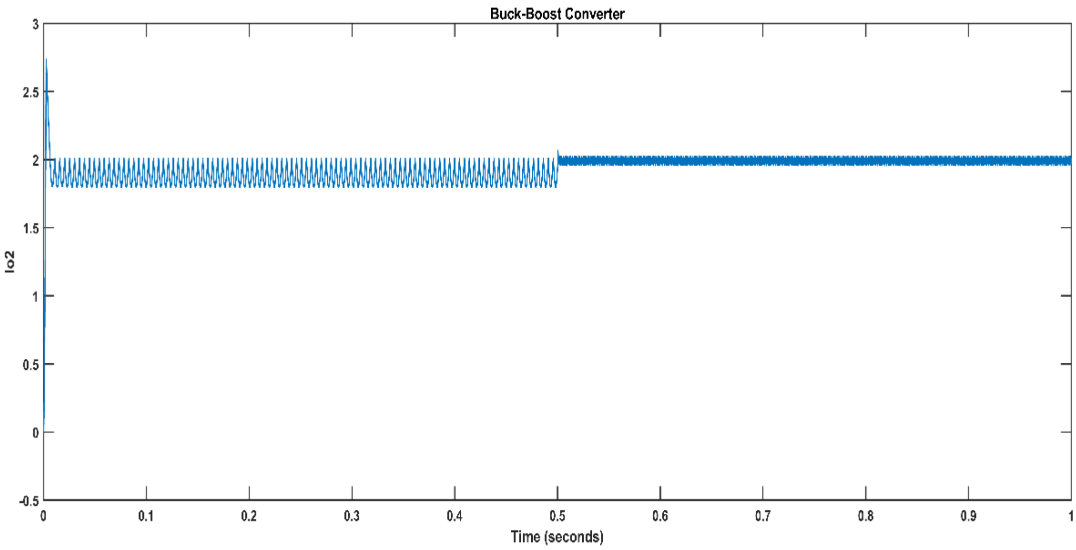

Fig 13 (b): Io2

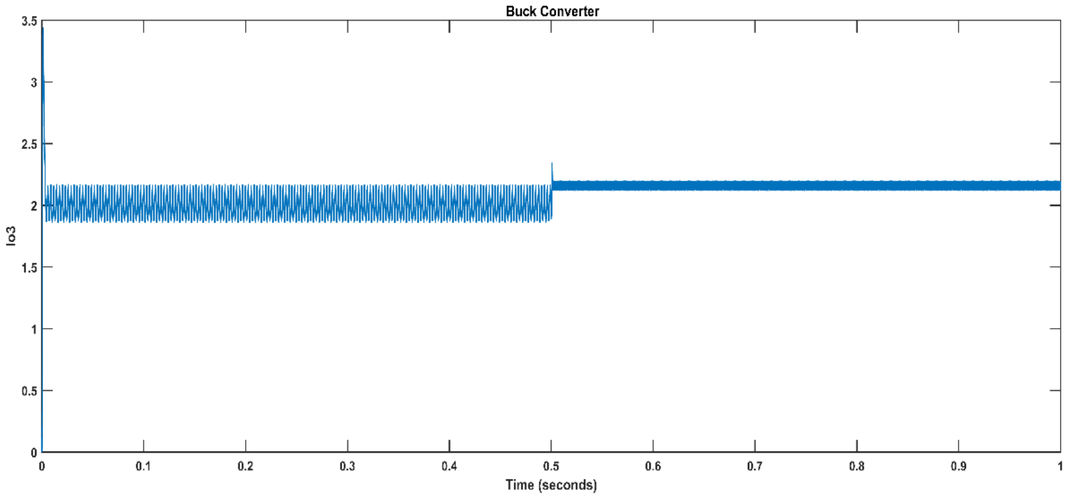

Fig 13 (c): Io3
Fig 13 (a, b, c): Case 2 Output Currents (Amps).
Figs 12 and 13 shows the effectiveness of the system.

V. CONCLUSION

The suggested single-input multi-output (SIMO) converter topology provides a reliable solution for electric vehicle (EV) applications. Further, the proposed SIMO converter generated efficient ripple management, cross-regulation elimination, and steady output voltage provision under a range of load scenarios. The incorporation of neural network controller that isolated load and keeps voltage levels constant leads to improve performances. The efficacy of the suggested system is confirmed by simulation results which shows the simplify of EV power management, cut costs. However, the proposed approach represented a significant advancement in multioutput DC to DC converter technology used in electrical vehicles.

REFERENCES

[1]. W. CaiandF. Yi (2016, April). "An integrated multiport power converter with small capacitance requirement for switched reluctance motor drive" IEEE Trans. Power Electron, vol. 31(4), pp. 3016–3026,
[2]. T. v. Sarathkumar, M. Poornanand, and A. K. Goswami (2020, July). "Modelling and simulation of electric vehicle drive through SAEJ227EUDC cycles,". doi:10.1109/SCES50439.2020.9236717.
[3]. B. Wang, V. R. K. Kanamarlapudi, L. Xian, X. Peng, K. T. Tan, and P. L. So (2016, July). "Model predictive voltage control for single-inductor multiple output DC–DC converter with reduced cross regulation," IEEE Trans. Ind. Electron., vol. 63(7), pp. 4187–4197
[4]. Gergana Vacheva, Vladimir Dimitrov, and Nikolay Hinov (2019). "Modelling and Control of Bidirectional Buck-Boost Converter for Electric Vehicles Applications," in IEEE, ELMA 16th Proceedings, vol. ELMA, no. 16th.
[5]. Y. Zheng, J. Guo, and K. N. Leung (2020, Nov). ''A single inductor multiple-output buck/boost DC–DC converter with duty-cycle and control-current predictor,'' IEEE Trans. Power Electron., vol. 35(11), pp. 12022–12039.
[6]. X. Zhang, B. Wang, X. Tan, H. B. Gooi, H. H.-C. Iu, and T. Fernando (2020, Dec). ''Deadbeat control for single inductor multiple-output DC–DC converter with effectively reduced cross regulation,'' IEEE J. Emerg. Sel. Topics Power Electron., vol. 8(4), pp. 3372– 3381.
[7]. B. Faridpak, M. Farrokhifar, M. Nasiri, A. Alahyari, and N. Sadoogi (2021, July). ''Developing a super-lift Luoconverter with integration of buck converters for electric vehicle applications, ''CSEE J. Power Energy Systems, vol.7(4), pp.811–820, doi: 10.17775/CSEEJPES.2020.01880.

[8]. M. Y. Hassani, M. Maalandish, and S. H. Hosseini (2021, Feb). A new single input multioutput interleaved high step-up DCDC converter for sustainable energy applications, IEEE Trans. Power Electron., vol. 36(2), pp. 15441552.
[9]. V. V. Krishna, P. A. Kumar and K. R. M. V. Chandrakala (2019, Oct). "Development of Hybrid Energy Storage System for DC Motor Powered Electric Vehicles, International Conference on Smart Structures and Systems (ICSSS), Chennai, India, pp. 1-4, doi: 10.1109/ICSSS.2019.8882838.
[10]. J. Marjani, A. Imani, E. Afjei, and A. Hekmati (2016, May). A new dual output DC-DC converter with enhancing output voltage level, in Proc. 24th Iranian Conf. Electr. Eng. (ICEE), pp. 573577.
[11]. Z. Saadatizadeh, P.C. Heris, E. Babaei, and M. Sabahi (2019, June). A new nonisolated single-input three-output high voltage gain converter with low voltage stresses on switches and diodes, IEEE Trans. Ind.Electron, vol. 66(6), pp. 43084318.
[12]. A. Ganjavi, H. Ghoreishy, and A. A. Ahmad (2018, Oct). A novel single-input dual output three-level DCDC converter, IEEE Trans. Ind. Electron, vol. 65(10), pp. 81018111.
[13]. D. Aranda, S. P. Litran, and M. B. F. Prieto (2022, Jan). An interleaved single input multiple-output DC-DC converter combination, CSEE J. Power Energy Syst., vol. 8(1), pp. 132142, doi: 10.17775/ CSEEJPES.2020.00300.
[14]. Dhananjaya, D. Ponuru, T. S. Babu, B. Aljafari and H. H. Alhelou (2022, Feb). "A New Multi-Output DCDC Converter for Electric Vehicle Application," in IEEE Access, vol. 10, pp. 19072-19082, doi:10.1109/ACCESS.2022.3151128.
[15]. G. Xu, M. Liu (2017, Feb). Photovoltaic Power Prediction Model Based on Parallel Neural Network and Genetic Algorithms, in Management of Information, Process and Cooperation, MIPaC, Communications in Computer and Information Science, J. Cao, J. Liu (Eds.). Springer, Singapore, vol. 686.
[16]. Isha, A.S. Chaudhary and D.K. Chaturvedi, (2020, Jan). Effects of Activation Function and Input Function of ANN for Solar Power Forecasting, in Advances in Data and Information Sciences, Lecture Notes in Networks and Systems, M. Kolhe, S. Tiwari, M. Trivedi, K. Mishra (Eds.), Springer, Singapore. Vol. 94. pp.329-342
[17]. T. Burianek, J. Stuchly and S. Misak (2016, Jan). Solar Power Production Forecasting Based on Recurrent Neural Network, in Proceedings of the Second International Afro-European Conference for Industrial Advancement AECIA, Advances in Intelligent Systems and Computing: A. Abraham, K. Wegrzyn-Wolska, A. Hassanien, V. Snasel, A. Alimi (Eds.), Springer, Cham. Vol. 427.
[18]. M. Ashar (2016, Feb). “Integration of Ultra Capacitor with Battery using DC-DC Bidirectional Buck Boost Converter in an Electric Vehicle,” International Research Journal of Engineering and Technology, vol. 3(2).