Solar and battery input super boost DC–DC converter for solar powered electric vehicle

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ABSTRACT

The electric vehicle (EV) is increasingly emerging as an attractive solution to reduce reliance on fossil fuels in India. In commercial EVs, solar photovoltaic (PV) technology is employed both to charge the battery and power the vehicle. However, the conventional bidirectional DC-DC converter layout results in underutilization of solar PV power when the battery's state of charge (SOC) reaches maximum capacity. This work offers a unique dual input super boost (DISB) DC-DC converter designed specifically for solar-powered electric vehicles (EVs) to address the aforementioned challenge. The recently suggested converter operates in six different modes to effectively capture solar photovoltaic (PV) power. Notable benefits of this design include a wide range of speed control and fewer conduction devices in each mode, which eventually result in increased overall efficiency. An extensive analysis of the suggested DISB DC-DC converter is carried out by the study, encompassing detailed examination of operating waveforms and dynamic evaluations. Furthermore, the converter's performance and operation under the six different modes are verified through simulation.

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1. INTRODUCTION

In contemporary times, electric vehicles (EVs), and solar-powered EVs (SPEVs) [1], plug-in hybrid EVs (PHEVs) [2]-[6] have gained significant popularity, leading to substantial business expansion. The Indian government, in particular, has prioritized SPEVs to combat pollution and achieve financial savings by reducing dependence on fossil fuel imports. Power electronic converters have a vital function in electric vehicles (EVs), supplying essential power for acceleration, storing and harnessing solar energy, and capturing energy during regenerative braking. Previous discussions have explored the combination of supercapacitors and batteries for PHEVs, and there is a growing interest in integrating fuel cell (FC) [7]-[9] technologies with other energy storage mediums. Several bidirectional battery charging topologies for PHEVs have been investigated to improve performance and unit sizing for optimal operation [10].

Different mechanisms, such as fast charging/discharging with an intelligent monitoring system (IMS) and peak current or predictive current control techniques, seemed implemented to enhance EVs' dynamic performance. Several converter configurations have been suggested to optimize EV performance, including multiphase converters with four unsymmetrical voltage ports [11]-[13]. However, these configurations often involve a higher quantity of inactive components, impacting operational effectiveness. Some designs introduce complexities, such as a novel converter with a single-coupled inductor, others involve the electronic component count of non-isolated multi-input DC-DC converters (MIDCs) with increased power [14]-[17]. Proposed converters for electric buses also face challenges related to increased complexity and device count [18].

To overcome these issues, researchers investigated MIDC converter topologies for incorporating diverse energy sources, such as solar PV, batteries, and FC, into hybrid energy systems (HES) [19]. However, these approaches often require separate DC-DC converters for different energy sources, contributing to cost and complexity. In contrast, the proposed converter offers flexibility in charging the battery without the need for an additional separate converter [20].

In the context of commercial EVs, the conventional approach involves a separate charge controller for solar PV charging and a bidirectional converter for simultaneous battery driving and charging from an external source (plug-in). Nonetheless, solar power is underutilized because the charge controller switches to standby mode when the battery SOC exceeds 80%. To circumvent this constraint, this study introduces a novel dual input super boost (DISB) [21]. The block diagram of the proposed DSIB converter is depicted in Figure 1.

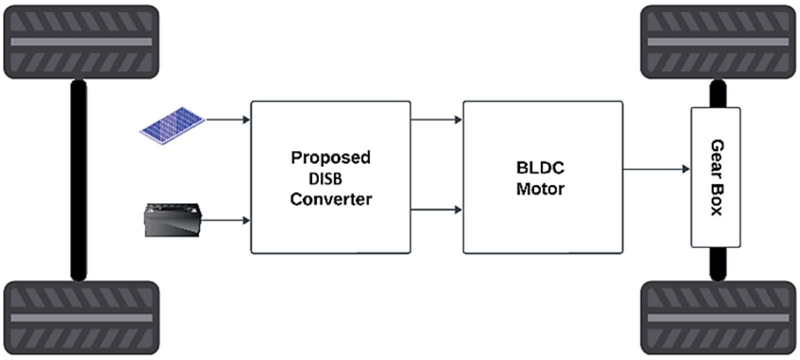

Figure 1. Block diagram of proposed DSIB converter

The DISB converter allows recharging batteries from various sources, providing fuel flexibility, quiet and efficient operation, and grid interface support in public parking lots. Additionally, it assists the utility grid by offering backup power, maintaining voltage and frequency, and mitigating peak demand [22], [23]. In comparison to the conventional configuration which requires three separate converters for the suggested DISB converter with a common buck-boost cell has six operating modes and uses a single-stage converter, which lowers the number of components and conduction devices needed for each working mode. Additionally, it provides improved dynamic performance and a broad range of speed control [24], [25]. The parts that follow provide more information on the voltage gain analysis and operating waveform.

2. METHOD

The DISB converter, as proposed, operates in six distinct modes, with five of them using the boost or buck operations. When the vehicle is operating at a fast speed, the solar PV and battery power are combined by the DISB converter to push the vehicle. One unique aspect of the suggested converter is this specific mode, which is called the super boost mode. The DISB converter's operating waveform in super boost mode is shown, displaying the waveforms of VL and IL as well as the gating signals of S1 and S2. The proposed DISB converter configuration is presented in Figure 2. Figure 2 depicts the proposed DISB converter, which operates in six unique modes.

- When the vehicle's state of charge (SOC) rises above 80%, the solar-powered mode is engaged.
- Vehicle mode powered by batteries.
- During the parking mode day.
- During night parking mode day.
- Mode of braking regeneration.
- High-speed operating mode.

When the battery level reaches 80%, the state of charge (SOC) for the DISB converter switches to solar-powered vehicle mode. In this configuration, the motor receives electricity from the solar PV and S2 regulates the vehicle's speed. When solar radiation isn't available, the battery source V2, which stands for the battery-powered vehicle mode, provides power to the motor. When there is no activity or during the day, parking, the Based on the battery's state of charge (SOC), the DISB converter functions in two modes: when SOC is less than 80%, solar power charges the battery; otherwise, solar power provides power to an external source. Parking mode at night is the mode in which the battery is charged by the external source (Vext) when the vehicle is parked. When the vehicle is in the regenerative braking mode, its inertial power is either transferred to the battery (if the state of charge is less than 80%) or dissipated as heat via a braking resistor (Rbrake).

In super boost mode, the DISB converter operates with specific time intervals and switching patterns. The maximum output voltage and an expression for the output voltage in super boost mode are obtained by applying the inductor's voltage-time balancing principle to compute the average output voltage. A unified output voltage (Vp.u) is provided to enable additional investigation, which reveals a wide adjustable range in the DISB converter. The corresponding circuits for the various operating modes shown in Simulink model Figure 3 such as the vehicle mode powered by solar energy, the vehicle mode powered by batteries, and the parking mode during the day are shown. Explanations of the energy storage and release procedures are included with each circuit. The inductor gathers energy from an external source and releases it to charge the battery when operating in buck mode (mode IV). When in regenerative mode (V), the energy produced by inertia is sent towards the brake resistor until the speed reaches zero. is achieved. Super boost mode (mode VI) is employed for high-speed operation, storing energy from both V1 and V2 sources and releasing it to the load. The proposed DISB converter facilitates flexible and efficient power control across various operating modes, enhancing its adaptability and performance in diverse scenarios. Simulink model of solar and battery input super boost DC–DC converter for solar powered electric vehicle is shown in Figure 3.

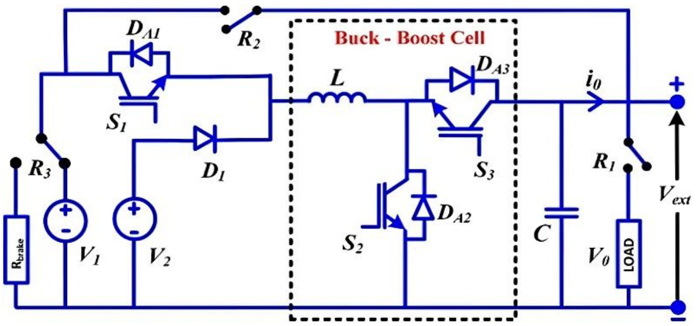

Figure 2. Proposed DISB converter configuration

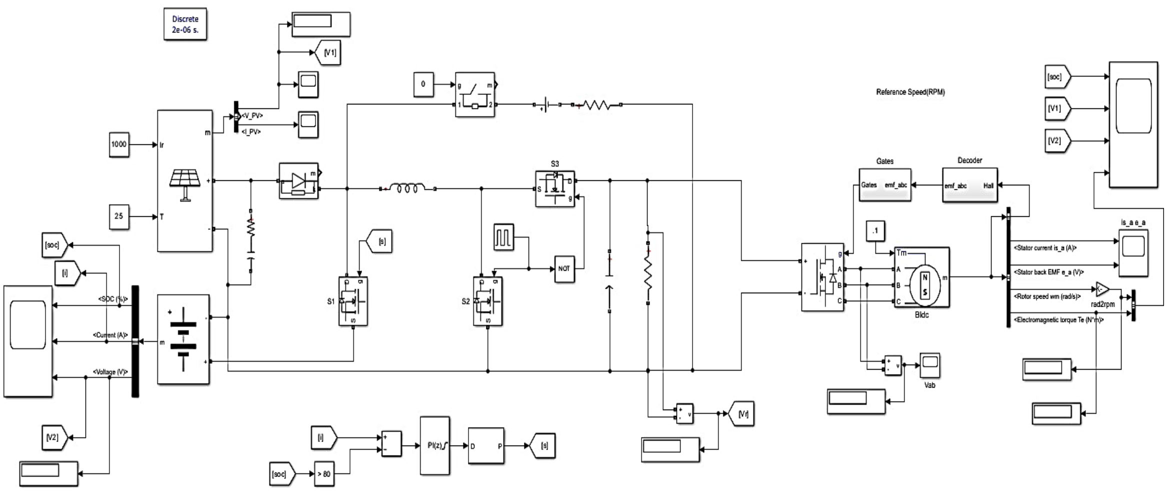

Figure 3. Simulink model of solar and battery input super boost DC-DC converter for solar-powered electric vehicle

3. RESULTS AND DISCUSSION

Figure 4 represents the solar mode. In this mode, the vehicle's state of charge (SOC) is greater than 80%. The solar panel will absorb sunlight and generates solar power. The DISB converter utilizes generated solar power (from solar PV) to provide electricity to the motor. In this mode battery is not utilized.

Figure 5 represents the battery mode. In this mode, the vehicle's state of charge (SOC) is 80% or below. The DISB converter is battery-powered. The motor is powered by the battery, ensuring continuous vehicle operation even when solar energy is not sufficient. Figure 6 shows the parking mode at day time. In this mode, the solar panel will harness sunlight and generate electric power to charge the vehicle's battery when state of charge is less than 80%.

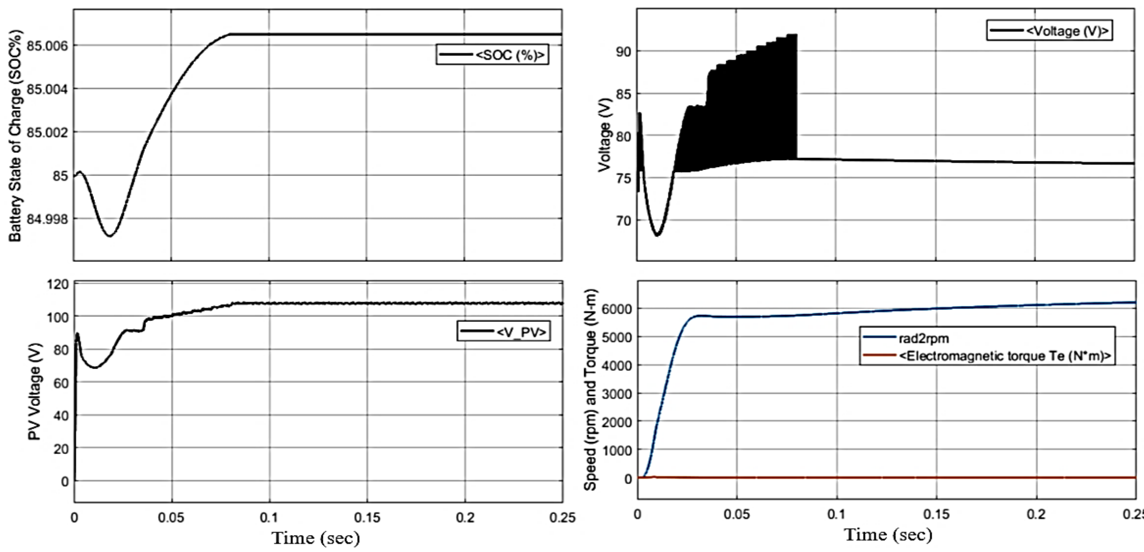

Figure 4. Vehicle mode powered by solar

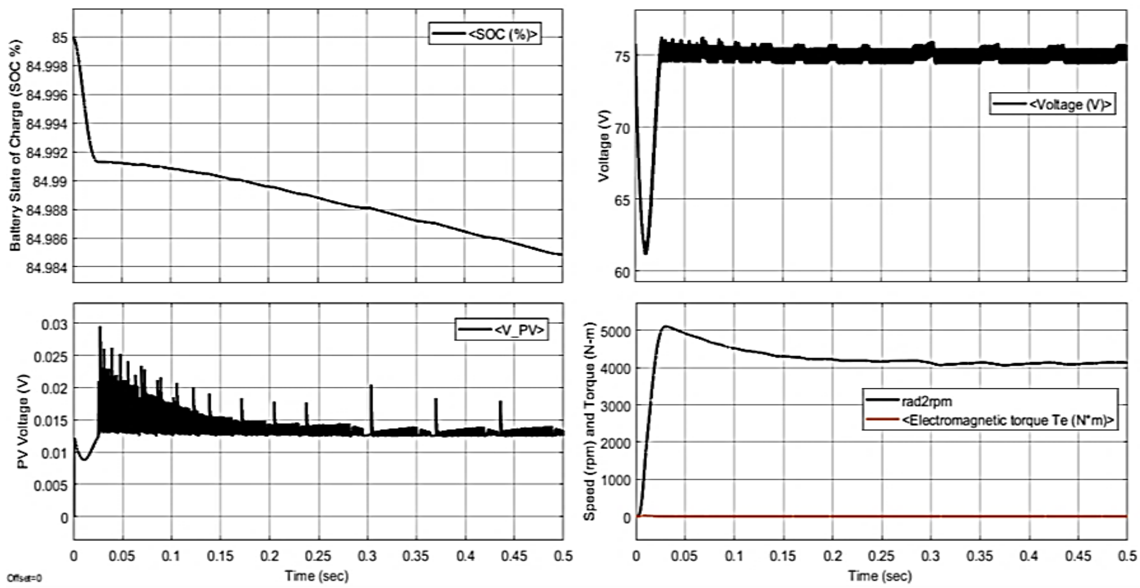

Figure 5. Vehicle mode powered by batteries

Figure 7 shows the parking mode at night-time. In this mode, solar energy is absent and the DISB converter charges the battery using an external source (Vext) while state of charge is less than 80%. This ensures that the vehicle's battery is replenished for the next day's operation. The Simulink output is shown in

Table 1 which shows the values of input voltages V1 and V2, output voltages, speed, and battery SOC condition during the solar mode, battery mode, during day-time parking mode, and during night-time parking mode.

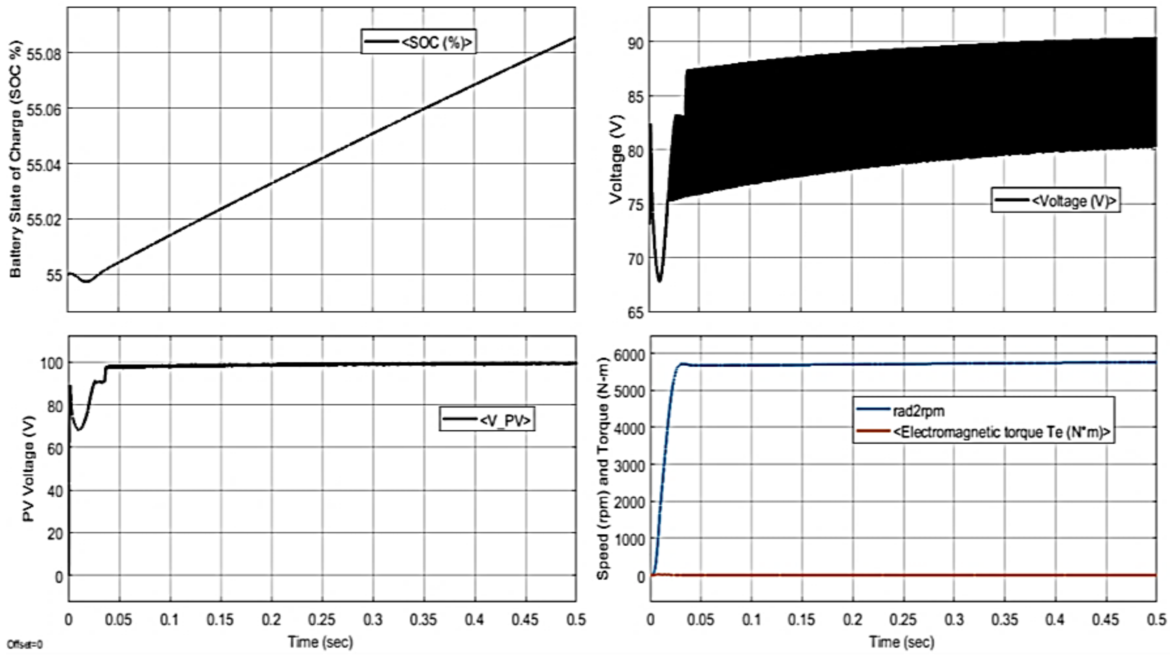

Figure 6. Parking mode during the day

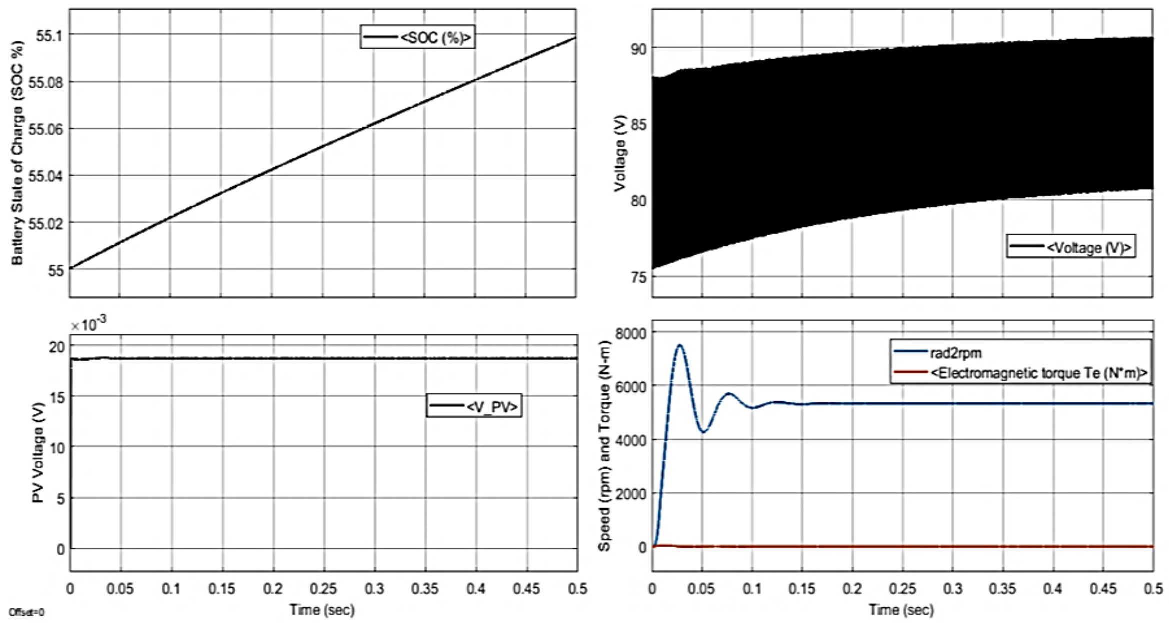

Figure 7. Parking mode during the night

Table 1. Simulink output

Modes	V1	V2	Output voltage	Speed	Battery SOC condition
Solar mode	108	76	611.1	6530	Constant
Battery mode	0	75.5	389.7	4181	Discharge
During day-time parking mode	100	82	543	-	Charging
During night-time parking mode	0	82	498	-	Charging

4. CONCLUSION

The solar and battery input super boost DC-DC converter solution is innovative for electric vehicles that run on solar energy. The proposed DISB converter stands as a promising technology to optimize the utilization of solar energy in electric vehicles. By operating in different modes underutilization of solar energy is maintained. It solves the problems of limited range and lengthy charging times, giving consumers more options when it comes to purchasing electric vehicles. The implementation is comparatively simple and economical, and it provides substantial benefits. MATLAB simulation has been used to validate the design.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. Authors state no conflict of interest.

DATA AVAILABILITY

The authors confirm that the data supporting the findings of this study are available within the article.

REFERENCES

[1] R. Sabzehgar, Y. M. Roshan, and P. Fajri, "Modelling and sliding-mode control of a single-phase single-stage converter with application to plug-in electric vehicles," *IET Power Electronics*, vol. 12, no. 3, pp. 620–626, 2019, doi: 10.1049/iet-pel.2018.5664.

[2] F. Naseri, E. Farjah, and T. Ghanbari, "An efficient regenerative braking system based on battery/supercapacitor for electric, hybrid, and plug-in hybrid electric vehicles with BLDC motor," *IEEE Transactions on Vehicular Technology*, vol. 66, no. 5, pp. 3724–3738, 2017, doi: 10.1109/TVT.2016.2611655.

[3] F. Yang, H. Ge, J. Yang, and H. Wu, "Dual-Input grid-connected photovoltaic inverter with two integrated DC-DC converters and reduced conversion stages," *IEEE Transactions on Energy Conversion*, vol. 34, no. 1, pp. 292–301, 2019, doi: 10.1109/TEC.2018.2878893.

[4] N. Kim and B. Parkhideh, "PV-battery series inverter architecture: A solar inverter for seamless battery integration with partial-power DC-DC optimizer," *IEEE Transactions on Energy Conversion*, vol. 34, no. 1, pp. 478–485, 2019, doi: 10.1109/TEC.2018.2873664.

[5] N. Saxena, I. Hussain, B. Singh, and A. L. Vyas, "Implementation of a grid-integrated PV-battery system for residential and electrical vehicle applications," *IEEE Transactions on Industrial Electronics*, vol. 65, no. 8, pp. 6592–6601, 2018, doi: 10.1109/TIE.2017.2739712.

[6] G. G. Kumar, K. Sundaramoorthy, S. Athikkal, and V. Karthikeyan, "Dual input superboost DC-DC converter for solar powered electric vehicle," *IET Power Electronics*, vol. 12, no. 9, pp. 2276–2284, 2019, doi: 10.1049/iet-pel.2018.5255.

[7] A. Mamadapur and G. Unde Mahadev, "Speed control of BLDC motor using neural network controller and PID controller," in *Proceedings of the 2019 2nd International Conference on Power and Embedded Drive Control, ICPEDC 2019*, 2019, pp. 146–151, doi: 10.1109/ICPEDC47771.2019.9036695.

[8] M. Nizam, H. Maghfiroh, A. Ubaidilah, I. Inayati, and F. Adriyanto, "Constant current-fuzzy logic algorithm for lithium-ion battery charging," *International Journal of Power Electronics and Drive Systems (IJPEDS)*, vol. 13, no. 2, p. 926, Jun. 2022, doi: 10.11591/ijpeds.v13.i2.pp926-937.

[9] K. Ahmed, S. Mohammed, S. Mohamed, and F. Fayez, "Brushless DC motor speed control using PID controller, fuzzy controller, and neuro fuzzy controller," *International Journal of Computer Applications*, vol. 180, no. 30, pp. 47–52, Apr. 2018, doi: 10.5120/ijca2018916783.

[10] S. Kaul, N. Tiwari, S. Yadav, and A. Kumar, "Comparative analysis and controller design for BLDC motor using PID and adaptive PID controller," *Recent Advances in Electrical & Electronic Engineering (Formerly Recent Patents on Electrical & Electronic Engineering)*, vol. 14, no. 6, pp. 671–682, Nov. 2021, doi: 10.2174/2352096514666210823152446.

[11] S. Gobinath and M. Madheswaran, "Deep perceptron neural network with fuzzy PID controller for speed control and stability analysis of BLDC motor," *Soft Computing*, vol. 24, no. 13, pp. 10161–10180, Jul. 2020, doi: 10.1007/s00500-019-04532-z.

[12] B. N. Kommula and V. R. Kota, "Design of MFA-PSO based fractional order PID controller for effective torque controlled BLDC motor," *Sustainable Energy Technologies and Assessments*, vol. 49, 2022, doi: 10.1016/j.seta.2021.101644.

[13] C. Chellaswamy and R. Ramesh, "Future renewable energy option for recharging full electric vehicles," *Renewable and Sustainable Energy Reviews*, vol. 76, pp. 824–838, 2017, doi: 10.1016/j.rser.2017.03.032.

[14] P. Unnikrishnan, V. Raveendran, and M. G. Nair, "Comparative analysis of modified INC and FLC for solar charger for electric two wheeler," *Proceedings - International Conference on Artificial Intelligence and Smart Systems, ICAIS 2021*, 2021, pp. 1625–1631, doi: 10.1109/ICAIS50930.2021.9395997.

[15] M. Mahmud, S. M. A. Motakabber, A. H. M. Zahirul Alam, and A. N. Nordin, "Adaptive PID controller using for speed control of the BLDC motor," in *IEEE International Conference on Semiconductor Electronics, Proceedings, ICSE*, 2020, pp. 168–171, doi: 10.1109/ICSE49846.2020.9166883.

[16] G. Naveen, T. H.-T. Yip, and Y. Xie, "Modeling and protection of electric vehicle charging station," in *2014 6th IEEE Power India International Conference (PIICON)*, Delhi, India, Dec. 2014, pp. 1–6, doi: 10.1109/POWERI.2014.7117733.

[17] R. P. Mandi, "Grid interactive rooftop solar PV power plant for educational institute," in *2017 International Conference On Smart Technologies For Smart Nation (SmartTechCon)*, Bengaluru, India, Aug. 2017, pp. 1473–1478, doi: 10.1109/SmartTechCon.2017.8358609.

[18] M. Mahmud, M. R. Islam, S. M. A. Motakabber, M. D. A. Satter, K. E. Afroz, and A. K. M. Ahasan Habib, "Control speed of BLDC motor using PID," *2022 IEEE 18th International Colloquium on Signal Processing and Applications, CSPA 2022 - Proceeding*, 2022, pp. 150–154, doi: 10.1109/CSPA55076.2022.9782030.

[19] R. Kandiban and R. Arulmozhiyal, "Speed control of BLDC motor using adaptive fuzzy PID controller," *Procedia Engineering*, vol. 38, pp. 306–313, 2012, doi: 10.1016/j.proeng.2012.06.039.

[20] P. K. Khanke and S. D. Jain, "Comparative analysis of speed control of BLDC motor using PI, simple FLC and fuzzy - PI controller," in *2015 International Conference on Energy Systems and Applications*, Pune, India, Oct. 2015, pp. 296–301, doi: 10.1109/ICESA.2015.7503359.

[21] Z. Zhang, O. C. Thomsen, and M. A. E. Andersen, "Dual-input soft-switched DC-DC converter with isolated current-fed half-bridge and voltage-fed full-bridge for fuel cell or photovoltaic systems," in *Conference Proceedings - IEEE Applied Power Electronics Conference and Exposition - APEC*, 2013, pp. 2042–2047, doi: 10.1109/APEC.2013.6520576.

[22] S. Naeiji, S. E. Abdollahi, S. R. Abdollahi, and B. Baigzadehnoe, "An improved bidirectional non-isolated dual-input DC-DC converter for electric vehicles application," in *2023 14th Power Electronics, Drive Systems, and Technologies Conference, PEDSTC 2023*, 2023, doi: 10.1109/PEDSTC57673.2023.10087176.

[23] Z. Zhang, O. C. Thomsen, M. A. E. Andersen, and H. R. Nielsen, "A novel dual-input isolated current-fed DC-DC converter for renewable energy system," in *2011 Twenty-Sixth Annual IEEE Applied Power Electronics Conference and Exposition (APEC)*, IEEE, Mar. 2011, pp. 1494–1501, doi: 10.1109/APEC.2011.5744790.

[24] A. Chambayil and S. Chattopadhyay, "A single-stage single phase bidirectional AC-AC converter for solid state transformer application," in *10th IEEE International Conference on Power Electronics, Drives and Energy Systems, PEDES 2022*, 2022, doi: 10.1109/PEDES56012.2022.10080768.

[25] J. D. Navamani, A. Geetha, D. Almakhles, A. Lavanya, and J. S. M. Ali, "Modified LUO high gain DC-DC converter with minimal capacitor stress for electric vehicle application," *IEEE Access*, vol. 9, pp. 122335–122350, 2021, doi: 10.1109/ACCESS.2021.3109273.

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