A self-lift quadratic boost converter topology for efficient marine propulsion drive systems

Subbulakshmy Ramamurthi[1], Dhandapani Meena[1], Velmurugan Palani[2], Shobana Devendiran[3], S. Ganesh Kumaran[4]
[1]Department of Electrical and Electronics Engineering, SRM Institute of Science and Technology, Ramapuram Campus, Chennai, India
[2]Department of Electrical and Electronics Engineering, St. Joseph's College of Engineering, Chennai, India
[3]Department of Electrical and Electronics Engineering, Panimalar Engineering College, Chennai, India
[4]Department of Electrical and Electronics Engineering, Sri Manakula Vinayagar Engineering College, Puducherry, India

Article Info

Article history:

Received May 16, 2025
Revised May 15, 2026
Accepted Jul 8, 2026

Keywords:

Efficient power conversion
High voltage gain
Induction motor renewable energy integration
Marine propulsion drive
NPC inverter
Self-lift quadratic boost converter

ABSTRACT

This paper proposes a high-gain self-lift quadratic boost converter (SL-QBC) topology tailored for efficient marine propulsion drive systems. The presented converter architecture incorporates a self-lift circuit embedded within a quadratic boost stage to achieve significant voltage gain while maintaining low component stress and high conversion efficiency. Specifically, the converter is capable of boosting a low input voltage of 45 V to a high output voltage of 473 V. The high-voltage output is then fed to the marine propulsion system through a three-phase, three-level neutral point clamped (NPC) inverter, which drives a three-phase induction motor. Designed to interface low-voltage DC sources such as batteries, photovoltaic panels, or fuel cells with high-power marine propulsion motors, the proposed topology offers a compact and cost-effective solution for electric and hybrid marine applications. The self-lift mechanism enhances voltage boosting capability by leveraging additional inductive and capacitive energy transfer paths. The topology ensures continuous current operation, reduced voltage ripple, and improved dynamic response, all of which are critical for smooth and reliable marine drive performance. Simulation results validate the converter's effectiveness, confirming its potential as a robust and efficient power conditioning stage in next-generation marine energy systems.

Corresponding Author:

Subbulakshmy Ramamurthi
Department of Electrical and Electronics Engineering, SRM Institute of Science and Technology
Ramapuram Campus, Chennai 600089, India
Email: subbular2@srmist.edu.in

1. INTRODUCTION

The marine sector is increasingly adopting electric and hybrid propulsion systems to achieve cleaner, quieter, and more energy-efficient operation. Batteries, fuel cells, and renewable energy sources are commonly used in electric vessels; however, their output voltage is often insufficient to directly supply a high-power propulsion inverter. Therefore, a high-gain DC–DC converter is required to increase and regulate the source voltage before feeding the motor-drive stage. Although a conventional boost converter can provide voltage amplification, a large conversion ratio requires an excessive duty cycle, resulting in increased conduction loss, current stress, and reduced practical voltage gain. Several high step-up converter topologies have been developed to address these limitations. Non-coupled-inductor SEPIC, resonant switched-capacitor, and active-clamped coupled-inductor converters were proposed in [1]-[3] to improve voltage gain and reduce switching stress. A continuous input-current converter using an integrated coupled inductor was presented in [4].

An interleaved converter incorporating voltage-multiplier cells and coupled inductors was introduced in [5] to improve gain and reduce source-current ripple. Although these configurations provide better conversion performance, additional magnetic components, multiplier cells, and passive devices increase circuit complexity, converter volume, leakage-inductance effects, and design cost.

Quadratic boost converters offer an attractive solution because they provide a high conversion ratio without requiring an extremely large duty cycle. Reduced semiconductor voltage stress, lower inductor currents, and different inductor-conduction modes were investigated in [6]-[8]. However, quadratic converters exhibit higher-order dynamic behavior, which makes their regulation more challenging than that of conventional boost converters. Fixed-frequency sliding-mode, improved voltage-mode, and modified current-mode control techniques were developed in [9]-[11]. A detailed mathematical model of a low-energy-storage quadratic converter was presented in [12] to analyze its internal energy transfer and passive-component behavior.

Recent studies have focused on improving voltage gain, input-current quality, and component utilization. Quadratic extended-duty-ratio converters, reduced-ripple topologies, and converters with continuous input and output currents were reported in [13]-[15]. Single-switch switched-capacitor, integrated coupled-inductor, and silicon-carbide-based quadratic converters were proposed in [16]-[18]. A non-series energy-transfer switching strategy was investigated in [19] to modify the power-transfer process of a conventional quadratic converter. Despite these developments, many reported configurations still require coupled inductors, additional switching cells, specialized semiconductor devices, or complicated operating strategies. Self-lift circuits provide another method for improving converter gain through the controlled charging and discharging of lift capacitors. The time-domain behavior of a quadratic boost converter incorporating a self-lift circuit was examined in [20], whereas the present work extends it by integrating the converter with a three-level NPC inverter for a complete marine induction-motor propulsion drive. A double-self-lift cell was subsequently integrated into a modified quadratic converter for fuel-cell applications in [21]. These studies demonstrated that self-lift techniques can improve voltage gain without forcing the converter to operate at an excessively high duty cycle. However, their application as the front-end power-conversion stage of a complete marine propulsion drive has received limited attention.

Converter regulation under variations in source voltage and propulsion load is also essential. Sliding-mode control, optimization-assisted PID control, and predictive control techniques were investigated for renewable-energy and multilevel converter systems in [22]-[24]. At the inverter stage, multilevel structures provide lower harmonic distortion and reduced semiconductor voltage stress compared with conventional two-level inverters. Reduced-switch multilevel inverter topologies for renewable-energy integration and motor-drive applications were reviewed in [25]. In this work, a self-lift quadratic boost converter is integrated with a three-phase, three-level neutral-point-clamped inverter for a marine induction-motor propulsion system. The proposed SLQBC combines quadratic voltage amplification with a self-lift network to generate the required DC-link voltage without an excessive duty cycle. The schematic representation of a marine propulsion system using SL-QBC and NPC inverter is shown in Figure 1.

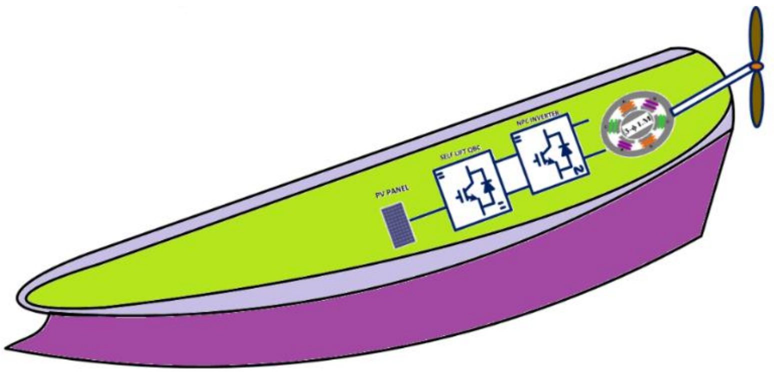

Figure 1. Marine propulsion system using SL-QBC and NPC inverter

2. PROPOSED SELF-LIFT QUADRATIC BOOST CONVERTER

The proposed self-lift quadratic boost converter (SL-QBC) is a high-gain DC-DC converter topology designed to interface low-voltage sources with high-voltage marine propulsion systems. Figure 2 depicts the proposed self-lift quadratic boost converter with NPC. This converter combines the benefits of a conventional quadratic boost converter with a self-lift circuit to significantly increase the voltage conversion ratio while maintaining high efficiency and reduced component stress. The circuit consists of a primary inductor L_1, auxiliary inductors L_2 and L_3, and several passive and active components including diodes D_0 to D_7, capacitors C_0 to C_4, and a power switch S. The input source V_{in}, typically a battery or a fuel cell stack, is connected to L_1, which plays a crucial role in the energy storage process.

The converter's structure can be broken down into three functional parts: the primary boost stage, the quadratic extension, and the self-lift unit. The primary boost stage includes L_1, diode D_1, and capacitor C_4, which initially step up the input voltage. The quadratic stage, formed through diode D_6 and capacitor C_1, further increases the voltage by using a voltage stacking principle. The most critical section is the self-lift circuit, comprising L_2, L_3, C_2, and diodes D_2, D_3, and D_7. This part of the converter facilitates energy regeneration and efficient voltage transfer to the output side by creating an additional boosting path. The final output is filtered through capacitor C_0 and delivered to the load R_0 through the diode network that also prevents reverse current. The design ensures continuous input current, minimized voltage stress on the switch, and an overall high step-up gain, which is critical in electric marine propulsion where high-voltage motors are driven by low-voltage renewable or battery sources.

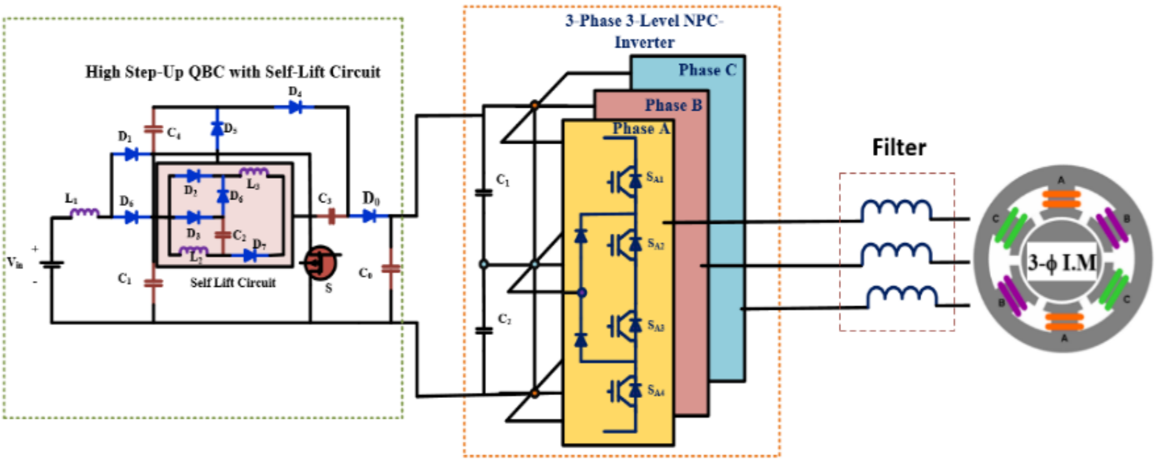

Figure 2. Self-lift quadratic boost converter with NPC inverter for marine induction motor drive

3. SIMULATION RESULTS AND DISCUSSION

MATLAB/Simulink was utilized to simulate the performance of the proposed self-lift quadratic boost converter (SL-QBC); the outputs are shown in the figures. The simulation outputs demonstrate the effectiveness of the designed converter-inverter architecture in delivering high gain and efficient motor control. The input voltage, as depicted in Figure 3, is maintained at 45 V. Through the high-gain DC-DC conversion stage, this input is efficiently boosted to an output voltage of 430 V across the R-load, as shown in Figure 4. This significant voltage gain validates the performance of the converter topology. Table 1 presents the simulation parameters of QBC.

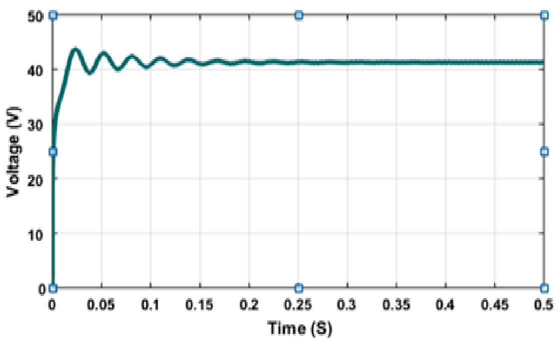

Figure 3. Input voltage of the converter

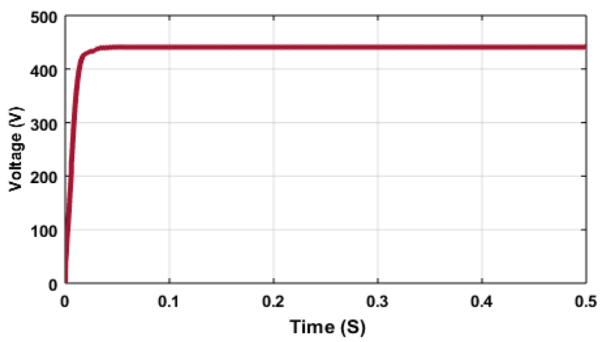

Figure 4. Output voltage of the converter

Table 1. Simulation parameters

Component	Value	Component	Value
Input voltage V_{in}	45 V	Inductor L2, L3	100 μH each
Output voltage V_{out}	473 V	Capacitor C1, C2	4 μF each
Switching frequency	10 kHz	Capacitor C3	2.2 μF
Duty cycle (D)	0.6	Capacitor C4, C5	650 nF each
Inductor L1	200 μH	Output capacitor C0	470 μF

The output current through the R-load, illustrated in Figure 5, is approximately 6.5 A, which complements the voltage waveform and confirms stable power delivery to the load. Correspondingly, Figure 6 presents the output power, which reaches around 1500 W, indicating efficient energy conversion with minimal losses. The output voltage of the NPC inverter, as shown in Figure 7, is approximately 2000 V. This high output voltage ensures the motor receives adequate excitation for operation. Induction motor performance is further validated in Figure 8, where the speed of the induction motor is recorded at 1800 RPM, representing synchronous operation under the given load. The corresponding electromagnetic torque, shown in Figure 9, is around 600 Nm, reflecting the system's ability to provide the necessary mechanical drive torque without significant fluctuations.

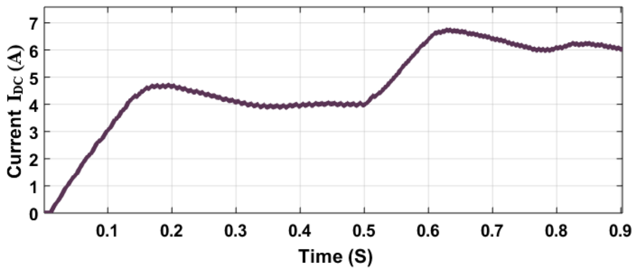

Figure 5. Output current of converter

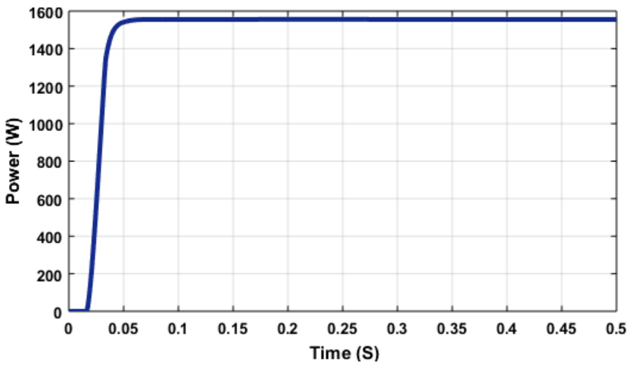

Figure 6. Output power of converter

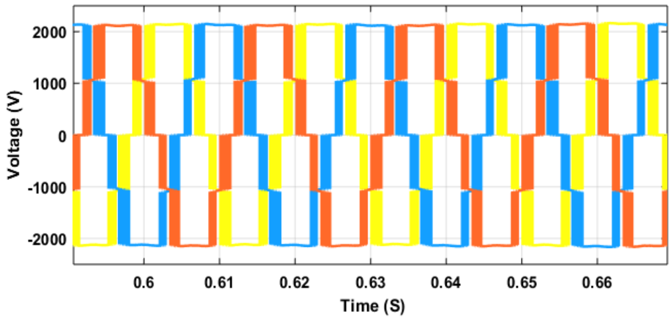

Figure 7. Output voltage of NPC inverter

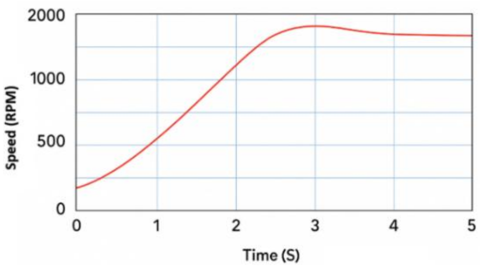

Figure 8. Speed of induction motor

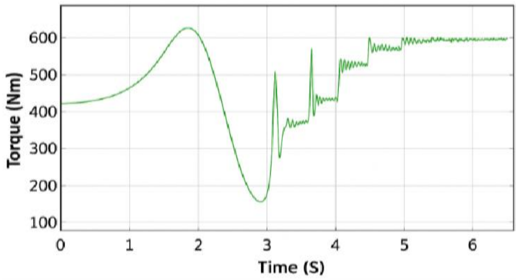

Figure 9. Torque of induction motor

4. CONCLUSION

This paper presented a self-lift quadratic boost converter integrated with an NPC inverter and induction motor drive for efficient marine propulsion applications. The proposed converter topology successfully achieves a high voltage gain from a low-level input, making it highly suitable for systems where space and power supply are constrained, such as marine environments. MATLAB/Simulink-based simulation results validated the converter's performance, demonstrating stable output voltage (430 V) and power (1500 W) with an input of just 45 V. The NPC inverter efficiently delivered 2000 V to the motor drive, achieving a steady speed of 1800 RPM and a torque output of 600 Nm, ensuring smooth and reliable propulsion. The proposed system not only enhances the efficiency and responsiveness of marine drives but also contributes to reduced component stress and improved system longevity. Future work may involve hardware implementation and performance evaluation under dynamic sea load conditions.

FUNDING INFORMATION

Authors state no funding was involved.

AUTHOR CONTRIBUTIONS STATEMENT

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

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Subbulakshmy Ramamurthi	✓	✓	✓	✓	✓	✓		✓	✓	✓			✓	
Dhandapani Meena		✓				✓		✓	✓	✓	✓	✓		✓
Velmurugan Palani	✓		✓	✓			✓			✓	✓		✓	✓
Shobana Devendiran	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓	
S. Ganesh Kumaran		✓	✓	✓	✓		✓	✓	✓	✓		✓		✓

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

Authors state no conflict of interest.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author, upon reasonable request. All simulation results and analysis outputs used in this research are documented within the manuscript. No publicly archived datasets were used or generated specifically for this study. Additional information may be provided to qualified researchers upon request.

REFERENCES

[1] S. A. Ansari and J. S. Moghani, “A novel high voltage gain noncoupled inductor SEPIC converter,” *IEEE Transactions on Industrial Electronics*, vol. 66, no. 9, pp. 7099–7108, 2019, doi: 10.1109/TIE.2018.2878127.

[2] Y. Ye, K. W. E. Cheng, and S. Chen, “A high step-up PWM DC-DC converter with coupled-inductor and resonant switched-capacitor,” *IEEE Transactions on Power Electronics*, vol. 32, no. 10, pp. 7739–7749, 2017, doi: 10.1109/TPEL.2016.2633381.

[3] K. I. Hwu and Y. T. Yau, “High step-up converter based on coupling inductor and bootstrap capacitors with active clamping,” *IEEE Transactions on Power Electronics*, vol. 29, no. 6, pp. 2655–2660, 2014, doi: 10.1109/TPEL.2013.2289387.

[4] H. Ardi, A. Ajami, and M. Sabahi, “A novel high step-up DC-DC converter with continuous input current integrating coupled inductor for renewable energy applications,” *IEEE Transactions on Industrial Electronics*, vol. 65, no. 2, pp. 1306–1315, 2018, doi: 10.1109/TIE.2017.2733476.

[5] M. L. Alghaythi, R. M. O’Connell, N. E. Islam, M. M. S. Khan, and J. M. Guerrero, “A high step-up interleaved DC-DC converter with voltage multiplier and coupled inductors for renewable energy systems,” *IEEE Access*, vol. 8, pp. 123165–123174, 2020, doi: 10.1109/ACCESS.2020.3007137.

[6] S. W. Lee and H. L. Do, “Quadratic boost DC-DC converter with high voltage gain and reduced voltage stresses,” *IEEE Transactions on Power Electronics*, vol. 34, no. 3, pp. 2397–2404, 2019, doi: 10.1109/TPEL.2018.2842051.

[7] G. Li, X. Jin, X. Chen, and X. Mu, “A novel quadratic boost converter with low inductor currents,” *CPSS Transactions on Power Electronics and Applications*, vol. 5, no. 1, pp. 1–10, 2020, doi: 10.24295/CPSSTPEA.2020.00001.

[8] O. Lopez-Santos, L. Martinez-Salamero, G. Garcia, H. Valderrama-Blavi, and D. A. Zambrano-Prada, “Steady-state analysis of inductor conduction modes in the quadratic boost converter,” *IEEE Transactions on Power Electronics*, vol. 32, no. 3, pp. 2253–2264, 2017, doi: 10.1109/TPEL.2016.2557582.

[9] S. H. Chincholkar and C. Y. Chan, “Design of fixed-frequency pulse width-modulation-based sliding-mode controllers for the quadratic boost converter,” *IEEE Transactions on Circuits and Systems II: Express Briefs*, vol. 64, no. 1, pp. 51–55, 2017, doi: 10.1109/TCSII.2016.2546902.

[10] C. Y. Chan, “An improved voltage-mode controller for the quadratic boost converter,” *IEEE Transactions on Circuits and Systems II: Express Briefs*, vol. 69, no. 2, pp. 454–458, 2022, doi: 10.1109/TCSII.2021.3080289.

[11] C. Y. Chan, S. Chincholkar, and W. Jiang, “A modified fixed current-mode controller for improved performance in quadratic boost converters,” *IEEE Transactions on Circuits and Systems II: Express Briefs*, vol. 67, no. 10, pp. 2014–2018, 2020, doi: 10.1109/TCSII.2019.2942057.

[12] O. Lopez-Santos, N. L. Varon, J. C. Rosas-Caro, J. C. Mayo-Maldonado, and J. E. Valdez-Resendiz, “Detailed modeling of the low energy storage quadratic boost converter,” *IEEE Transactions on Power Electronics*, vol. 37, no. 2, pp. 1885–1904, 2022, doi: 10.1109/TPEL.2021.3105081.

[13] A. Gupta, N. Korada, and R. Ayyanar, “Quadratic-extended-duty-ratio boost converters for ultra high gain application with low input current ripple and low device stress,” *IEEE Transactions on Industry Applications*, vol. 59, no. 1, pp. 938–948, 2023, doi: 10.1109/TIA.2022.3207132.

[14] M. A. B. Kumar and V. Krishnasamy, “Quadratic boost converter with less input current ripple and rear-end capacitor voltage stress for renewable energy applications,” *IEEE Journal of Emerging and Selected Topics in Power Electronics*, vol. 10, no. 2, pp. 2265–2275, 2022, doi: 10.1109/JESTPE.2021.3122354.

[15] H. Gholizadeh, S. A. Gorji, and D. Sera, “A quadratic buck-boost converter with continuous input and output currents,” *IEEE Access*, vol. 11, pp. 22376–22393, 2023, doi: 10.1109/ACCESS.2023.3253102.

[16] D. V. S. Reddy, M. Golla, and S. Thangavel, “High-performance single switch high step-up quadratic DC-DC converter with switched capacitor cell,” *IEEE Access*, vol. 12, pp. 62850–62860, 2024, doi: 10.1109/ACCESS.2024.3395539.

[17] S. S. Algharrawi and M. Delshad, “A new quadratic boost converter featuring an integrated coupled inductor and low input-current ripple for renewable energy sources,” *Energy Reports*, vol. 15, 2026, doi: 10.1016/j.egyr.2026.109216.

[18] V. Srimaheswaran and M. M. R. Singaravel, “SiC-based high-gain quadratic boost converter with continuous input current for renewable energy applications,” *IEEE Transactions on Circuits and Systems II: Express Briefs*, vol. 73, no. 4, pp. 488–492, 2026, doi: 10.1109/TCSII.2026.3666233.

[19] L. H. Diaz-Saldierna, J. C. Rosas-Caro, J. Leyva-Ramos, J. G. González-Hernández, F. Beltran-Carbajal, and J. Posada, “Different switching strategy for a quadratic boost converter based on non-series energy transfer (QBC-NSET),” *Electricity*, vol. 7, no. 2, 2026, doi: 10.3390/electricity7020031.

[20] S. Ramamurthi, P. Velmurugan, S. Devendiren, and S. Manivannan, “Time-domain performance of QBC with self-lift circuit,” *International Journal of Power Electronics and Drive Systems*, vol. 16, no. 4, pp. 2491–2499, 2025, doi: 10.11591/ijpeds.v16.i4.pp2491-2499.

[21] S. Behera, R. Patel, B. Nayak, A. Abhishek, T. Roy, and J. M. Guerrero, “Double self-lift (DSL) cell based high gain modified quadratic converter for fuel cell application,” in *2025 3rd IEEE International Conference on Industrial Electronics: Developments & Applications (ICIDeA)*, IEEE, Feb. 2025, pp. 1–6. doi: 10.1109/ICIDeA64800.2025.10963326.

[22] S. C. Selvi, R. Govindaraj, S. Chowdhury, S. Singh, and B. Khan, “Embedded-based quadratic boost converter with sliding-mode controller for the integration of solar photo-voltaic source with microgrid,” *IEEE Journal of the Electron Devices Society*, vol. 12, pp. 831–841, 2024, doi: 10.1109/JEDS.2023.3340249.

[23] W. Margaret Amutha and P. Srinivasan, “Hybrid falcon optimization algorithm-PID controller based wind powered improved bridgeless CUK converter for telecom applications,” *Arabian Journal for Science and Engineering*, vol. 50, no. 21, pp. 17863–17872, Nov. 2025, doi: 10.1007/s13369-025-10155-4.

[24] L. Pu, W. Yue, C. Wulong, and L. Wanjun, “Study on predictive control strategy of modular multilevel converter optimization model,” in *Proceeding of the CSEE*, 2014, pp. 6380–6388.

[25] P. R. Bana, K. P. Panda, R. T. Naayagi, P. Siano, and G. Panda, “Recently developed reduced switch multilevel inverter for renewable energy integration and drives application: topologies, comprehensive analysis and comparative evaluation,” *IEEE Access*, vol. 7, pp. 54888–54909, 2019, doi: 10.1109/ACCESS.2019.2913447.

BIOGRAPHIES OF AUTHORS

Subbulakshmy Ramamurthi received her B.E. (EEE) and M.E. (PED) from Mailam Engineering College, which is affiliated with Anna University, Chennai, India, in 2007 and 2009. She received her Ph.D. degree from the SRM Institute of Science and Technology, Chennai, India, in 2024. She is currently working as an assistant professor in the Department of Electrical and Electronics Engineering, SRM Institute of Science and Technology, Ramapuram. Her current research interests include DC converters, multilevel inverters, renewable energy systems, and electric vehicles. She can be contacted at email: subbular2@srmist.edu.in.

Dhandapani Meena received the B.E. degree in electrical and electronics engineering from Annamalai University in 2007 and the M.E degree in power electronics and drives from Anna University in 2010, and completed her Ph.D. from Annamalai University in 2025. She is currently working as an assistant professor in the Department of Electrical and Electronics Engineering, SRM Institute of Science and Technology, Ramapuram. Her areas of interest include the field of power converters, applications of optimization in power converters, and electric vehicle battery charging systems. She can be contacted at email: meenad@srmist.edu.in.

Velmurugan Palani received B.E. degree in electrical and electronics engineering from V.R.S. College of Engineering and Technology, India, in 2007. He did a Master of Engineering in Power Electronics and Drives from Mailam Engineering College, India in 2009. He received his Ph.D. in electrical engineering from Annamalai University, India, in 2017. Currently, he is working as an associate professor in the Department of Electrical and Electronics Engineering at St. Joseph's College of Engineering with 15 years of teaching and research experience. He has published a number of research papers in various journals and conferences. His research interests include power quality converters, special electrical machines, machine design, drives and control, electric vehicles, and battery management systems. He can be contacted at email: velmuruganp@stjosephs.ac.in.

Shobana Devendiren has obtained her B.E. degree from Madras University in 2003. She has obtained an M.E. degree in Power Electronics and Drives from Anna University, Tirunelveli in 2009. Presently, she is doing research work with Sathyabama Institute of Science and Technology, Chennai, Tamil Nadu, India, in the area of power converters. Her areas of interest include the field of power electronics, motor drives, renewable energy, and control system engineering. She can be contacted at email: shobana_d80@yahoo.co.in.

S. Ganesh Kumaran has obtained his B.Tech. degree in electrical and electronics engineering from Pondicherry University in 2008 and the M.E. degree in power systems from Annamalai University in 2011. He completed his Ph.D. in 2017 from Annamalai University. Currently, he is working as an associate professor in the Department of Electrical and Electronics Engineering at Sri Manakula Vinayagar Engineering College, Puducherry, with 15 years of teaching and research experience. His areas of interest are power quality converters, renewable energy, and smart grid. He can be contacted at email: drsganeshkumaran@smvec.ac.in.