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Review on Innovative DC-DC Converter Design for High Efficiency and High Voltage Gain Applications

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ABSTRACT

This paper reviewed the advancements in DC-DC converter technologies, emphasizing their role in addressing the demands of high efficiency and high voltage gain in renewable energy systems, electric vehicles (EVs), and distributed energy networks. Advanced topologies, including hybrid, quadratic, triple-boost, coupled inductor, and voltage multiplier designs, were evaluated for their ability to overcome the limitations of traditional converters. Key findings highlighted significant improvements in energy efficiency, exceeding 95%, and a substantial reduction in voltage ripple. Performance metrics such as scalability, thermal management, and component stress were analyzed, demonstrating the suitability of these designs for diverse applications. Comparative analyses illustrate the superiority of innovative designs in meeting the energy needs of emerging technologies. Applications in renewable energy, EV infrastructure, and distributed networks underscore the transformative potential of these converters in optimizing power delivery and enhancing system reliability. This review bridged the gap between theoretical advancements and practical implementations, showcasing the pivotal contribution of DC-DC converter to modern energy systems.

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1. INTRODUCTION

DC-DC converters represent a cornerstone in modern power electronics, offering indispensable functionality as intermediaries between generation systems and their load. Their critical role in regulating voltage ensures the seamless integration of renewable energy sources, electric vehicles (EVs), and DC microgrids. As the global adoption of photovoltaic (PV) arrays, fuel cells, and battery systems accelerates, the demand for efficient, reliable DC-DC converters has grown substantially. These converters must not only provide the necessary voltage step-up for low and variable input levels but also maintain high efficiency under diverse and challenging caused by variable solar irradiance, ensuring stable output and efficient power delivery to storage or grid systems.

Traditional boost converters have been widely employed due to their simplicity and low cost. However, they face significant limitations in applications requiring high voltage gains and dynamic load regulation. As duty cycles approach extreme values, conduction and switching losses escalate, reducing efficiency and increasing thermal stress on components. These challenges highlight the need for advanced DC-DC converter topologies, including switched inductors, coupled inductors, voltage scalability, and significantly higher voltage gains, addressing the limitations of conventional design.

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The innovations in DC-DC converter technology have far-reaching implications across multiple domains. High-efficiency converters in EV systems enable rapid charging, optimized energy utilization, and extended battery lifespan. In DC microgrids, the modular and scalable design facilitates stable voltage regulation and efficient power distribution, even under dynamic loading conditions. Advanced innovations such as coupled inductors, transformerless configurations, and hybrid topologies have not only improved efficiency but also reduced size and material costs, positioning these systems as vital components in next-generation energy architecture.

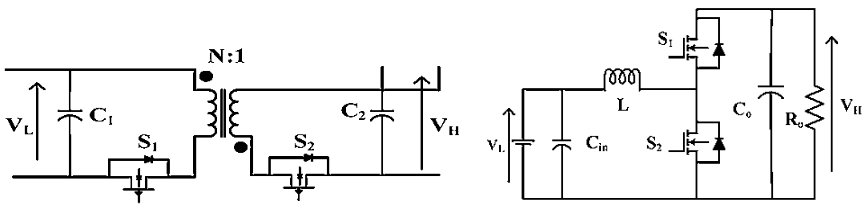
This comprehensive review explores the state-of-the-art in DC-DC converter technologies, focusing on their operational principles, innovative topologies, and key applications. Through detailed analyses of their performance metrics and design advancements, this paper offers insights into the current trends and identifies pathways for further development and optimization.

2. RESEARCH METHOD

DC-DC converters are critical tools in power electronics, designed to convert input voltage into levels suitable for specific applications. These converters are categorized into isolated and non-isolated types, each offering distinct advantages and applications. This section also explores advanced configurations such as switched inductors, coupled inductors, and voltage multipliers, highlighting their operational principles, performance benefits, and challenges.

2.1. Isolated and Non-isolated Converter

Isolated converters employ transformers to achieve electrical separation between the input and output, ensuring enhanced safety and fault isolation. This feature makes them indispensable in high-voltage and safety-critical applications, such as industrial power supplies, medical devices, and grid-tied renewable energy systems. The flyback topology, illustrated in **Figure 1a**, exemplifies this approach, storing energy in the transformer's primary winding during the switch-on phase and transferring it to the output during the switch-off phase. Despite their scalability issues, restricting their application to low-power systems [1].



(a) (b)

Figure 2. Isolated and non-isolated converter topology, (a) Flyback converter; (b) Boost converter

Advanced isolated topologies such as push-pull, half-bridge, and full-bridge converters address the challenges. Push-pull converter, for instance, employs two switches to alternately drive the transformer windings, enhancing flux utilization and reducing core losses. Full-bridge converters, as depicted in [2], [3], leverage multiple switches and advanced control strategies to achieve superior efficiency and high-power capacity. The modular resonant topologies presented by [4] also highlight the improvement in energy transfer efficiency for grid-connected renewable systems.

Further research by [5] focuses on isolated bidirectional designs that ensure efficient energy transfer in high-frequency transformers in isolated designs, such as the work by [6], which enhances performance by reducing core size and improving power density in PV-fed microgrids. An isolated high-gain topology by [7] integrates magnetic flux balancing to mitigate transformer saturation, further enhancing efficiency and voltage regulation.

Non-isolated converters are compact, cost-effective, and efficient, making them ideal for applications where electrical isolation is necessary. Examples include boost, buck-boost, SEPIC, and Cuk converters. The boost converter, shown in **Figure 1b**, operates by storing energy in an inductor during the on-state and releasing it into the load during the off-state. While effective for basic step-up applications, boost converters exhibit limitations such as high ripple and restricted voltage gain under extreme duty cycles [8].

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SEPIC converters address these constraints by enabling bidirectional energy flow and offering step-up and step-down capabilities, making the battery management systems versatile. Similarly, Cuk converter excels in minimizing input and output current ripple, which is crucial for applications such as LED drivers and portable electronics. Research by [9] demonstrated how transformerless configurations improve efficiency and compactness, addressing the traditional limitations of these topologies. Voltage boosting techniques using cascade networks in SEPIC and Cuk designs have also been explored, achieving high efficiency in renewable systems [10].

2.2. Switched Inductor

Switched inductor converters achieve substantial voltage gains by alternately configuring inductors for parallel charging and series discharging. This topology, illustrated in **Figure 2**, minimizes duty cycle requirements and optimizes transfer efficiency. These converters are particularly effective in medium-voltage renewable energy systems and microgrids, where robust voltage regulation is essential under load conditions.

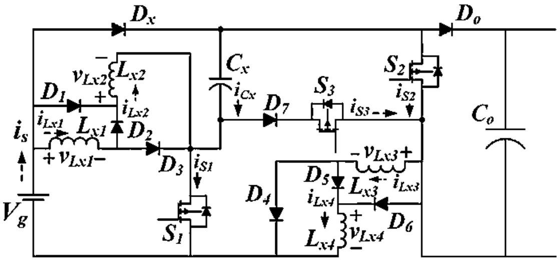

Figure 2. Switched inductor converter topology

Research [11] emphasizes the advantages of interleaved switched inductor designs in reducing ripple and thermal stress. Such configurations also improve power density and dynamic response, as highlighted by [12]. Advanced implementations like active clamping and dual-phase interleaving minimize switching applications such as EV charges and grid-connected PV [13]. Additional contributions by [14] showcase an optimized switched inductor topology integrating soft-switching mechanism to reduce noise and improve efficiency under high power loads.

2.3. Coupled Inductor

Coupled inductor topologies leverage magnetic coupling to achieve high voltage gain within compact designs. By integrating primary and secondary windings into a single core, these converters reduce core losses and enhance flux utilization [15]. **Figure 3** depicts a coupled inductor-based boost converter with clamping circuits to suppress leakage inductance and improve efficiency [15]. Such designs are particularly advantageous in high-power applications such as grid-tied renewable systems, EV fast chargers, and DC microgrids [16].

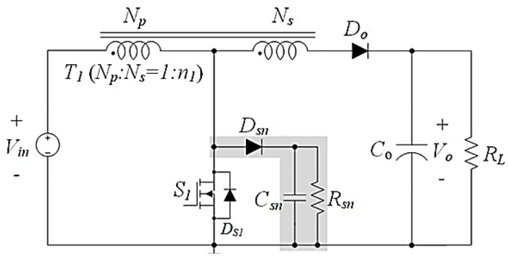

Figure 3. Conventional boost converter using a coupled inductor

Advanced coupled inductor configuration distributed power across multiple phases, reducing ripple and electromagnetic interference. Research by [17] explores the integration of high-saturation magnetic materials, enabling these converters to accommodate higher power densities. In [18], the researcher reviewed active flux balancing techniques, which ensure reliable performance in high-demand scenarios such as multi-source renewable energy setups. Recent contribution by [19] have expanded the applicability of coupled inductors in hybrid microgrid configurations, demonstrating their capability to handle variable renewable inputs while maintaining high system stability.

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2.4. Voltage Multiplier

Voltage multipliers amplify output voltage incrementally through cascaded diodes and capacitors. **Figure 4** illustrates this approach, where each stage adds discrete voltage increments, achieving high gains in compact configurations [20]. Transfomerless designs address the complexity of traditional voltage multipliers, enhancing efficiency and reducing component counts. The designs are particularly effective in low-power applications, such as portable electronics, LED drivers, and compact renewable systems [21].

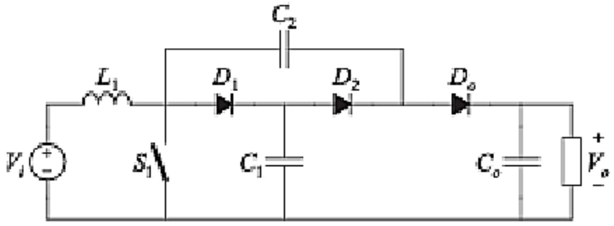


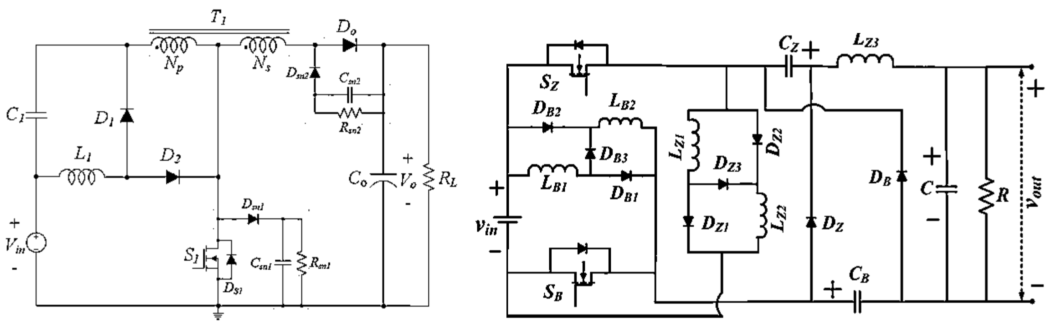
Figure 4. Non-isolated dc-dc converters based on the voltage multiplier

A hybrid voltage multiplier combines switched capacitors and inductors to achieve higher gains and improve stability under dynamic loads. In [22] demonstrate these configurations in high-frequency applications, highlighting their adaptability and cost-effectiveness for compact systems. In other ways, [23] further analyzed a modular voltage multiplier design integrated into multi-input systems, enabling enhanced energy sharing and fault tolerance across diverse energy sources.

2.5. Innovative Topologies

Innovative DC-DC converter designs integrated features from multiple topologies to maximize performance. Quadratic and triple-boost converters, depicted in **Figure 5a**, utilize multi-stage inductor-capacitor networks to achieve voltage gains exceeding 20x. These designs, evaluated by [24], are particularly effective for PV systems, energy storage, and PV power management, where high step-up ratios and low losses are paramount.

Quadratic converter leverage cascaded inductor and capacitor arrangements to minimize component stress and increase energy transfer efficiency [25]. By employing stages, quadratic converter achieves stable output with reduced ripple, making them ideal for a renewable system. Triple-boost converter, on the other hand, expands upon this concept by integrating an additional stage, further enhancing voltage gain while maintaining a compact form factor. These designs have been pivotal in grid-connected applications where scalability and reliability are critical [26].



(a) (b)

Figure 5. Innovative DC-DC converter, (a) Quadratic boost DC-DC converter using a coupled-inductor, (b) Hybrid zeta-boost converter

A hybrid converter combines switched inductors, coupled inductors, and voltage multiplier elements, creating modular, scalable configurations. **Figure 5b** illustrates the hybrid topology's ability to balance efficiency, fault tolerance, and adaptability, making it ideal for high-voltage DC applications and grid-connected renewable systems [27]. Recent study by [28] has emphasized the potential of hybrid designs in adapting to load variability in microgrids, ensuring consistent performance under fluctuating demand.

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Hybrid design also facilitates seamless integration with multi-source energy systems, such as PV arrays and battery storage units, providing superior fault tolerance and adaptability. Advanced implementations include high frequency switching techniques and active component balancing, further enhancing reliability and scalability. These features make hybrid converters particularly suitable for high demand applications, including EV fast chargers and large-scale renewable installations.

3. RESULTS AND DISCUSSION

Performance evaluation of DC-DC converters is crucial to understanding their efficacy in real-world applications. Metrics such as energy efficiency, voltage ripple, thermal management, scalability, and component stress are pivotal in determining their suitability for diverse applications. Each metric provides unique insights into how these converters perform under varying operational conditions.

3.1 Energy efficiency

Energy efficiency remains a cornerstone metric for DC-DC converters, particularly in renewable and battery-powered systems where energy conservation is paramount. Tradition boost converter typically achieve efficiencies around 85% - 90% under moderate load conditions [12]. However, advanced topologies, such as hybrid design, interleaved converters, and quadratic configurations, routinely exceed 95%. These high-efficiency designs leverage soft-switching mechanisms, optimized magnetic material, and reduce conduction losses to deliver superior energy utilization [29]. For instance, hybrid converter employing coupled inductors minimize switching losses and magnetic saturation, making the ideal for high-frequency applications.

3.2 Voltage Ripple

Voltage ripple, a measure of output voltage stability, significantly impacts the performance and reliability of DC-DC converters. Applications such as electric vehicle (EVs) and sensitive electronic systems require converter with minimal ripple to ensure stable operation. Coupled inductor and interleaved topologies demonstrate ripple reduction of up to 50% compared to conventional designs [30]. Voltage multiplier configurations, particularly in hybrid converters, offer ripple levels below 2%, making them indispensable for applications demanding high precision [31].

3.3 Thermal Management

Thermal performance is a critical aspect of converter design, influencing both efficiency and longevity. Advanced topologies incorporate features like interleaving, soft-switching, and active clamping to mitigate thermal buildup during high-power operations. Interleaved converters, for example, distribute power across multiple phases, reducing thermal hotspots and enhancing heat dissipation [32]. Hybrid designs integrate coupled inductors with advanced thermal management techniques to ensure consistent operation under high-load conditions [33].

3.4 Scalability and Component Stress

Scalability is a defining characteristic of modern DC-DC converter topologies. Design such as modular hybrid converters and quadratic configurations enable seamless integration into large systems, including renewable energy farm and microgrids [34]. These scalable design address dynamic power requirements while minimizing component stress. Stress on components, including switches and capacitors, is mitigated in advanced design through techniques like flux balancing and active control, enhancing reliability and reducing maintenance costs [14].

3.5 Comparative Analysis

Table 1 provides a detailed comparative analysis of converter performance metrics across different topologies. Each metric highlights the advantages and trade-offs associated with each design.

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Table 1. Comparative analysis of different topologies converter performance

Topology	Efficiency (%)	Voltage Ripple (%)	Thermal Management	Scalability	Component Stress	Cost
Traditional Boost [35]	85-90	5-8	Basic	Moderate	High	Low
Hybrid Boost [36]	> 95	< 2	Advanced	High	Low	Moderate
Coupled inductor [37], [38]	> 92	< 3	Intermediate	Moderate-High	Moderate	Moderate
Voltage Multiplier [39]	90-93	< 3	Limited	High	Moderate	Low
Quadratic [40], [41], [42]	94-96	< 2.5	Advanced	High	Low	Moderate
Triple Boost [43], [44]	> 96	< 2	Advance	High	Low	High

3.6 Application In Emerging Energy Technologies

DC-DC converter plays a pivotal role in advancing modern energy systems, addressing a diverse range of applications across renewable energy, electric vehicles (EVs), and distributed energy networks. Their versatility and efficiency make them essential for emerging technological ecosystems.

In renewable energy, DC-DC converters are integral to photovoltaics (PV) and wind energy systems, here they regulate variable input voltage and optimize power extraction through maximum power poin tracking (MPPT). Advanced technologies such as hybrid and quadratic converters achieve high voltage gains with reduced losses ensuring efficient power delivery to storage systems or grids [45]. Interleaved design with coupled inductors improve power density and minimize thermal stress, making them ideal for residential and industrial installations. High-efficiency converters, such as those employing voltage multiplier techniques, enhance the performance of microgrids by stabilizing output under dynamic loading conditions [46].

In EV infrastructure, DC-DC converters facilitate rapid charging and efficient power distribution. High-efficiency converters like triple-boost and interleave coupled inductor designs enable faster charging by minimizing voltage ripple and thermal stress on battery systems [47]. Transformerless topologies are gaining prominence for their compact form factors, crucial for onboard EV applications. Coupled inductor-based designs also enable bidirectional energy transfer, a critical feature for vehicle-to-gris (V2G) applications, ensuring stability and efficiency in decentralized energy systems [48].

In distributed energy networks, the adaptability of DC-DC converter ensures seamless integration of multiple energy sources. Hybrid converters are particularly effective in managing diverse inputs, such as PV arrays and energy storage systems, optimizing power flow and enhancing fault tolerance [49]. Their modularity supports scalability, enabling efficient operation in large-scale renewable installations and microgrid configurations. Quadratic and triple-boost topologies have demonstrated exceptional performance in balancing high voltage gains and efficiency, critical for grid stabilization and energy storage management [50].

These advancements underline the transformative impact of DC-DC converter technologies in addressing future energy challenges. By offering scalable, efficient, and reliable solutions, the converter continues to drive innovation across multiple domains, supporting the transition toward a sustainable energy landscape.

4. CONCLUSION

This review underscores the critical role of DC-DC converters in enabling high-efficiency and high-gain applications across renewable energy, electric vehicles, and distributed networks. Advanced topologies, including hybrid, quadratic, and triple-boost designs, demonstrated significant performance improvements in energy efficiency, scalability, and thermal management. These innovations provide robust solutions to contemporary energy challenges, ensuring optimized power delivery and supporting the global transition toward sustainable energy systems.

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REFERENCES

[1] Q. Huang, A. Q. Huang, R. Yu, P. Liu, "High-efficiency and high-density single-phase dual-mode cascaded buck–boost multilevel transformerless PV inverter with GaN AC switches," *IEEE Transactions*, 2018, [Online]. Available: https://ieeexplore.ieee.org/abstract/document/8514053/

[2] S. Sarani, A. Nikbahar, H. A. Zarchi, and X. Liang, "An Isolated High Boost Ratio DC-DC Converter With Very Low Input Current Ripples," *IEEE Transactions on Circuits and Systems II: Express Briefs*, 2024, doi: 10.1109/TCSII.2024.3386158.

[3] J. Lu, Y. Wang, X. Li, and C. Du, "High-Conversion-Ratio Isolated Bidirectional DC-DC Converter for Distributed Energy Storage Systems," *IEEE Trans Power Electron*, vol. 34, no. 8, pp. 7256–7277, Aug. 2019, doi: 10.1109/TPEL.2018.2881085.

[4] X. Zhu, L. Jiang, B. Zhang, and K. Jin, "The Resonant Modular Multilevel DC-DC Converter Adopting Switched-Inductor Cells for High Step-Up Ratio," *IEEE J Emerg Sel Top Power Electron*, vol. 10, no. 6, pp. 6634–6647, Dec. 2022, doi: 10.1109/JESTPE.2022.3157618.

[5] Y. E. Wu and B. H. Pan, "High Efficiency and Voltage Conversion Ratio Bidirectional Isolated DC-DC Converter for Energy Storage System," *IEEE Access*, vol. 10, pp. 55187–55199, 2022, doi: 10.1109/ACCESS.2022.3177206.

[6] B. Gu, J. Dominic, J. S. Lai, Z. Zhao, and C. Liu, "High boost ratio hybrid transformer DC-DC converter for photovoltaic module applications," *IEEE Trans Power Electron*, vol. 28, no. 4, pp. 2048–2058, Apr. 2013, doi: 10.1109/TPEL.2012.2198834.

[7] M. Kumar, M. Ashirvad, and Y. N. Babu, "An integrated Boost-Sepic-Ćuk DC-DC converter with high voltage ratio and reduced input current ripple," in *Energy Procedia*, Elsevier Ltd, 2017, pp. 984–990. doi: 10.1016/j.egypro.2017.05.219.

[8] Y. Zheng and K. M. Smedley, "Analysis and design of a single-switch high step-up coupled-inductor boost converter," *IEEE Transactions on Power …*, 2019, [Online]. Available: https://ieeexplore.ieee.org/abstract/document/8708262/

[9] A. Andrade, T. Faistel, R. Guisso, and A. Toebe, "Hybrid High Voltage Gain Transformerless DC-DC Converter," *IEEE Transactions on Industrial Electronics*, vol. 69, no. 3, pp. 2470–2479, Mar. 2022, doi: 10.1109/TIE.2021.3066939.

[10] A. Alzahrani, M. Ferdowsi, and P. Shamsi, "A family of scalable non-isolated interleaved DC-DC boost converters with voltage multiplier cells," *IEEE Access*, 2019, [Online]. Available: https://ieeexplore.ieee.org/abstract/document/8606084/

[11] S. Gopinathan, V. S. Rao, and S. Kumaravel, "Enhanced Voltage Gain Boost DC-DC Converter With Reduced Voltage Stress and Core Saturation," *IEEE Transactions on Circuits and Systems II: Express Briefs*, vol. 70, no. 8, pp. 3019–3023, Aug. 2023, doi: 10.1109/TCSII.2023.3252721.

[12] E. Babaei, H. M. Maheri, M. Sabahi, and ..., "Extendable nonisolated high gain DC–DC converter based on active–passive inductor cells," *IEEE transactions on …*, 2018, [Online]. Available: https://ieeexplore.ieee.org/abstract/document/8301592/

Volume 12, Issue 1, April 2025, pp. 87-94
ISSN 2355-5068 ; e-ISSN 2622-4852
DOI: 10.33019/jurnalecotipe.v12i1.4533

[13] P. Sharma and R. Chinnappa Naidu, "Optimization Techniques for Grid-Connected PV with Retired EV Batteries in Centralized Charging Station with Challenges and Future Possibilities: A review," 2022, *Ain Shams University*. doi: 10.1016/j.asej.2022.101985.

[14] S. M. NithyaDevi, V. Krishnasamy, and J. D. Navamani, "Transformerless high voltage gain Y-source converter with reduced switch stress," *e-Prime - Advances in Electrical Engineering, Electronics and Energy*, vol. 8, Jun. 2024, doi: 10.1016/j.prime.2024.100558.

[15] S. W. Lee and H. L. Do, "High step-up coupled-inductor cascade boost DC–DC converter with lossless passive snubber," *IEEE Transactions on Industrial Electronics*, 2018, [Online]. Available: https://ieeexplore.ieee.org/abstract/document/8286907/

[16] M. Das and V. Agarwal, "Design and analysis of a high-efficiency DC–DC converter with soft switching capability for renewable energy applications requiring high voltage gain," *IEEE Transactions on Industrial Electronics*, 2016, [Online]. Available: https://ieeexplore.ieee.org/abstract/document/7374681/

[17] A. Andrade, E. Mattos, L. Schuch, and ..., "Synthesis and comparative analysis of very high step-up DC–DC converters adopting coupled-inductor and voltage multiplier cells," *... on Power Electronics*, 2017, [Online]. Available: https://ieeexplore.ieee.org/abstract/document/8017435/

[18] R. Rajesh, N. Prabaharan, and T. K. Santhosh, "Design and Analysis of a Non-Isolated DC-DC Converter With a High-Voltage Conversion Ratio," *IEEE Transactions on Circuits and Systems II: Express Briefs*, vol. 70, no. 6, pp. 2036–2041, Jun. 2023, doi: 10.1109/TCSII.2022.3226187.

[19] H. C. Liu and F. Li, "Novel High Step-Up DC-DC Converter with an Active Coupled-Inductor Network for a Sustainable Energy System," *IEEE Trans Power Electron*, vol. 30, no. 12, pp. 6476–6482, Dec. 2015, doi: 10.1109/TPEL.2015.2429651.

[20] L. Schmitz, D. C. Martins, and ..., "Generalized high step-up DC-DC boost-based converter with gain cell," *IEEE Transactions on ...*, 2016, [Online]. Available: https://ieeexplore.ieee.org/abstract/document/7588175/

[21] T. Yao, Y. Cheng, Y. Guan, W. Wang, Y. Wang, and D. Xu, "A Family of High Step-Up DC-DC Converters Based on Enhanced Boost Cells With Coupled Inductor," *IEEE Trans Power Electron*, vol. 38, no. 10, pp. 12932–12945, Oct. 2023, doi: 10.1109/TPEL.2023.3298683.

[22] C. H. Lin, M. S. Khan, J. Ahmad, H. D. Liu, and T. C. Hsiao, "Design and Analysis of Novel High-Gain Boost Converter for Renewable Energy Systems (RES)," *IEEE Access*, vol. 12, pp. 24262–24273, 2024, doi: 10.1109/ACCESS.2024.3365705.

[23] A. Kumar and P. Sensarma, "Single Active Switch High Voltage Gain DC-DC Converter with Reduced Devices Stress," *2020 IEEE International Conference on ...*, 2020, [Online]. Available: https://ieeexplore.ieee.org/abstract/document/9379829/

[24] M. Samiullah, M. A. A. Hitmi, A. Iqbal, and S. Islam, "Novel Scalable Topologies of High Power Density Quadratic Converters with Low Voltage Stress on Power Diode," *IEEE Open Journal of the Industrial Electronics Society*, vol. 5, pp. 386–399, 2024, doi: 10.1109/OJIES.2024.3393757.

[25] S. W. Lee and H. L. Do, "Quadratic boost DC–DC converter with high voltage gain and reduced voltage stresses," *IEEE Trans Power Electron*, 2018, [Online]. Available: https://ieeexplore.ieee.org/abstract/document/8369098/

[26] S. N V, L. A, and D. N. J, "Dual input single Output quadratic Boost converter for DC microgrid," *e-Prime - Advances in Electrical Engineering, Electronics and Energy*, vol. 9, Sep. 2024, doi: 10.1016/j.prime.2024.100683.