Addressing Key Challenges in Dual Active Bridge (DAB) Converters: A Review of Voltage Gain Flexibility, Voltage Imbalance and Fault Detection

Intan Mastura Saadon[1,2]*, Mohamad Fathi Mohamad Elias[2], Emy Zairah Ahmad[1]

[1]Faculty of Electrical Technology and Engineering, Universiti Teknikal Malaysia Melaka, 77200 Melaka, Malaysia

[2]Universiti Malaya Power Energy Dedicated Advanced Centre, Universiti Malaya, 59990 Kuala Lumpur, Malaysia

***Corresponding Author**

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ABSTRACT

Dual Active Bridge (DAB) converters are widely employed in isolated bidirectional DC–DC power conversion for applications such as electric vehicles, renewable energy systems, aerospace, and solid-state transformers because of their high-power density, galvanic isolation, and soft-switching capability. However, their practical deployment remains constrained by several operational challenges, including restricted voltage gain flexibility, voltage imbalance in multilevel and modular configurations, and vulnerability to fault conditions during high-speed operation. Although numerous topological, control, and modulation-based solutions have been reported, most existing review papers classify these approaches according to methodology rather than the operational challenges they address, limiting direct comparison between different solution domains. To address this gap, this paper presents a challenge-oriented review of three major operational challenges in DAB converters: limited voltage gain flexibility, voltage imbalance in multilevel and modular systems, and fault detection and protection in high-speed operation. The reviewed solutions are systematically categorized into topology, control, and modulation domains and compared in terms of effectiveness, implementation complexity, computational burden, hardware requirements, and practical applicability. The comparative analysis shows that multilevel and modular topologies, such as Triple Active Bridge and modular high-frequency-transformer architectures, provide the greatest improvements in voltage gain flexibility, while active voltage balancing strategies that combine real-time control with modulation outperform passive balancing methods in multilevel and modular DAB systems. For fault detection, observer-based and sensorless topological methods deliver fast, low-cost diagnosis, whereas AI-driven and modulation-based approaches, such as pulse-injection and spread-spectrum monitoring, extend detection sensitivity at the cost of additional signal-processing complexity. Model Predictive Control emerges consistently across all three challenges as a strategy offering strong dynamic performance, though at higher computational cost. This review identifies current research gaps and outlines future research directions toward integrated, adaptive, and intelligent DAB converter architectures for next-generation power electronic systems.

Keywords: Dual Active Bridge (DAB), Challenge-Oriented Review, Voltage Gain Flexibility, Voltage Balancing, Fault Detection and Protection

INTRODUCTION

Dual Active Bridge (DAB) converter is a bidirectional DC-DC power conversion architecture featuring two active full-bridge converters connected through a high frequency (HF) transformer. Since its introduction, the DAB has become one of the most widely adopted isolated bidirectional DC–DC converter topologies for applications requiring galvanic isolation, high power density, and bidirectional power transfer [1]. Figure 1 illustrates the conventional configuration of a DAB with two full-bridge circuits employing four semiconductor switches each, linked through an HF isolation transformer. The phase shift between the gate signals allows power flow across the two bridges. A leakage inductor Llk, representing the transformer's leakage inductance or an external series inductor, facilitates power transfer and helps achieve soft-switching. At its core, the DAB operates by modulating the phase difference between the AC-like square-wave voltages generated by the primary and secondary bridges. The HF transformer not only ensures isolation but also enables size reduction of magnetic components and supports flexible voltage scaling across different ports [2].

The DAB converter has become one of the preferred isolated bidirectional DC-DC converter topologies because it combines high power density, galvanic isolation, bidirectional power transfer, and soft-switching capability within a relatively simple converter structure [3]. These advantages make it well suited for electric vehicle chargers, renewable energy systems, and energy storage applications. Nevertheless, practical implementation remains constrained by several operational limitations, including restricted voltage gain flexibility, voltage imbalance under multilevel or modular configurations, and vulnerability to fault conditions during high-speed switching, which continue to motivate research on advanced topologies, control strategies, and modulation techniques [4].

This review focuses on three major operational challenges commonly encountered in practical DAB converters, namely restricted voltage gain flexibility, voltage imbalance in multilevel and modular configurations, and vulnerability to fault conditions during high-speed operation. These challenges collectively limit converter flexibility, reliability, and fault resilience under practical operating conditions, highlighting the need for coordinated topological, control, and modulation-based solutions [5], [6], [7]. Previous review papers have comprehensively summarized DAB converter topologies, transformer design, modelling, modulation techniques, and control strategies [2], [3], [4]. However, these reviews primarily classify the literature according to methodological categories or specific application domains rather than the practical operational challenges encountered during DAB operation. Consequently, a systematic comparison of topological, control, and modulation-based solutions for addressing these specific converter challenges remains limited. To bridge this gap, this paper adopts a challenge-oriented comparative framework that systematically maps existing solutions to these three major operational challenges encountered in practical DAB applications.

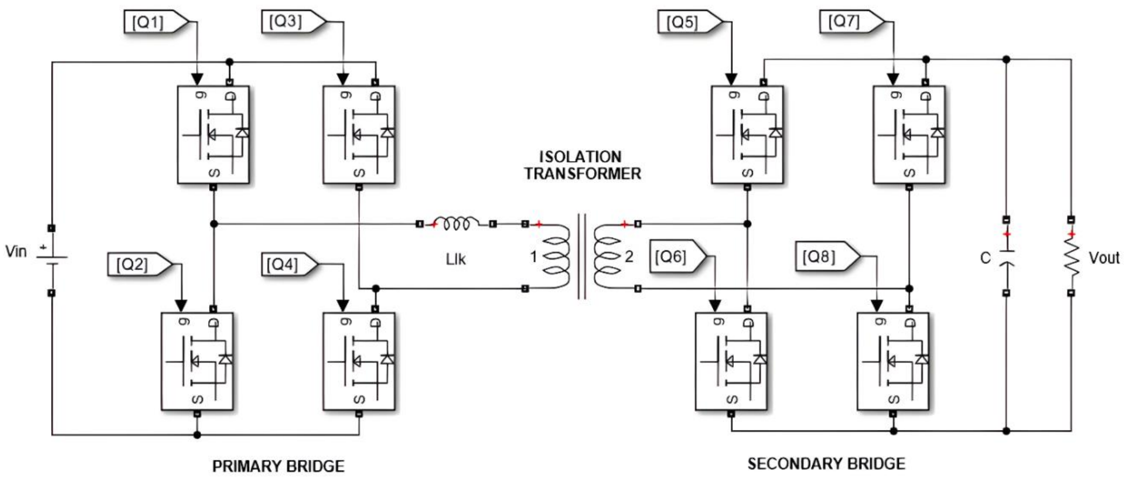

Figure 1. Conventional topology of a DAB converter

Challenges In Dual Active Bridge Converters

Challenge 1: Limited Voltage Gain Flexibility

Another critical limitation of the conventional DAB converter is its narrow voltage gain flexibility, particularly under fixed-frequency operation. The voltage transfer ratio of a DAB is inherently coupled to the phase shift and transformer turns ratio, which constrains its ability to adapt to wide input/output voltage variations. In practice, when the input voltage fluctuates, as in battery systems or photovoltaic arrays, the DAB struggles to maintain efficient, bidirectional power transfer across a broad voltage range [8]. This limitation becomes more severe in grid-tied and renewable systems where wide voltage dynamics are intrinsic. Moreover, to preserve soft-switching and low reactive power, certain gain values fall outside the DAB's achievable range unless the modulation frequency or topology is altered.

Multilevel DAB topologies are widely adopted to improve voltage gain flexibility while reducing voltage stress and enhancing soft-switching performance. Neutral Point Clamped (NPC)-DAB employs hybrid modulation based on voltage-second balancing to improve peak current characteristics and switching performance [9], [10]. Hybrid Multilevel DAB (HML-DAB) further extends the ZVS operating range through variable-level modulation while maintaining balanced current stress [11], [12]. Triple Active Bridge (Tri-DAB) enhances voltage gain flexibility by introducing an additional power port and advanced modulation strategies, including asymmetrical modulation and TPS control [13], [14], [15], [16]. More recently, modular DAB converters incorporating adjustable-tap high-frequency transformers and GaN devices have achieved efficiencies exceeding 97% across wide voltage ranges [17], [18]. Overall, multilevel and modular topologies provide the greatest voltage gain flexibility but require increased hardware complexity, synchronization, and thermal management.

Modulation techniques improve voltage gain flexibility without requiring significant hardware modification. TPS minimizes RMS current and power loss under non-unity voltage gain conditions through optimized phase-shift control [3], [19]. EPS further extends the operating range by improving soft-switching capability and enabling segmented-region optimum modulation (SROM) for wide voltage variation [20], while modified EPS strategies incorporating auxiliary inductors and internal phase-shift optimization enhance bidirectional power transfer in V2G applications [21]. Asymmetrical modulation further increases achievable voltage gain by independently controlling duty cycle and phase shift [15]. Compared with topological solutions, modulation strategies provide a more economical approach for improving voltage gain, although their performance remains constrained by the converter topology and operating conditions.

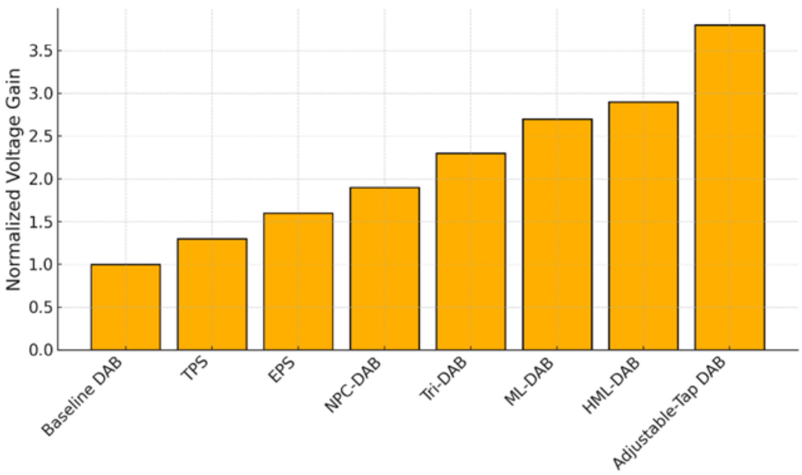

Figure 2. Estimated normalized voltage gain comparison of DAB converter topologies and modulation strategies

Challenge 2: Voltage Imbalance in Multilevel and Modular DAB Systems

Voltage imbalance is a subtle but critical issue in DAB converters, particularly in multilevel, modular, or cascaded configurations. Under non-ideal conditions such as load transients, switching mismatches, or thermal drift, these voltage levels can diverge. Unchecked imbalance leads to uneven power sharing, circulating current loops, and localized overvoltage or undervoltage stress, which significantly degrade efficiency and accelerate device aging, especially in high-power applications, since DAB converters often lack intrinsic mechanisms to enforce voltage uniformity across stages or modules [22]. DAB voltage balancing includes passive and active approaches. Passive voltage balancing relies on the DAB's inherent characteristics, where components such as flying capacitors, NPC structures, and symmetric circuit arrangements naturally promote charge redistribution across capacitors. These often include freewheeling diodes and resonant current paths without requiring control, but may not maintain accuracy during dynamic operation. In contrast, active voltage balancing employs real-time control and modulation techniques to monitor and correct capacitor voltage imbalances, incorporating capacitor voltage feedback into modulation schemes to redistribute energy and ensure capacitor voltage uniformity. Although more complex, active balancing offers superior performance under varying load conditions and is essential for maintaining reliability in multilevel or high-voltage DAB systems [23].

Passive capacitor voltage balancing is demonstrated in a SiC-based three-level DAB using a hybrid NPC-flying capacitor (NPC-FC) structure in medium-voltage solid-state transformers, mitigating voltage imbalance by leveraging the flying capacitor as a buffer between the dc-link capacitors on a switching-cycle basis [24]. Furthermore, active balancing in large battery packs is exemplified by a differential dual-active bridge (DDAB) that reduces component count and cost by balancing two cells with a single converter, utilizing both pulse-width modulation and phase-shift modulation for effective control; dividing the input using a centre-tapped transformer and an additional inductor allows active control of currents from the two cells, reducing component count and improving cost and volume efficiency [25]. Moreover, the proposed bipolar symmetric output topology in [26] improves voltage balancing in DAB converters by enabling self-balancing of the bipolar output voltage without additional components, achieved through the integration of magnetic components into a coupled inductor, which reduces complexity besides applying EPS for wide-range ZVS especially in bipolar voltage imbalance. Finally, [27] employs a dedicated winding connection in the ac-link transformer, allowing full decoupling of the two dc poles on the input side. This design enables independent control of positive and negative pole dc currents through dedicated differential and common-mode current controllers, consequently enhancing efficiency even in the event of a fault in one pole, thus maintaining power supply continuity. Figure 3 shows the topological approach for better voltage balancing.

One of the controller solutions for voltage imbalance is the use of Proportional-Integral (PI) controllers, valued for their simplicity and effectiveness in maintaining desired output voltages that remain stable despite variations in load or input conditions. For instance, in the Three-Level Dual Active Half Bridge (TL-DAHB) converter, a PI controller is utilized to achieve closed-loop voltage control and maintain voltage balance under different operating conditions [28]. Similarly, in conventional DAB converters used in solid-state transformers and electric vehicles, PI controllers are implemented to model and control the output voltage, with simulations confirming the accuracy of this approach [29]. However, precise tuning of PI coefficients is crucial to prevent voltage stress on power switches [30]; mistuning can lead to overshoot and excessive transformer current, degrading performance. To address these challenges, [31] eliminates the need for PI controllers by introducing intermediate control variables that simplify decoupling control structures, thereby reducing dynamic interference between input and output voltage regulators. The application of PI controllers in DAB converters remains a practical choice due to their simplicity and proven effectiveness in maintaining output voltage; however, it requires precise tuning and remains vulnerable to dynamic coupling issues in applications such as electric vehicles and solid-state transformers.

The integration of MPC with various modulation strategies, such as TPS and PWM, enhances the performance of DAB converters by improving dynamic response and maintaining a constant output voltage across a wide range of operating conditions [32], [33], [34], [35]. The use of TPS with MPC optimizes current stress, reduces converter losses, and improves efficiency [35]. Furthermore, incorporating online parameter identification techniques into MPC frameworks can reduce the effects of parameter mismatches, thereby improving prediction accuracy and output-voltage regulation [36]. The Moving Discretized Control Set Model Predictive Control (MDCS-MPC) strategy is particularly effective for applications requiring both voltage and current control, as it anticipates system behaviour and manages output current perturbations, ensuring safe operation within specified limits [34]. Overall, integrating MPC with advanced modulation techniques significantly enhances DAB performance [37] by offering predictive optimization, multi-variable control, and faster dynamic response, especially when combined with modulation techniques.

In modulation-based approaches, boundary control methods address voltage balancing in the presence of DAB capacitor voltage imbalance, which can otherwise increase voltage or current stress and affect converter stability. In the context of two/three-level NPC DAB converters, a fast-transient boundary control method has been proposed, utilizing elliptic and circular boundaries to regulate the dynamic trajectory of the converter in the geometrical domain via capacitor charging and discharging, thereby enhancing dynamic performance [38]. In contrast, for Input Series Output Series (ISOS)-connected DAB converters, a voltage balancing control method without auxiliary circuits has been developed, focusing on controlling the input-side DC voltage under heavy loads and generating reactive power in no-load states to discharge excessive voltage, effectively balancing the

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DC voltage during bidirectional power transmission [39]. Additionally, a novel five-level DAB converter topology has been introduced, stacking two neutral-point-clamped converters to quadruple the input DC-bus voltage; this topology employs a voltage balancing method to actively balance the voltages of four series-connected DC-bus capacitors, ensuring safe operation for all semiconductor switches [40].

Furthermore, the cooperative triple phase shift (CTPS) control strategy for Input Parallel Output Series (IPOS) DAB converters achieves voltage self-adapting balance with a wide output voltage range and reduced reverse power [41]. The multiple natural switching surface (MNSS) boundary control method also significantly improves the dynamic response [42]. Lastly, [43] discusses a capacitor voltage balancing control scheme for DAB converters using the complementary switching-state (CSS) method, which addresses voltage imbalance by replacing adverse switching states with CSSs, effectively controlling the neutral-point current while maintaining unchanged voltage and current waveforms. This approach minimizes power fluctuations and simplifies the determination of transformer current polarity, enhancing the reliability of the converter during the balancing process.

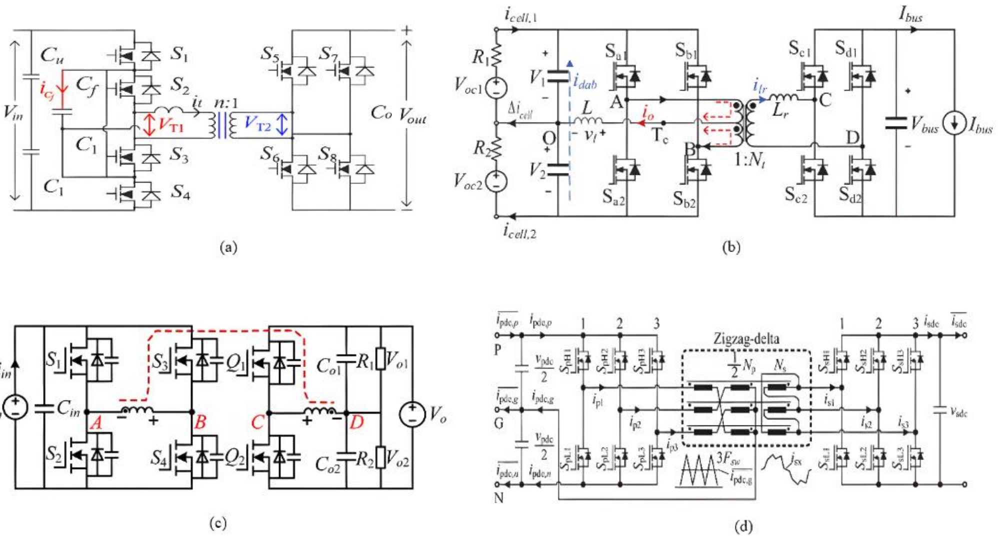

Figure 3. Topology of (a) hybrid NPC-FC DAB converter [24], (b) three-port DAB converter for active balancing [25], (c) self-balancing bipolar symmetric output topology [26], and (d) zigzag-delta winding ac-link transformer voltage balancing capability dual active bridge circuit [27]

Challenge 3: Fault Detection and Protection in High-Speed DAB Systems

Topological approaches improve fault detection in DAB converters through sensorless voltage monitoring, selective sensing, and reconfigurable architectures. Sensorless methods provide fast and low-cost fault detection, while selective sensing improves fault localization with moderate complexity [44], [45], [46], [47], [48]. Reconfigurable DAB topologies further enhance reliability by enabling rapid fault isolation, making them suitable for high-reliability applications such as EV charging and aerospace systems [49].

Control-based fault detection methods mainly include observer-based, AI-driven, and MPC-integrated approaches. Observer-based techniques offer fast and accurate fault detection with low hardware overhead but depend heavily on accurate system models [50], [51], [52], [53]. AI-based methods improve adaptability and fault classification under nonlinear conditions, although they require extensive training data and validation [44], [54], [48]. MPC-based protection integrates fault detection directly into the control loop, enabling rapid response and dynamic compensation during abnormal conditions [46]. From a computational perspective, MPC and AI-based fault detection present different trade-offs between online execution requirements and detection capability. MPC predicts converter behaviour and evaluates the required control action at each sampling instant, allowing system deviations to be addressed directly within the control loop [7], [34], [37]. This predictive capability can provide a fast dynamic response, but the repeated model evaluation and optimization increase the online computational burden, particularly at high switching frequencies [7], [34]. In contrast, AI-based methods can achieve rapid fault classification once a trained model is deployed, although their overall implementation

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requires sufficient training data, model development, and validation under different operating and fault conditions [53]. Therefore, MPC provides a model-based approach with direct integration, whereas AI-based techniques offer greater flexibility for nonlinear fault classification at the expense of additional training and implementation requirements [34], [53].

Modulation-based fault detection methods include diagnostic pulse injection and spread-spectrum monitoring techniques. Pulse injection methods enable simple and rapid fault identification during light-load conditions [55], [48], [56], while spread-spectrum approaches provide continuous and non-intrusive monitoring through HF signal analysis [57], [58]. These strategies improve detection sensitivity and support early fault diagnosis, although advanced signal processing and noise mitigation are often required.

Table 1. Cross-mapping of topological, control, and modulation strategies against the reviewed challenges (voltage gain, voltage imbalance, and fault detection)

Challenge	Topological Solutions	Control Strategies	Modulation Techniques
Challenge 1 – Limited Voltage Gain Flexibility	Triple Active Bridge (Tri-DAB) [3], [5], [30], [39]; Modular DAB [16], [49]	—	EPS / Modified EPS [35], [45]; TPS / Modified TPS [12], [51]; PWM/PSM/VFM/Asymmetrical [30]
Challenge 2 – Voltage Imbalance in Multilevel and Modular DAB Systems	Triple Active Bridge (Tri-DAB) [55]; Active Clamp / NPC [6]; Reactive Component Adjustment DAB [13], [53]	PI-based [1], [20], [24], [29]; MPC-based [10], [21], [22], [28]	TPS / Modified TPS [56]; Boundary Control / CSS / ISOS / ISOP / Other Modified Switching [4], [33], [38], [41], [57]
Challenge 3 – Fault Detection and Protection in High-Speed DAB Systems	Active Clamp / NPC [19], [40]; Reactive Component Adjustment DAB [18], [32], [37]	ANN / RL-based control [18], [48]; MPC-based control [37]; Computer-based (FLC/GA/Observer)-based [9], [31], [34], [52]	PWM/PSM/VFM/Unified/SROM/Asymmetrical [14], [18], [19], [26], [44]

CONCLUSION AND FUTURE RESEARCH DIRECTIONS

In summary, this review highlights three major challenges affecting DAB converter performance: limited voltage gain flexibility, voltage imbalance in multilevel and modular systems, and fault detection and protection in high-speed operation. Various topological solutions, control strategies, and modulation techniques have been developed to address these issues, each offering different trade-offs between performance, complexity, and implementation cost. Table 1 summarizes the reported methods and their corresponding strategy categories for these three challenges, providing a comparative overview to support future research and application-oriented DAB converter design. Overall, multilevel and modular topologies deliver the greatest gains in voltage gain flexibility and voltage balancing capability; active control strategies such as MPC and PI-based schemes provide reliable dynamic regulation, observer-based, AI-driven, and modulation-based methods continue to advance fault detection sensitivity and response speed. Future development should focus on integrated designs that combine flexible topologies, intelligent control, and adaptive modulation to achieve efficient, robust, and fault-resilient DAB systems. The integration of wide-bandgap semiconductor devices, particularly SiC and GaN, also represents an important direction for future DAB converter development. Their high-frequency switching capability and lower switching losses offer opportunities to increase converter power density, reduce the size of magnetic components, and improve overall efficiency. However, operation at higher switching frequencies introduces additional design considerations, including electromagnetic interference, parasitic effects, gate-drive requirements, thermal management, and high-frequency transformer design. Future research should therefore investigate the coordinated integration of SiC and GaN devices with DAB topology, modulation, and control strategies to fully exploit their performance advantages while addressing these practical implementation challenges.

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REFERENCES

1. H. Jin, Y. Pei, L. Wang, J. Wen, C. Yang, and X. Dong, “Achieving Rated Power and ZVS for Dual Active Bridge Converter Considering the Interaction of Nonidealities,” IEEE Transactions on Industrial Electronics, vol. 70, no. 8, pp. 7867–7878, Aug. 2023, doi: 10.1109/TIE.2022.3232662.
2. H. Ataullah et al., “Analysis of the Dual Active Bridge-Based DC-DC Converter Topologies, HF Transformer, and Control Techniques,” Energies, vol. 15, no. 23, Dec. 2022, doi: 10.3390/en15238944.
3. Garcia-Bediaga et al., “Analytical and Normalized Equations to Implement the Optimized Triple Phase-Shift Modulation Strategy for DAB Converters,” IEEE Journal of Emerging and Selected Topics in Power Electronics, vol. 11, no. 3, pp. 3535–3546, Jun. 2023, doi: 10.1109/JESTPE.2023.3236097.
4. L. Li, G. Xu, D. Sha, Y. Liu, Y. Sun, and M. Su, “Review of Dual-Active-Bridge Converters With Topological Modifications,” IEEE Transactions on Power Electronics, vol. 38, no. 7, pp. 9046–9076, Jul. 2023, doi: 10.1109/TPEL.2023.3258418.
5. N. Fritz, D. Heidenberger, D. Bündgen, and R. W. De Doncker, “Flux Control Modulation for Three-Phase Dual-Active-Bridge DC-DC Converters.”
6. J. Huang, Z. Li, L. Shi, Y. Wang, and J. Zhu, “Optimized Modulation and Dynamic Control of a Three-Phase Dual Active Bridge Converter with Variable Duty Cycles,” IEEE Transactions on Power Electronics, vol. 34, no. 3, pp. 2856–2873, Mar. 2019, doi: 10.1109/TPEL.2018.2842021.
7. J. Sun, L. Qiu, X. Liu, J. Zhang, J. Ma, and Y. Fang, “Improved Model Predictive Control for Three-Phase Dual-Active-Bridge Converters With a Hybrid Modulation,” IEEE Transactions on Power Electronics, vol. 37, no. 4, pp. 4050–4064, 2022, doi: 10.1109/TPEL.2021.3126589.
8. N. Wang, Y. Wang, and Z. Chen, “A Novel DC-bias Current Suppression Strategy for DAB converter under TPS Modulation,” in 2024 IEEE 10th International Power Electronics and Motion Control Conference, IPEMC 2024 ECCE Asia, pp. 1265–1269, 2024, doi: 10.1109/IPEMC-ECCEAsia60879.2024.10568013.
9. J. Wang, Y. Huang, and J. Hu, “Peak Current Optimized Hybrid Modulation for NPC DAB Converter with a Wide Voltage Range,” in 2024 CPSS & IEEE International Symposium on Energy Storage and Conversion (ISESC), pp. 929–934, 2024, doi: 10.1109/ISESC63657.2024.10785381.
10. Z. Feng et al., “Loss Balance and Transient DC-Bias Suppression Strategies in Three-Level DAB Converters Modulated With Five DoFs,” IEEE Transactions on Power Electronics, vol. 38, no. 7, pp. 8150–8164, 2023, doi: 10.1109/TPEL.2023.3262797.
11. C. Liu, S. Zhou, J. Zou, X. Zou, H. Peng, and Y. Kang, “Hybrid-Type Multi-Level DAB Converter for High and Ultrawide Input-Voltage Range,” IEEE Transactions on Industrial Electronics, vol. 71, no. 12, pp. 16875–16881, 2024, doi: 10.1109/TIE.2024.3390749.
12. G. Xu, D. Sha, Y. Xu, and X. Liao, “Hybrid-Bridge-Based DAB Converter With Voltage Match Control for Wide Voltage Conversion Gain Application,” IEEE Transactions on Power Electronics, vol. 33, no. 2, pp. 1378–1388, 2018, doi: 10.1109/TPEL.2017.2678524.

13. R. Chattopadhyay, G. Gohil, S. Acharya, V. Nair, and S. Bhattacharya, “Efficiency improvement of three port high frequency transformer isolated triple active bridge converter,” in 2018 IEEE Applied Power Electronics Conference and Exposition (APEC), pp. 1807–1814, 2018, doi: 10.1109/APEC.2018.8341262.
14. M. Dezhbord, S. Mohamadian, A. Ghasemian, C. Buccella, and C. Cecati, “Enhancing Voltage Gain and Assessing Current THD in Transformer of Photovoltaic Applications through a New Triple Active Bridge Converter,” in 2024 IEEE 33rd International Symposium on Industrial Electronics (ISIE), pp. 1–6, 2024, doi: 10.1109/ISIE54533.2024.10595709.
15. M. Mahdavifard and A. Khajehoddin, “Asymmetrical Modulation of DAB Converters for Voltage Gains Higher than Unity,” Jun. 2024, pp. 1–8, doi: 10.1109/ECCEEurope62508.2024.10751894.
16. L. Shu, W. Chen, M. Shi, R. Liu, S. Gao, and F. Deng, “Improved Control Strategy of Triple-Voltage Three-Phase DAB (T2-DAB) Converter for Current Stress and Zero-Voltage-Switching Optimization,” IEEE Journal of Emerging and Selected Topics in Power Electronics, vol. 10, no. 1, pp. 773–784, 2022, doi: 10.1109/JESTPE.2021.3060477.
17. Jafari, M. S. Nikoo, F. Karakaya, and E. Matioli, “Enhanced DAB for Efficiency Preservation Using Adjustable-Tap HF Transformer,” IEEE Transactions on Power Electronics, vol. 35, no. 7, pp. 6673–6677, 2020, doi: 10.1109/TPEL.2019.2958632.
18. Y. Xia et al., “Modular DC Power Conversion System and Control Method for an Ultra-Wide Output Voltage Range of 5-500V Application,” in 2023 2nd Asia Power and Electrical Technology Conference (APET), pp. 338–343, 2023, doi: 10.1109/APET59977.2023.10489714.
19. H. Xie, T. Zhang, Y. Zhou, R. Xie, and Y. Zhang, “The Triple Phase-Shift Control of DAB Converter with Reconfigurable Transformer to Optimize the RMS Current for Wide Voltage Applications,” in 2024 CPSS & IEEE International Symposium on Energy Storage and Conversion (ISESC), pp. 299–303, 2024, doi: 10.1109/ISESC63657.2024.10785486.
20. Y. Qu, Z. Lu, W. Qiu, and G. Xu, “Modified EPS Control and Topology Modification for Two-Stage Bidirectional AC-DC Converter for V2G Applications,” Journal of Physics: Conference Series, vol. 2785, p. 12051, Jun. 2024, doi: 10.1088/1742-6596/2785/1/012051.
21. J. Tian, F. Wang, F. Zhuo, Y. Liu, and H. Deng, “A segmented-region optimum EPS modulation scheme based on unified parameter algorithm in DAB-based EV charger circuit,” IET Power Electronics, vol. 17, no. 10, pp. 1235–1250, 2024, doi: 10.1049/pel2.12621.
22. C. Song, A. Sangwongwanich, Y. Yang, Y. Pan, and F. Blaabjerg, “Analysis and Optimal Modulation for 2/3-Level DAB Converters to Minimize Current Stress With Five-Level Control,” IEEE Transactions on Power Electronics, vol. 38, no. 4, pp. 4596–4612, 2023, doi: 10.1109/TPEL.2023.3235938.
23. J. He, Y. Chen, J. Lin, J. Chen, L. Cheng, and Y. Wang, “Review of Modeling, Modulation, and Control Strategies for the Dual-Active-Bridge DC/DC Converter,” Energies, vol. 16, pp. 6646–6677, 2023, doi: 10.3390/en16186646.
24. H. Feng et al., “Passive Capacitor Voltage Balancing of SiC-Based Three-Level Dual-Active-Bridge Converter Using Hybrid NPC-Flying Capacitor Structure,” IEEE Transactions on Power Electronics, vol. 37, no. 4, pp. 4183–4194, 2022, doi: 10.1109/TPEL.2021.3119210.
25. D. Babu Yelaverthi, M. Muneeb Ur Rehman, and R. Zane, “Differential Power Processing Three-Port Dual Active Bridge Converter for Active Balancing in Large Battery Packs,” in 2018 IEEE Energy Conversion Congress and Exposition (ECCE), pp. 5591–5597, 2018, doi: 10.1109/ECCE.2018.8558266.
26. W. Xiong, Q. Xie, G. Xu, G. Ning, and M. Su, “Coupled Inductor-Based DC–DC Converter With Bipolar Self-Balancing Voltage and Full Load Range of ZVS,” IEEE Transactions on Power Electronics, vol. 40, no. 5, pp. 6951–6962, 2025, doi: 10.1109/TPEL.2024.3522354.
27. J.-S. Hong, J.-I. Ha, S. Cui, and J. Hu, “Topology and Control of an Enhanced Dual-Active Bridge Converter With Inherent Bipolar Operation Capability for LVDC Distribution Systems,” IEEE Transactions on Power Electronics, vol. 38, no. 10, pp. 12774–12789, 2023, doi: 10.1109/TPEL.2023.3297389.
28. Y. Li, D. Zuo, and H. Zhang, “Modeling and simulation of three level dual active half bridge based on PI control,” in Eighth International Conference on Energy System, Electricity, and Power (ESEP 2023), SPIE, 2024, p. 131599H, doi: 10.1117/12.3024210.

29. X. Ai, D. Zuo, and Y. Zhang, "Modeling and Simulation of Dual-Active-Bridge Based on PI Control," Journal of Physics: Conference Series, vol. 2221, no. 1, p. 12007, May 2022, doi: 10.1088/1742-6596/2221/1/012007.
30. J. Lee, H. Choi, and J. Jung, "Three level NPC dual active bridge capacitor voltage balancing switching modulation," in 2017 IEEE International Telecommunications Energy Conference (INTELEC), pp. 438–443, 2017, doi: 10.1109/INTLEC.2017.8214175.
31. C. Luo and S. Huang, "Novel Voltage Balancing Control Strategy for Dual-Active-Bridge Input-Series-Output-Parallel DC-DC Converters," IEEE Access, vol. 8, pp. 103114–103123, 2020, doi: 10.1109/ACCESS.2020.2999034.
32. X. Li et al., "Model Predictive Control with Parameter Identification for DAB Converter Improving Dynamic and Static Performance," in Proceedings of the 3rd International Symposium on New Energy and Electrical Technology, Singapore: Springer Nature Singapore, 2023, pp. 288–297.
33. M. López, N. Mijatovic, J. Rodriguez, and T. Dragičević, "Voltage Control Strategy for DAB power converter based on MDCS-MPC," in 2022 IEEE Transportation Electrification Conference & Expo (ITEC), pp. 584–588, 2022, doi: 10.1109/ITEC53557.2022.9813869.
34. M. López, N. Mijatovic, J. Rodríguez, and T. Dragičević, "Model Predictive Voltage and Current Control of Dual Active Bridge Using Enhanced Moving Discretized Control Set," in IECON 2023 - 49th Annual Conference of the IEEE Industrial Electronics Society, pp. 1–8, 2023, doi: 10.1109/IECON51785.2023.10312249.
35. T. Hagawane, M. R. Sindhu, and R. Patankar, "Model Predictive Control of Dual Active Bridge DC-DC Converter based on PWM plus TPS Modulation for Automotive Applications," in 2022 International Virtual Conference on Power Engineering Computing and Control: Developments in Electric Vehicles and Energy Sector for Sustainable Future (PECCON), pp. 1–6, 2022, doi: 10.1109/PECCON55017.2022.9851171.
36. T.-Q. Duong and S.-J. Choi, "Moving Discretized Control Set Model Predictive Control with Dominant Parameter Identification Strategy for Dual Active Bridge Converters," Mathematics, vol. 12, no. 4, Art. no. 563, 2024, doi: 10.3390/math12040563.
37. H. Zhang et al., "A Model-Predictive-Control Strategy for Hybrid Dual Active Bridges Based DC Transformer," in 2020 IEEE 9th International Power Electronics and Motion Control Conference (IPEMC2020-ECCE Asia), pp. 2073–2079, 2020, doi: 10.1109/IPEMC-ECCEAsia48364.2020.9368180.
38. L. Dai et al., "Boundary Control Based Capacitor Voltage Balancing for Two/Three-Level Neutral-Point-Clamped Dual-Active-Bridge Converters," in 2024 IEEE 10th International Power Electronics and Motion Control Conference (IPEMC2024-ECCE Asia), pp. 3101–3106, 2024, doi: 10.1109/IPEMC-ECCEAsia60879.2024.10567808.
39. K. Oi, H. Higa, K. Morita, S. Urushibata, Y. Tadano, and Y. Sato, "Voltage Balancing Control of Bidirectional Input-Series Output-Series Dual Active Bridge DC/DC Converters without Auxiliary Circuits," in 2022 International Power Electronics Conference (IPEC-Himeji 2022-ECCE Asia), pp. 899–905, 2022, doi: 10.23919/IPEC-Himeji2022-ECCE53331.2022.9807147.
40. F. Zhang, Y. Ren, X. Yang, W. Chen, and H. Wu, "Capacitor Voltage Balancing Control for a Novel 5-Level Dual Active Bridge Converter," IEEE Transactions on Power Electronics, vol. 37, no. 12, pp. 14738–14754, 2022, doi: 10.1109/TPEL.2022.3194960.
41. C. Zhang, Y. Zhou, and D. Yu, "Self-Adapting Voltage Balancing Method for IPOS DAB Converter With TPS Control," IEEE Transactions on Applied Superconductivity, vol. 34, no. 8, pp. 1–6, 2024, doi: 10.1109/TASC.2024.3468072.
42. H. Shi and H. Wen, "Multiple Natural Switching Surface Boundary Control of the Dual Active Bridge Converter," in 2020 IEEE 9th International Power Electronics and Motion Control Conference (IPEMC2020-ECCE Asia), pp. 1254–1259, 2020, doi: 10.1109/IPEMC-ECCEAsia48364.2020.9367808.
43. C. Song, A. Sangwongwanich, Y. Yang, and F. Blaabjerg, "Capacitor Voltage Balancing for Multilevel Dual-Active-Bridge DC–DC Converters," IEEE Transactions on Industrial Electronics, vol. 70, no. 3, pp. 2566–2575, 2023, doi: 10.1109/TIE.2022.3174287.

44. S. S. Khan and H. Wen, "Universal Sensorless Open-Circuit Fault Detection and Isolation Method of Dual-Active-Bridge Converters With Low-Cost Diagnostic Circuit," IEEE Transactions on Power Electronics, vol. 37, no. 11, pp. 13652–13667, 2022, doi: 10.1109/TPEL.2022.3182382.
45. T. J. Nistane, K. Jayaraman, and S. Payami, "Transient Analysis and Detection of Terminal Short Circuit of Medium Frequency Transformer in Dual Active Bridge Converter," in IECON 2023 - 49th Annual Conference of the IEEE Industrial Electronics Society, pp. 1–5, 2023, doi: 10.1109/IECON51785.2023.10312454.
46. H. Shi and H. Wen, "Fault detection method for dual active full-bridge convertor," CN111237834A, 2020.
47. C. Song, A. Sangwongwanich, and F. Blaabjerg, "Sensorless Open-Circuit-Fault Diagnosis Method for NPC-Based DAB Converter," IEEE Transactions on Power Electronics, vol. 39, no. 9, pp. 10699–10703, 2024, doi: 10.1109/TPEL.2024.3409060.
48. J. Wu, M. Ma, and J. Liang, "An Open-Circuit Fault Diagnosis And Location Method For Dual Active Bridge DC/DC Converter," in 2022 IEEE Transportation Electrification Conference and Expo, Asia-Pacific (ITEC Asia-Pacific), pp. 1–6, 2022, doi: 10.1109/ITECAsia-Pacific56316.2022.9941894.
49. S. S. Khan, H. Wen, H. Shi, Y. Hu, L. Jiang, and G. Chen, "Multiple Open-Circuit Fault Detection and Isolation Using Universal Low-Cost Diagnosis Circuits for Reconfigurable Dual-Active-Bridge Converters," IEEE Transactions on Power Electronics, vol. 38, no. 5, pp. 6504–6521, 2023, doi: 10.1109/TPEL.2023.3234592.
50. F. Guo, X. Ren, Z. Li, and C. Han, "Observer-based fault detection for a dual-motor driving servo system," in 2016 35th Chinese Control Conference (CCC), pp. 6431–6436, 2016, doi: 10.1109/ChiCC.2016.7554368.
51. D.-D. Nguyen, G. Fujita, Q. Bui-Dang, and M. C. Ta, "Reduced-Order Observer-Based Control System for Dual-Active-Bridge DC/DC Converter," IEEE Transactions on Industry Applications, vol. 54, no. 4, pp. 3426–3439, 2018, doi: 10.1109/TIA.2018.2810805.
52. J. Qi, F. Yu, X. Yue, and H. Xue, "State Observer-Based Open-Circuit Fault Diagnosis and Localization Research of DAB Converter," 2024, doi: 10.1109/ICPST61417.2024.10602052.
53. Z. Xing, J. Chen, Y. Zhao, Y. Fu, Y. He, and W. Zhang, "An Online Open-Switch Fault Diagnosis Method for the DAB Converter Based on Multimodal Fusion Neural Controlled Differential Equations," IEEE Transactions on Instrumentation and Measurement, vol. 72, pp. 1–11, 2023, doi: 10.1109/TIM.2023.3234093.
54. E. Ribeiro, A. J. M. Cardoso, and C. Boccaletti, "Fault analysis of dual active bridge converters," in IECON 2012 - 38th Annual Conference on IEEE Industrial Electronics Society, pp. 398–403, 2012, doi: 10.1109/IECON.2012.6388787.
55. C. Liu, X. Zou, S. Zhou, H. Peng, and Y. Kang, "Pulse Injection Modulation Method for Current-Fed Dual Active Bridge Converter With Full Load Range ZVS Under Wide Input-Voltage Range," IEEE Transactions on Power Electronics, vol. 40, no. 2, pp. 2668–2673, 2025, doi: 10.1109/TPEL.2024.3457847.
56. D. Xie and X. Ge, "Open-Circuit Fault Diagnosis of Dual Active Bridge DC-DC Converter Based on Residual Analysis," in 2018 IEEE International Power Electronics and Application Conference and Exposition (PEAC), pp. 1–6, 2018, doi: 10.1109/PEAC.2018.8590495.
57. C. Hu, A. Guo, Y. Deng, and M. Luo, "Application of Spread Spectrum Time Domain Method in New Energy Cable Fault Detection," in 2024 International Conference on Electronics and Devices, Computational Science (ICEDCS), pp. 7–13, 2024, doi: 10.1109/ICEDCS64328.2024.00007.
58. V. Taylor and M. Faulkner, "Line monitoring and fault location using spread spectrum on power line carrier," IEE Proceedings - Generation, Transmission and Distribution, vol. 143, no. 5, pp. 427–434, 1996, doi: 10.1049/ip-gtd:19960189.