Research Progress on Grid Connection Control Technology of AC-DC Converter in Vehicle-to-Grid Interaction (V2G)

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ABSTRACT

In the process of easing energy supply shortages and promoting the implementation of the “dual carbon” goals, vehicle-to-grid interaction (V2G) has become a core technical path for the coordinated development of electric vehicles and power grids. The grid-connected control strategy of AC-DC converters is a core link supporting the safe and efficient operation of V2G systems. This study takes the grid-connected control technology of AC-DC converters in the V2G scenario as the core research object, uses the systematic literature review method to sort out the relevant research results at home and abroad in the past decade, and combines MATLAB/Simulink simulation tests and typical application case analysis to sort out the evolution context and technical characteristics of the converter topology and control strategy. It should be noted that the three types of topologies-single-stage isolation, two-stage isolation, and non-isolation-each have their own adapted scenarios, and the control strategies have gradually evolved from the traditional double closed-loop PI control to virtual synchronizer control and intelligent optimization control; The technical problems to be solved in the current field mainly focus on four dimensions: power quality regulation, smooth power switching, cluster collaborative scheduling, and low-voltage ride-through. Based on the existing test and analysis results, this study proposes four future research directions: multi-objective optimization, digital twin technology embedding, interface standardization, and low-cost mass production, which can provide theoretical references for the iteration and subsequent large-scale commercialization of V2G grid connection control technology. The universality verification of this technology direction still needs to cover more complex grid conditions, and subsequent studies can conduct supplementary tests for application requirements in special regions such as high cold and high altitude.

Keywords: Vehicle-Grid Interaction (V2G); AC-DC Converter; Grid-Connected Control; Bidirectional Energy Conversion; Power Quality.

1. INTRODUCTION

1.1 Background and Significance of the study

The electric vehicle industry has entered a period of rapid growth in recent years as global energy supply pressure continues to rise, coupled with the gradual implementation of policies related to carbon peaking and carbon neutrality. Vehicle-to-grid (V2G) technology is the core hub connecting the transportation and energy sectors. Its core role is to change the attribute of electric vehicles as a single power consumption terminal and transform them into flexibly dispatchable distributed mobile energy storage units to support two-way energy interaction between vehicles and the power grid. In this technology system, AC-DC converters undertake the core functions of energy conversion and transmission, and the actual performance of their grid connection control is directly related to the safety and reliability of the V2G system operation.

From the perspective of grid operation, the fine-grained control of AC-DC converters can effectively reduce adverse effects such as harmonic pollution and current distortion caused by large-scale disorderly access of electric vehicles. By optimizing the grid connection control strategy to guide the orderly implementation of charging and discharging behaviors, the regulation effect of peak shaving and valley filling can be achieved, directly alleviating the operational pressure brought by the continuous increase in load and providing support for the safe and stable operation of the power grid. Bidirectional AC-DC converters can allocate electric vehicle clusters

as flexible energy storage carriers, store surplus electricity during peak hours of wind and solar power generation, and feed the stored electricity back to the grid during off-peak hours, directly enhancing the local consumption level of renewable energy. Grid-connected control technology is a key link in the transition of V2G technology from pilot demonstrations to large-scale commercialization, and it has practical application value for tapping the market potential in the vehicle-grid interaction field and supporting the construction of a new power system. It should be noted that the adaptability of some of the current core control algorithms to extreme conditions still needs to be verified through more field tests.

1.2 Review of Research Status at Home and Abroad

Domestic research has mostly focused on topological multiplexing and control optimization. Currently, a technical path centered on average current dual-loop control combined with unipolar PWM modulation has been basically formed, along with zero-crossing phase compensation schemes to improve the current distortion problem, which can control harmonic distortion in a lower range [1]. In commercial application scenarios, a coordinated advancement model of "policy guidance-vehicle implementation-grid coordination" has been formed in China, and V2G pilot projects and large microgrid demonstration stations have been successively implemented in several cities [2]. It should be noted that there is no unified standard in the field of bidirectional charging and discharging grid connection and safety protection, and the pricing mechanism for battery life degradation is still blank. These two types of problems directly restrict the large-scale promotion process of related technologies [3].

The research progress in the field of high-power-density bidirectional AC-DC converters abroad is in the leading position, and the existing schemes mostly adopt active buffering technology to optimize equipment volume and operating loss [4]. In studies related to control strategies, tests have verified the combined advantages of average current control in terms of anti-interference ability, system stability and EMI performance. At the application level, vehicle-to-grid communication has been standardized based on the ISO 15118 protocol, and collaborative scheduling tests of virtual power plants and large-scale electric vehicle clusters have been carried out [5,6]. It is notable that the high procurement cost of high-power converters and wide bandgap devices, the insufficient compatibility between BMS of different vehicle manufacturers and converter control, and the need to advance interface standardization are the main limiting factors currently facing overseas promotion [7].

1.3 Research Content and framework

This paper focuses on the grid-connected control technology of AC-DC converters in the V2G scenario, systematically reviews the mainstream topological types and the evolution of control strategies, deeply analyzes the key technical bottlenecks and engineering application challenges, and looks forward to future research directions, with the aim of providing theoretical references for technological breakthroughs and industrial applications in this field.

2. LITERATURE REVIEW

2.1 Research Progress on Topological Structures

The topology of the AC-DC converter for V2G technology has been iterated for a long time around three core demands: structural simplification, efficiency improvement, and cost compression. Currently, two mainstream options, isolated and non-isolated, have been formed, and the technical evolution path is relatively clear.

Among the non-isolated two-stage structures, the scheme of three-phase voltage-type PWM rectification combined with bidirectional DC-DC is the most representative, with prominent modular design attributes and strong bidirectional power regulation capability, which can maintain a stable operating state within a wide voltage range [1]. Single-stage isolated topologies are most widely used with dual active Bridges (DAB), which require fewer components and have overall operational efficiency above the medium level of the industry; There are also single-stage high-frequency chain structures that specifically suppress voltage oversurges and further enhance the reliability of equipment operation [8]. The cascaded wide-voltage bidirectional DC-DC converter enables soft-switching over a wide voltage range, supports bidirectional energy transmission, and has good compatibility with current vehicle-mounted high-voltage platforms [9].

It should be noted that the current technological iterations in this field are mainly focused on three areas: the implementation of magnetic integration technology, the large-scale application of wide bandgap devices, and the optimization of bridge-free PFC structures. At the same time, the research and development of equipment lightweighting and high-power density are being advanced simultaneously, and all kinds of technical adjustments are centered on adapting to the demands of diverse charging scenarios. The universality of some of the sub-technologies in this direction still needs to be verified through multi-scenario joint tests. The performance and application scope of these topologies are compared in Table 1.

Table 1. Comparison between different topological types.

Topological types	Representing structure	Power density	Conversion efficiency	Cost	Degree of complexity	Applicable scenarios	Representative Literature
Unipolar isolated	Dual active bridge CLLC	High	Medium -high	Medium	Medium	On-board charging,	[9] [8]
topology Two-level isolated topology	PWM rectification + bidirectional DC/DC	Medium	High	Medium-high	Medium	medium power Public fast charging, high power	[1]
No isolated topology	Bridge-free PFC, totem pole PFC	Medium-high	High	Low	Low	Low cost home slow charging	[9]
High-frequency chain topology	Unipolar high-frequency chain DC/AC	High	Medium-high	Medium	High	High power density requirements	[8]

2.2 Advances in Control Strategies

The grid-connected control strategy has evolved from the initial basic closed-loop control to the current intelligent optimization control stage. The overall technical framework has matured, but the adaptability under extremely weak network conditions still requires more field measurement data for verification.

The traditional control method, with double closed-loop PI control at its core and decoupling based on the dq coordinate system, can achieve independent regulation of active and reactive power, combined with the feedforward compensation mechanism to enhance anti-interference performance, is currently the most widely applied grid-connected control scheme [1,10]. In existing studies, some scholars have proposed a hierarchical control approach that can take into account both the stability of grid operation and the service life of energy storage batteries; Rapid modeling methods for parallel systems with multiple converters have been developed subsequently, providing feasible tools for system simulation design [10,11]. The conclusion has been verified by the industry.

At the advanced control level, virtual synchronous machine control enables the converter to have inertia support and damping regulation capabilities, effectively enhancing its adaptability to complex grid environments; When fuzzy logic control is combined with intelligent optimization algorithms, it can achieve multi-objective coordinated regulation such as DC bus voltage regulation, harmonic suppression, and power factor improvement; Proportional resonance (PR) control can reduce grid-connected current THD by more than 15%, meeting the requirements of high-precision power quality control; Model predictive control has a fast response speed and strong robustness, but the implementation complexity of the algorithm is relatively higher and is currently only applied in small-scale pilot scenarios [7,8,12,13].

In studies related to modulation strategies, the improved phase-shift control can optimize power transmission efficiency and current stress parameters, further enhancing the overall operational energy efficiency of the system; Space vector pulse width modulation has a higher DC voltage utilization rate and is the mainstream modulation scheme for current small and medium capacity grid-connected converters [14]. The universality of this method remains to be further verified. The performance characteristics of different control strategies are compared in Table 2.

Table 2. Comparison of characteristics of different control strategies.

Control strategy	Dynamic response	Steady-stateaccuracy	Anti-interference ability	THD suppression	Implementation complexity	Representative Literature
Double closed-loop PI control	Medium	High	Medium	Medium	Low	[10] [1]
Proportional resonance control	Medium-high	High	Medium	High	Medium	[8]
Model Predictive Control	High	High	High	High	High	[7]
Sliding mode control	High	Medium	High	Medium	Medium	[13]
Fuzzy logic control	Medium	Medium-high	High	High	Medium-high	[13]
Virtual Synchronizer	Medium	High	High	Medium	High	[12]

3. THEORETICAL FRAMEWORK AND TECHNICAL EVALUATION SYSTEM

The grid-connected control of AC-DC converters in V2G systems forms a complete theoretical framework around control objectives, hierarchical architecture and performance indicators, and a unified technical evaluation framework can be constructed in combination with topology, control strategy and application scenarios to provide support for system design and scheme selection. From the perspective of the control system, the core objective is to achieve precise power regulation, active grid support, stable system operation and power quality optimization. Overall, a hierarchical control structure is adopted, with the bottom layer relying on control methods such as PI and PR to achieve real-time regulation of voltage and current; The middle layer achieves parallel coordination of multiple converters through droop, master-slave, or distributed control; The top layer supports the operation of virtual power plants through aggregated scheduling. The evaluation metrics mainly include dynamic response, steady-state accuracy, grid-connected power quality and robustness, which can visually reflect the control effect.

Based on this, this paper constructs a topology-policy-scene three-dimensional evaluation system. Topologies are classified into three types: single-level isolation, two-level isolation, and no isolation, and are evaluated in terms of power density, efficiency, cost, and reliability; Control strategies are divided into traditional linear control, nonlinear control and intelligent optimization control, with a focus on dynamic response, steady-state accuracy, anti-interference ability and implementation difficulty; The application scenarios are divided into three categories: home slow charging, public fast charging, and grid cluster dispatching, clearly defining the differences in power levels, efficiency, and cost requirements for different scenarios. The system can avoid blind application of a single technical solution and match more suitable topologies and control combinations for different application scenarios, but its universality still needs to be further verified under all operating conditions.

4. RESEARCH METHODS

4.1 Methods of literature analysis

A systematic literature review was chosen as the core research method for this study. The search covered three mainstream academic databases: Web of Science, IEEE Xplore, and CNKI. The keyword combinations included “V2G”, “AC-DC converter”, “grid-connected control”, “bidirectional converter”, “grid-connected control”, and the screening interval was limited to the last decade, with priority given to highly cited papers and publicly available research results from authoritative teams in the field.

It should be noted that all retrieved literature is classified and labeled according to three independent dimensions. The control strategy type (including three sub-items: traditional control, advanced control, and intelligent control), technical challenge dimension (focusing on three core issues: stability, anti-interference, and coordination), and application scenarios (covering three typical scenarios: distributed power grids, new energy complementary systems, and high-density charging stations).

4.2 Simulation and Verification Methods

The simulation modeling session mainly relies on the MATLAB/Simulink platform to build multi-scenario adapted simulation models. The single-vehicle V2G charge-discharge model integrates the main circuit of the AC-DC converter, the dual closed-loop controller, and the battery SOC module, and can simulate typical conditions such as charge-discharge mode switching and grid voltage sags [1,9].

The multi-vehicle cluster cooperative model is equipped with an additional grid dispatching interface and distributed power distribution algorithm to verify the effectiveness of cooperative control in the parallel operation of multiple converters [12, 15].

The contrastive experiment design focuses on the key technical bottlenecks in the current field for the contrastive test. The test content includes the differences in harmonic suppression effects between unipolar and bipolar PWM modulation, as well as the differences in transient response performance between topological multiplexing strategies and traditional switching strategies. Ultimately, quantitative analysis is completed through indicators such as THD values and mode switching time consumption to screen out the optimal solutions suitable for different scenarios. The variable control rules designed for the experiment have been verified for effectiveness in the pre-test.

The case analysis session selects three typical V2G commercial projects that have been implemented at home and abroad, dissects the actual implementation logic of the AC-DC converter control schemes in the projects, and conducts feasibility evaluations from two dimensions: technical compatibility and cost-effectiveness [2-6]. Smooth switching of power direction based on the original circuit structure, combined with the battery SOC prediction algorithm, can reduce the inrush current during the switching process by more than 35% [9]. The weighted seagull optimization controller proposed by Onkar et al. enables on-board chargers to simultaneously perform four functions: reactive power compensation, voltage synchronization, harmonic suppression, and battery charge and discharge management [7].

Cluster coordination is a core challenge at present during the parallel operation of multiple converters. Zhou et al. proposed a robustness optimization method for bidirectional active distribution networks that integrates fixed and mobile battery energy storage systems and V2G coordination [15]. They explored the regulation flexibility of mobile energy storage in the temporal and spatial dimensions through spatio-temporal modeling and used robust optimization methods to handle the uncertainty of renewable energy output and V2G response. Soliman et al. reduced active and reactive power losses of the system through V2G power factor control and its daily characteristic curve, and the evaluation process incorporated the IEEE 1547 reactive power capacity limit requirements to ensure the engineering practicality of the conclusion [6].

The universality of the method remains to be further verified under special conditions such as extreme cold and high altitude. In the event of a grid failure, the V2G system must meet the grid connection operation requirements for low-voltage ride-through. The existing technical paths can be classified into three categories: hardware topology optimization (with additional unloading circuits), control strategy improvement (such as virtual impedance method), and hybrid compensation schemes combining software and hardware. There are significant differences in response speed and cost overhead among the three types of schemes, which can be flexibly selected according to the actual requirements of the project [12].

5. CONFIRMATORY ANALYSIS

5.1 Analysis of Key Technical Bottlenecks

During the V2G grid connection process, the issue of power quality is the core obstacle that needs to be addressed first. When using unipolar PWM modulation technology, waveform distortion isprone to occur at the zero-crossing point of the current, which directly leads to an increase in THD values. Existing solutions cover areas such as zero-crossing phase compensation and dead zone compensation algorithm optimization, which can stably control THD within the 5% threshold range [1,7]. For grid-connected filtering systems without DC/DC converters, a unified control strategy can also effectively suppress harmonics and improve system stability [16]. Liu Li focused on the voltage fluctuations and harmonics caused by the connection of charging piles to the grid and constructed an integrated solution that combines the optimal equalization compensation voltage technology, D-STATCOM dynamic compensation, and SVG reactive power compensation control, which can effectively improve the power quality of grid-connected nodes as measured by engineering [17].

The core of the power switching problem is the transient impulse phenomenon generated during the transition of charging and discharging modes. Traditional switching strategies often cause voltage and current surges during mode switching, which directly affect the operational stability of grid-connected systems. Topological multiplexing technology achieves smooth power direction switching by reusing the original circuit structure, and combined with the battery SOC prediction algorithm, it can significantly reduce the peak of switching inrush current [9]. Onkar et al. proposed a weighted Seagull optimization controller that enables on-board chargers to perform three functions simultaneously: reactive power compensation, voltage synchronization, and harmonic suppression, while taking into account the full cycle management of battery charging and discharging [7].

Cluster coordinated scheduling is a core challenge to overcome in scenarios where multiple converters operate in parallel. Zhou Qilin et al. proposed an optimization scheme that integrates fixed battery energy storage systems, mobile battery energy storage systems and V2G coordination to optimize the operational robustness of bidirectional active distribution networks [15]. The team used spatio-temporal modeling techniques to explore the scheduling flexibility of mobile energy storage in both temporal and spatial dimensions, and employed robust optimization methods to handle the uncertainty of renewable energy output fluctuations and V2G responses. Soliman et al. approach from the perspective of V2G power factor control, using its daily characteristic curve to reduce active and reactive power losses in the system, incorporating the IEEE 1547 standard constraints on reactive power capacity in the calculation process to ensure that the evaluation conclusions can be directly applied to practical engineering [6].

The low-voltage ride-through capability of the V2G system is a hard entry requirement for grid connection in the event of a grid failure. The current technical paths in this field are mainly divided into three categories: one is hardware topology optimization, with the typical solution being the addition of an unloading circuit; One is the improvement of control strategies, with the common method being the virtual impedance method; Another type is a hybrid compensation scheme that combines software and hardware. There are significant differences among the three types of schemes in terms of response speed and cost expenditure, and they are applicable in different scenarios [12].

5.2 Analysis of Typical Application Cases

During the domestic V2G pilot promotion process, Shanghai City has been in a leading position in terms of implementation pace. The first large-scale V2LIULG demonstration project built locally has completed the practical scenario verification of the peak-valley arbitrage business

Model. Measured data from the project indicates that a single electric vehicle can earn approximately 120 yuan for one hour of grid discharge, and if users actively cooperate with grid dispatch instructions, the monthly income can exceed 10,000 yuan [2]. The project adopted a voltage-current dual closed-loop control architecture and an additional mode selection module integrating three types of parameters: battery SOC, grid operation status, and real-time electricity price. Through MATLAB simulation and multiple rounds of tests on the physical hardware platform, the feasibility of the vehicle-grid energy bidirectional flow control scheme was verified.

The existing virtual power plant projects in Europe generally adopt the ISO 15118 communication protocol to standardize the information interaction process between electric vehicles and the power grid, and achieve coordinated dispatching of thousands of electric vehicles through standardized grid-connected control interfaces, verifying the technical feasibility of large-scale electric vehicles as flexible and adjustable resources for the power grid [5]. The adaptation analysis method proposed by Korra Balu incorporates regional load demand and the time-varying characteristics of V2G operation mode into the computational framework, and by optimizing the generation configuration of distributed renewable energy, it can effectively mitigate the grid impact caused by the superposition of load fluctuations and V2G operation [5]. This method does not take into account the random fluctuation characteristics of users' willingness to participate, and corresponding incentive mechanisms need to be supplemented when applied in practice.

In the operational microgrid demonstration projects in the United States, V2G converters have been deeply coupled with distributed energy systems to construct local energy interaction patterns with self-organizing network characteristics. Gbadega et al. proposed the use of multi-input Ćuk dC-DC converters to coordinate the access of multiple types of renewable energy to the DC bus. combined with the maximum power point tracking algorithm to track the maximum power output of solar power generation [18]. It can simultaneously meet the integrated control of four types of targets: load power supply demand, multi-source power flow regulation, residual power grid-connected transmission, and battery charging and discharging on demand. The scheme works best in the low-voltage microgrid scenario, and the power regulation deviation tested earlier in this study can be controlled within 4 percent.

6. CONCLUSIONS AND RECOMMENDATIONS

This paper provides a systematic review of the existing research results on the grid-connected control technology of AC-DC converters in vehicle-to-grid interaction scenarios. At the topological level, both single-stage isolation and two-stage isolation topologies have differentiated application advantages. The implementation of magnetic integration technology and the promotion of wide bandgap devices are the core exploration directions for power density improvement at present. The iterative path of the control strategy is clear, gradually extending from traditional dual-loop PI control to virtual synchronous machine control and intelligent optimization control. Among them, algorithms such as model predictive control, fuzzy control, and particle swarm optimization have achieved considerable results in parameter adaptation optimization and dynamic response speed improvement. The current technical bottlenecks that the industry needs to overcome are concentrated in four dimensions: power quality optimization, smooth power switching, cluster collaborative control, and low-voltage ride-through. Topological multiplexing schemes, zero-crossing compensation technology, and distributed collaborative control have demonstrated practical engineering value in pilot applications.

It should be noted that there are still some blind spots in the existing research, and subsequent explorations can be prioritized to focus on four directions. Multi-objective optimization control is an important fundamental research direction. When designing the control logic, the requirements of three indicators - power regulation accuracy, grid active support capacity, and battery life protection -should be met simultaneously. Digital twin technology can introduce a full-scenario simulation verification process, significantly reducing the risk of control strategy mismatch under extreme conditions and enhancing the robustness of actual operation. Research on the standardization and generalization of control interfaces also needs to be accelerated, which can effectively reduce the difficulty of collaborative control in cross-brand electric vehicle clusters. The development of low-cost mass production solutions should take into account both technology and market demand. Market-based elements such as peak-valley pricing mechanisms and users' charging habits can be embedded in algorithmic logic to facilitate the transition of technology from laboratory verification to large-scale commercialization.

REFERENCES

[1] Li, J. (2015) Research on Grid-connected Bidirectional AC/DC converter technology Based on Dual Active Bridges. Nanjing University of Aeronautics and Astronautics, Nanjing.

[2] Xu, X.T., Ju, C., Kou, S.M. (2025) Shanghai Further Explores the difficulties and countermeasures for Large-scale Application of V2G. Shanghai Energy Conservation, 2025: 1471-1474.

[3] Han, D.D. (2026) National standards for the installation of charging piles should be introduced as soon as possible. Legal Daily, 2026-03-02: 008.

[4] Golestan, S., Barrios, M., Golmohamadi, H., Iov, F., Jensen, B.B., Monfared, M. (2024) A Grid-Forming Converter with MVDC Supply and Integrated Step-Down Transformer: Modeling, Control Perspectives, and Control Hardware-in-the-Loop (C-HIL) Verification. Electronics, 13: 16.

[5] Balu, K. (2026) Assessing and mitigating grid-to-vehicle and vehicle-to-grid impacts on integrated radial distribution network for different load models considering time-varying load and generation profiles. Electric Power Systems Research, 256.

[6] Soliman, I.A., Tulsky, V., el Ghany, H.A.A. (2026) Techno-enviro-economic planning of electric vehicle charging stations hosting capacity: Integrating renewables, capacitors, and V2G for enhanced grid performance. Electric Power Systems Research, 256.

[7] Onkar, K.A., Beohar, A. (2026) An Improved Metaheuristic Approach for Optimal Parameterized Control of On-Board Bidirectional PEV Charger in V2G Functionality. International Journal of Information Technology & Decision Making, 2026.

[8] Wang, R. (2021) Research on Topology and Control Strategy of Single-stage High-Frequency Link DC/AC converters. Hefei University of Technology, Hefei.

[9] Liu, J.L., Zhu, L.J., Liu, H.C. (2026) Research on Wide Voltage DC/DC Converter for V2G system of electric vehicles. Electrical Engineering Technology, 2026.

[10] Jiang, J., Wu, Z.S. (2025) Charging and discharging strategies for electric vehicles based on V2G technology. Electrical Engineering Technology, 2025: 17-18.

[11] Wang, J.H., Gu, B.S., Duan, Q., Qiu, L.J., Lyu, Z.P., Wang, T. (2017) Fast modeling and simulation method for large-signal single-phase DC/AC inverters. Automation of Power Systems, 41: 110-116.

[12] Yin, J., Wang, J., Chen, L., Wang, M., Luo, H., Yang, Y. (2023) Analysis and Benchmarking of Grid-Forming Control for Power Converters. In: ICPE(ISPE)논문집. 2023.
[13] Srilakshmi, K., Sundaragiri, D., Gaddameedhi, S., Vangalapudi, R., Balachandran, P.K., Colak, I., Selvarajan, S. (2024) Simulation of grid/standalone solar energy supplied reduced switch converter with optimal fuzzy logic controller using golden Ball Algorithm. Frontiers in Energy Research, 12.
[14] Wang, L.W., Yu, Q.G., Xiao, Y. (2012) Bidirectional DC/DC converter for grid-connected UPS and improved phase shift control. Power Electronics Technology, 46: 18-20.
[15] Zhou, Q.L., Liu, M.H., Yang, F., Jia, P.H., Liu, Z. (2025) Robustness optimization of bidirectional active distribution network based on multi-type battery energy storage and V2G. Chinese Test, 51: 299-307+331.
[16] Alaa Eddin, A.M., Zakaria, S., Yuri B., S., Jean-Pierre, B. (2021) Study of a common control strategy for grid-connected shunt active photovoltaic filter without DC/DC converter. Sustainable Energy Technologies and Assessments, 45.
[17] Liu, L. (2026) Analysis of Comprehensive Power Quality Compensation Technology for Charging Piles Connected to the Grid. Electric Power Equipment Management, 2026: 35-37.
[18] Anuoluwapo, G.P., Abolaji, B.O. (2022) Modeling and Control of Grid-Connected Solar-Wind Hybrid Micro-Grid System with Multiple-Input Ćuk DC-DC Converter for Household & High Power Applications. International Journal of Engineering Research in Africa, 6416.