World Electric Vehicle Journal

Review

Annotated Survey on the Research Progress within Vehicle-to-Grid Techniques Based on CiteSpace Statistical Result

Ruifeng Shi [1,2,*], Shuaikang Peng [1], Tai Chang [1] and Kwang Y. Lee [3]

1 School of Control and Computer Engineering, North China Electric Power University, Beijing 102206, China; pengshuaikang@ncepu.edu.cn (S.P.); changtai@ncepu.edu.cn (T.C.)
2 China Institute of Energy and Transportation Integrated Development, Beijing 102206, China
3 Department of Electrical and Computer Engineering, Baylor University, Waco, TX 76798, USA; kwang_y_lee@baylor.edu
* Correspondence: shi.ruifeng@ncepu.edu.cn

Abstract: Vehicle-to-grid (V2G) technology has received a lot of attention as a smart interconnection solution between electric vehicles and the grid. This paper analyzes the relevant research progress and hotpots of V2G by using CiteSpace 6.1.R6 software to construct a visualization graph, which includes keyword co-occurrence, clustering, and burstiness, and further systematically summarizes the main trends and key results of V2G research. First, the connection between electric vehicles and the grid is outlined and the potential advantages of V2G technology are emphasized, such as energy management, load balancing, and environmental sustainability. The important topics of V2G, including renewable energy consumption, power dispatch, regulation and optimization of the grid, and the smart grid, are discussed. This paper also emphasizes the positive impacts of V2G technologies on the grid, including reduced carbon emissions, improved grid reliability, and the support for renewable energy integration. Current and future challenges for V2G research, such as standardization, policy support, and business models, are also considered. This review provides a comprehensive perspective for scholars and practitioners in V2G research and contributes to a better understanding of the current status and future trends of V2G technology.

Keywords: vehicle-to-grid; electric vehicles; grid; CiteSpace; visual analytics

Citation: Shi, R.; Peng, S.; Chang, T.; Lee, K.Y. Annotated Survey on the Research Progress within Vehicle-to-Grid Techniques Based on CiteSpace Statistical Result. *World Electr. Veh. J.* **2023**, *14*, 303. https://doi.org/10.3390/wevj14110303

Academic Editor: Ghanim A. Putrus

Received: 30 September 2023
Revised: 25 October 2023
Accepted: 26 October 2023
Published: 2 November 2023

1. Introduction

Electric vehicles (EVs) are considered to be the cleanest form of transportation [1,2]; however, the popularization of EVs brings challenges, not only to the power grid but also to our lifestyles. Vehicle-to-grid (V2G) technology, as shown in Figure 1, is a pivotal component of the smart grid paradigm and has garnered significant attention in recent years [3]. This technology enables EVs to obtain electricity from the grid; it stores renewable energy, including wind [4], solar [5], and water [6], as mobile energy storage devices and feeds back power to the grid when needed [7]. With the intensified global push for sustainable energy solutions and the improvement in battery capacity and storage efficiency of EVs [8], the integration of EVs with the grid has become increasingly crucial as it can offer potential solutions to challenges such as grid stability [9], peak demand management [10,11], and renewable energy integration [12].

The rapid evolution of V2G technology has led to a plethora of research endeavors aiming to address its multifaceted challenges and harness its potential benefits [13]. From technical intricacies related to grid integration and battery health to economic considerations [14,15] and policy implications, the V2G research landscape is both diverse and dynamic. Given the burgeoning interest and the vast scope of this field, a comprehensive survey has become a pressing need; such a survey can encapsulate the current state of V2G research, as well as highlight key findings, trends, and future directions.

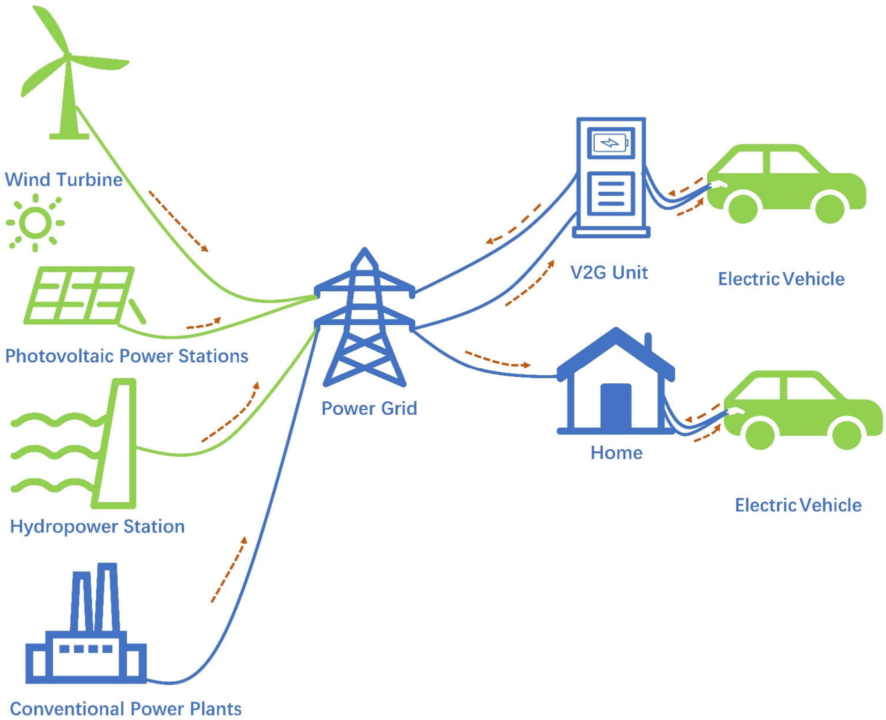

Figure 1. V2G service diagram.

As a popular bibliometric analysis tool, CiteSpace offers a robust mechanism to statistically analyze the vast corpus of V2G literature. By leveraging CiteSpace, researchers can gain insights into the most influential works, emerging trends, and potential research gaps in the V2G domain. This paper aims to systematically review the V2G research landscape and draw upon the statistical insights gleaned from CiteSpace to offer a roadmap for researchers, policymakers, and industry stakeholders.

The object of this paper and its main results are as follows:

Firstly, the CiteSpace software is employed to conduct a visual analysis of the keywords in the current published papers within the research field; the aim is to analyze the co-occurrence relationship of each keyword in the papers from 2013 to 2023.

Secondly, clusters are formed by the keywords with strong relationships, representing the research trends of V2G over the past decade. Then, by examining the inheritance relationships of co-occurring keywords on the research timeline, a summary of past research achievements is made, and the recent hot research directions of the last two years are identified.

Finally, based on the summary of the past research achievements, the prospects for potential future research trends are provided.

2. Literature Search and Analysis

The literature analyzed in this paper is from the SCI-EXPANDED collection in the core collection of the Web of Science. During the collections, the category of "articles" published in English was sought by searching for the subject term "V2G" or "VEHICLE TO GRID", and a total of 2009 papers published from 2005 to 2023 were identified. Then, excluding the review papers, 1768 papers published from 2013 to 2023 (retrieved on 3 August 2023) were identified; they were distributed as shown below. Following the analytics, it can be concluded that the research on V2G is in a rapid development stage and that the annual number of articles is steadily growing, reflecting the continuous increase in the attention given to this topic. The year-by-year distribution of these papers is shown in Figure 2.

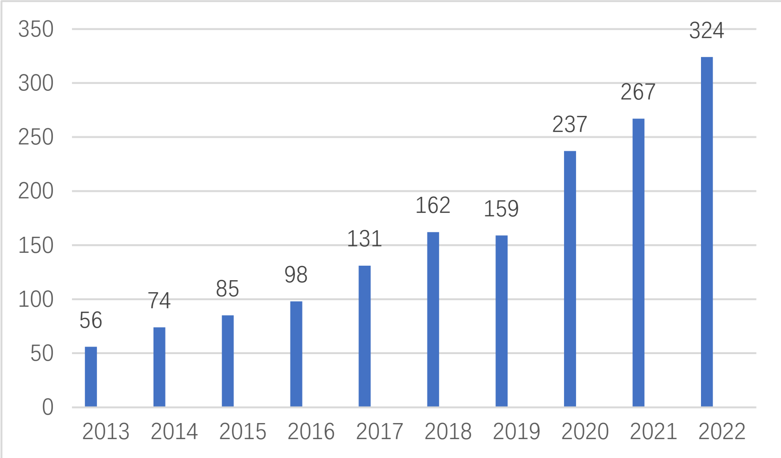

Figure 2. Annual trend of publications.

2.1. Keyword Visualization Analysis of V2G Literature

Keywords play a pivotal role in reflecting the essence and ideas presented within the paper. Based on their prevalence, these keywords offer a viable means of discerning the cutting-edge areas of research, the focal points of interest, and the trajectories of growth within specific disciplines. Centrality serves as a crucial metric for evaluating the significance of these keywords. If the centrality score of a particular node surpasses 0.1, it signifies that the node holds a central position and exerts a substantial impact on the pertinent research domains [16].

Based on screening and filtering, the keywords with the same meaning were merged by recognizing the keywords of the documents in the database; ultimately, 294 keyword nodes and 1098 node links were obtained. CiteSpace was used to create a keyword co-occurrence matrix and generated a keyword co-occurrence network. In this case, the color of the connecting line between two nodes indicates the earliest time when these two keywords co-occurred; the size of the node indicates how often it occurs, and the color of the centermost part of the node indicates the earliest time when the keyword appeared, as shown in Figure 3.

Tables 1 and 2 showcase the results of our statistical analysis concerning keywords with a substantial frequency, i.e., those which had more than 50 occurrences, and the centrality of these keywords across 1768 pertinent research documents spanning the period from 2013 to 2023. The Year in the header row is the time node in the literature when the keyword was first mentioned in the cited literature. Among the high-frequency keywords, those that emerged more than 50 times include terms like “electric vehicle”, “vehicle-to-grid (v2g)”, “system”, “management”, “impact”, “optimization”, and “smart grid”. Conversely, keywords with a centrality exceeding 0.1 comprised “hybrid”, “generation”, “design”, “wind power”, “renewable energy”, “demand response”, “storage”, “cost”, and others. From these findings, it is evident that these keywords serve as pivotal nodes within the evolutionary trajectory of this interconnected body of research.

The clustering of keywords and the automatic labeling of clusters are important to CiteSpace when identifying the main research topics related to V2G. Figure 4 illustrates the clustering outcomes. According to the log-likelihood ratio (LLR) algorithm, the keywords in the cited literature were clustered and analyzed to generate a keyword clustering diagram. Within this network, it is important to consider two values: Q (modularity, indicating the clustering module value) and S (silhouette, representing the cluster average contour value). These values gauge the quality of the clustering grid. Typically, a Q value greater than 0.3 suggests a significant clustering structure, while an S value surpassing 0.5 indicates a reasonable clustering. Moreover, when S exceeds 0.7, it signifies a clustering with high credibility. In this paper’s clustering analysis, the obtained values are as follows: Q = 0.8411 (>0.3), affirming the significant clustering structure, and S = 0.9413 (>0.7), indicating the high credibility of the clustering.

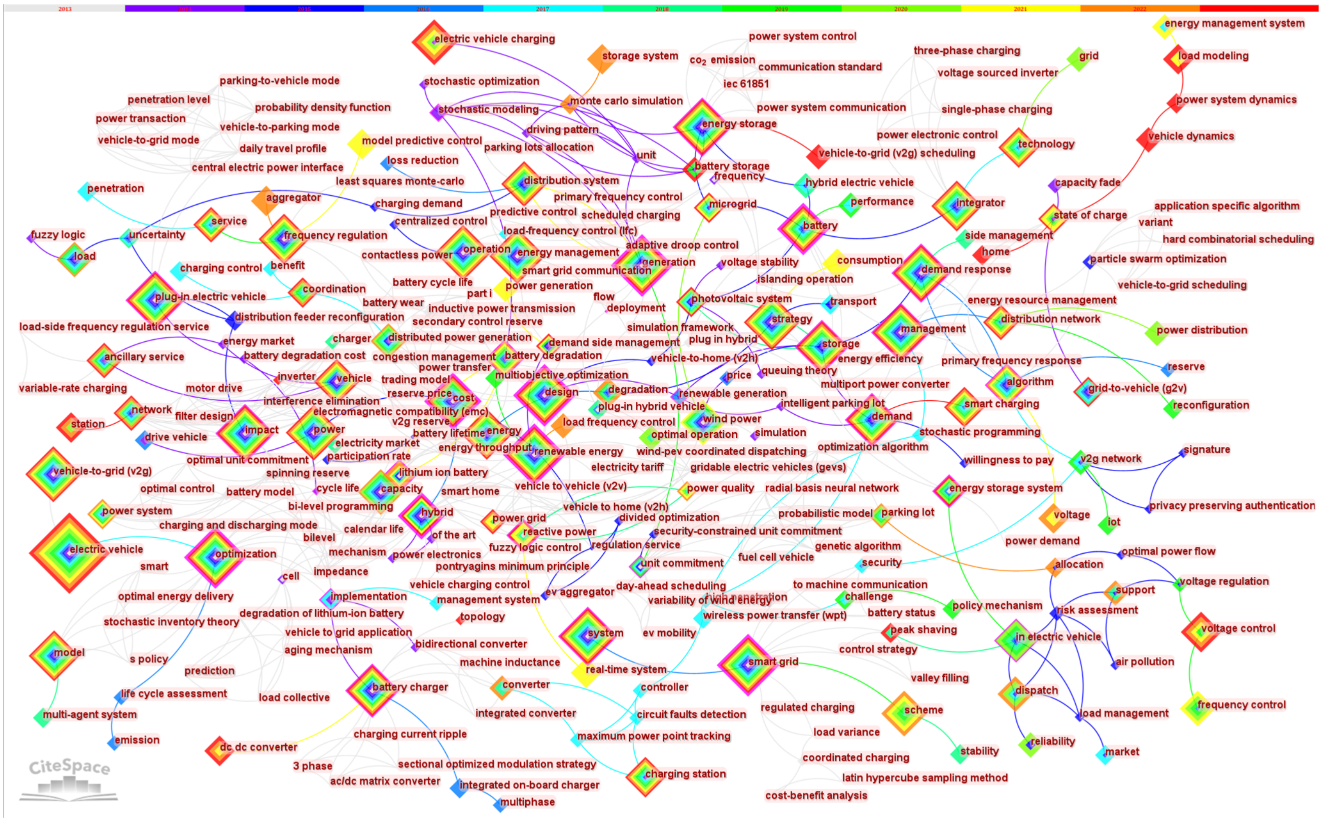

Figure 3. Knowledge mapping for the keywords' co-occurrence.

Table 1. Statistics of high-frequency keywords.

NO.	Frequency	Year	Keywords	NO.	Frequency	Year	Keywords
1	1015	2013	electric vehicle	21	97	2014	storage
2	486	2013	vehicle-to-grid (v2g)	22	90	2013	generation
3	374	2013	system	23	90	2013	energy storage
4	233	2013	management	24	81	2013	battery
5	224	2013	optimization	25	77	2013	battery charger
6	223	2013	impact	26	71	2013	frequency regulation
7	215	2013	renewable energy	27	70	2013	wind power
8	202	2013	smart grid	28	69	2016	distribution network
9	174	2013	integrator	29	69	2016	technology
10	160	2013	strategy	30	68	2013	distribution system
11	149	2013	model	31	65	2013	vehicle
12	147	2013	demand	32	64	2013	algorithm
13	146	2013	power	33	63	2014	electric vehicle charging
14	134	2013	plug-in electric vehicle	34	61	2013	power system
15	126	2013	operation	35	60	2013	network
16	125	2013	energy	36	58	2013	battery degradation
17	121	2013	design	37	56	2016	smart charging
18	120	2013	demand response	38	55	2013	capacity
19	118	2013	energy management	39	52	2013	cost
20	105	2014	charging station				

Table 2. Statistics of high-centrality keywords.

NO.	Centrality	Year	Keywords	NO.	Centrality	Year	Keywords
1	0.39	2013	renewable energy	17	0.14	2014	stochastic modeling
2	0.34	2013	hybrid	18	0.13	2013	management
3	0.30	2013	generation	19	0.13	2013	impact
4	0.26	2013	design	20	0.13	2015	plug-in electric vehicle
5	0.24	2013	cost	21	0.13	2014	renewable generation
6	0.21	2013	optimization	22	0.12	2013	demand response
7	0.21	2013	smart grid	23	0.12	2013	implementation
8	0.21	2013	battery	24	0.11	2013	plug-in electric vehicle
9	0.17	2013	system	25	0.11	2013	algorithm
10	0.17	2014	storage	26	0.11	2013	battery degradation
11	0.16	2013	demand	27	0.11	2013	reactive power
12	0.16	2013	energy storage	28	0.10	2013	strategy
13	0.16	2013	cycle life	29	0.10	2013	energy storage system
14	0.15	2013	unit commitment	30	0.10	2014	photovoltaic system
15	0.15	2013	deployment	31	0.10	2013	lithium ion battery
16	0.14	2013	battery charger	32	0.10	2013	islanding operation

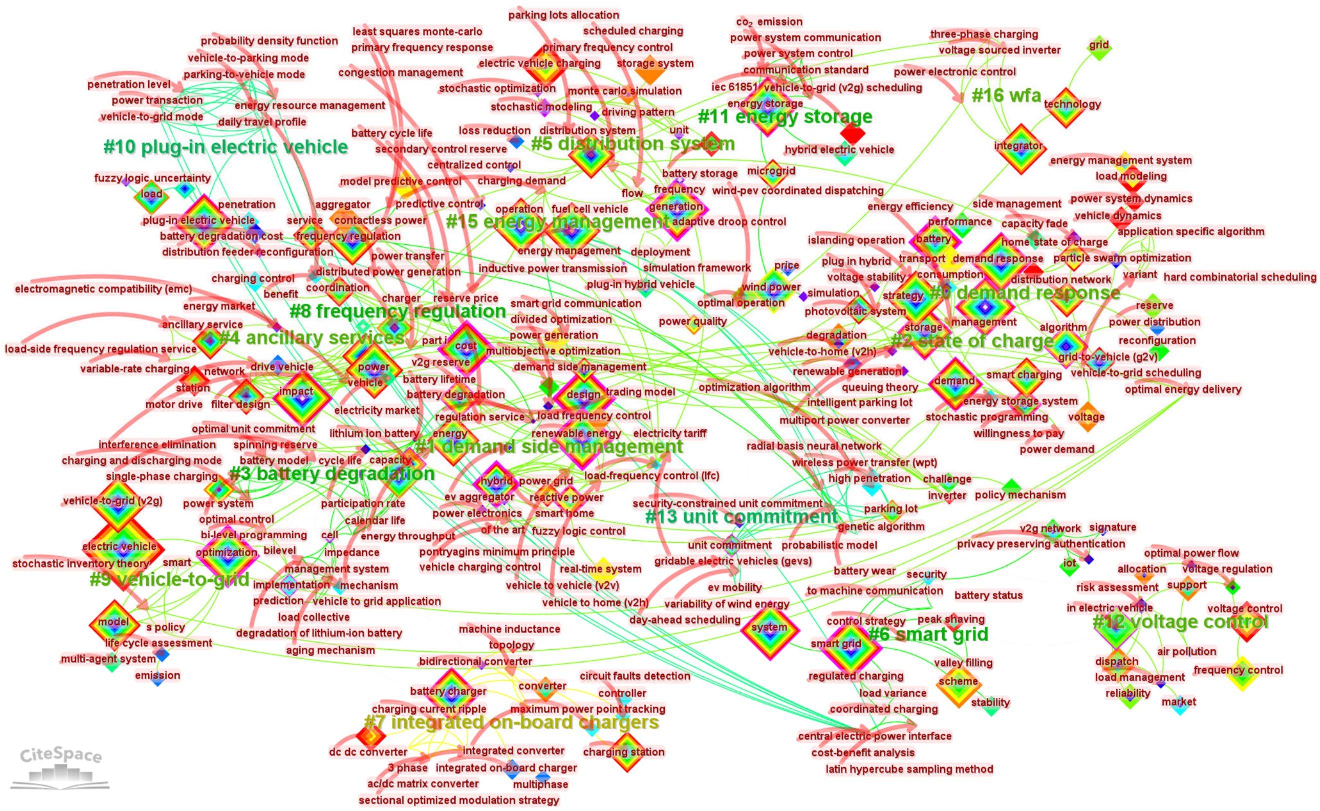

Figure 4. Analysis atlas of keyword clustering.

2.2. Time Distribution of Literature Retrieval

For a comprehensive portrayal of the evolution of V2G development and knowledge clusters, Figure 5 presents a visual timeline analysis of the keyword clusters. The length of the timeline represents the continuity of the clustering. As can be seen from the figure, "state of charge" and "energy storage" in the clusters have been the focus of the scholars' attention, and they have continued to be the focus to this day. "Demand side management", "frequency regulation", and "distribution system" in the cluster-related studies ended in 2022. Section 3 provides a specific analysis of the clusters in Figure 4.

Table 3 displays the statistical data for the reference clusters, with the Silhouette (S) values indicating the sound data clustering within these primary research fields. The keywords have been organized into 12 distinct categories and labeled numerically from 0 to 12. The cluster names, in order, are #0 demand response, #1 demand-side management, #2 state of charge, #3 battery degradation, #4 ancillary services, #5 distribution system, #6 smart grid, #7 integrated on-board chargers, #8 frequency regulation, #9 vehicle-to-grid, #10 plug-in electric vehicle, #11 energy storage, and #12 voltage control. Each cluster comprises a collection of closely related keywords, with the smaller cluster numbers indicating a higher number of keywords within that cluster. Table 3 provides an inventory of the primary keywords within each cluster along with their respective frequencies.

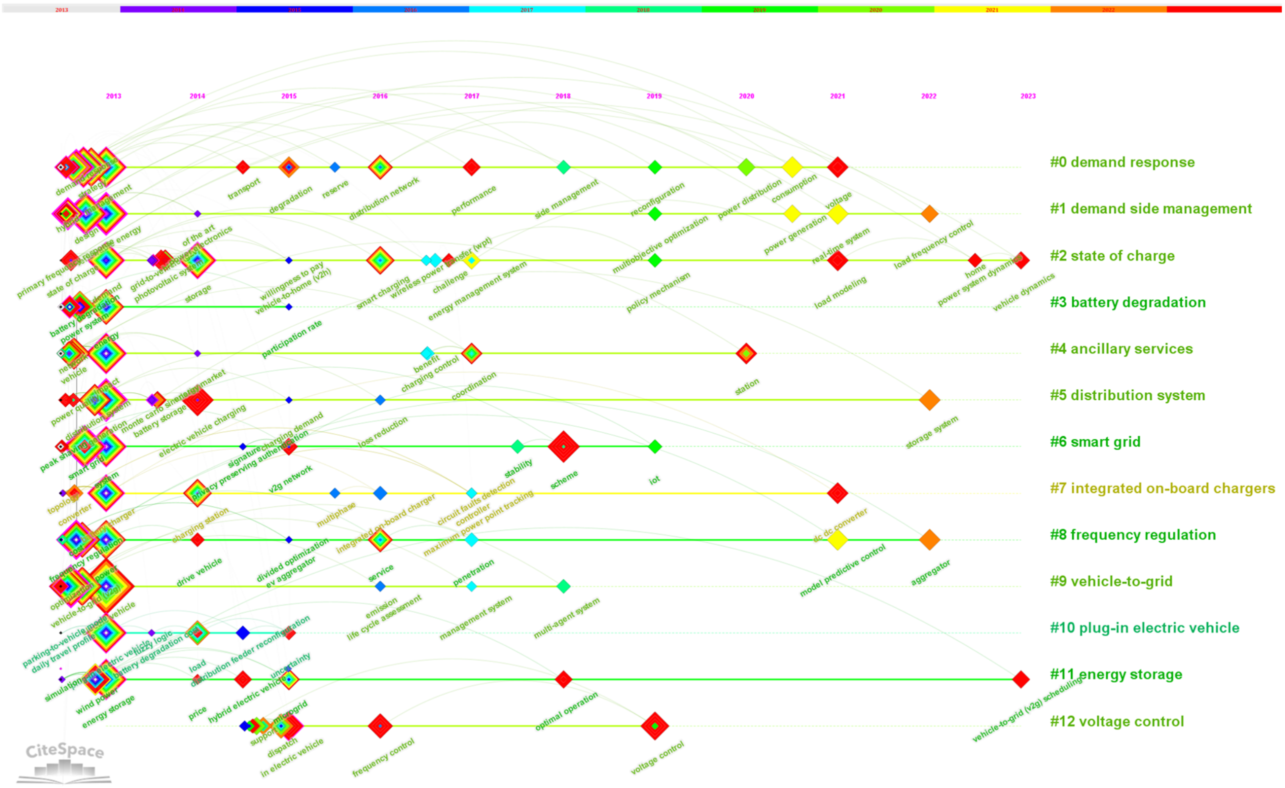

Figure 5. The evolution view of the keywords' co-occurrence network.

Table 3. The cluster data statistics of references.

Cluster Label (LLR)	Size	Silhouette	Mean Year	Ranked Terms and Their Frequency
demand response	27	0.864	2014	management (233); demand response (120); battery (81); algorithm (64); energy storage system (30); degradation (26); performance (10); transport (7); power distribution (7);
demand-side management	25	0.953	2014	renewable energy (215); design (121); hybrid (34); reactive power (28); power grid (27); demand-side management (26); real-time system (11); power generation (7); load frequency control (7);
state of charge	24	0.858	2016	demand (147); storage (97); smart charging (56); state of charge (33); photovoltaic system (30); grid-to-vehicle (g2v) (22); load modeling (14); energy management system (13); challenge (8); vehicle dynamics (7);
battery degradation	23	0.934	2013	energy (125); power system (61); battery degradation (58); capacity (55); lithium ion battery (26);
ancillary services	22	0.976	2013	impact (223); vehicle (65); network (60); coordination (47); distributed power generation (45); ancillary service (42); station (24); charger (6);

Table 3. *Cont.*

Cluster Label (LLR)	Size	Silhouette	Mean Year	Ranked Terms and Their Frequency
distribution system	20	0.895	2014	generation (90); distribution system (68); electric vehicle charging (63); power quality (26); battery storage (10); plug-in hybrid vehicle (10); Monte Carlo simulation (9); storage system (8);
smart grid	19	0.988	2014	system (374); smart grid (202); scheme (48); v2g network (20); peak shaving (10); security (9);
integrated on-board chargers	17	0.941	2014	charging station (105); battery charger (77); converter (24); DC–DC converter (23);
frequency regulation	16	0.936	2014	power (146); frequency regulation (71); cost (52); service (40); aggregator (11); model predictive control (8); drive vehicle (6); electricity market (6);
vehicle-to-grid	15	0.968	2014	electric vehicle (1015); vehicle-to-grid (v2g) (486); optimization (224); model (149); implementation (9);
plug-in electric vehicle	14	0.978	2013	plug-in electric vehicle (134); load (43); uncertainty (15);
energy storage	14	1	2014	energy storage (90); wind power (70); microgrid (40); hybrid electric vehicle (13); optimal operation (11); price (7); vehicle-to-grid (v2g) scheduling (7);
voltage control	13	1	2015	voltage control (44); frequency control (32); plug-in electric vehicle (32); dispatch (27); support (15); reliability (11); allocation (9); market (8); voltage regulation (6);

Figure 6 illustrates the top 25 keywords with citation bursts. In this visualization, the blue line represents the time intervals, and the red line marks the specific time points when a keyword experienced a burst in citations [16,17]. The strongest keyword for a citation explosion, "smart grid", appeared in 2014, indicating the importance of the smart construction of the grid in interconnecting vehicles to the grid. The most recent keywords, which appeared in the citation explosion in 2021, were "electric vehicle charging", "voltage control", and "DC-DC converter". In addition, "load modeling" continued into 2023.

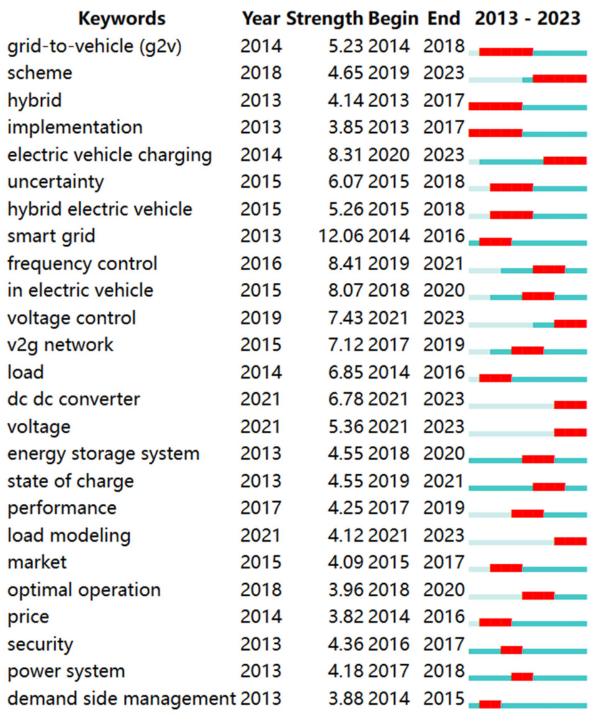

Figure 6. Top 25 keywords with the strongest citation bursts.

3. Keyword Analysis and Application Analysis of V2G

Many scholars have conducted in-depth studies on the potential problems that may be encountered in V2G theory and applications. In this section, these research results are summarized to facilitate the subsequent studies. In this section, a literature review of the clusters appearing in Figure 5 is conducted, and as #0 demand-side response, #1 demand-side management, #4 ancillary services, and #7 integrated on-board chargers all fall within the scope of the scheduling, they are combined in scheduling to review the research progress. In addition, #5 distributed systems is also combined with renewable energy. The cluster #3 battery degradation is not reviewed in detail due to the small timespan. The relevant studies are summarized in Table S1 of Supplementary Materials.

3.1. Energy Storage, Renewable Energy Sources, and Scheduling

3.1.1. Energy Storage

Numerous scholars have conducted in-depth research on the planning and management of V2G and energy storage. Electric vehicle batteries, because of their high capacity, can be used as storage units to store excess power when the load on the grid is low and then to release it when the demand peaks, thus ensuring the stable operation of the grid [18].

The combination of V2G technology and energy storage systems provides new opportunities to realize a more efficient, flexible, and reliable power system [19]. As an energy storage medium, EV batteries can reduce investment and the construction of RE and stationary storage and minimize resource waste [20]; the introduction of smart battery technology further facilitates the realization of V2G [21]. In terms of economics, battery recession costs, electricity sales prices [22], and infrastructure costs [23] affect the ability of EVs to provide short-term operational reserves to the grid as energy storage units [24]; however, EVs still have the potential to service other facilities. For example, V2G can be embedded as energy storage in homes and IES to provide energy for domestic and commercial centers, which can reduce energy costs and improve the environmental benefits [25,26]. Sun et al. investigated how the SOC of EV batteries affects the total cost of residential energy systems that use EVs as part of the residential energy system. The results showed that the battery aging cost is still an important factor affecting the willingness of EV users to discharge their batteries [27]. By embedding V2G as energy storage in IES, Wei et al. allowed the two to be coupled to maximize the economic and environmental benefits of IES [25]. Hipolito, Vandet, and Rich estimated the energy storage potential of EVs and concluded that the willingness of EV users to discharge their batteries increases significantly only when the battery utilization is below 40% [28].

In summary, it is possible to regulate electricity prices to allow EVs to actively participate in energy storage, but if EVs are allowed to supply power to the grid, a reasonable peak-to-valley electricity differential needs to be established to compensate for the cost of battery depletion to increase the willingness of users to discharge their batteries.

3.1.2. Renewable Energy Sources

The high volatility of wind and light energy brings considerable challenges to grid-connected power generation [29]. As V2G technology has a fast response time [30], a flexible in-and-out mechanism, and an energy storage device that is relatively fixed, it does not require additional investment and plays a unique and irreplaceable role in consuming excess power from clean energy sources.

Many researchers have tried to consume these renewable energy sources with EVs. Gao et al. integrated the wind power generators and EVs with V2G operation capability in the distribution grid, formulated a mathematical model of V2G power control, and deployed a dynamic power regulation for EVs [31]. Jin et al. presented a coordinated control strategy for large-scale EVs, BESSs, and traditional FR resources involved in AGC which could improve the frequency stability and facilitate the integration of renewable energy [32]. Fattori, Anglani, and Muliere analyzed the impact of PVs and EVs on the grid under different penetration scenarios, where V2G gains were not promising because the desynchronization of EV charging behavior with PV generation led to increased demand for capacity that non-PVs had to provide, and at the time, battery costs were high in relation to PV costs [11]. Fathabadi et al. analyzed the impact of power sources on the distribution network; these sources include conventional generators (CPG), DG renewable energy sources, and EVs. Experiments have demonstrated that the simultaneous use of CPG, DG renewable energy sources, and charging/discharging EVs results in the lowest cost of power production and the optimal voltage profile; thus, the lowest power loss is obtained by utilizing both CPG and DG in the grid [33]. Haddadian et al. deployed EV fleets as distributed storage and achieved their optimal coordination with wind energy. Studies indicate that the method could cut the diurnal operation cost, lower the emissions, and enable thorough consumption of forecasted wind with zero wind curtailment [34]. Uddin et al. developed a battery degradation model and seamlessly integrated it into a smart grid algorithm. This innovative approach demonstrated that linking an EV to this intelligent grid system not only effectively addressed the power network's demand with a greater infusion of clean renewable energy but also, notably, extended the lifespan of the EV battery [35]. Robledo et al. introduced the results of a demonstration project, including building-integrated photovoltaic (BIPV) solar panels, which indicated that FCEVs can integrate transport and electricity sectors in a sustainable energy system [36]. Bhatti and Salam considered daytime EV charging in an office parking lot by means of the PV grid system and proposed a rule-based energy management scheme (REMS). This work can integrate other RE sources such as wind, tidal, and biomass [37]. Sufyan et al. conducted an analysis of the influence of system costs and energy losses across varying levels of RE integration, EV capacities, and travel distances. Their simulation results clearly indicate a substantial reduction in operational expenses when renewable energy sources (RESs) are seamlessly integrated into the distribution network. Furthermore, the utilization of V2G technology has proven to be advantageous for EV users, particularly in scenarios with a high level of RES penetration [38]. Noorollahi et al. introduced a novel framework for an electric vehicle aggregator and devised models for four distinct EV charging scenarios. Their approach takes into account a wide array of renewable energy sources, including wind turbines, solar PV panels, and geothermal units. They have implemented an energy scheduling model to optimize these scenarios effectively [39]. Bartolini et al. conducted an analysis to explore how a fleet of EVs can contribute to enhancing the self-consumption capacity of a district, particularly in the context of a high and growing presence of non-controllable renewable energy sources (RES), with a specific focus on PV systems. Furthermore, their study delved into the consequences of both EVs and the extent of RES integration on the district's emissions of CO_2 [40]. Rahbari et al. proposed a method for planning the size and siting of EV smart parking lots, considering RE consumption and using EVs as energy storage devices, and they introduced an adaptive intelligent control strategy applicable to V2G and G2V to reduce the system voltage deviation and power loss [12]. Shi et al. used V2G techniques to stabilize the intermittency of renewable energy sources, where the uncertainty of wind energy and the EV charging state are modeled using a robust worst-case strategy [41]. Sangswang and Konghirun developed a scheduling strategy for a home energy management system (HEMS) that integrates solar, energy storage, and V2G functionality and optimizes the charging and discharging scheduling of electric vehicles and home batteries using real-time pricing and emergency load shedding [42].

Researchers have proposed a variety of strategies and approaches, including dynamic power tuning for EVs, coordinated control strategies, integration of energy systems, and battery life extension, to achieve more efficient integration of renewable energy sources.

3.1.3. Scheduling

V2G scheduling is influenced by several key factors, including user anxiety about mileage, the wear and condition of EV batteries [43], user revenue expectations, and the geographic location of users. It is crucial to ensure that the power transfer from electric vehicles to the grid is controlled and managed effectively.

Wang and Wang investigated the impact of the number of networked EVs and the characteristics of EV battery packs on grid peak and trough regulation [10]. Farzin, Fotuhi-Firuzabad, and Moeini-Aghtaie considered the impact of EV battery wear on V2G scheduling and developed a battery degradation cost model to accurately assess the economic cost of V2G [44]. Huang, Yang, and Li introduced an option pricing model for price fluctuations in transactions between EV users and the grid, and derived analytical relationships between V2G reserve cooperation coefficients, trade deposits, and power contract prices in equilibrium [45]. Erdogan, Erden, and Kisacikoglu proposed a two-stage V2G discharge control scheme for peaking the grid; it determines the peak shaving and duration of V2G services based on forecasted demand and EV mobility modeling and then dynamically adjusts the EV discharge rate by considering the actual grid load and the grid-connected EV characteristics [46]. Maeng et al. analyzed the effect of EV energy (hybrid or pure EV) sources on EV users' discharge preferences and investigated the effect of the EV remaining power on the users' willingness to discharge, which is similar to the effect of EV users' mileage anxiety on the willingness to discharge [47]. Jiao et al. designed a model to study the impact of EV users' mileage anxiety on V2G scheduling, and the result shows that EV users' mileage anxiety can be mitigated by improving the average operating cost and discharge power, which in turn affects the charge/discharge scheduling plan [48]. Wei, Yi, and Yun used Q-learning to predict the power of wind turbines and proposed a reinforcement learning-based approach for optimal energy management in smart grids to dissipate RE while providing optimal power scheduling and reducing grid costs [49]. Wang, Gao, and Tang created a lightning scale transformation model to describe the demand response behavior of EV users in order to support load aggregators in making scheduling decisions. The model enhances the initial unidirectional scale transformation approach, encompassing the depth scale transformation mode and the generalized scale transformation mode, by evolving it into a hybrid bidirectional method. This innovative approach facilitates concurrent and synergistic transformations of both spatial and temporal observation scales [50]. The energy scheduling does not occur solely between EVs and the grid; many studies have delved into the inter-scheduling of various energy sources [36,51–54].

Overall, V2G scheduling will be smarter and more user-oriented in the future, focusing on battery management, pricing strategies, and renewable energy integration to meet evolving grid needs and to improve power system efficiency and reliability.

3.2. Frequency Regulation and Voltage Control

To facilitate grid functionality, the production and consumption of active and reactive power should be constantly balanced to ensure that the amplitudes of frequency and voltage are close to their rated values. Effective control of active power is attainable through the regulation of system frequency, whereas the management of reactive power hinges on the control of the system voltage. Therefore, frequency and voltage are important factors in measuring the power quality of the grid. Achieving overall voltage and frequency management through the V2G mode will go a step further towards active and reactive power quality improvement.

3.2.1. Frequency Regulation

Frequency control is essential for power systems to maintain stable operation; it involves the synergistic action of all the generators and loads in the power system and can keep the grid frequency within the normal range. In this context, V2G technology has emerged as a promising resource that can be used to assist in the frequency regulation of power systems. EVs, when utilized as distributed storage devices, hold the potential to offer frequency regulation services owing to their ability to swiftly adjust their charging and discharging power.

Liu et al. proposed a V2G control strategy for EV aggregators based on frequency regulation capacity (FRC) and expected V2G (EV2G) power; this control strategy can shift the regulation task from the EV aggregator to the EV charging station to satisfy both the frequency regulation and the charging demand of the EV charging station [55]. Lam, Leung, and Li designed a queuing network-based EV aggregation model that can be used to estimate regulation-up and regulation-down capacity to help establish a regulation contract between the aggregator and the grid operator [56]. Chen et al. proposed a hierarchical V2G system communication architecture containing a smart V2G aggregator (SVA), and they designed a multilevel online V2G (MLOV) algorithm for hierarchical V2G scheduling to achieve a balance between service quality and computation time [57]. Wang, Wang, and Liu proposed a dynamic scheduling strategy for V2G frequency regulation capacity based on deep Q-learning to evaluate the hourly regulation capacity in real time for maximizing the revenue of frequency regulation services provided by battery swapping stations [58]. Alfaverh, Denaï, and Sun scheduled EV battery charging and discharging using the deep deterministic policy gradient (DDPG) to meet driving needs and to participate in frequency regulation, as well as to meet the driving needs of car owners and the interests of aggregators [59].

Frequency regulation of the grid by V2G is related to the state of EVs, the charging demand, and the changing grid frequency, which requires understanding the state of EVs on the grid; however, accessing these states involves issues such as communication security, user privacy security and control security between the information network and the energy network [60].

3.2.2. Voltage Control

Voltage control is one of the key elements in the stable operation of power systems, and large generators and transformers are conventional means of controlling voltage. However, the operation and control of power systems have become more complex with the popularization of distributed energy resources [61,62].

In this context, V2G technology offers new possibilities for voltage control. With V2G, EVs can act as distributed energy storage devices to provide the necessary reactive power support to the grid [63], thus helping to maintain voltage stability [64]. García-Villalobos et al. solved voltage problems and load balancing issues in low-voltage distribution networks by optimizing the charging behavior of PEVs. This was conducted by executing intelligent charging algorithms through the processor unit built into the PEV and by developing an optimal charging strategy based on factors such as the price of electricity and battery life [65]. This article proposes an intelligent sag control method that is independent of line parameters, and it devises a new strategy to enable PHEVs to participate in voltage and frequency control of islanded microgrids (MGs) without a communication link, thus maintaining MG stability more efficiently [66]. Huang proposed a day-ahead optimal control model based on three-phase power flow and sensitivity methods that could solve the overrun voltage problem and mitigate the neutral potential rise, thus improving the voltage regulation of residential grids [67]. Nimalsiri et al. introduced a network-aware EV charging and discharging scheduling approach known as N-EVC(D). This method is designed to efficiently coordinate the charging and discharging of EVs within a distributed network, with the primary objectives of reducing operational costs and ensuring the stability of the supply voltage [68].

In conclusion, V2G technology is driving advancements in voltage control for power systems and harnessing EVs as dynamic energy resources. These developments are expected to enhance voltage stability and regulation, particularly as distributed energy resources become more prevalent. Researchers are focusing on intelligent algorithms and strategies to optimize voltage control through V2G for a more resilient and reliable power grid in the future.

3.3. Smart Grid and Communication Networks

3.3.1. Smart Grid

As with the application of V2G and smart grid technology [69], EV grid technology is an important part of "smart grid technology" in the solving of the problems related to the large-scale development of EVs brought about by the grid load pressure [70]. Moreover, EVs, as mobile distributed energy storage units, are connected to the power grid for peak shaving, valley filling, and rotating standby in order to improve the flexibility of the power supply and the reliability and efficiency of energy utilization and to slow down investment in power grid construction.

Waraich et al. proposed an agent-based transport simulation framework tailored for PHEVs. Furthermore, they expanded the framework to encompass V2G capabilities and decentralized smart grid functionalities [71]. In a separate study, Jian et al. explored the concept of a household smart microgrid. They investigated how to potentially reduce load variance within the household microgrid by adjusting the charging patterns of family PHEVs. Their findings revealed a significant reduction in the variance of load power when such regulations were implemented [72]. Kennel, Goerges, and Liu proposed an energy management system designed for smart grids. This system incorporates load frequency control (LFC), economic efficiency optimization, and the integration of electric vehicles through a HiMPC approach. The simulation findings underscore the fact that electric vehicles can play a significant role in mitigating fluctuations in renewable energy generation, thereby contributing to grid stability [60]. Vachirasricirikul and Ngamroo presented the new coordinated V2G control and frequency controller for robust LFC in the smart grid system with wind power penetration. The simulation results clearly showcase the resilience and effectiveness of the suggested V2G control strategy and proportional–integral (PI) controllers in LFC, even when subjected to altered system parameters and diverse operating conditions [53]. Morais et al. considered the evaluation of the EV impact on the power demand curve under a smart grid environment and further addressed the impact of EVs on system operation costs and on the power demand curve for a distribution network with the deep penetration of distributed generation (DG) units [73]. In another study by Jian et al., they discussed a V2G implementation scenario within regional smart grids. They introduced a double-layer optimal charging (DLOC) strategy to address the computational challenges posed by large-scale PEVs and charging stations [74]. Liang and Zhuang believe that the forthcoming smart grid is anticipated to take the form of an interconnected network comprising small-scale, self-sustained microgrids. They also provided an overview of the latest advancements in stochastic modeling and optimization tools which was aimed at facilitating the planning, operation, and control of these microgrids [75].

The integration of EVs and smart grid technology continues to evolve, and numerous studies have been conducted to explore the potential benefits and challenges of this integration. These studies encompass various aspects, from enhancing the self-consumption of PV power to the development of comprehensive battery degradation models. Van der Kam and van Sark presented a model designed to investigate the augmentation of the self-consumption of PV power through the utilization of smart charging EVs with smart grid technology. The outcomes of their study conspicuously illustrate the advantages of employing smart charging and V2G technologies within a microgrid context [5]. López et al. proposed an optimization-driven model for executing load shifting within the framework of smart grids. They presented findings based on a test system derived from the IEEE 37-bus distribution grid. These results not only demonstrate the efficacy of their approach but also highlight the impact of hourly energy prices on the smoothing out of the load curve [76]. Xing et al. concentrated on acquiring load shifting services through the optimal scheduling of PEVs for charging and discharging within smart grids, adopting a decentralized approach. Their research culminated in the development of a decentralized algorithm rooted in iterative water-filling techniques [77]. Soares et al. presented a decision-making framework designed to aid virtual power plants (VPPs) in the management of smart grids characterized by a substantial presence of sensitive electricity loads. They further devised a two-stage optimization algorithm, leveraging the weighted sum methodology, to facilitate this management process [78]. Uddin et al. developed a comprehensive battery degradation model based on long-term ageing data and integrated a comprehensive battery ageing model into a smart grid algorithm. The result demonstrated that linking an EV to this smart grid system can effectively meet the power network's demand, particularly as the proportion of clean renewable energy in the system increases [79]. Dileep gave an overview of the evolution of the smart grid and explained various smart grid technologies, like smart meters, smart sensors, V2G, and PHEV, and their application in the smart grid [35]. The integration of EVs and smart grid technology holds significant promise for the future of sustainable energy. Through various models, algorithms, and frameworks, researchers are paving the way for a more efficient, reliable, and environmentally friendly power grid system.

Ambiguous definitions of smart grids, or technologically oriented definitions, often lead to the ignoring of the differences between the smart grid concepts and to the overlooking of the important aspects for the customers that implement them. For the time being, most of the research on smart grids has focused on distributed smart grids and less on centralized grids or centralized–decentralized connections.

3.3.2. Communication Networks

The integration of communication networks with battery-operated vehicles and the electrical grid is a transformative step in the evolution of energy systems. This integration streamlines the coordination of the electric load, but it introduces challenges, especially with regard to security and privacy.

Communication networks bridge the gap between user battery-operated vehicles and the electrical grid, enhance the coordination of electric loads, and improve energy efficiency and reliability. Zhang et al. discussed the V2G network architecture and described the different security challenges during V2G power and communication interactions. A new context-aware authentication solution was also proposed for this problem [80]. Saxena et al. described the challenges of the security and privacy in smart V2G networks and proposed a cybersecurity architecture that attempted to address the problem; this architecture encompassed anonymous authentication, blind signatures, fine-grained access control, and payment system security [81]. Tao et al. proposed a hybrid computing model based on fog and cloud computing for V2G networks in 5G networks. This hybrid computing model can respond more flexibly and in a more timely manner to EV mobility; it can provide auxiliary power services for renewable energy sources in V2G systems, as well as manage and monitor power usage [82]. A privacy-friendly and efficient secure communication (PESC) framework was proposed by He, Chan, and Guizani [83]. It used group signatures and public key cryptography for access control from each EV to the aggregator and established shared keys (with the Diffie–Hellman key exchange algorithm), which could reduce the communication and computation overhead while ensuring privacy and security. Ahmed et al. designed a signature-encrypted, privacy-preserving authentication key agreement scheme that enables all participants to verify each other; it uses a one-way hash function to improve verification efficiency [84]. Umoren, Shakir, and Tabassum proposed a strategy to balance the efficiency of both spectral considerations and cost by expressing resource efficiency as a weighting factor, which improved the efficiency of V2G wireless communication networks [85]. Pokhrel and Hossain developed a novel, adaptive demand-side energy management framework for the wireless charging of V2G systems that employed privacy-preserving techniques based on federated learning [86]. Hossain, Pokhrel, and Vu proposed a demand-side energy management approach based on reinforcement learning using rechargeable batteries for V2G cost-friendly privacy, efficient scheduling, and accurate billing [87].

In summary, the communication network of the future V2G should focus on reliability, security, scalability, interoperability, energy efficiency, and environmental friendliness in order to promote the development and application of V2G technology.

4. Discussions

4.1. Knowledge Framework

In this paper, we discuss the emerging trend of focus topics in V2G from the perspectives of literature co-citation and keyword co-occurrence.

First, we mapped the keyword co-occurrence network in Section 2 based on the retrieval data to analyze the centrality and frequency of the keywords; it can be seen that even without high frequency, some keywords, such as "reactive power" and "unit commitment", still have high centrality and huge influences. Secondly, we clustered the centrality of the keywords and obtained a keyword clustering diagram, as shown in Figure 4, where the guiding line indicates the order of keyword appearance. From these visualization results, it can be seen that V2G has a wide range of applications in many scenarios, such as frequency regulation, spinning reserve, and peak–valley regulation, which alleviates the pressure on the grid, reduces carbon emissions, and reduces the investment into the construction of energy storage. Additionally, for EV users it can also reduce the charging and discharging expense and help with low buying and high selling, which creates an extensive income and reduces the cost of EV utilization.

Finally, based on the clustering network in Section 2, we established a keyword co-occurrence network from the perspective of the timeline to analyze the emergence and development trend of keywords, and we arranged the important literature on the timeline in Section 3. From the distribution of major clusters along the timeline in Figure 5, it can be seen that energy storage and SOC have been long-term research topics in the V2G field. As shown in Figure 6, the keywords that exploded in recent years include scheduling, voltage control, DC–DC converter [88], load modeling [89], etc., which indicates that the theoretical validation of V2G has been basically perfected and that researchers have paid more attention to the technological challenges encountered in the implementation stage of V2G. It is mainly limited by the technology in terms of battery degradation as well as the communication and scheduling between the EV user side and the power grid side. In addition, V2G involves a number of stakeholders, such as power generation, transmission, distribution, charging pile operation, individual vehicle owners, etc. It is difficult to coordinate the resources of all the parties; in addition, there is no unified standard for the battery industry that may constrain the development.

4.2. Future Research Trends

Given the above research progress, subsequent research can be carried out to consider the following aspects: In the field of energy storage and dispatching, it is necessary to improve the prediction accuracy of wind power and photovoltaic power; frequent charging and discharging processes may shorten the lifespan of EV batteries. Thus, enhancing consumption capacity and strengthening battery lifecycle management to minimize battery wear and reduce maintenance costs are required. In addition, since the vehicle power exchange mode has almost the same replenishment time and experience as traditional fuel vehicles, with the promotion of the power exchange mode the VS2G (power exchange vehicle, battery swapping station, and power grid in one), upgraded from V2G, will give more benefits to the power grid, users, and operators. Through the "power exchange + energy storage" mode, the management of the entire lifecycle application of the battery can achieve the value of the bidirectional energy interaction of the "vehicle-station-network" and contribute to the practice of orderly power consumption in the power grid. It is also possible to enable operators to achieve "share energy exchange" and "exchange power" through "shared power exchange". "Shared power exchange" allows operating vehicles and private cars to give full play to the value of the battery cycle times; moreover, it allows the battery to become an energy storage carrier so that it can continue to play a valuable role after the cycle time value of the battery has been played out and the battery has been withdrawn from the operation at the vehicle end.

In the area of intelligent charging and discharging control for electric vehicles, it is crucial to improve the accuracy of energy demand and load forecasting and develop scheduling strategies for orderly charging and discharging. EV charging facilities are an important part of microgrids and future smart grids and include physical charging facilities (connectors and meters), billing, scheduling, smart charging during off-peak hours, or other intelligent functions for PV power storage during low-demand hours.

In terms of data security and privacy protection, it is necessary to prevent data leakage or misuse by focusing on data encryption and authentication technologies to ensure data security and to explore the application of blockchain and other distributed ledger technologies in the V2G system to improve data traceability and transparency and enhance user confidence. In terms of market mechanisms and business models, a trading strategy is established for charging stations and new energy vehicle users to fully participate in electricity spot trading, green electricity trading, and auxiliary service markets.

5. Conclusions

In this paper, the research results in the fields of EV charging and V2G are summarized and discussed in terms of both the status of EVs and future research trends to provide a comprehensive understanding of this field.

First, many scholars have analyzed the economics of V2G for EVs. With the continuous advancement of battery technology and price reduction, the market share of EVs has been expanding, which creates more opportunities for the implementation of V2G technology, and the considerable and dispatchable battery capacity of EVs makes them powerful participants in the power grid.

Secondly, this paper summarizes the research progress of V2G technology in energy management and grid stability. The V2G technology is intertwined with the fields of the smart grid, energy storage, and the integration of distributed energy resources. It is a good way to consume renewable energy resources such as wind, solar, and hydro power in order to cope with the problem of insufficient energy reserves, achieve load balancing, and improve the resilience of the power grid. However, V2G scheduling cannot accurately obtain the dispatchable battery capacity due to the spatial and temporal distribution of EVs, which are closely related to the SOC.

In addition, the solutions to the deep-seated problems, such as the deep impact of large-scale vehicle–network interaction on the grid, the aggregator transaction and profit model, and the user incentive mechanism, have not yet formed a mature technical framework system. Because V2G scheduling and reasonable aggregator management are crucial for the large-scale integration of renewable energy and emergency response, research on this model in the future is still urgent.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/wevj14110303/s1, Table S1: Relevant studies within V2G research field.

Author Contributions: Conceptualization, R.S., S.P. and K.Y.L.; methodology, R.S. and S.P.; software, R.S. and S.P.; validation, S.P. and T.C.; formal analysis, S.P.; investigation, T.C.; resources, R.S. and T.C.; data curation, R.S.; writing—original draft preparation, R.S. and S.P.; writing—review and editing, R.S. and K.Y.L.; visualization, S.P.; supervision, R.S. and K.Y.L.; project administration, R.S.; funding acquisition, R.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research is financially supported by the National Key R&D plan Foundation of China (Grant No. 2021YFB2601300) and the Fundamental Research Funds for the Central Universities (Grant No. 2023JC007).

Data Availability Statement: Data is available withing the article.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Taiebat, M.; Xu, M. Synergies of four emerging technologies for accelerated adoption of electric vehicles: Shared mobility, wireless charging, vehicle-to-grid, and vehicle automation. *J. Clean. Prod.* **2019**, *230*, 794–797. [CrossRef]
2. Yao, X.; Fan, Y.; Zhao, F.; Ma, S. Economic and climate benefits of vehicle-to-grid for low-carbon transitions of power systems: A case study of China's 2030 renewable energy target. *J. Clean. Prod.* **2022**, *330*, 129833. [CrossRef]
3. Ravi, S.S.; Aziz, M. Utilization of Electric Vehicles for Vehicle-to-Grid Services: Progress and Perspectives. *Energies* **2022**, *15*, 589. [CrossRef]
4. Ahmadian, A.; Asadpour, M.; Mazouz, A.; Alhameli, F.; Mohammadi-Ivatloo, B.; Elkamel, A. Techno-economic evaluation of PEVs energy storage capability in wind distributed generations planning. *Sust. Cities Soc.* **2020**, *56*, 102117. [CrossRef]
5. van der Kam, M.; van Sark, W. Smart charging of electric vehicles with photovoltaic power and vehicle-to-grid technology in a microgrid; a case study. *Appl. Energy* **2015**, *152*, 20–30. [CrossRef]
6. Román, A.; García De Jalón, D.; Alonso, C. Could future electric vehicle energy storage be used for hydropeaking mitigation? An eight-country viability analysis. *Resour. Conserv. Recycl.* **2019**, *149*, 760–777. [CrossRef]
7. Liu, C.; Chau, K.T.; Wu, D.; Gao, S. Opportunities and Challenges of Vehicle-to-Home, Vehicle-to-Vehicle, and Vehicle-to-Grid Technologies. *Proc. IEEE* **2013**, *101*, 2409–2427. [CrossRef]
8. Martyushev, N.V.; Malozyomov, B.V.; Khalikov, I.H.; Kukartsev, V.A.; Kukartsev, V.V.; Tynchenko, V.S.; Tynchenko, Y.A.; Qi, M. Review of Methods for Improving the Energy Efficiency of Electrified Ground Transport by Optimizing Battery Consumption. *Energies* **2023**, *16*, 729. [CrossRef]
9. Gajduk, A.; Todorovski, M.; Kurths, J.; Kocarev, L. Improving power grid transient stability by plug-in electric vehicles. *New J. Phys.* **2014**, *16*, 115011–115014. [CrossRef]
10. Wang, Z.; Wang, S. Grid Power Peak Shaving and Valley Filling Using Vehicle-to-Grid Systems. *IEEE Trans. Power Deliv.* **2013**, *28*, 1822–1829. [CrossRef]
11. Fattori, F.; Anglani, N.; Muliere, G. Combining photovoltaic energy with electric vehicles, smart charging and vehicle-to-grid. *Sol. Energy* **2014**, *110*, 438–451. [CrossRef]
12. Rahbari, O.; Vafaeipour, M.; Omar, N.; Rosen, M.A.; Hegazy, O.; Timmermans, J.; Heibati, S.; Bossche, P.V.D. An optimal versatile control approach for plug-in electric vehicles to integrate renewable energy sources and smart grids. *Energy* **2017**, *134*, 1053–1067. [CrossRef]
13. Liu, X.; Zhao, F.; Hao, H.; Liu, Z. Opportunities, Challenges and Strategies for Developing Electric Vehicle Energy Storage Systems under the Carbon Neutrality Goal. *World Electr. Veh. J.* **2023**, *14*, 170. [CrossRef]
14. Hidrue, M.K.; Parsons, G.R. Is there a near-term market for vehicle-to-grid electric vehicles? *Appl. Energy* **2015**, *151*, 67–76. [CrossRef]
15. Liu, J.; Zhong, C. An economic evaluation of the coordination between electric vehicle storage and distributed renewable energy. *Energy* **2019**, *186*, 115821. [CrossRef]
16. Chen, C.; Song, M. Visualizing a field of research: A methodology of systematic scientometric reviews. *PLoS ONE* **2019**, *14*, e223994. [CrossRef] [PubMed]
17. Chen, C.; Dubin, R.; Kim, M.C. Emerging trends and new developments in regenerative medicine: A scientometric update (2000–2014). *Expert. Opin. Biol. Ther.* **2014**, *14*, 1295–1317. [CrossRef]
18. Ioakimidis, C.S.; Thomas, D.; Rycerski, P.; Genikomsakis, K.N. Peak shaving and valley filling of power consumption profile in non-residential buildings using an electric vehicle parking lot. *Energy* **2018**, *148*, 148–158. [CrossRef]
19. Hosseini, S.S.; Badri, A.; Parvania, M. A survey on mobile energy storage systems (MESS): Applications, challenges and solutions. *Renew. Sustain. Energy Rev.* **2014**, *40*, 161–170. [CrossRef]
20. Forrest, K.E.; Tarroja, B.; Zhang, L.; Shaffer, B.; Samuelsen, S. Charging a renewable future: The impact of electric vehicle charging intelligence on energy storage requirements to meet renewable portfolio standards. *J. Power Sources* **2016**, *336*, 63–74. [CrossRef]
21. Teodorescu, R.; Sui, X.; Vilsen, S.B.; Bharadwaj, P.; Kulkarni, A.; Stroe, D. Smart Battery Technology for Lifetime Improvement. *Batteries* **2022**, *8*, 169. [CrossRef]
22. Rahman, M.M.; Gemechu, E.; Oni, A.O.; Kumar, A. The development of a techno-economic model for assessment of cost of energy storage for vehicle-to-grid applications in a cold climate. *Energy* **2023**, *262*, 125398. [CrossRef]
23. Gough, R.; Dickerson, C.; Rowley, P.; Walsh, C. Vehicle-to-grid feasibility: A techno-economic analysis of EV-based energy storage. *Appl. Energy* **2017**, *192*, 12–23. [CrossRef]
24. Atia, R.; Yamada, N. More accurate sizing of renewable energy sources under high levels of electric vehicle integration. *Renew. Energy* **2015**, *81*, 918–925. [CrossRef]
25. Wei, H.; Zhang, Y.; Wang, Y.; Hua, W.; Jing, R.; Zhou, Y. Planning integrated energy systems coupling V2G as a flexible storage. *Energy* **2022**, *239*, 122215. [CrossRef]
26. Dik, A.; Kutlu, C.; Omer, S.; Boukhanouf, R.; Su, Y.; Riffat, S. An approach for energy management of renewable energy sources using electric vehicles and heat pumps in an integrated electricity grid system. *Energy Build.* **2023**, *294*, 113261. [CrossRef]
27. Sun, Y.; Yue, H.; Zhang, J.; Booth, C. Minimization of Residential Energy Cost Considering Energy Storage System and EV With Driving Usage Probabilities. *IEEE Trans. Sustain. Energy* **2019**, *10*, 1752–1763. [CrossRef]
28. Hipolito, F.; Vandet, C.A.; Rich, J. Charging, steady-state SoC and energy storage distributions for EV fleets. *Appl. Energy* **2022**, *317*, 119065. [CrossRef]

29. Shang, B.; Dai, N.; Cai, L.; Yang, C.; Li, J.; Xu, Q. V2G Scheduling of Electric Vehicles Considering Wind Power Consumption. *World Electr. Veh. J.* **2023**, *14*, 236. [CrossRef]
30. Singh, M.; Kumar, P.; Kar, I. A Multi Charging Station for Electric Vehicles and Its Utilization for Load Management and the Grid Support. *IEEE Trans. Smart Grid* **2013**, *4*, 1026–1037. [CrossRef]
31. Gao, S.; Chau, K.T.; Liu, C.; Wu, D.; Chan, C.C. Integrated Energy Management of Plug-in Electric Vehicles in Power Grid With Renewables. *IEEE Trans. Veh. Technol.* **2014**, *63*, 3019–3027. [CrossRef]
32. Zhong, J.; He, L.; Li, C.; Cao, Y.; Wang, J.; Fang, B.; Zeng, L.; Xiao, G. Coordinated control for large-scale EV charging facilities and energy storage devices participating in frequency regulation. *Appl. Energy* **2014**, *123*, 253–262. [CrossRef]
33. Fathabadi, H. Utilization of electric vehicles and renewable energy sources used as distributed generators for improving characteristics of electric power distribution systems. *Energy* **2015**, *90*, 1100–1110. [CrossRef]
34. Haddadian, G.; Khalili, N.; Khodayar, M.; Shahiedehpour, M. Security-constrained power generation scheduling with thermal generating units, variable energy resources, and electric vehicle storage for V2G deployment. *Int. J. Electr. Power Energy Syst.* **2015**, *73*, 498–507. [CrossRef]
35. Uddin, K.; Jackson, T.; Widanage, W.D.; Chouchelamane, G.; Jennings, P.A.; Marco, J. On the possibility of extending the lifetime of lithium-ion batteries through optimal V2G facilitated by an integrated vehicle and smart-grid system. *Energy* **2017**, *133*, 710–722. [CrossRef]
36. Robledo, C.B.; Oldenbroek, V.; Abbruzzese, F.; van Wijk, A.J.M. Integrating a hydrogen fuel cell electric vehicle with vehicle-to-grid technology, photovoltaic power and a residential building. *Appl. Energy* **2018**, *215*, 615–629. [CrossRef]
37. Bhatti, A.R.; Salam, Z. A rule-based energy management scheme for uninterrupted electric vehicles charging at constant price using photovoltaic-grid system. *Renew. Energy* **2018**, *125*, 384–400. [CrossRef]
38. Sufyan, M.; Rahim, N.A.; Muhammad, M.A.; Tan, C.K.; Raihan, S.R.S.; Bakar, A.H.A. Charge coordination and battery lifecycle analysis of electric vehicles with V2G implementation. *Electr. Power Syst. Res.* **2020**, *184*, 106307. [CrossRef]
39. Noorollahi, Y.; Golshanfard, A.; Aligholian, A.; Mohammadi-Ivatloo, B.; Nielsen, S.; Hajinezhad, A. Sustainable Energy System Planning for an Industrial Zone by Integrating Electric Vehicles as Energy Storage. *J. Energy Storage* **2020**, *30*, 101553. [CrossRef]
40. Bartolini, A.; Comodi, G.; Salvi, D.; Ostergaard, P.A. Renewables self-consumption potential in districts with high penetration of electric vehicles. *Energy* **2020**, *213*, 118653. [CrossRef]
41. Shi, R.; Li, S.; Zhang, P.; Lee, K.Y. Integration of renewable energy sources and electric vehicles in V2G network with adjustable robust optimization. *Renew. Energy* **2020**, *153*, 1067–1080. [CrossRef]
42. Sangswang, A.; Konghirun, M. Optimal Strategies in Home Energy Management System Integrating Solar Power, Energy Storage, and Vehicle-to-Grid for Grid Support and Energy Efficiency. *IEEE Trans. Ind. Appl.* **2020**, *56*, 5716–5728. [CrossRef]
43. Tabatabaee, S.; Mortazavi, S.S.; Niknam, T. Stochastic scheduling of local distribution systems considering high penetration of plug-in electric vehicles and renewable energy sources. *Energy* **2017**, *121*, 480–490. [CrossRef]
44. Farzin, H.; Fotuhi-Firuzabad, M.; Moeini-Aghtaie, M. A Practical Scheme to Involve Degradation Cost of Lithium-Ion Batteries in Vehicle-to-Grid Applications. *IEEE Trans. Sustain. Energy* **2016**, *7*, 1730–1738. [CrossRef]
45. Huang, S.; Yang, J.; Li, S. Black-Scholes option pricing strategy and risk-averse coordination for designing vehicle-to-grid reserve contracts. *Energy* **2017**, *137*, 325–335. [CrossRef]
46. Erdogan, N.; Erden, F.; Kisacikoglu, M. A fast and efficient coordinated vehicle-to-grid discharging control scheme for peak shaving in power distribution system. *J. Mod. Power Syst. Clean. Energy* **2018**, *6*, 555–566. [CrossRef]
47. Maeng, K.; Ko, S.; Shin, J.; Cho, Y. How Much Electricity Sharing Will Electric Vehicle Owners Allow from Their Battery? Incorporating Vehicle-to-Grid Technology and Electricity Generation Mix. *Energies* **2020**, *13*, 4248. [CrossRef]
48. Jiao, Z.; Ran, L.; Zhang, Y.; Ren, Y. Robust vehicle-to-grid power dispatching operations amid sociotechnical complexities. *Appl. Energy* **2021**, *281*, 115912. [CrossRef]
49. Wei, L.; Yi, C.; Yun, J. Energy drive and management of smart grids with high penetration of renewable sources of wind unit and solar panel. *Int. J. Electr. Power Energy Syst.* **2021**, *129*, 106846. [CrossRef]
50. Wang, A.; Gao, X.; Tang, M. A space variable-scale scheduling method for digital vehicle-to-grid platform under distributed electric energy storage. *Appl. Soft Comput.* **2023**, *133*, 109911. [CrossRef]
51. Wu, T.; Yang, Q.; Bao, Z.; Yan, W. Coordinated Energy Dispatching in Microgrid With Wind Power Generation and Plug-in Electric Vehicles. *IEEE Trans. Smart Grid* **2013**, *4*, 1453–1463. [CrossRef]
52. Honarmand, M.; Zakariazadeh, A.; Jadid, S. Integrated scheduling of renewable generation and electric vehicles parking lot in a smart microgrid. *Energy Conv. Manag.* **2014**, *86*, 745–755. [CrossRef]
53. Vachirasricirikul, S.; Ngamroo, I. Robust LFC in a Smart Grid With Wind Power Penetration by Coordinated V2G Control and Frequency Controller. *IEEE Trans. Smart Grid* **2014**, *5*, 371–380. [CrossRef]
54. Paterakis, N.G.; Erdinc, O.; Pappi, I.N.; Bakirtzis, A.G.; Catalao, J.P.S. Coordinated Operation of a Neighborhood of Smart Households Comprising Electric Vehicles, Energy Storage and Distributed Generation. *IEEE Trans. Smart Grid* **2016**, *7*, 2736–2747. [CrossRef]
55. Liu, H.; Hu, Z.; Song, Y.; Wang, J.; Xie, X. Vehicle-to-Grid Control for Supplementary Frequency Regulation Considering Charging Demands. *IEEE Trans. Power Syst.* **2015**, *30*, 3110–3119. [CrossRef]
56. Lam, A.Y.S.; Leung, K.; Li, V.O.K. Capacity Estimation for Vehicle-to-Grid Frequency Regulation Services With Smart Charging Mechanism. *IEEE Trans. Smart Grid* **2016**, *7*, 156–166. [CrossRef]

57. Chen, X.; Leung, K.; Lam, A.Y.S.; Hill, D.J. Online Scheduling for Hierarchical Vehicle-to-Grid System: Design, Formulation, and Algorithm. *IEEE Trans. Veh. Technol.* **2019**, *68*, 1302–1317. [CrossRef]
58. Wang, X.; Wang, J.; Liu, J. Vehicle to Grid Frequency Regulation Capacity Optimal Scheduling for Battery Swapping Station Using Deep Q-Network. *IEEE Trans. Ind. Inform.* **2021**, *17*, 1342–1351. [CrossRef]
59. Alfaverh, F.; Denaï, M.; Sun, Y. Optimal vehicle-to-grid control for supplementary frequency regulation using deep reinforcement learning. *Electr. Power Syst. Res.* **2023**, *214*, 108949. [CrossRef]
60. Kennel, F.; Gorges, D.; Liu, S. Energy Management for Smart Grids With Electric Vehicles Based on Hierarchical MPC. *IEEE Trans. Ind. Inform.* **2013**, *9*, 1528–1537. [CrossRef]
61. Azzouz, M.A.; Shaaban, M.F.; El-Saadany, E.F. Real-Time Optimal Voltage Regulation for Distribution Networks Incorporating High Penetration of PEVs. *IEEE Trans. Power Syst.* **2015**, *30*, 3234–3245. [CrossRef]
62. Cheng, L.; Chang, Y.; Huang, R. Mitigating Voltage Problem in Distribution System With Distributed Solar Generation Using Electric Vehicles. *IEEE Trans. Sustain. Energy* **2015**, *6*, 1475–1484. [CrossRef]
63. Sun, X.; Qiu, J. A Customized Voltage Control Strategy for Electric Vehicles in Distribution Networks With Reinforcement Learning Method. *IEEE Trans. Ind. Inform.* **2021**, *17*, 6852–6863. [CrossRef]
64. Hu, J.; Ye, C.; Ding, Y.; Tang, J.; Liu, S. A Distributed MPC to Exploit Reactive Power V2G for Real-Time Voltage Regulation in Distribution Networks. *IEEE Trans. Smart Grid* **2022**, *13*, 576–588. [CrossRef]
65. García-Villalobos, J.; Zamora, I.; Knezović, K.; Marinelli, M. Multi-objective optimization control of plug-in electric vehicles in low voltage distribution networks. *Appl. Energy* **2016**, *180*, 155–168. [CrossRef]
66. Pournazarian, B.; Karimyan, P.; Gharehpetian, G.B.; Abedi, M.; Pouresmaeil, E. Smart participation of PHEVs in controlling voltage and frequency of island micrograms. *Int. J. Electr. Power Energy Syst.* **2019**, *110*, 510–522. [CrossRef]
67. Huang, Y. Day-Ahead Optimal Control of PEV Battery Storage Devices Taking Into Account the Voltage Regulation of the Residential Power Grid. *IEEE Trans. Power Syst.* **2019**, *34*, 4154–4167. [CrossRef]
68. Nimalsiri, N.I.; Ratnam, E.L.; Mediwaththe, C.P.; Smith, D.B.; Halgamuge, S.K. Coordinated charging and discharging control of electric vehicles to manage supply voltages in distribution networks: Assessing the customer benefit. *Appl. Energy* **2021**, *291*, 116857. [CrossRef]
69. Shaukat, N.; Khan, B.; Ali, S.M.; Mehmood, C.A.; Khan, J.; Farid, U.; Majid, M.; Anwar, S.M.; Jawad, M.; Ullah, Z. A survey on electric vehicle transportation within smart grid system. *Renew. Sustain. Energy Rev.* **2018**, *81*, 1329–1349. [CrossRef]
70. Shen, J.; Jiang, C.; Li, B. Controllable Load Management Approaches in Smart Grids. *Energies* **2015**, *8*, 11187–11202. [CrossRef]
71. Waraich, R.A.; Galus, M.D.; Dobler, C.; Balmer, M.; Andersson, G.; Axhausen, K.W. Plug-in hybrid electric vehicles and smart grids: Investigations based on a microsimulation. *Transp. Res. Part C Emerg. Technol.* **2013**, *28*, 74–86. [CrossRef]
72. Jian, L.; Xue, H.; Xu, G.; Zhu, X.; Zhao, D.; Shao, Z.Y. Regulated Charging of Plug-in Hybrid Electric Vehicles for Minimizing Load Variance in Household Smart Microgrid. *IEEE Trans. Ind. Electron.* **2013**, *60*, 3218–3226. [CrossRef]
73. Morais, H.; Sousa, T.; Vale, Z.; Faria, P. Evaluation of the electric vehicle impact in the power demand curve in a smart grid environment. *Energy Conv. Manag.* **2014**, *82*, 268–282. [CrossRef]
74. Jian, L.; Zhu, X.; Shao, Z.; Niu, S.; Chan, C.C. A scenario of vehicle-to-grid implementation and its double-layer optimal charging strategy for minimizing load variance within regional smart grids. *Energy Conv. Manag.* **2014**, *78*, 508–517. [CrossRef]
75. Liang, H.; Zhuang, W. Stochastic Modeling and Optimization in a Microgrid: A Survey. *Energies* **2014**, *7*, 2027–2050. [CrossRef]
76. Lopez, M.A.; de la Torre, S.; Martin, S.; Aguado, J.A. Demand-side management in smart grid operation considering electric vehicles load shifting and vehicle-to-grid support. *Int. J. Electr. Power Energy Syst.* **2015**, *64*, 689–698. [CrossRef]
77. Xing, H.; Fu, M.; Lin, Z.; Mou, Y. Decentralized Optimal Scheduling for Charging and Discharging of Plug-In Electric Vehicles in Smart Grids. *IEEE Trans. Power Syst.* **2016**, *31*, 4118–4127. [CrossRef]
78. Soares, J.; Ghazvini, M.A.F.; Vale, Z.; de Moura Oliveira, P.B. A multi-objective model for the day-ahead energy resource scheduling of a smart grid with high penetration of sensitive loads. *Appl. Energy* **2016**, *162*, 1074–1088. [CrossRef]
79. Dileep, G. A survey on smart grid technologies and applications. *Renew. Energy* **2020**, *146*, 2589–2625. [CrossRef]
80. Zhang, Y.; Gjessing, S.; Liu, H.; Ning, H.; Yang, L.; Guizani, M. Securing vehicle-to-grid communications in the smart grid. *IEEE Wirel. Commun.* **2013**, *20*, 66–73. [CrossRef]
81. Saxena, N.; Grijalva, S.; Chukwuka, V.; Vasilakos, A.V. Network Security and Privacy Challenges in Smart Vehicle-to-Grid. *IEEE Wirel. Commun.* **2017**, *24*, 88–98. [CrossRef]
82. Tao, M.; Ota, K.; Dong, M. Foud: Integrating Fog and Cloud for 5G-Enabled V2G Networks. *IEEE Netw.* **2017**, *31*, 8–13. [CrossRef]
83. He, D.; Chan, S.; Guizani, M. Privacy-friendly and efficient secure communication framework for V2G networks. *IET Commun.* **2018**, *12*, 304–309. [CrossRef]
84. Ahmed, S.; Shamshad, S.; Ghaffar, Z.; Mahmood, K.; Kumar, N.; Parizi, R.M.; Choo, K.R. Signcryption Based Authenticated and Key Exchange Protocol for EI-Based V2G Environment. *IEEE Trans. Smart Grid* **2021**, *12*, 5290–5298. [CrossRef]
85. Umoren, I.A.; Shakir, M.Z.; Tabassum, H. Resource Efficient Vehicle-to-Grid (V2G) Communication Systems for Electric Vehicle Enabled Microgrids. *IEEE Trans. Intell. Transp. Syst.* **2021**, *22*, 4171–4180. [CrossRef]
86. Pokhrel, S.R.; Hossain, M.B. Data Privacy of Wireless Charging Vehicle to Grid (V2G) Networks With Federated Learning. *IEEE Trans. Veh. Technol.* **2022**, *71*, 9032–9037. [CrossRef]
87. Hossain, M.B.; Pokhrel, S.R.; Vu, H.L. Efficient and Private Scheduling of Wireless Electric Vehicles Charging Using Reinforcement Learning. *IEEE Trans. Intell. Transp. Syst.* **2023**, *24*, 4089–4102. [CrossRef]

88. Al Attar, H.; Hamida, M.A.; Ghanes, M.; Taleb, M. LLC DC-DC Converter Performances Improvement for Bidirectional Electric Vehicle Charger Application. *World Electr. Veh. J.* **2022**, *13*, 2. [CrossRef]
89. Lu, S.; Feng, X.; Lin, G.; Wang, J.; Xu, Q. Non-Intrusive Load Monitoring and Controllability Evaluation of Electric Vehicle Charging Stations Based on K-Means Clustering Optimization Deep Learning. *World Electr. Veh. J.* **2022**, *13*, 198. [CrossRef]