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A Review on Standardizing Electric Vehicles Community Charging Service Operator Infrastructure

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Abstract: The deployment of charging infrastructure is one of the main challenges that need to be tackled due to the increasing demand for electric vehicles (EVs). Moreover, EVs associated with different charging standards can face compatibility issues while charging via public or private infrastructure. Many solutions were surveyed by researchers on EVs, but they were not focused on addressing the issue of charging infrastructure standardization. Motivated by this, we present a comprehensive survey on standardizing EV charging infrastructure. We also present a taxonomy on various aspects such as charging levels, charging modes, charging standards, charging technologies (based on the different charging types such as conductive charging and wireless charging), and types of vehicle (i.e., 2-wheeler (2W), 3-wheeler (3W), and 4-wheeler (4W)). Furthermore, we target the benefits associated with community EV charging operated by the community charging service operator. Furthermore, we propose an architecture for standardized EV community charging infrastructure to provide adaptability for EVs with different charging standards. Finally, the research challenges and opportunities of the proposed survey have been discussed for efficient EV charging.

Keywords: electric vehicle; community charging service operator; standardized; charging standards; conductive charging; wireless charging

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1. Introduction

The evolution of the automobile industry has led to the wide-spread adoption of electric vehicles (EVs) over fossil fuel vehicles. The depletion of fossil fuels adversely affects the environment and increases the emission of harmful gases, such as carbon dioxide (CO_2) or nitrogen oxide. EVs overcome these environmental issues by reducing the emission of CO_2 and greenhouse gases. Furthermore, cost-efficiency issues of gasoline or diesel vehicles can be tackled with the help of lithium–ion batteries equipped in EVs [1–5]. Therefore, the UK government has estimated a reduction in CO_2 emissions by 2050 due to the increased usage of EVs in the coming years that will lead to the complete replacement of petrol or diesel vehicles [6]. The rapid surge in EVs on the road has led to the need to install more charging station (CS) infrastructures based on requirement and utilization by the consumers. This issue can be mitigated by installing more CSs at multiple locations, i.e., public, private, and semi-public spaces based on demand [7,8].

Consumers can opt for different charging infrastructures based on their traveling destination and advantages. For example, public charging infrastructure is generally utilized for longer routes with easy accessibility, whereas private charging infrastructure is utilized for shorter routes. However, public charging infrastructure owned by the government can be quiet costly for consumers. To overcome the cost issues of public charging infrastructure, private charging infrastructure at a low cost might be a better option for consumers. However, it is not practically possible for consumers to deploy and install CS infrastructure at their home or private garage. Additionally, charging EVs using private charging infrastructure can take several hours due to low electricity voltages at homes/garages [9–11]. As per the literature, numerous surveys focusing on public and private charging infrastructure have been reviewed to deal with the cost, charging time, and infrastructure deployment issues to ensure charging is beneficial and efficient for consumers [12–15]. In relation to EV charging, the authors in [16] conducted an exhaustive survey on consumer preferences for EV charging infrastructure. They also provided an overview of charging modes, charging levels, charging price, charging management, interoperability, and the number of required charging points.

Funke et al. [17] presented a survey on the need for charging infrastructure across different countries. They reviewed the nation-wise benefits of public and private charging infrastructures and their demands. Ding et al. [12] studied the approaches for EV charging demand management. They mainly focused on infrastructure planning with siting, sizing, and co-planning of charging infrastructures. The authors in [18] also presented a survey on the siting and sizing of charging infrastructure and the optimal placement of CS based on the optimization algorithms. Then, based on communication technologies, ElGhanam et al. [19] reviewed EV charging management and coordination; they extended the survey in [12] in which they discuss the communication requirements and technologies for EV charging infrastructure.

Shafiei et al. [20] conducted a comprehensive survey on designing fast CSs to address the challenges and issues arising in the EV charging time for social welfare. Existing surveys provide insights on charging time, infrastructure installation, and charging cost-related challenges while deploying the EV charging infrastructure. However, most researchers focus on the isolated aspects while ignoring discussions on various charging standards, charging modes/levels, and the standardization of charging infrastructure for compatible EV charging. Motivated by this gap in the literature, we present a comprehensive survey on standardizing EVs charging infrastructure to minimize the CS deployment cost. We also present a taxonomy on charging levels, charging modes, charging standards, charging technologies based on the different charging types such as conductive charging and wireless charging, and types of vehicle, i.e., 2-wheeler (2W), 3-wheeler (3W), and 4-wheeler (4W). Moreover, we considered a scenario of EV community charging infrastructure similar to that of private charging with the advantage of the infrastructure being utilized by several households and managed by a community charging service operator. In this context, EVs of several households would be able to utilize the infrastructure for compatible and reliable charging to overcome the challenges associated with public and private charging infrastructure. To make this possible, we propose the architecture of standardized EV charging infrastructure to provide compatible charging standards for efficient EV charging. Therefore, standardized EV charging standards can be quite beneficial in providing adaptability for consumers as EVs associated with the various charging standards can opt for charging.

1.1. Motivations

- The standardization of EV community charging infrastructure is one of the primary criteria to ensure charging compatibility and minimize the infrastructure deployment cost. For example, if there are five different types of vehicles in a particular area with diverse charging port types, the CS needs to have different infrastructures for each vehicle type, which raises the overall CS deployment cost. Thus, there is a need for the standardization of charging ports for EVs.
- The existing literature predominantly highlights the charging time, cost, and deployment issues in EV charging infrastructure with less emphasis on the standardization

of EV charging infrastructure for adaptable charging. Therefore, this raises the need to present a comprehensive survey that provides insights on standardized EV community charging infrastructure.

1.2. Research Contributions

The research contributions of the paper are as follows:

- We present an exhaustive survey on standardizing EVs charging infrastructure handled by the community charging service operator. We also highlighted the benefits of public or private charging infrastructure.
- We present a taxonomy of charging levels, charging modes, charging standards, and charging technologies based on the charging types, i.e., conductive and wireless charging.
- We propose a standardized EV community charging service operator infrastructure architecture to enable universally compatible EV charging.
- Finally, the paper discusses security issues and research challenges in standardized EV charging infrastructure.

1.3. Key Takeaways from the Survey

The key takeaways of this survey that will lay the foundations for future research are as follows:

- Detailed description of the charging modes, levels, technologies, and standards based on charging types, i.e., conductive and wireless charging.
- How EV charging standards can be standardized based on the different parameters such as vehicle and charging types.
- Integration of charging standards and EV owners in standardized EV community charging infrastructure architecture.
- Readers will come to understand the challenges and opportunities for future works in the EVs standardization field.

1.4. Organization

The rest of the paper is organized as follows. Section 2 presents the state-of-the-art works in the same area. Section 3 describes the background information of related technologies. Section 4 shows the description of diverse charging types associated with EVs. Section 5 presents the proposed architecture for standardizing EVs charging ports for universal adaptability. Section 6 presents the open issues and research challenges; finally, Section 7 concludes the paper.

2. Scope of the Survey

The existing surveys and reviews highlight the importance of deploying efficient EV charging infrastructure. However, they do not consider the important aspect of the standardization of charging standards for EV charging. For example, Rubino et al. [21] presented a comprehensive survey on EV charging architecture based on the different charging technologies. They addressed and resolved the issues related to scalability, efficiency, and modularity. In [22], the author studied wireless EV charging systems. The review analyzed various wireless charging components, such as charging infrastructure allocation, driving range analyses, cost analysis, etc., that ensure environment-friendly charging. Later, Panchal et al. [23] surveyed the deployment of static and dynamic wireless EV charging systems. The survey highlighted various wireless energy transfer methods to deal with the critical issues of power transfer efficiency and compatibility. Nevertheless, these works do not cover some of the critical issues such as standardized charging standards, charging time, charging cost, scalability, and reliability. Then, Funke et al. [17] analyzed the concept of standardized charging infrastructure and compared the international standards of different countries. Furthermore, the authors in [24] presented a broad survey on the deployment of EV charging networks in Europe. The research work mainly focuses on analyzing the demand and accessibility of EV charging stations in an eco-friendly environment. However, there is no consideration of standardized charging connectors and charging cost for scalable and compatible charging. Then, Schoenberg et al. [25] explored the survey on siting and sizing EV charging infrastructure, focusing on reducing the charging time and charging points. Although, most of the surveyed research works omit the concept of standardized charging standards and compatibility charging. This motivates us to review a comprehensive survey on standardized EVs community charging infrastructure supervised by the community charging service operator. The proposed survey discusses the taxonomy of charging levels, charging modes, charging standards, and charging technologies based on the different charging types such as conductive charging and wireless charging, and types of vehicle, i.e., 2W, 3W, and 4W. Table 1 shows the comparative analysis of various state-of-the-art surveys with the proposed survey showing the benefits of standardized EV charging infrastructure.

Table 1. Comparative analysis of various state-of-the-art surveys with the proposed survey.

Author	Year	Aim	Pros	Cons	1	2	3	4	5	6	7	8	9	10	11	12	13	14
[21]	2017	An exhaustive survey on EV charging architectures	High modularity, high scalability, high efficiency, and utilized charging standards	No effort on standardization of charging standards, no discussion on manufacturing cost	Y	N	N	N	N	Y	Y	N	Y	Y	Y	Y	N	N
[22]	2018	Various research issues discussed in wireless EV charging infrastructure and systems	Environment friendly and provides cost analysis	No discussion on scalability, efficiency, standardization of charging standards, and optimized charging cost	N	N	N	Y	N	N	N	N	N	N	N	N	Y	N
[23]	2018	A comprehensive survey on the deployment of static and dynamic wireless EV charging	High power transfer efficiency, compatible, and high convenience	Lack of standardization of charging standards, no discussion on charging time, charging cost, scalability, and reliability	Y	N	N	N	N	Y	Y	N	Y	N	N	N	N	N
[17]	2019	Analyzed EV charging infrastructure based on the different countries	Standardized charging infrastructure based on different countries	No effort to standardize the charging standards, scalability, efficiency, reliability, and interoperability	N	N	N	N	N	N	Y	N	N	N	N	N	N	N
[26]	2020	Survey of various EV charging technologies and methods	Low charging cost, utilized charging standards, and reliable	No consideration of manufacturing costs, standardization of charging, scalability, and efficiency	Y	Y	N	N	N	Y	Y	N	N	N	N	N	N	N
[27]	2020	Review of various dynamic pricing schemes for optimal charging scheduling of EVs	Minimized electricity cost, regulated voltage, and minimized power loss	More complex, no focus on charging infrastructure, scalability, and efficiency	N	Y	N	N	Y	Y	Y	N	N	N	N	N	N	Y
[24]	2021	Analyzed the deployment of EV charging network in Europe	Environment friendly	No consideration of scalability, efficiency, charging cost, and lack in standardization of charging standards	N	N	N	N	N	N	N	N	N	N	N	N	Y	N
[28]	2021	Thorough review on different EV wireless charging technologies	Improved feasibility	Low efficiency, low power density, and no standardization of charging standards	Y	N	N	N	N	Y	N	N	N	Y	N	N	Y	N

Table 1. *Cont.*

Author	Year	Aim	Pros	Cons	1	2	3	4	5	6	7	8	9	10	11	12	13	14
[29]	2021	Comprehensive survey on EV charging stations architecture in microgrids	Low charging cost, environment friendly, and reduced charging time	Less effort on scalability, efficiency, and standardization of charging standards	Y	N	N	Y	N	Y	Y	N	Y	N	Y	Y	Y	N
[30]	2021	Review possible EV technologies along with their charging methods and standards	Optimized and reliable charging	Should focus on eco-friendly charging, efficiency, and include considerations of manufacturing charging cost	Y	Y	N	N	N	Y	Y	N	N	N	N	N	N	N
[25]	2022	Survey on siting and sizing of EV charging infrastructure	Reduced charging time and charging points	No focus on scalability, efficiency, reliability, and standardization of charging standards	N	N	N	N	N	Y	N	N	N	Y	N	N	N	N
The proposed survey	2022	An exhaustive survey on standardizing EVs community charging service operator infrastructure	Scalable, efficient, reliable, and standardization of charging standards	-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

1: Charging level, 2: Optimization technique, 3: Charging manufacture cost, 4: Charging operating cost, 5: Scheduling algorithm, 6. Architecture, 7: Charging standards, 8: Standardization of charging connector, 9: Efficiency, 10: Charging time, 11: Scalability, 12: Energy storage technologies, 13: Environment friendly, 14: Dynamic Pricing.

3. Background

Over the last few years, gasoline or petrol vehicles have become the easiest mode of transportation. Nowadays, people mostly prefer to travel via their personal vehicles, especially in metro cities, which provide ease of driving driving dependent on traveling destination [31,32]. However, driving is not suitable for users who cannot afford their private vehicles. Additionally, the emission of greenhouse gases in fuel-powered vehicles can be hazardous to the environment [33,34]. Due to the inherent disadvantages of gasoline vehicles, the car industry has gradually transitioned to EVs with several advantages such as low energy consumption, low cost, and reduced greenhouse gas emissions [35,36]. According to the research of the EV30@30 campaign, the EVs trade will increase exponentially by 30% within the next 10 years. Moreover, EVs have evolved in terms of technologies, specifications, and manufacturing [37].

Figure 1 shows the evolution of EVs based on the different manufacturing companies and several charging standards specifications. However, the huge number of EVs on the road require the deployment of more charging infrastructure installed at different locations such as residential areas, offices, parks, or shopping malls [38]. EV charging infrastructure mainly consists of EV supply equipment (EVSE), which comprises numerous charging connectors based on the different manufacturing companies in different countries. Depending on the location, EV charging infrastructure can be categorized into public, private, and semi-public. A detailed description of public, private, and semi-public charging infrastructures is as follows.

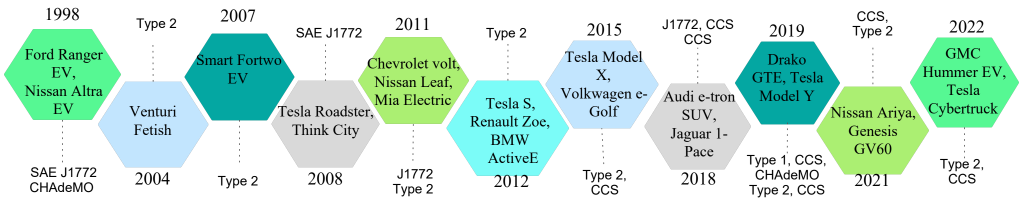

Figure 1. Evolution of EVs.

3.1. Public Charging Infrastructure

An easily accessible and affordable charging infrastructure is advantageous for users willing to charge their vehicles conveniently. Public CSs should be installed based on the most visited places, such as hospitals, workplaces, shopping malls, or nature parks. In a public charging infrastructure, the availability of charging points within the proximity of users reduces energy consumption and saves time, further enhancing the accessibility for charging. However, the accessibility of on-street EV charging infrastructure depends on the availability of the parking space which will be charged by some government or private institution, which can be quite costly for consumers [39,40]. Therefore, it is essential to optimize the charging cost to make such facilities reliable and affordable for users arriving at a public location.

Public charging infrastructure benefits users who require fast DC (Level-3) charging based on their traveling choice, i.e., whether they want to travel a longer or shorter route. DC charging mainly works on the principle that vehicles can be charged directly through interaction with the battery of the vehicles. DC charging will be explained in the next section in detail. However, DC charging requires costly charging infrastructure that needs to be minimized and maintained [41]. For example, the authors in [42] formulated a policy to incorporate the residential charging infrastructure in Canada by adopting the three-way agenda. Further, the authors [43] extended their implementation to recommend demand-based policies and regulations to deploy the EV charging infrastructure in residential buildings in the metro cities of British Columbia. Then, Bosch et al. [44] explored the sustainability of public EV charging infrastructures in the context of France and Germany by adopting the scale-up strategy for efficient infrastructure.

3.2. Private Charging Infrastructure

Private charging infrastructure is used to charge EVs either at home or at workplaces using slow alternating current (AC) chargers. For example, an individual can arrange the setup for chargers, or multi-residential charging can be put in place, which can be considered under the public charging [45]. EVs are equipped with on-board chargers for charging vehicles with AC (Level 1 and Level 2) slow charging by converting the power generated into the direct current (DC) that can be transferred to the battery of the EVs. AC slow charging is mostly considered when users want to travel a shorter distance, and vehicles can be charged at home overnight or at a workplace [46]. However, the charging time using AC charging tends to be higher than DC fast charging due to the limited power exchange between the vehicle and electricity grid. AC charging is further described in the next section in greater detail. If a user can set up private charging infrastructure at home, it may reduce the time spent traveling in searching for a public CS. However, it requires the installation of an electricity grid and charging connectors at home, which incur lower costs than public charging stations [47].

Moreover, slow charging can sometimes be a disadvantage in an emergency situation or when fast charging is required. Therefore, to address and resolve the issues of residential or private EV charging infrastructure, Melliger et al. [48] implemented a simulation model for two countries, i.e., Switzerland and Finland, to analyze the benefit of home charging which provides freedom for users to charge their vehicles fully before traveling to their destination. Ou et al. [35] analyzed the variation in residential or home parking availability in china by considering the essential aspects such as the resources required for charging, rules, or regulations that need to be followed for efficient charging and the required cost of the infrastructure.

3.3. Semi-Public Charging Infrastructure

Semi-public charging infrastructure is a combination of public and private charging infrastructure. Practically, it is not possible for all EV users to own a personal charging infrastructure at home and it also increases the charging time of the EVs, which can discourage users from charging in emergency situations. On the other hand, public charging infrastructure seems to be quite a costly choice for EV users for charging their vehicle. Therefore, the high charging cost and high charging time challenges of public and private charging infrastructure lead to the need for semi-public charging infrastructure. Semi-public charging infrastructure can be considered to be managed by the charging service operator in which EVs of several households or apartments can charge their vehicles, which is termed as community charging [49–51]. For example, Hecker et al. [52] analyzed the best option of charging for users by considering the charging infrastructure of Beijing. They discussed the case study of Beijing in relation to the suitability of semi-public and private charging stations for users.

Therefore, we considered different types of EV charging infrastructures based on the requirement of users or their traveling habits. However, the standardization of EVs community charging infrastructure will help to overcome the issues of public and private charging infrastructure. This means that EVs manufactured by different companies with different specifications and charging standards can opt for charging. However, it is not possible to make available all types of charging types at a charging station. Therefore, we considered the critical issue of standardization of EVs community charging infrastructure in the proposed survey.

4. Charging Type

This section discusses the different charging types, i.e., conductive and wireless charging. Figure 2 depicts the basic architecture of conductive and wireless charging in which conductive charging can use an electric cable for EV with different charging standards. On the other hand, wireless charging involves ground assembly for EV charging without any electric cable. Furthermore, Figure 3 shows the taxonomy of the charging mode, charging level, charging type, and charging standard based on conductive and wireless charging.

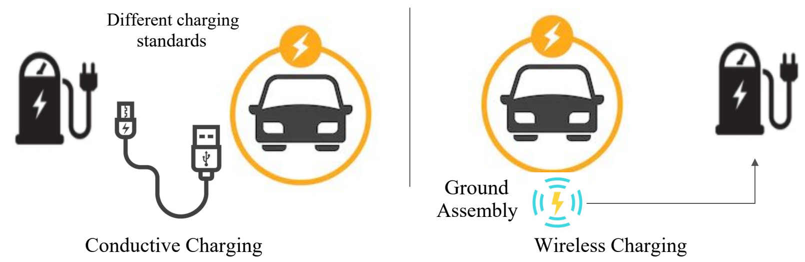

Figure 2. Conductive and wireless charging for EVs.

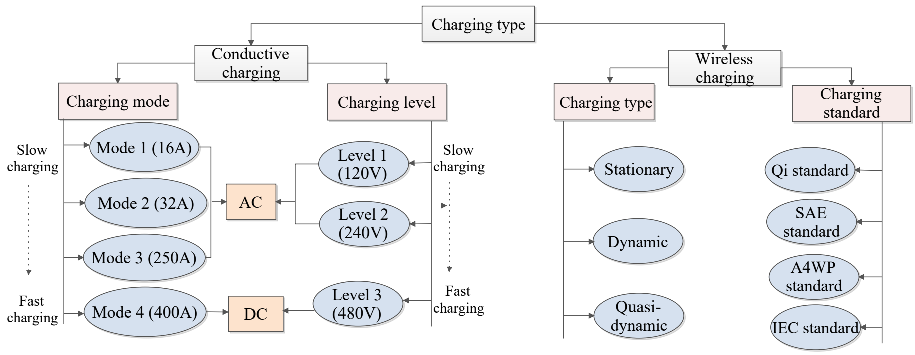

Figure 3. Taxonomy on EV charging types.

4.1. Conductive Charging

EV charging infrastructure with EVSE components should be developed and maintained based on the different charging standards suitable for several households of the community in a particular country. Conductive charging uses a charging cable through which any EV can charge their vehicle by connecting to a connector depending on the required charging standards. There should be a physical connection between the electricity grid and the battery of the EVs for charging. EVSE plays an important role in charging the EVs by interfacing the powered grid with the electrified battery of the EVs. Therefore, it is a simple method for charging with a low cost due to the utilization of the electric cable and charging connector required for wired charging. Conductive charging is further categorized into AC slow charging and DC fast charging. We can classify AC charging into different charging levels and modes based on the fast, moderate, or slow power supply to the EVs. Charging modes can be categorized as Mode 1 and Mode 2 for AC slow charging, Mode 3 for AC moderate charging, and Mode 4 for DC fast charging. Similarly, charging levels can be divided into Level 1, Level 2, and Level 3 [53].

Different charging levels and charging modes are defined based on the need of the varying power supplies and the equipment (for example, protection cable) required for the installation of CSs in different communities at the different locations in the city.

4.1.1. Charging Mode

- Mode 1: AC slow charging
  Mode 1 AC charging requires EVs to accommodate an on-board charger to enable the transfer of electricity to the battery through the passage of the current (i.e., 16 A) by converting AC to DC with the requirement of several electronic components. The on board charger consists of various converters and a transformer, i.e., a two-stage power converter along with a front-end AC–DC converter along with a DC–DC converter equipped with a high-frequency transformer [53]. Usually, on-board chargers have

a limited power supply which restricts the charging to a certain extent due to the incurred additional cost and mass for the inbuilt electronics. Therefore, it is mainly suitable for EVs looking to make short trips with low a energy consumption of the EVs battery. Kamat et al. [54] designed a low-power AC single phase charger for EV. They designed the charger with an AC–DC converter and a simple buck DC–DC converter for regulating the power of the battery. Then, similarly, Thanakam et al. [55] investigated a novel approach involving on-board AC charging for plug-in EVs consisting of an open-end winding AC motor drive along with a nine-switch converter.

- Mode 2: AC moderate charging
  Mode 2 AC charging works similarly to Mode 1 AC charging but with a higher passage of current (32 A) and power to the EV battery. Therefore, it can charge EVs in less time than Mode 1 AC charging. Moreover, there is an additional feature of Mode 2 charging, i.e., integration of a particular type of protection cable with the standard socket equipped in the EV for charging. The standard socket provides protection to the EVs against high temperature, high current, and ground earth rise. For example, the IEC60309 charging standard operates at the current level of 32 A with the AC moderate charging in mode 2 [56].
- Mode 3: AC fast charging
  Mode 3 can be used for EVs charging at households or commercial CSs, which provides a higher current and a greater power passage to the EVs battery than other charging modes. It consists of EVSEs, such as charging connectors, a protection cable, etc., which needs to be installed directly into a CS. People can also deploy Mode 3 CS fast charging. Still, they need to deploy the infrastructure of high output power voltage to charge the vehicles efficiently, which can increase the overall expense of charging, thereby making it unaffordable for users [57]. Maliat et al. [58] designed an on-board AC fast-charging system for EVs. They mainly focused on mitigating the issue of slow charging with the integration of a full-bridge phase-shifted DC–DC converter to achieve efficient charging for EVs.
- Mode 4: DC charging
  Mode 4 DC is mainly utilized for EVs charging at public locations such as on streets, highways, or petrol pumps where there is a need for efficient, fast charging in comparison to other modes. It is essential to integrate an AC–DC converter in the CS to charge the EVs in AC charging. However, DC charging enables direct interfacing with the battery of the EVs through the use of an off-board charger without the need for a converter. Off-boarding charging facilitates high power charging and yields high charging costs, which can discourage users from charging [56]. For example, Wang et al. [59] addressed the efficiency and cost issues by introducing a dual-inverter drive in three-phase DC fast charging for EVs. They achieved improved charging efficiency corresponding to the International Electro-technical Commission standards. Then, further improving the charging efficiency, the authors in [60] designed a low-voltage EV charging technique to charge an up to 800 V battery. They considered a battery selection circuit with a DC–DC converter to outperform the conventional scheme in terms of high efficiency and low power loss. EVs can be charged at different charging levels with the help of chargers, thereby providing power in a unidirectional or bidirectional flow. Charging levels mainly decide the charging time, cost, equipment, and power level required to charge the EV.

4.1.2. Charging Level

Different types of charging levels can be defined, which reflect the power supply to the EV at the CS for community charging. Level 1, Level 2, and Level 3 charging are defined as follows:

- Level 1: AC charging
  Level 1 AC charging is defined as slow charging, especially for low-powered vehicles. Most countries utilize Level 1 charging using a 120 V power outlet, which seems to be

a cheaper choice, but with a higher charging duration of 7–8 h. The setup for Level 1 AC can be installed in a household or an apartment with no additional requirement of infrastructure. However, people are more interested in Level 2 charging than Level 1 charging due to its longer charging duration [61]. Semsar et al. [62] proposed a single-phase AC charging scheme that combines the motor and inverter in a dual-inverter to improve the voltage level of AC charging compared to conventional chargers.

- Level 2: AC charging
  Level 2 AC charging is primarily suitable to be installed at a private or public location equipped with on-board chargers. It provides a higher voltage output of 240 V than Level 1 charging to the battery of EVs with the installation of suitable infrastructure. People are encouraged to charge their vehicle with Level 2 charging due to the shorter charging time. This type of charging level can be used for community charging in which multiple residential buildings or households can utilize a dedicated charger with an affordable cost of charging [42]. For example, Shen et al. [63] designed a two-level optimum hybrid EV charging strategy using an adaptive-equivalent consumption minimization strategy integrated with adaptive dynamic programming. They mainly worked to achieve high efficiency, low energy consumption, and to maintain the charging for vehicles.
- Level 3: DC charging
  Level 3 DC charging uses off-board chargers to provide fast charging for EVs for commercial purposes. Level 3 DC charging stations can charge EVs at up to a 480 V to facilitate more rapid charging than the other levels. However, despite fast charging, the incurred cost for DC charging may be unaffordable. Additionally, a high output power voltage in case of fast charging can overburden the electricity grid, whereas Level 1 and Level 2 charging overcome the overburdening issues of the power grid for private and public charging [64]. To achieve efficient DC fast charging, Thanakam et al. [65] developed an algorithm for a three-phase off-board charger to control the utility grid of high power voltage from any distortion due to the increased demand for EVs for fast charging. Although, people belonging to a community of several apartments can utilize the Level 2 charging efficiently with lower charging costs. Table 2 presents a comparative analysis of various EV charging levels and modes based on conductive charging.

Table 2. Comparative analysis of various EV charging Levels/Modes.

Author	Year	Aim	Charging Mode	Pros	Cons
[54]	2019	Designed a low power AC single phase charger	Mode 1	Controlled voltage and current supply	Ignored charging efficiency, cost, and EVs standardized connectors
[55]	2021	Discussed an on-board AC charger for plug-in EVs	Mode 1	Dynamic adaptability, steady charging, and controlled power supply	Ignorance of charging cost and specific charging ports
[58]	2021	Designed a 48V on-board AC fast charger for Evs	Mode 3	Reduced charging time, high charging efficiency, and controlled charging	Need to highlight charging cost, controlled power supply, and charging connectors
[59]	2022	Introduced a three phase fast DC charger for Evs	Mode 4	High efficiency, low distortion rate, high power yield	No discussion on charging cost and different charging connectors
[60]	2022	Designed a low voltage charging technique for EV	Mode 4	Low voltage stress, high efficiency with high output voltage	Need to deal with charging cost and standardized charging standards
[63]	2022	Proposed a two-level charging strategy for hybrid EVs using an adaptive dynamic programming	Level 2	Low energy consumption, high efficiency	Should focus in real-time scenario, less adaptability of dynamic networks
[65]	2022	Designed a three-phase off-board charger algorithm to control the powered grid from fast charging	Level 3	Improved feasibility, controlled power flow, and low distortion rate	No discussion on charging efficiency, cost, and standardization of charging standards

4.1.3. Charging Standards

This section discusses the different charging standards based on the conductive charging. Figures 4–6 shows the existence of charging standards based on the different countries, manufacturers, and types of EV. These can be mentioned as follows:

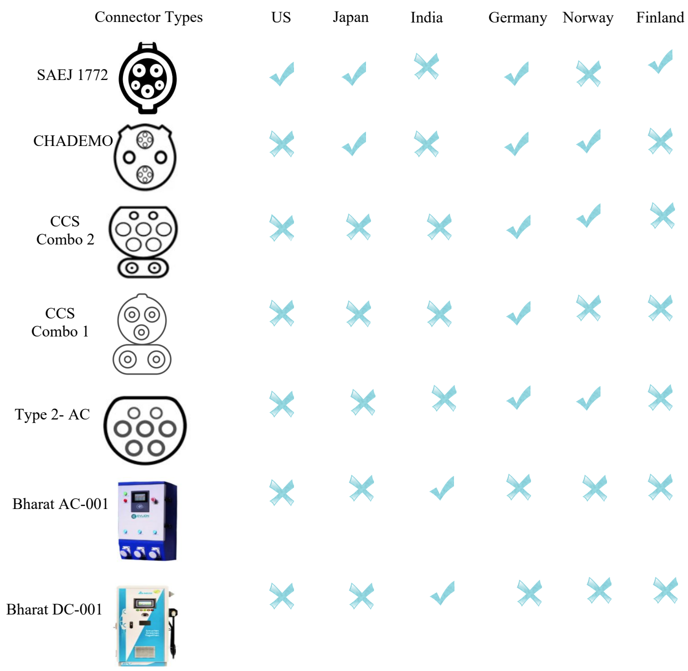

Figure 4. Taxonomy of charging standards based on the countries.

- SAEJ1772
  The SAEJ1772 charging standard is used for EV conductive AC charging, especially in North America. However, the SAEJ1772 charging standard also supports DC charging to achieve high-level energy transfer for fast EV charging. The International Society of Automotive Engineers mainly initiates it. The essential features of the standard can be characterized with the help of various parameters such as power supply level, different charging levels, charging time, charging cost, adaptability in different countries, and the network communication protocol between the charger and EV [66]. The charging time and voltage involved in the standard for conductive charging vary with the charging levels for 2W, 3W, and 4W EVs. The charging time for SAEJ1772 lies in the range of 4–7 h for charging Level 1 with the charging power level of 120 V. With charging Level 2 and Level 3, EVs can be charged with a charging time of 2–3 h and 0.5 h, corresponding to the charging power level of 240 V and 450 V [67]. Previously, EVs were charged wirelessly with the help of the inductive charging method. However, the government agency of California, i.e., the California Air Resources Board proposed the idea of the SAEJ1772 standard in the year 2001. Since 2001, most EVs have started adopting the SAEJ1772 standard in countries such as the USA, Germany, Japan, and Finland, and are manufactured by various companies such as Yazaski, Chevrolet Volt, Nissan Leaf, Teison, etc. [68].
- CHAdeMO
  The CHAdeMO charging standard is mainly used for EV conductive fast DC charging developed with considerations for compatibility with the industry. Japanese manufacturers first developed the standard to support three level charging [69]. Some countries, including Japan and Germany, use the CHAdeMO charging standard for EVs with a charging time of 0.5–1 h based on charging Level 3 along with the charging power level of 480 V for 4W vehicles. The EV requirement of charging determines the adaptability of the CHAdeMO charging standard. If EVs want to opt for fast

charging, they can use the CHAdeMO charging standard. However, they should also contain the same charging connector to achieve efficient and fast charging [70,71]. CHAdeMO has been utilized widely in several countries such as Japan, Norway, and Germany, in which many manufacturers such as Nissan Leaf, Yazaki, Fuzikura, etc., have started expanding their business by manufacturing the charging standard for fast DC EV charging.

- CCS Combo 1/Combo 2
  Many countries such as Japan and others in Europe are expanding their infrastructures to introduce fast charging connectors for efficient EV charging. Unlike CHAdeMO, the CCS charging standard is being adopted by countries worldwide. CCS combo 1, based on the SAEJ1772 conductive charging standard, was first coordinated and employed by a company named CharIN to facilitate EVs with fast DC charging. After this, CCS combo 1 (based on the AC type 1) was upgraded to the CCS combo 2 charging standard, which is based on AC type 2 charging. CCS combo 1 and CCS combo 2 charging standards can charge 4W EVs with a variable charging power, which lies between 600 V and 1000 V [72]. Moreover, EVs do not need to acquire extra space for this type of connector due to the usage of AC type 1 and type 2 chargers with DC connector pins for low voltage fast DC charging. The sustainable feature of the CCS charging standard has been adopted by Tesla since 2018. It means they can make use of the CCS combo 2 charging connector with superchargers for EV charging, increasing its usability [73,74]. Many manufacturers incorporate the CCS combo charger along with the Tesla, which includes Honda, VW eGolf, Mini Electric, Mercedes etc.
- Type 2-AC/DC
  Type 2-AC can be generalized as the European charging standard that supports both a single phase as well as three phase (Level 1, Level 2, Level 3) power supply to EVs [75]. The Type 2-AC charging standard associated with the three phase charging level can charge EVs (2W, 3W, 4W) with a variable charging power of 120 V for Level 1, 240 V for Level 2, and 410 V for Level 3. Thus, the charging standard is used for slow EV charging at specific locations, i.e., gyms, parks, shopping centres, etc. Therefore, it can also be utilized for community charging in which EVs have sufficient time to charge. However, Tesla is an exception that utilizes the Type 2 charging standard as the DC fast charger. These chargers are available for Tesla EVs only [76]. Regardless of the limited utilization of Type 2-AC for slow charging, many manufacturers, including Citroen C-Zero, Renault Zoe, and Smart EQ (For-Four, For-Two), have invested in designing the charging standard to expand their business further and provide flexible charging standards for EVs.
- Bharat AC-001/ Bharat DC-001
  India attempted to deploy EV charging standards with the help of Bharat chargers, i.e., Bharat AC-001 for low-powered charging vehicles. It can be equipped with 2W, 3W, and 4W EVs embedded with on-board chargers of low voltage. The variable charging power required for Bharat slow chargers ranges from 110 V to 450 V, based on the different charging levels [77]. On the other hand, to enhance the power supply to the EVs for fast charging, Bharat AC-001 can be upgraded to the Bharat DC-001 charging standard. The upgraded Bharat charging standard is built based on the IEC61851 that can transfer a maximum power of 72 V to the EVs. Moreover, the power supply for charging level 2 and charging level 3 can vary between 30 V and 48 V. To provide fast EV charging, Sharma et al. [78] investigated the conversion of the Bharat AC-001 to Bharat DC-001 charging standard considering the delta Vienna rectifier and a unidirectional DC/DC converter. Therefore, the aforementioned charging standards with variable charging power can be utilized for community charging based on the requirement and travelling destination of the users. Table 3 presents a comparative analysis of various EV conductive charging standards based on parameters such as charging level, charging time, voltage, and type of vehicle.

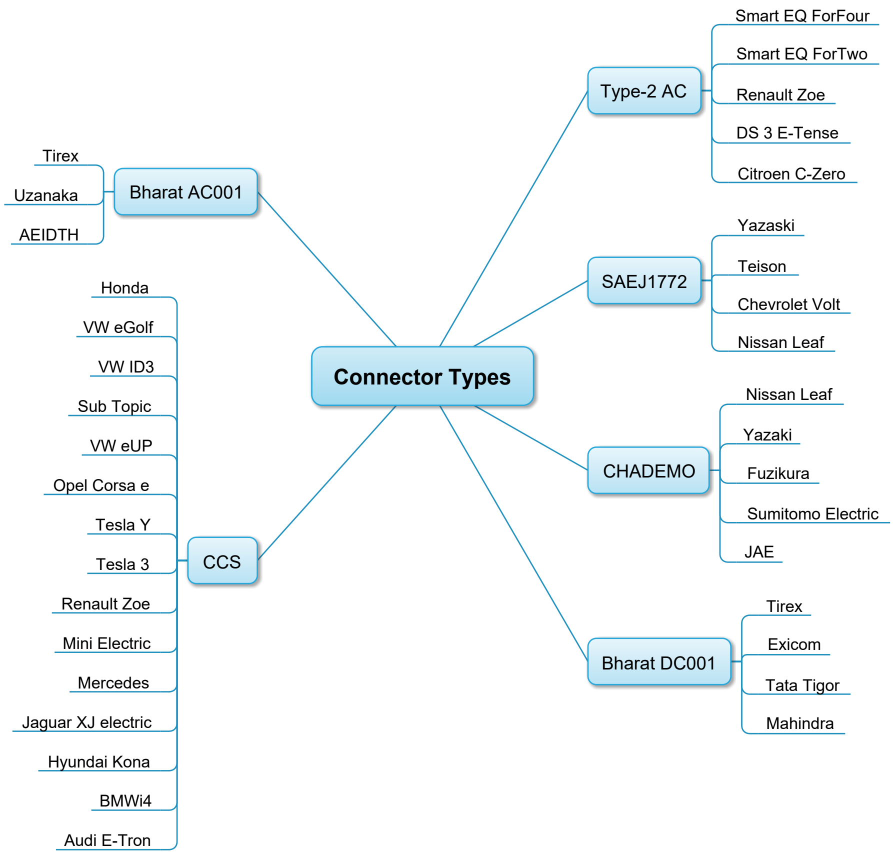

Figure 5. Taxonomy of charging connectors based on the manufacturers.

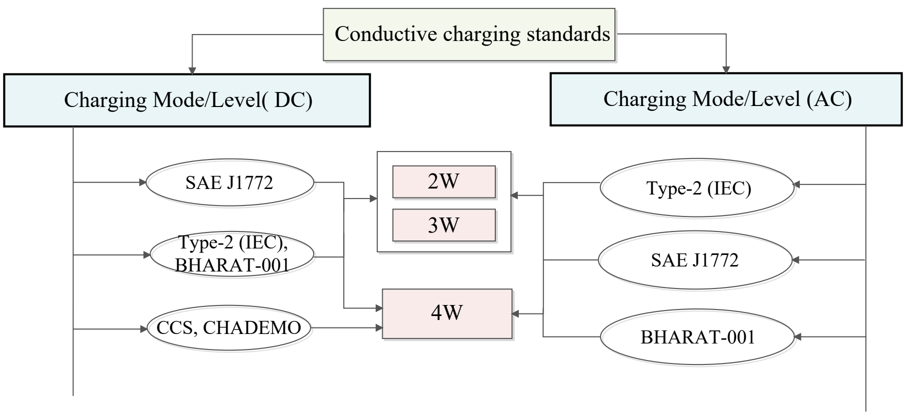

Figure 6. Taxonomy of conductive charging standards based on the type of EV.

Table 3. Comparative analysis of various EV charging standards based on the charging level, charging time, voltage, and types of vehicle [46,48,52,67].

Charging Standards	Description	Charging Level	Charging Time (hour (h))	Type of EV	Voltage (V)
SAEJ1772	Society of Automotive Engineers EV charging standard	Level 1, Level 2, Level 3	4–7 h, 2–3 h, 0.5 h	2W, 3W	120 V, 240 V, 450 V
CHADEMO	Charging standard developed by the japan for EV fast DC charging	Level 3	0.5–1 h	4W	480 V
CCS Combo 1	Charging standard developed by Society of Automotive Engineers	Level 3	0.4–1 h	4W	600 V
CCS Combo 2	Charging standard developed by Society of Automotive Engineers	Level 3	0.4–1 h	4W	1000 V
Type-2 AC	EV charging standard specified by IEC 62196	Level 1, Level 2, Level 3	8–9 h, 4–5 h, 3 h	2W, 3W, 4W	120 V, 240 V, 410 V
Bharat AC-001	EV slow charging standard developed by IEC 62196	Level 1, Level 2, Level 3	8 h, 5 h, 4 h	2W, 3W, 4W	100 V, 110 V, 415 V
Bharat DC-001	EV fast charging standard	Level 1, Level 2, Level 3	5 h, 4.5 h, 4 h	2W, 3W, 4W	72 V, 48 V, 30 V

4.2. Wireless Charging: Charging Type

Wireless charging is a plausible solution with which to tackle the security and privacy issues of the conductive charging of EVs [79,80], as it does not involve any physical connection for EV charging. It utilizes electromagnetic fields to charge EVs wirelessly through the battery without the need to establish any connection cable. Inductive coupling or inductive power transfer is the main principle that facilitates the transfer of energy to EVs without any cable connection [22,77]. For example, Suh et al. [81] discussed wireless charging in relation to the pickup system that is embedded within the EV, which accumulates energy transferred by the power supply system wirelessly installed at the CS. These wireless charging types are as follows:

- Stationary wireless charging
  After conductive charging, stationary wireless charging is one of the technologies that facilitate the charging of EVs at a static location. It signifies that EVs can only be charged in public parking spaces or garages. It means a community of multiple residents can also adopt stationary wireless charging infrastructure to provide static charging. However, EVs are not operable during this period, as the stationary wireless charging infrastructure does not facilitate this. Many National Laboratories have worked on stationary wireless charging technology to provide commuter satisfaction. For example, Oak Ridge National Laboratory collaborated with Toyota Research Institute and Hyundai American Technical Center to develop a prototype for stationary wireless charging systems [82]. Stationary wireless charging is beneficial for users who want to charge their EVs in a safe and convenient environment. There is no physical connection between EVs and the power grid for charging. Despite these advantages, stationary wireless charging does not provide an efficient solution for EV charging in terms of CS scheduling, efficiency, charging time, power supply, etc. [83].
  To tackle the aforementioned issues of stationary wireless EV charging, many researchers have conducted experimental studies to provide a stationary wireless charger for EVs. Some of the research works are as follows: the authors in [84] proposed an optimized procedure for a stationary wireless EV charger equipped with an LCC-series resonant network. The simulation analysis achieved a 94.8% efficiency with low power loss due to the incorporated series of resonant networks. Then, Zhang et al. [85] designed a 200 kW stationary wireless charger for Light-Duty EV to ensure a safer environment for electromagnetic emission by handling the misalignment issues. The simulation performance reduced field emissions by 26.8%. Similar to the authors in [84], Yenil et al. [86] also proposed high efficiency wireless charging for stationary

EVs. However, they considered an LC/S compensation network to obtain an accuracy of 91.9% with a full-load condition.

- Dynamic wireless charging
  Stationary wireless charging involves a longer charging period as passengers belonging to a community have to wait or stop at a particular location to charge their vehicles. It can also cause interruptions to their travelling schedule. Dynamic wireless charging mitigates the charging time issues by enabling the charging of EVs while they are in motion so that they can travel to their destination without any delay, thereby extending the driving range of EVs [87]. The dynamic wireless charging EV, i.e., the online EV, was first developed by the Korea Advanced Institute of Science and Technology (KAIST, South Korea) [88]. Later, the authors of [89] improved the proposed online EV [88] in terms of efficiency and power supply. A dynamic wireless charging structure involves EV charging in which electrical energy is transferred via the wireless charger installed beneath the underground road surface.
  Now, the electrical energy can be transmitted utilizing the resonant inductive power transfer (RIPT) between primary coils embedded underneath the road and secondary coils attached at the bottom of the EV [90]. However, despite the ease of dynamic EV charging in transit, such a system has a complex architecture, deployment, privacy, and cost issues which have been discussed by many researchers. For example, Li et al. [91] investigated dynamic wireless charging for private EVs. They studied an optimization policy to optimize the profit for EVs and to balance the powered grid. The results of their research work indicate an increase in efficiency of 90% and a reduction in cost of 50%. However, they did not consider the important aspect of the maximized utility and security of the system. Conversely, Wang et al. [92] addressed the security and privacy issues in dynamic wireless charging for EVs in Vehicular Energy Networks. They optimized the user's utility with the help of the introduced hierarchical game-based approach. Similarly, Tavakoli et al. [93] presented cost-efficient dynamic wireless charging for EVs by optimizing the ground assemblies and considering the misalignment and cost issues. The simulation yielded a result of 96% efficiency and cost of ground assembly of USD 1004.
- Quasi-Dynamic wireless charging
  Quasi-dynamic wireless charging can be considered as a subcategory of dynamic wireless charging. In quasi-dynamic wireless charging, EVs can charge in transit. However, the charging will be performed at a slower speed than in the case of dynamic wireless charging. EVs that are charged with quasi-dynamic charging technology can opt for CS near traffic signals or parking slots. Therefore, they have the advantage of a low charging time for dynamic wireless charging, with reduced architecture cost and increased efficiency [19]. Due to the cost-efficiency and reliability benefits, many companies have developed and introduced quasi-dynamic wireless charging to ensure the ease of EV wireless charging. For example, IPT Technology has provided wireless charging solutions for light duty and heavy duty vehicles since 1997. They developed various series of wireless charging buses that can be charged at a bus stop or if they are parked for an extended duration [94].
  However, it is more difficult to manage and plan quasi-dynamic wireless charging compared to dynamic wireless charging due to the frequent requirement of charging at a parking space or traffic signal. Many researchers have provided solutions for efficient, quasi-dynamic wireless charging. For example, Mohamed et al. [95] discussed the feasibility analysis of quasi-dynamic wireless power transfer for EV charging. They proposed an algorithm to manage the fluctuation of charging and discharging of EVs at a traffic signal which further extends the charging duration. Then, Carmeli et al. [96] presented an analysis of quasi-dynamic wireless power transfer for EV charging considering several misalignment scenarios. They performed a simulation to achieve an optimized charging and recharging scenario by handling the air-gap conditions in EVs. Later, Zhang et al. [97] addressed the electromagnetic security issues in

dynamic wireless EV charging. The simulation model was developed to secure the EV against the exposed magnetic field while charging in transit considering the various EV charging scenarios. Table 4 represents the analysis of various wireless charging types (static, dynamic, and quasi-dynamic) along with their advantages and disadvantages to improve wireless charging for EVs.

Table 4. Comparative analysis of various wireless charging types.

Author	Year	Objective	Pros	Cons	Wireless Charging Technology
[95]	2017	Presented a feasibility analysis of quasi-dynamic wireless power transfer for EV charging	Extended driving range and operating time	No focus on safe and user friendly environment	Quasi-dynamic
[96]	2018	Performed an analysis of quasi-dynamic wireless power transfer for EV charging	Optimized charging, low energy loss, low conduction loss	Some scenarios of misalignment are not considered	Quasi-dynamic
[84]	2019	Proposed a wireless EV charger with a LCC-series resonant network	High efficiency, improved flexibility	Charging time and EV scheduling is not considered	Stationary
[85]	2020	Designed a 200 kW wireless charger for Light-Duty EV	Safer environment, reduced field emissions, no misalignment issues	Security concerns are not discussed	Stationary
[97]	2021	Discussed security issues for dynamic wireless EV charging	Secure charging environment	No consideration of hardware development	Quasi-dynamic
[86]	2022	Discussed wireless EV charging with a LC/S network	High efficiency	No consideration of safer and user friendly environment	Stationary
[91]	2022	Investigated a dynamic wireless charging for private EVs	Low cost, high efficiency	Security and privacy concern	Dynamic
[92]	2022	dynamic wireless charging for EVs in Vehicular Energy Networks	Highly secure, maximized utility	No focus on efficiency	Dynamic
[93]	2022	Presented a cost-efficient dynamic wireless charging for Evs	High efficiency, low cost	Privacy issues are not discussed	Dynamic

4.2.1. Categorization of Wireless Charging Based on the Charging Standards

Wireless charging can be classified into various charging standards such as Qi, SAE, A4WP, and IEC charging, and can be operated with different power supplied and charging times based on the different coupling techniques. The coupling techniques are as follows [98,99]:

- Qi wireless charging standard
  The Qi charging standard was developed by the Wireless Power Consortium and can be utilized to charge an EV up to a certain distance of 4 cm. It comprises two essential components, i.e., base stations and mobile devices. Base stations are generally attached to an electric grid to provide the power supply for wireless charging. In addition, it contains a power transmitter that induces the electromagnetic field at the receiving end of mobile devices to perform wireless power transfer between two devices, i.e., the base station and mobile device. Moreover, the base station comprises a flat surface on which a number of mobile devices can be placed for the wireless charging procedure. However, the Qi charging standard supports power transfer to a certain extent, as once mobile devices are fully charged, base stations can stop transmitting the power through electromagnetic induction. Power transfer in the Qi charging standard provides a low power of 5 W and high power of 120 W. One more critical aspect needs to be considered to ensure efficient power transmission between the base station and mobile device, i.e., placement of the components. Components can be placed according to two methods categorized as guided positioning and placement anywhere. Guided positioning works on the principle that the user should be adequately guided to position the mobile device at the correct place between the sender and receiver magnetic coil. W With placement anywhere, a user can randomly position their mobile device on the base station in a broader interface area with the help of multiple transmission magnetic coils.

In the literature, many authors have mentioned the Qi standard to ensure wireless power transfer for EVs. However, the solutions provided can suffer from security attacks such as eavesdropping and hijacking due to the transmission of power supply through the exposed electromagnetic field, and there is no security provided during the power transmission between devices through the open communication channel [100–103]. For example, Hu et al. in [104] discussed the estimation of the coupling coefficient for efficient wireless charging with the designed Qi standard. The experimental analysis yielded efficiencies of 70% and 60% based on the different charging distances. Furthermore, the authors in [105] proposed an optimal transmission maximization algorithm to reduce the charging time in Qi standards wireless power transfer systems. Further, they simulated Qi charging systems to improve the performance in terms of transmission range. However, Qi charging wireless charging needs to be secured against exposure to electromagnetic fields during power transmission, which was not discussed in [104,105].

To alleviate the security issues, Wu et al. in [106] addressed several security attacks such as eavesdropping, hijacking, and data snooping in Qi wireless charging. They performed different experiments to demonstrate the eavesdropping and hijacking attack through adversarial message injection and inductive voltage, thereby affecting the charging time, performance, and efficiency of Qi wireless chargers. They suggested some defense strategies against eavesdropping and hijacking attacks.

- SAE wireless charging standard
  The adoption of the SAE wireless charging standard has been a great advantage for EVs in terms of enhanced charging time and efficiency. SAE International has permitted the SAE TIR j2954 charging standard to be utilized for light-duty EVs for wireless charging. The SAE charging standard offers a better power transfer level than the Qi charging standard. It provides three levels of power supply, i.e., Level 1 (3.7 kW), Level 2 (7.7 kW), and Level 3 (11 kW), facilitating the fast charging of EVs. However, despite of high power transfer, it still needs to be further developed in the future as it only allows unidirectional wireless charging, i.e., from the electric grid to EV. Therefore, the electric grid cannot utilize sufficient energy power from EVs. Moreover, it supports static wireless charging which needs to be changed to dynamic charging due to its extended driving range and better power transfer efficiency [107]. Many companies and manufacturers such as WiTricity, Qualcomm, and Evatran are investing in establishing the SAE wireless charging standard [108]. However, with the static feature of the SAE charging standard, the performance of EV charging is not effective in terms of key metrics such as driving range and power transfer efficiency.
  To overcome these challenges, many authors have put tremendous efforts to introduce the SAE wireless charging with the improved key metrics. For example, Huang et al. [109] proposed an LCC compensation network to optimize the reactance of wireless power transfer considering the SAE J2954 charging standard. The experimental simulation emphasizes to obtain the improved transfer efficiency of 92%. Further, to enhance the power transfer efficiency, the authors in [110] assessed a 230 V wireless power transfer for EVs based on the SAE charging standard. The research study analyzed the key parameters of wireless power transfer using magnetic resonance coupling. It shows the optimized power transfer and the maximized coupling coefficient between 0.02 and 0.32.
- A4WP wireless charging standard
  The Alliance for wireless power transfer was developed to provide additional spatial freedom for wireless charging over other charging standards. It is mainly designed to provide a varied power range from a low supply to high supply based on the requirement and charging level of the EVs. For example, Level 1 and Level 2 involve a power supply of 7.5 kW and 12W for wireless charging. On the other hand, Level 3 incurs a high power supply of 3.3 kW for wireless charging. As a result of the high power supply, it utilizes the wider interface for the positioning of the device for

charging purposes so that multiple devices can be charged simultaneously through the use of the magnetic resonance coupling technique.

It differs from other charging standards due to the advantages of high frequency and the control and management protocol. The frequency of the A4WP charging standard is 6.78×10^3 KHz, which reduces the probability of overheating issues in wireless chargers more than the Qi and SAE charging standards along with frequencies of 300 kHz and 85 kHz [111,112]. Many authors have devised integrated circuits with the help of the A4WP charging standard to enable efficient charging for EVs. For example, Jang et al. [113] designed a 15 W triple mode wireless power transmitting unit integrated with the power amplifier and DC–DC converter.

- IEC wireless charging standard

  The International Electrotechnical Commission has published several charging standards, i.e., IEC 62827-1 (2016) and IEC 61980-1 (2015) with variable charging power supplies of 7.5 kW, 15 kW, and 120 kW based on the different charging levels, i.e., Level 1, Level 2, and Level 3, to fulfill certain requirements for EV charging, such as avoiding overheating issues, increasing efficiency, and adequately managing the exposed electromagnetic field. However, charging involves transmitting the magnetic field from the transmitter coil to the receiver coil, which can lead to misalignment, compatibility, and electromagnetic interference issues. Facing these issues, authors have tried to address the challenges by considering the various misalignment conditions for EV charging with IEC charging standards.

  Some of the research works are as follows: Niu et al. [114] addressed misalignment conditions by performing a thermal behavior analysis of wireless EV charging. They conducted the experiment to perform a sensitivity analysis of numerous types of misalignment between ground assembly and vehicle assembly based on the temperature measurement. However, they did not highlight the compatibility issues for EV charging with different charging standards. Then, the authors in [115] also discuss the misalignment issues in wireless EV charging by assessing the power loss and thermal analysis of wireless EV charging considering the increased temperature of ground assembly. Despite handling these issues, they need to improve their system in terms of power loss and thermal performance. Alternatively, the authors in [116] overcome the compatibility and electromagnetic interference issues of [114] by performing an analysis of inductive power transfer following the IEC charging standards. However, they have not considered the misalignment conditions, which can also cause overheating issues due to the rise in temperature in continuous EV wireless charging.

  Table 5 presents several wireless charging standards along with comparison parameters, i.e., the power supply, coupling technique, and manufacturer. Furthermore, Table 6 shows the comparison of numerous wireless charging standards based on the optimized communication parameter along with limitations to better highlight the limitations of the existing literature.

Table 5. Comparison of wireless charging standards based on the power supply and coupling technique [98,117,118].

Wireless Charging Standards	Objective	Power Supply (W/kW)			Coupling Technique	Manufacturer
		Level 1	Level 2	Level 3		
Qi	Wireless power transfer standard developed by Wireless Power Consortium	5 W	120 W	N	Magnetic inductive coupling technique	Nokia, Sony, HTC
SAE	Standard for wireless charging developed by SAE International	3.7 kW	7.7 kW	11 kW	Magnetic resonance coupling technique	WiTricity, Qualcomm, Evatran
A4WP	Wireless charging standard for spatial power	7.5 W	12W	3.3 kW	Magnetic resonance coupling technique	WiTricity, Intel
IEC	Standard developed for EV wireless power transfer for electrical safety	7.5 kW	15 kW	120 kW	Magnetic resonance coupling technique	WiTricity

Table 6. Comparison of wireless charging standards based on the different communication parameters.

Wireless Charging Standard	Author	Year	Definition	Optimized Communication Parameter	Limitations
Qi charging standard	[105]	2020	Proposed an optimization algorithm for Qi wireless power transfer	Charging time, transmission range	No discussion on comparability and charging efficiency
	[104]	2020	Designed a compatible wireless power transfer system for Qi charging standard	Charging distance, efficiency, power transfer	Charging time is not considered
	[106]	2021	Investigated the defense strategies to tackle the security issues in wireless charging	Security against hijacking and eavesdropping attack	Low charging efficiency, low battery life
SAE charging standard	[109]	2020	Studied an optimized LCC wireless power transfer system based on the SAE J2954	Optimal reactance, efficiency	No consideration of charging time
	[110]	2021	Discussed a magnetic resonance coupled wireless power transfer for Evs using SAE	Power transfer, efficiency	Needs to be validated with an experiment
	[119]	2021	Designed a SAE J2954 and Si MOSFET-based wireless charger	Efficiency, regulated power transfer	Need to focus on fast wireless charging
A4WP charging standard	[113]	2020	Devised a 15W triple mode integrated wireless power transfer circuit using DC-DC converter	Efficiency, output power transfer	No discussion on comparability issues of charging standards
IEC charging standard	[114]	2020	Carried out the thermal behavior analysis of wireless EV charging system	Misalignment conditions, temperature measured	Compatibility issues
	[115]	2020	Performed the power loss and thermal analysis of wireless EV charging	Accuracy, temperature measured, misalignment condition	High power loss, less effort on thermal performance
	[116]	2021	Conducted the analysis for inductive power transfer based on the IEC standards	Electromagnetic compatibility, electromagnetic interference	Need to focus on misalignment issues

4.2.2. Categorization of Wireless Charging Based on the Wireless Charging Technologies

This section presents the classification of wireless charging systems based on the considered wireless charging technologies, such as inductive wireless charging, capacitive wireless charging, and resonant wireless charging. Figure 7 depicts the taxonomy of wireless charging based on the technologies, which is further classified based on the manufacturers as shown in Figure 8. The wireless charging technologies are as follows:

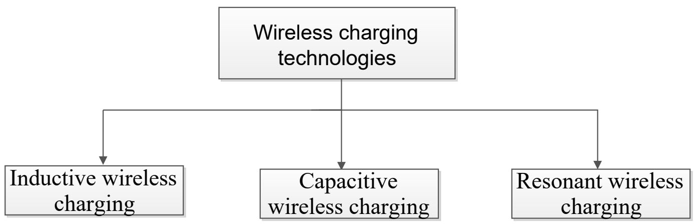

Figure 7. Taxonomy on wireless charging based on the technologies.

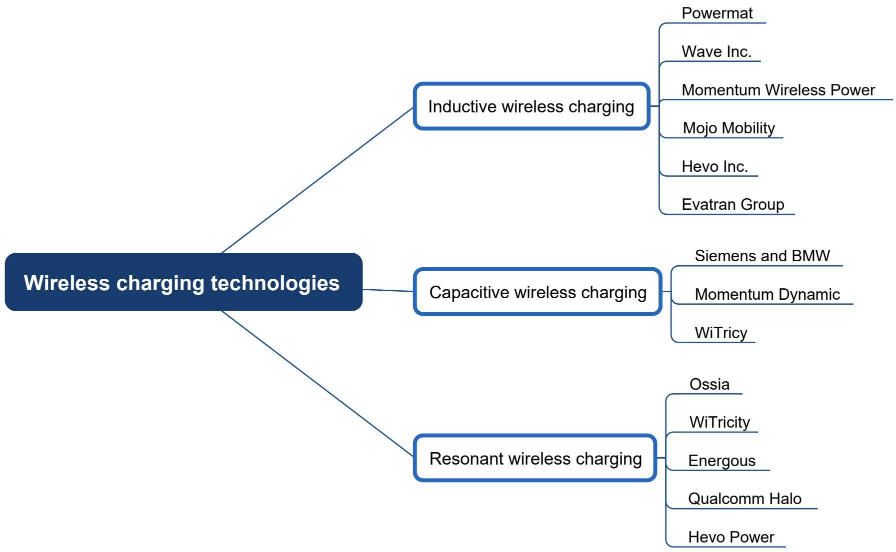

Figure 8. Taxonomy of wireless technologies based on the manufacturer.

- Inductive wireless charging
  In 1914, Nikola Tesla first designed the method of conventional inductive wireless charging to transfer power with the help of an induced electromagnetic field. It basically involves a primary coil, i.e., charging pad that creates an electromagnetic field to transfer the power wirelessly to the secondary coil present in the EV. The secondary coil helps to charge the EV by converting the induced electromagnetic field into an electric current. The University of Georgia showcased a inductive wireless EV charger of 66×10^2 W power which is capable of charging a battery of up to 400 V [23,120]. Moreover, fluctuations in the power supply and lower compatibility can affect the performance of EV inductive wireless charging. To mitigate these challenges, many researchers have tried to address these research issues for efficient and regulated power transfer wireless charging. Some of the research works related to this issue are as follows: Jeschke et al. [121] addressed the electromagnetic compatibility (EMC) testing challenges in inductive wireless charging. The authors regulated the power supply transferred to the EVs with the integration of a DC–DC converter at the secondary coil. Further, they studied the impact of alignment and air gap on the induced magnetic field to analyze the issues of EMC testing in wireless charging. However, they did not highlight the misalignment issues due to the induced magnetic field between EVs and the electric grid.
  To alleviate the misalignment issues in [121], the authors in [122] introduced an 11 kW inductive charging prototype for wireless power transfer. They compared the upgraded prototype with the already designed prototype in [123] to validate the parameters of their research work, such as misalignment and prototype efficiency. However, there is no discussion on regulated power supply, which can make the prototype less efficient. Therefore, to manage the power supply and efficiency concerns, Jafari et al. [124] discussed a virtual inertia-based EV charging system for inductive wireless power transfer. They analyzed the efficiency of the charging system to manage the power supply by connecting it to a LabVolt testbed system.
- Capacitive wireless charging
  Capacitive wireless charging is another wireless power transfer technology that utilizes the capacitive interface to transfer the current to the EVs instead of using an electromagnetic field. Coupling capacitors are the main criteria in capacitive wireless charging, used to transfer the AC power to a circuit known as the power factor. The power factor is basically used to measure the amount of power transferred to the EV

to enhance the efficiency and reduce the power loss when transmitting the wireless power to the EVs [125–127]. Moreover, capacitive wireless charging has great potential for inductive charging by managing the power fluctuations and overheating issues efficiently [128]. Many researchers have discussed capacitance wireless charging in their research works to highlight the balance between output power and charging voltage [129]. For example, the authors in [130] studied a capacitance EV charging system to handle the misalignment and power supply challenges considering the different arrangements of the capacitive coupler. They performed the simulation of the designed capacitance in ANSYS Maxwell to provide better coupling capacitance. Despite its advantages, the designed prototype needs to work on the efficiency of the charging system. Further, Kodeeswaran et al. [131] addressed the challenges of [130] by introducing the capacitive EV wireless charging topologies. They have considered three types of compensation circuits, i.e., LC LCL, and LCLC that are being simulated in the Matlab to highlight the improved efficiency, coupling capacitance, and voltage level of the wireless charging.

- Resonant wireless charging
  Resonance wireless charging works on the principle that maximum power transfer can be performed when the coilw at the sender and receiver's side are at the same resonant frequency. To achieve the resonant frequency, compensation circuits can be added to the wireless charging system to lessen the incurred power loss in the system. While considering the important aspect of wireless charging, i.e., power loss, many authors have ignored the efficiency and misalignment challenges that can occur between the sender's coil and receiver's coil [132]. To highlight and resolve the aforementioned challenges, the authors in [133] utilized the resonant inductive coupling technique for wireless EV charging. They simulated the charging system to obtain optimal power transfer efficiency for charging. However, misalignment and compatibility issues between the magnetic coils are still not discussed to this extent. Misalignment issues of [133] were covered in [134] by designing a load-independent framework for a resonant LCC compensation circuit for EV wireless charging. Table 7 shows a comparison of wireless charging technologies categorized as inductive wireless, capacitive wireless, or resonant wireless charging based on various parameters.

Table 7. Comparison of wireless charging technologies based on the performance evaluation parameters.

Wireless Charging Technologies	Author	Year	Objective	Merits	Demerits	Performance Evaluation Parameters
Inductive wireless charging	[121]	2018	Addressed the issues in EMC testing for EV inductive wireless charging	Improved power supply	Less effort on compatibility issues	Impact of alignment and air gap on induced magnetic field, power transfer
	[122]	2018	Designed a 11kW inductive charging prototype for wireless power transfer	Consideration of misalignment issues	No discussion on compatibility and power supply	Protoype efficiency
	[124]	2021	Discussed a virtual inertia-based EV charging system for inductive power transfer	Regulated power transfer	No consideration of misalignment	Efficiency analysis
Conductive wireless charging	[130]	2021	Designed a capacitive wireless charging system for EV	Tackle capacitance, misalignment, output power, and voltage stress	No consideration of efficiency	Coupling capacitance
	[131]	2021	Investigated capacitive EV wireless charging topologies	Increased voltage level, coupling capacitance, and efficiency	Compatibility and misalignment issues are ignored	Input voltage, output voltage
	[135]	2022	Proposed a kW-scale capacitive wireless power transfer system for EV	Enhanced efficiency and power transfer	Compatibility is ignored	Power density, efficiency, quality factor
Resonant wireless charging	[133]	2017	Performed an analysis for wireless EV charging using resonant inductive coupling technique	optimized power transfer efficiency	Misalignment issues are not considered	Power loss, efficiency, resonant frequency
	[134]	2020	Devised a load independent architecture for resonant LCC wireless charging converter for EV	Deal with misalignment, air gap, wide range of frequencies, and improved efficiency	Need to discuss compatibility issues	Frequency control, phase shift control
	[136]	2021	Comparative analysis of phase shift control strategy for resonance wireless EV charging	Improved performance	No focus on Misalignment, efficiency, and compatibility concerns	Output voltage

5. The Proposed Architecture

This section presents the proposed architecture of standardized EV community charging infrastructure. It aims to ensure that charging is easier for arriving EVs by ensuring the compatibility of different charging standards for several apartments or households in a community. It also benefits EV owners with the standardized charging ports for different types of EVs, such as 2W, 3W, and 4W, which minimizes the infrastructure setup cost. Figure 9 shows the main elements of the proposed architecture, i.e., the EV Charging connector layer, standardized layer, and EV owner layer. The functionalities of the layers along with their specific role in the proposed architecture can be described as follows:

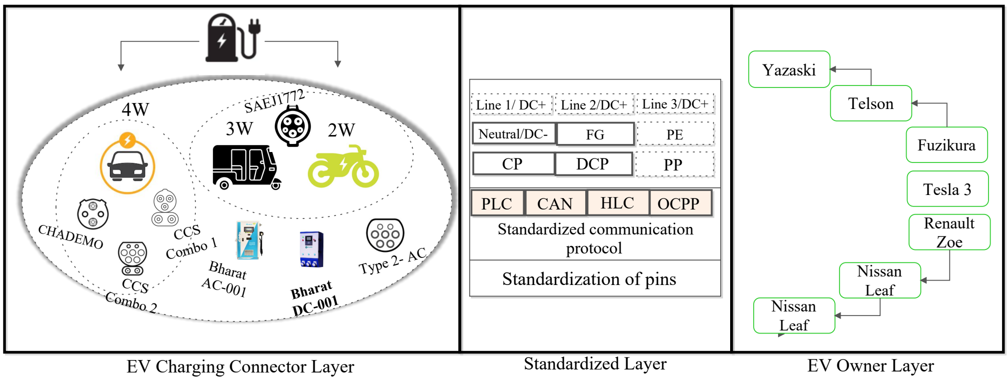

Figure 9. The proposed EV charging station standardization architecture.

5.1. Connector Layer

The connector layer mainly involves different types of EV charging associated with the specific charging standards developed by the manufacturers or EV owners. Manufacturers focus on developing charging standards for EVs with a configuration designed based on different countries. However, charging standards equipped in the EVs should be compatible with the charging port available at the CS. The main principle of the EV charging connector layer highlights 2W, 3W, and 4W EVs associated with several charging standards. For example, we considered 2W and 3W EVs that support the SAEJ1772 charging standard. However, other charging standards are CHADEMO, CCS Combo 1, and CCS Combo 2 compatible with the 4W EV. Moreover, charging standards such as Bharat AC-001, Bharat DC-001, and Type 2-AC are supported by all types of EVs. The charging standards can be used for EV conductive charging. However, these charging standards differ in terms of the configuration, the number of pins, and the communication protocol required to facilitate charging between the electric grid and EV. Therefore, these charging standards need to be standardized to ensure their adaptability for various types of EVs. For example, if a 2W EV associated with the SAEJ1772 charging standard arrives at a CS, but the available charging connector of the CS does not support the configuration of SAEJ1772, EVs arriving at the CS cannot utilize community infrastructure for charging and it can further delay their travel plans. Moreover, different countries work on different charging standards, which can cause a difficult situation for efficient and adaptable EV charging. So, we considered a standardized layer to assimilate the different charging standards into a standardized charging standard considering the common number of pins and the communication protocols of several charging standards, i.e., SAEJ1772, CHADEMO, CCS combo 1/combo 2, Type 2-AC, Bharat AC-001, and Bharat DC-001, for efficient community charging.

5.2. Standardized Layer

The EV charging connector layer comprises different types of EVs along with the compatible charging standards that need to be standardized. Therefore, the key criterion of the standardized layer is to work on developing the required standardized pins and communication protocol that to fulfill the basic configuration and specifications of the arriving EVs with different charging standards at the charging station. For example, the SAEJ1772 charging standard contains five pins, including Line 1, neutral, control pilot (CP), proximity pilot (PP), protective earth (PE), signalling, and the powerline communication (PLC) protocol. Line 1 is used as a single phase power supply for slow EV charging.

The other component control pilot is responsible for charging EVs from the electric grid with the help of a transferred signal. Another is PP, which transfers the signal to the vehicle while connected to the CS to avoid any kind of interruption during charging. On the other hand, Type-AC also includes similar components with the additions of Line 2 and Line 3 to accentuate the three-phase supply for fast EV charging, and power can be supplied from the charger to the EV through the electric cable using the signaling communication protocol. Similarly, charging standards such as CCS Combo 1 and combo 2 also resemble the Type-2 AC charging standard along with the two additional pins, i.e., the DC+ and DC− lines to facilitate fast DC charging for EVs using High level communication (HLC) protocol. Alternatively, CHADEMO consists of ten pins with two additional pins, i.e., DC+ and DC− with one more pin to communicate the signal for charging to the EV using the Controller Area Network (CAN) bus protocol. On the other hand, Bharat AC and DC-001 charging standards have a similar number of pins to the Type-2 AC charging standard, but do not contain the CP and PP pins, respectively. Therefore, we incorporated the standard features and communication protocols of these charging standards to develop a standardized charging standard for sustainable and adaptable EV charging (we will analyze the important aspect of charging time and charging cost while implementing the EV standardized charging infrastructure for efficient charging in the future).

5.3. EV Owner Layer

Standardization of the charging standards is an essential measure for the versatile and flexible charging of EVs. Different manufacturers or companies design EVs equipped with various charging standards due to which they can face uncompatiblity during charging. Therefore, we discussed the standardized layer which consists of combinatorial pins and a communication protocol to form a standardized charging standard for EVs. The EV owner layer specifies the number of manufacturers, such as Yazaski, Telson, Tesla 3, etc., who can utilize the standardized charging standard to provide efficient charging to EVs arriving at the CS. For example, Yazaski and Telson mainly manufacture the SAEJ1772 charging standard, whereas Tesla 3 invests in developing CCS charging standards. So, we can consider the characteristics of these charging standards to form a standardized charging standard that can be utilized by various EVs, i.e., Yazaski, Telson, and Tesla. So, we considered all the possible conductive charging standards to manufacture a combinatorial charging standard using a standardized communication protocol that companies can incorporate to build a standard charging standard.

6. Open Issues and Research Challenges/ Future Challenges and Research Opportunities

In this section, we discuss various open security issues and research challenges in the standardization of charging standards for EV charging. These can be mentioned as follows.

6.1. Multi-EV Charging Standards

What is the challenge?
Organizations or companies worldwide have developed several charging standards with different specifications, i.e., the number of pins, configuration, communication protocol, etc. Every manufacturer has their own interest to develop precise charging standards based on the requirement and the demand of EVs in different countries. Moreover, it is quite complicated and costly for manufacturers to develop or manage the multiple charging standards.
Possible solution: Inclusion of charging standards

We propose a possible idea to resolve the issue of multiple charging standards for EVs. Multiple charging standards can be incorporated to develop an inclusive charging standard that can fulfill the criteria of the design requirements of any EVs worldwide. However, the development of an inclusive charging standard can be a complex task to achieve as per the fulfillment of the specifications and features of multiple charging standards.

6.2. EV Charging Methods

What is the challenge?

EVs can be charged via different charging methods and technologies based on the type of EVs, i.e., 2W, 3W, and 4W. It also depends on the charging type, i.e., conductive or inductive charging in which different charging technologies are involved. We can consider the example of numerous wireless charging technologies such as inductive wireless charging, capacitive wireless charging, and resonant wireless charging. Additionally, charging standards use distinct communication protocols, which can cause incompatibility in the charging.

Possible solution: Universal charging methodology or communication protocol

The possible solution is to adapt a universal charging technology or communication protocol for efficient and scalable EV charging. It can also reduce the infrastructure cost and complexity of the CS due to the use of a universal charging methodology or communication protocol that makes the charging of EVs easier.

6.3. Consumer's Satisfaction

What is the challenge?

EVs can be charged at a public site, i.e., a mall, park, office, etc., or at a private location, i.e., home charging. However, the charging time is a serious concern that needs to be tackled efficiently. Home charging requires a longer charging time which can affect the overall efficiency of EV charging. However, EV charging at a public location tends to take less time, but it requires a complex infrastructure that can be quite costly for EVs.

Possible solution: Charging time

The feasible solution to resolve issues with charging time is to design an efficient EV charging infrastructure that also has a low cost so as to make it affordable for EVs.

6.4. Charging Safety

What is the challenge?

EV charging safety seems to be a major concern to be mitigated to ensure safe and secure EV charging. However, there are certain factors affecting the safety of EV charging. These factors can be overheating, the battery short circuiting, a fault in charging equipment, environmental factors, etc., which can lead to accidents with EVs [137]. These factors can adversely affect the performance of EV charging, especially the economic performance of the charging process due to the replacement of a faulty battery or equipment involved in charging. Ev accidents represent the main challenge needing to be tackled and mitigated to ensure safety and protection.

Possible solution: Insulation and short circuit detection

Charging safety is the major issue that can be protected by adapting insulation for electric cables and the communication lines used in EV charging. Additionally, EVs accident can be controlled by minimizing the impact of environmental factors on the charging equipment. If the battery short circuits, this will majorly affect the charging safety of the EV. It needs to be detected beforehand to attenuate the number of EV accidents. The internal short circuit detection method is a promising solution that analyzes parameters such as the temperature, voltage, and current to detect the short circuit earlier.

6.5. Reliable Communication Protocol

What is the challenge?

Communication protocols for EV charging play an important role in the charging safety of

EVs along with its equipment, such as electric cable, communication line, etc. For example, as we already discussed, different charging standards use different communication protocols, which can cause an interruption in EV charging due to compatibility issues. For example, we can consider if EVs along with the CHADEMO (CAN communication protocol) charging standard arrives at a CS with the available CCS combo 1 (PLC communication protocol) charging standard for charging. However, the incompatible communication protocol can transmit the wrong message to the CS for charging, which can cause overcharging or even a battery explosion of the EV. Therefore, it is essential to prevent communication threats for safe EV charging.
Possible solution: Compatible communication protocol
The compatible communication protocol is a plausible solution to ensure the reliability of communication between an EV and CS or electric grid for efficient charging. In 2009, Open Charge Alliance established an open charge point protocol (OCPP), so that EVs and CS can communicate with the same open-source communication protocol. However, if is a mismatch exists between communication protocols, the charging performance and reliability of the EV can be affected.

6.6. Battery Overcharge and Overheating

What is the challenge?
Lithium–ion batteries are considered to be the most common battery used in EVs. Battery overcharge can occur due to the incompatibility of the communication protocols required for EV charging, as discussed in the previous research challenge. Battery overcharge needs to be diagnosed to further prevent the battery overheating issues. Battery overcharging leads to the overheating of the electric motor of the EV, which can also be the reason for the failure of the insulation of the charging equipment. Therefore, protection measures should be adapted to maintain and control the burden of EV battery charging.
Possible solution: Overcharge protection method
The overcharge protection method is a credible solution that can be used to reduce the risk of overcharging and overheating while an EV is charged at a CS. Several researchers studied the overcharging mechanism in the lithium–ion battery and tried to mitigate thermal overheating in the charging equipment and components [138]. However, these research works do not support the upgraded lithium–ion battery. Therefore, EVs can be protected from overcharging with the help of a protection method with upgraded features for lithium–ion batteries.

6.7. Power Supply Quality

What is the challenge?
Power supply quality is one of the critical aspects that need to be considered while ensuring the charging safety of the EV. Different measures are responsible for the poor power supply quality, i.e., high voltage load, harmonic fluctuations in voltage, current, etc., causing EV charging distortion. So, the power supply needs to be improved to improve EV charging efficiency.
Possible solution: Battery management system
A battery management system is a plausible solution to monitor parameters such as high voltage load, harmonics fluctuation, current, etc., which affect the quality of power supply to the EVs. Monitoring is required to maintain the battery voltage and current level to ensure controlled EV charging.

7. Conclusions

In this paper, we present an exhaustive survey on standardizing EV charging infrastructure considering the taxonomy of charging levels, charging modes, charging standards, and charging technologies based on the different charging types such as conductive charging and wireless charging, and types of vehicle, i.e., 2W, 3W, and 4W. Moreover, we considered a scenario in which the community charging service operator manages the EV charging infrastructure at which users of a particular community can charge their vehicles. For that, we propose an architecture for standardized EV charging infrastructure to provide compatibility of the charging standards for efficient and durable charging. Finally, the research challenges and opportunities of the proposed survey have been discussed in this research area.

In future work, we can consider one more charging type, i.e., battery exchange to explore more about the power supply, current, and efficiency of EVs. Additionally, we need to highlight one more charging standard, i.e., GB/T, in future to discuss supporting countries and manufacturers for the future. Additionally, we can implement the standardized charging standards in real-time scenarios to enable the adaptability and compatibility for the arriving EVs at a CS across the countries. However, the important aspects of charging cost and charging time need to be considered while implementing the standardized charging infrastructure for reliable charging so that it is affordable for the users. Another scenario needs to be incorporated to verify the adaptability and affordability of specialized CSs for EVs considering the different charging levels and modes such as DC or AC with different phases for charging.

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Abbreviations

The following abbreviations are used in this manuscript:

EV	Electric Vehicle
CS	Charging Station
2W	2-wheeler
3W	3-wheeler
4W	4-wheeler
EVSE	Electric vehicle supply equipment
AC	Alternating current
DC	Direct current
RIPT	Resonant inductive power transfer
IPT	Inductive power transfer

EMC	Electromagnetic compatibility
PLC	Powerline communication
HLC	High level communication
CP	Control pilot
PP	Proximity pilot
PE	Protective earth
CAN	Controller Area Network

References

1. Poornima, S.; Phaneendra, S.; Nivedita, H.; Khan, A.; Jalaluddin, M. Charging of EV using Solar and Wind Energy: A review. In Proceedings of the 2022 International Conference on Electronics and Renewable Systems (ICEARS), Tuticorin, India, 16–18 March 2022; pp. 47–50. [CrossRef]
2. Samsara. How Are Electric Vehicles Better for the Environment? Available online: https://www.samsara.com/guides/how-are-electric-vehicles-better-for-the-environment/ (accessed on 10 May 2022).
3. Dixit, P.; Bhattacharya, P.; Tanwar, S.; Gupta, R. Anomaly detection in autonomous electric vehicles using AI techniques: A comprehensive survey. *Expert Syst.* **2022**, *39*, e12754. [CrossRef]
4. Ding, Z.; Zhang, Y.; Tan, W.; Pan, X.; Tang, H. Pricing based Charging Navigation Scheme for Highway Transportation to Enhance Renewable Generation Integration. *IEEE Trans. Ind. Appl.* **2022**, 1–10. [CrossRef]
5. Tanwar, S.; Tyagi, S.; Budhiraja, I.; Kumar, N. Tactile Internet for Autonomous Vehicles: Latency and Reliability Analysis. *IEEE Wirel. Commun.* **2019**, *26*, 66–72. [CrossRef]
6. Edfenergy. Benefits of Electric Cars on the Environment. Available online: https://www.edfenergy.com/for-home/energywise/electric-cars-and-environment (accessed on 10 May 2022).
7. Affolabi, L.; Shahidehpour, M.; Rahimi, F.; Aminifar, F.; Nodehi, K.; Mokhtari, S. Hierarchical Transactive Energy Scheduling of Electric Vehicle Charging Stations in Constrained Power Distribution and Transportation Networks. *IEEE Trans. Transp. Electrif.* **2022**, 1. [CrossRef]
8. La Monaca, S.; Ryan, L. *The State of Play in Electric Vehicle Charging Services: Global Trends with Insight for Ireland*; Technical Report; School of Economics, University College Dublin: Dublin, Ireland, 2018.
9. Porru, M.; Serpi, A.; Mureddu, M.; Damiano, A. A Combined Planning and Design Approach of a Public Charging Infrastructure for Electric Vehicles. In Proceedings of the 2018 IEEE Vehicle Power and Propulsion Conference (VPPC), Chicago, IL, USA, 27–30 August 2018; pp. 1–5. [CrossRef]
10. Odeh, Y.S.; Elkahlout, I.S.; Naeimi, P.V.; ElGhanam, E.A.; Hassan, M.S.; Osman, A.H. Planning and Allocation of Dynamic Wireless Charging Infrastructure for Electric Vehicles. In Proceedings of the 2022 9th International Conference on Electrical and Electronics Engineering (ICEEE), Alanya, Turkey, 29–31 March 2022; pp. 306–310. [CrossRef]
11. Paul Sathiyan, S.; Benin Pratap, C.; Stonier, A.A.; Peter, G.; Sherine, A.; Praghash, K.; Ganji, V. Comprehensive Assessment of Electric Vehicle Development, Deployment, and Policy Initiatives to reduce GHG Emissions: Opportunities and Challenges. *IEEE Access* **2022**, *10*, 53614–53639. [CrossRef]
12. Ding, Z.; Teng, F.; Sarikprueck, P.; Hu, Z. Technical Review on Advanced Approaches for Electric Vehicle Charging Demand Management, Part II: Applications in Transportation System Coordination and Infrastructure Planning. *IEEE Trans. Ind. Appl.* **2020**, *56*, 5695–5703. [CrossRef]
13. Deb, S. Machine Learning for Solving Charging Infrastructure Planning: A Comprehensive Review. In Proceedings of the 2021 5th International Conference on Smart Grid and Smart Cities (ICSGSC), Tokyo, Japan, 18–20 June 2021; pp. 16–22. [CrossRef]
14. Aghamohamadi, M.; Mahmoudi, A.; Ward, J.K.; Haque, M.H. Review on the State-of-the-art Operation and Planning of Electric Vehicle Charging Stations in Electricity Distribution Systems. In Proceedings of the 2021 IEEE Energy Conversion Congress and Exposition (ECCE), Vancouver, BC, Canada, 10–14 October 2021; pp. 733–738. [CrossRef]
15. Duan, X.; Hu, Z.; Song, Y.; Strunz, K.; Cui, Y.; Liu, L. Planning Strategy for an Electric Vehicle Fast Charging Service Provider in a Competitive Environment. *IEEE Trans. Transp. Electrif.* **2022**, *8*, 3056–3067. [CrossRef]
16. A review of consumer preferences of and interactions with electric vehicle charging infrastructure. *Transp. Res. Part D Transp. Environ.* **2018**, *62*, 508–523. [CrossRef]
17. Funke, S.Á.; Sprei, F.; Gnann, T.; Plötz, P. How much charging infrastructure do electric vehicles need? A review of the evidence and international comparison. *Transp. Res. Part D Transp. Environ.* **2019**, *77*, 224–242. [CrossRef]
18. Bilal, M.; Rizwan, M. Electric vehicles in a smart grid: A comprehensive survey on optimal location of charging station. *IET Smart Grid* **2020**, *3*, 267–279. [CrossRef]
19. ElGhanam, E.; Hassan, M.; Osman, A.; Ahmed, I. Review of Communication Technologies for Electric Vehicle Charging Management and Coordination. *World Electr. Veh. J.* **2021**, *12*, 92. [CrossRef]
20. shafiei, M.; Ghasemi-Marzbali, A. Fast-charging station for electric vehicles, challenges and issues: A comprehensive review. *J. Energy Storage* **2022**, *49*, 104136. [CrossRef]
21. Rubino, L.; Capasso, C.; Veneri, O. Review on plug-in electric vehicle charging architectures integrated with distributed energy sources for sustainable mobility. *Appl. Energy* **2017**, *207*, 438–464. [CrossRef]

22. Jang, Y.J. Survey of the operation and system study on wireless charging electric vehicle systems. *Transp. Res. Part C Emerg. Technol.* **2018**, *95*, 844–866. [CrossRef]
23. Panchal, C.; Stegen, S.; Lu, J. Review of static and dynamic wireless electric vehicle charging system. *Eng. Sci. Technol. Int. J.* **2018**, *21*, 922–937. [CrossRef]
24. Falchetta, G.; Noussan, M. Electric vehicle charging network in Europe: An accessibility and deployment trends analysis. *Transp. Res. Part D Transp. Environ.* **2021**, *94*, 102813. [CrossRef]
25. Schoenberg, S.; Buse, D.S.; Dressler, F. Siting and Sizing Charging Infrastructure for Electric Vehicles with Coordinated Recharging. *IEEE Trans. Intell. Veh. (T-IV)* 2022, *early access*. [CrossRef]
26. Brenna, M.; Foiadelli, F.; Leone, C.; Longo, M. Electric vehicles charging technology review and optimal size estimation. *J. Electr. Eng. Technol.* **2020**, *15*, 2539–2552. [CrossRef]
27. Amin, A.; Tareen, W.U.K.; Usman, M.; Ali, H.; Bari, I.; Horan, B.; Mekhilef, S.; Asif, M.; Ahmed, S.; Mahmood, A. A review of optimal charging strategy for electric vehicles under dynamic pricing schemes in the distribution charging network. *Sustainability* **2020**, *12*, 10160. [CrossRef]
28. Triviño, A.; González-González, J.M.; Aguado, J.A. Wireless power transfer technologies applied to electric vehicles: A review. *Energies* **2021**, *14*, 1547. [CrossRef]
29. Savio Abraham, D.; Verma, R.; Kanagaraj, L.; Giri Thulasi Raman, S.R.; Rajamanickam, N.; Chokkalingam, B.; Marimuthu Sekar, K.; Mihet-Popa, L. Electric Vehicles Charging Stations' Architectures, Criteria, Power Converters, and Control Strategies in Microgrids. *Electronics* **2021**, *10*, 1895. [CrossRef]
30. Arif, S.M.; Lie, T.T.; Seet, B.C.; Ayyadi, S.; Jensen, K. Review of electric vehicle technologies, charging methods, standards and optimization techniques. *Electronics* **2021**, *10*, 1910. [CrossRef]
31. Bhattacharya, P.; Tanwar, S.; Bodkhe, U.; Kumar, A.; Kumar, N. EVBlocks: A Blockchain-Based Secure Energy Trading Scheme for Electric Vehicles underlying 5G-V2X Ecosystems. *Wirel. Pers. Commun.* **2021**, 1–39. [CrossRef]
32. Gupta, R.; Kumari, A.; Tanwar, S. A taxonomy of blockchain envisioned edge-as-a-connected autonomous vehicles. *Trans. Emerg. Telecommun. Technol.* **2021**, *32*, e4009. [CrossRef]
33. Tanwar, S.; Kakkar, R.; Gupta, R.; Raboaca, M.S.; Sharma, R.; Alqahtani, F.; Tolba, A. Blockchain-based electric vehicle charging reservation scheme for optimum pricing. *Int. J. Energy Res.* **2022**, *46*, 14994–15007. [CrossRef]
34. Wu, T.; Li, G.; Bie, Z. Charging Price Determination and Energy Management of EV Parking Lot Considering Price Elasticity. In Proceedings of the 2019 IEEE 8th International Conference on Advanced Power System Automation and Protection (APAP), Xi'an, China, 21–24 October 2019; pp. 1789–1793. [CrossRef]
35. Ou, S.; Lin, Z.; He, X.; Przesmitzki, S. Estimation of vehicle home parking availability in China and quantification of its potential impacts on plug-in electric vehicle ownership cost. *Transp. Policy* **2018**, *68*, 107–117. [CrossRef]
36. Kakkar, R.; Agrawal, S.; Gupta, R.; Tanwar, S. Blockchain and Zero-Sum Game-based Dynamic Pricing Scheme for Electric Vehicle Charging. In Proceedings of the IEEE INFOCOM 2022—IEEE Conference on Computer Communications Workshops (INFOCOM WKSHPS), New York, NY, USA, 2–5 May 2022; pp. 1–6. [CrossRef]
37. Clean Energy EV30@30 CAMPAIGN. Available online: https://www.cleanenergyministerial.org/initiatives-campaigns/ev3030-campaign/ (accessed on 10 May 2022).
38. Kakkar, R.; Gupta, R.; Agrawal, S.; Tanwar, S.; Altameem, A.; Altameem, T.; Sharma, R.; Turcanu, F.E.; Raboaca, M.S. Blockchain and IoT-Driven Optimized Consensus Mechanism for Electric Vehicle Scheduling at Charging Stations. *Sustainability* **2022**, *14*, 12800. [CrossRef]
39. Gharbaoui, M.; Bruno, R.; Martini, B.; Valcarenghi, L.; Conti, M.; Castoldi, P. Assessing the effect of introducing adaptive charging stations in public EV charging infrastructures. In Proceedings of the 2014 International Conference on Connected Vehicles and Expo (ICCVE), Vienna, Austria, 3–7 November 2014; pp. 299–305. [CrossRef]
40. Terada, L.Z.; López, J.C.; Arias, N.B.; Rider, M.J.; Pereira da Silva, L.C.; Lacusta Junior, E.P. EV Charging Simulator for Public Infrastructure Considering Smart Charging and Price Policies. In Proceedings of the 2021 IEEE PES Innovative Smart Grid Technologies Conference—Latin America (ISGT Latin America), Lima, Peru, 15–17 September 2021; pp. 1–5. [CrossRef]
41. Gjelaj, M.; Træholt, C.; Hashemi, S.; Andersen, P.B. Cost-benefit analysis of a novel DC fast-charging station with a local battery storage for EVs. In Proceedings of the 2017 52nd International Universities Power Engineering Conference (UPEC), Heraklion, Greece, 28–31 August 2017; pp. 1–6. [CrossRef]
42. Lopez-Behar, D.; Tran, M.; Mayaud, J.R.; Froese, T.; Herrera, O.E.; Merida, W. Putting electric vehicles on the map: A policy agenda for residential charging infrastructure in Canada. *Energy Res. Soc. Sci.* **2019**, *50*, 29–37. [CrossRef]
43. Lopez-Behar, D.; Tran, M.; Froese, T.; Mayaud, J.R.; Herrera, O.E.; Merida, W. Charging infrastructure for electric vehicles in Multi-Unit Residential Buildings: Mapping feedbacks and policy recommendations. *Energy Policy* **2019**, *126*, 444–451. [CrossRef]
44. Pardo-Bosch, F.; Pujadas, P.; Morton, C.; Cervera, C. Sustainable deployment of an electric vehicle public charging infrastructure network from a city business model perspective. *Sustain. Cities Soc.* **2021**, *71*, 102957. [CrossRef]
45. Zinnari, F.; Strada, S.; Tanelli, M.; Formentin, S.; Savaresi, S.M. Electrification Potential of Fuel-Based Vehicles and Optimal Placing of Charging Infrastructure: A Large-Scale Vehicle-Telematics Approach. *IEEE Trans. Transp. Electrif.* **2022**, *8*, 466–479. [CrossRef]

46. Patt, A.; Aplyn, D.; Weyrich, P.; van Vliet, O. Availability of private charging infrastructure influences readiness to buy electric cars. *Transp. Res. Part A Policy Pract.* **2019**, *125*, 1–7. [CrossRef]
47. Costa, E.; Vanhaverbeke, L.; Coosemans, T.; Seixas, J.; Messagie, M.; Costa, G. Optimizing The Location Of Charging Infrastructure For Future Expansion Of ElectricVehicle In Sao Paulo, Brazil. In Proceedings of the 2019 IEEE International Smart Cities Conference (ISC2), Casablanca, Morocco, 14–17 October 2019; pp. 632–637. [CrossRef]
48. Melliger, M.A.; van Vliet, O.P.; Liimatainen, H. Anxiety vs. reality–Sufficiency of battery electric vehicle range in Switzerland and Finland. *Transp. Res. Part D Transp. Environ.* **2018**, *65*, 101–115. [CrossRef]
49. Nezamuddin, O.N.; Nicholas, C.L.; Santos, E.C.d. The Problem of Electric Vehicle Charging: State-of-the-Art and an Innovative Solution. *IEEE Trans. Intell. Transp. Syst.* **2022**, *23*, 4663–4673. [CrossRef]
50. Wolbertus, R.; van den Hoed, R. Fast Charging Systems for Passenger Electric Vehicles. *World Electr. Veh. J.* **2020**, *11*, 73. [CrossRef]
51. Goh, D.; Sokolowski, P.; Jalili, M. Multi-day Residential EV Charging Strategy Using Reinforcement Learning. In Proceedings of the 2021 IEEE 30th International Symposium on Industrial Electronics (ISIE), Kyoto, Japan, 20–23 June 2021; pp. 1–6. [CrossRef]
52. Hecker, A.; Wies, R. Charging infrastructure for EVs in Beijing: A spatial analysis from real customer data at two districts. In Proceedings of the 2015 International Conference on Connected Vehicles and Expo (ICCVE), Shenzhen, China, 19–23 October 2015; pp. 336–341. [CrossRef]
53. Vu, V.B.; González-González, J.M.; Pickert, V.; Dahidah, M.; Triviño, A. A Hybrid Charger of Conductive and Inductive Modes for Electric Vehicles. *IEEE Trans. Ind. Electron.* **2021**, *68*, 12021–12033. [CrossRef]
54. Kamat, S.; Jadhav, S. Design and Simulation of Low Power Charging Station for Electric Vehicle. In Proceedings of the 2019 International Conference on Advances in Computing, Communication and Control (ICAC3), Mumbai, India, 20–21 December 2019; pp. 1–4. [CrossRef]
55. Thanakam, T.; Kumsuwan, Y. A Novel On-Board Battery Charger Configuration Based on Nine-Switch Converter fed Open-End Winding AC Motor Drive for Plug-In Electric Vehicles. In Proceedings of the 2021 24th International Conference on Electrical Machines and Systems (ICEMS), Gyeongju, Korea, 31 October–3 November 2021; pp. 988–991. [CrossRef]
56. Bahrami, A. EV Charging Definitions, Modes, Levels, Communication Protocols and Applied Standards. *Changes* **2020**, *1*, 10-01.
57. Mineeshma, G.R.; Bhavya, Y.V.; Chandrasekar, V. Electric Vehicle Supply Equipment: An Overview on Design Requirements as per AIS-138. In Proceedings of the 2022 2nd International Conference on Power Electronics IoT Applications in Renewable Energy and Its Control (PARC), Mathura, India, 21–22 January 2022; pp. 1–6. [CrossRef]
58. Maliat, A.; al Mahmud, M.; Razzak, M.A. Design and Analysis of a 48V On-board Fast Charging System for Electric Vehicles. In Proceedings of the 2021 Innovations in Power and Advanced Computing Technologies (i-PACT), Kuala Lumpur, Malaysia, 27–29 November 2021; pp. 1–6. [CrossRef]
59. Wang, S.; Lehn, P.W. A Three-Phase Electric Vehicle Charger Integrated with Dual-Inverter Drive. *IEEE Trans. Transp. Electrif.* **2022**, *8*, 82–97. [CrossRef]
60. Kim, J.Y.; Lee, B.S.; Kwon, D.H.; Lee, D.W.; Kim, J.K. Low Voltage Charging Technique for Electric Vehicles with 800 V Battery. *IEEE Trans. Ind. Electron.* **2022**, *69*, 7890–7896. [CrossRef]
61. Khalid, M.R.; Khan, I.A.; Hameed, S.; Asghar, M.S.J.; Ro, J.S. A Comprehensive Review on Structural Topologies, Power Levels, Energy Storage Systems, and Standards for Electric Vehicle Charging Stations and Their Impacts on Grid. *IEEE Access* **2021**, *9*, 128069–128094. [CrossRef]
62. Semsar, S.; Soong, T.; Lehn, P.W. Integrated Single-Phase Electric Vehicle Charging Using a Dual-Inverter Drive. In Proceedings of the 2018 IEEE Transportation Electrification Conference and Expo (ITEC), Long Beach, CA, USA, 13–15 June 2018; pp. 320–325. [CrossRef]
63. Shen, Z.; Luo, C.; Dong, X.; Lu, W.; Lv, Y.; Xiong, G.; Wang, F.Y. Two-Level Energy Control Strategy Based on ADP and A-ECMS for Series Hybrid Electric Vehicles. *IEEE Trans. Intell. Transp. Syst.* **2022**, *23*, 13178–13189. [CrossRef]
64. Kumar, S.; Usman, A. A Review of Converter Topologies for Battery Charging Applications in Plug-in Hybrid Electric Vehicles. In Proceedings of the 2018 IEEE Industry Applications Society Annual Meeting (IAS), Portland, OR, USA, 23–27 September 2018; pp. 1–9. [CrossRef]
65. Thanakam, T.; Kumsuwan, Y. A Developed PLL Control Technique for Distorted and Unbalanced Grid Voltages with a Three-Level NPC Converter-Based Off-Board Battery Charger. In Proceedings of the 2022 International Electrical Engineering Congress (iEECON), Khon Kaen, Thailand, 9–11 March 2022; pp. 1–4. [CrossRef]
66. EVEXPERT. Connector Types for EV Charging around the World. Available online: https://www.evexpert.eu/eshop1/knowledge-center/connector-types-for-ev-charging-around-the-world (accessed on 6 April 2022).
67. Das, S.; Acharjee, P.; Bhattacharya, A. Charging scheduling of electric vehicle incorporating grid-to-vehicle (G2V) and vehicle-to-grid (V2G) technology in smart-grid. In Proceedings of the 2020 IEEE International Conference on Power Electronics, Smart Grid and Renewable Energy (PESGRE2020), Cochin, India, 2–4 January 2020; pp. 1–6.
68. Shuttleworth, J. New SAE Wireless Charging Standard is EV Game-Changer. Available online: https://www.sae.org/news/2020/10/new-sae-wireless-charging-standard-is-ev-game-changer (accessed on 6 April 2022).
69. Driving Electric. What Is CHAdeMO Charging? Available online: https://www.drivingelectric.com/your-questions-answered/114/what-chademo-charging (accessed on 8 April 2022).
70. Electrek. Electric Vehicle (EV) Charging Standards and How They Differ. Available online: https://electrek.co/2021/10/22/electric-vehicle-ev-charging-standards-and-how-they-differ/ (accessed on 8 April 2022).

71. Sutopo, W.; Nizam, M.; Rahmawatie, B.; Fahma, F. A Review of Electric Vehicles Charging Standard Development: Study Case in Indonesia. In Proceedings of the 2018 5th International Conference on Electric Vehicular Technology (ICEVT), Surakarta, Indonesia, 30–31 October 2018; pp. 152–157. [CrossRef]
72. Driving Electric, M.K. CCS Combo Charging Standard Map: See Where CCS1 and CCS2 Are Used. Available online: https://insideevs.com/news/488143/ccs-combo-charging-standard-map-ccs1-ccs2/ (accessed on 11 April 2022).
73. Beedham, M. Your Guide to Electric Vehicle Charging. Available online: https://thenextweb.com/news/guide-to-electric-vehicle-charging-what-is-ccs-combined-charging-system-chademo (accessed on 11 April 2022).
74. Versinetic. EV Charging Connector Types Guide. Available online: https://versinetic.com/ev-charging-connector-types-guide/ (accessed on 11 April 2022).
75. Mankame, S. Different Electric Vehicle Charging Standards and How They Are Different. Available online: https://www.charzer.com/blog/2021/07/20/different-electric-vehicle-charging-standards-and-how-they-are-different/ (accessed on 10 May 2022).
76. What Is a Type 2 Charging Cable? Available online: https://www.ag-elec.com/what-is-a-type-2-charging-cable.html (accessed on 10 May 2022).
77. EVreporter. A Guide to EV Charging and EV Standards in India. Available online: https://evreporter.com/guide-to-ev-charging-and-standards-in-india/ (accessed on 12 April 2022).
78. Sharma, A.; Gupta, R. Bharat DC001 Charging standard Based EV Fast Charger. In Proceedings of the IECON 2020 the 46th Annual Conference of the IEEE Industrial Electronics Society, Singapore, 18–21 October 2020; pp. 3588–3593. [CrossRef]
79. Doss, S.; Nayyar, A.; Suseendran, G.; Tanwar, S.; Khanna, A.; Hoang Son, L.; Huy Thong, P. APD-JFAD: Accurate Prevention and Detection of Jelly Fish Attack in MANET. *IEEE Access* **2018**, *6*, 56954–56965. [CrossRef]
80. Kakkar, R.; Gupta, R.; Agrawal, S.; Tanwar, S.; Sharma, R. Blockchain-based secure and trusted data sharing scheme for autonomous vehicle underlying 5G. *J. Inf. Secur. Appl.* **2022**, *67*, 103179. [CrossRef]
81. Suh, N.; Cho, D. *The On-line Electric Vehicle: Wireless Electric ground Transportation Systems*; Springer: Cham, Switzerland, 2017; pp. 1–402. [CrossRef]
82. Onar, O.C.; Campbell, S.L.; Seiber, L.E.; White, C.P.; Chinthavali, M.S.; Tang, L.; Chambon, P.H.; Ozpineci, B.; Smith, D.E. *Oak Ridge National Laboratory Wireless Charging of Electric Vehicles-CRADA Report*; Technical Report; Oak Ridge National Lab. (ORNL): Oak Ridge, TN, USA, 2016.
83. Cirimele, V.; Freschi, F.; Mitolo, M. Inductive power transfer for automotive applications: State-of-the-art and future trends. In Proceedings of the 2016 IEEE Industry Applications Society Annual Meeting, Portland, OR, USA, 2–6 October 2016; pp. 1–8. [CrossRef]
84. Ramezani, A.; Farhangi, S.; Iman-Eini, H.; Farhangi, B.; Rahimi, R.; Moradi, G.R. Optimized *LCC*-Series Compensated Resonant Network for Stationary Wireless EV Chargers. *IEEE Trans. Ind. Electron.* **2019**, *66*, 2756–2765. [CrossRef]
85. Zhang, B.; Carlson, R.B.; Galigekere, V.P.; Onar, O.C.; Pries, J.L. Electromagnetic Shielding Design for 200 kW Stationary Wireless Charging of Light-Duty EV. In Proceedings of the 2020 IEEE Energy Conversion Congress and Exposition (ECCE), Detroit, MI, USA, 11–15 October 2020; pp. 5185–5192. [CrossRef]
86. Yenil, V.; Cetin, S. High efficiency implementation of constant voltage control of LC/S compensated wireless charging system for stationary electrical vehicles. *Electr. Eng.* **2022**, *104*, 3197–3206. [CrossRef]
87. Zhang, S.; Yu, J.J.Q. Electric Vehicle Dynamic Wireless Charging System: Optimal Placement and Vehicle-to-Grid Scheduling. *IEEE Internet Things J.* **2022**, *9*, 6047–6057. [CrossRef]
88. Song, B.; Shin, J.; Lee, S.; Shin, S.; Kim, Y.; Jeon, S.; Jung, G. Design of a high power transfer pickup for on-line electric vehicle (OLEV). In Proceedings of the 2012 IEEE International Electric Vehicle Conference, Greenville, SC, USA, 4–8 March 2012; pp. 1–4. [CrossRef]
89. Miller, J.M.; Onar, O.C.; Chinthavali, M. Primary-Side Power Flow Control of Wireless Power Transfer for Electric Vehicle Charging. *IEEE J. Emerg. Sel. Top. Power Electron.* **2015**, *3*, 147–162. [CrossRef]
90. ElGhanam, E.A.; Hassan, M.S.; Osman, A.H. Deployment Optimization of Dynamic Wireless Electric Vehicle Charging Systems: A Review. In Proceedings of the 2020 IEEE International IOT, Electronics and Mechatronics Conference (IEMTRONICS), Vancouver, BC, Canada, 9–12 September 2020; pp. 1–7. [CrossRef]
91. Li, C.; Dong, X.; Cipcigan, L.M.; Haddad, A.; Sun, M.; Liang, J.; Ming, W. Economic viability of dynamic wireless charging technology for private EVs. *IEEE Trans. Transp. Electrif.* **2022**, 1. [CrossRef]
92. Wang, Y.; Luan, H.T.; Su, Z.; Zhang, N.; Benslimane, A. A Secure and Efficient Wireless Charging Scheme for Electric Vehicles in Vehicular Energy Networks. *IEEE Trans. Veh. Technol.* **2022**, *71*, 1491–1508. [CrossRef]
93. Tavakoli, R.; Dede, E.M.; Chou, C.; Pantic, Z. Cost-Efficiency Optimization of Ground Assemblies for Dynamic Wireless Charging of Electric Vehicles. *IEEE Trans. Transp. Electrif.* **2022**, *8*, 734–751. [CrossRef]
94. Foote, A.; Onar, O.C. A review of high-power wireless power transfer. In Proceedings of the 2017 IEEE Transportation Electrification Conference and Expo (ITEC), Chicago, IL, USA, 22–24 June 2017; pp. 234–240.
95. Mohamed, A.A.S.; Lashway, C.R.; Mohammed, O. Modeling and Feasibility Analysis of Quasi-Dynamic WPT System for EV Applications. *IEEE Trans. Transp. Electrif.* **2017**, *3*, 343–353. [CrossRef]
96. Carmeli, M.S.; Castclli-Dezza, F.; Mauri, M.; Rossi, M.; Dolata, A.; Pedretti, M.; Simonini, I. Analysis of a quasi-dynamic Wireless Power Transfer System for EV batteries charging. In Proceedings of the 2018 International Symposium on Power Electronics, Electrical Drives, Automation and Motion (SPEEDAM), Amalfi, Italy, 20–22 June 2018; pp. 383–388. [CrossRef]

97. Zhang, B.; Carlson, R.B.; Galigekere, V.P.; Onar, O.C.; Mohammad, M.; Dickerson, C.C.; Walker, L.K. Quasi-Dynamic Electromagnetic Field Safety Analysis and Mitigation for High-Power Dynamic Wireless Charging of Electric Vehicles. In Proceedings of the 2021 IEEE Transportation Electrification Conference Expo (ITEC), Chicago, IL, USA, 21–25 June 2021; pp. 1–7. [CrossRef]
98. Lu, X.; Wang, P.; Niyato, D.; Kim, D.I.; Han, Z. Wireless Charging Technologies: Fundamentals, Standards, and Network Applications. *IEEE Commun. Surv. Tutorials* **2016**, *18*, 1413–1452. [CrossRef]
99. Habib, S.; Khan, M.M.; Abbas, F.; Sang, L.; Shahid, M.U.; Tang, H. A Comprehensive Study of Implemented International Standards, Technical Challenges, Impacts and Prospects for Electric Vehicles. *IEEE Access* **2018**, *6*, 13866–13890. [CrossRef]
100. Jakubowski, K.; Paś, J.; Rosiński, A. The Issue of Operating Security Systems in Terms of the Impact of Electromagnetic Interference Generated Unintentionally. *Energies* **2021**, *14*, 8591. [CrossRef]
101. Gupta, R.; Tanwar, S.; Kumar, N.; Tyagi, S. Blockchain-based security attack resilience schemes for autonomous vehicles in industry 4.0: A systematic review. *Comput. Electr. Eng.* **2020**, *86*, 106717. [CrossRef]
102. Patel, D.; Jadav, D.; Gupta, R.; Jadav, N.K.; Tanwar, S.; Ouni, B.; Guizani, M. Deep Learning and Blockchain-based Framework to Detect Malware in Autonomous Vehicles. In Proceedings of the 2022 International Wireless Communications and Mobile Computing (IWCMC), Dubrovnik, Croatia, 30 May–3 June 2022; pp. 278–283. [CrossRef]
103. Jadav, D.; Obaidiat, M.S.; Tanwar, S.; Gupta, R.; Hsiao, K.F. Amalgamation of Blockchain and AI to Classify Malicious Behavior of Autonomous Vehicles. In Proceedings of the 2021 International Conference on Computer, Information and Telecommunication Systems (CITS), Istanbul, Turkey, 11–13 November 2021; pp. 1–5. [CrossRef]
104. Hu, J.; Zhao, J.; Cui, C. A Wide Charging Range Wireless Power Transfer Control System with Harmonic Current to Estimate the Coupling Coefficient. *IEEE Trans. Power Electron.* **2021**, *36*, 5082–5094. [CrossRef]
105. de Sousa, A.D.; Vieira, L.F.M.; Vieira, M.A.M. Optimal Transmission Range and Charging Time for Qi-Compliant Systems. *IEEE Trans. Power Electron.* **2020**, *35*, 12765–12772. [CrossRef]
106. Wu, Y.; Li, Z.; Nostrand, N.V.; Liu, J. Time to Rethink the Design of Qi Standard? Security and Privacy Vulnerability Analysis of Qi Wireless Charging. In Proceedings of the Annual Computer Security Applications Conference, Virtual Event, 6–10 December 2021; pp. 916–929. [CrossRef]
107. Trung, N.K.; Diep, N.T. A Maximum Transfer Efficiency Tracking Method for Dynamic Wireless Charging Systems of Electric Vehicles. *J. Electr. Comput. Eng.* **2021**, *2021*, 5562125. [CrossRef]
108. INSIDEEVs. SAE International Releases J2954 Wireless Charging Standard. Available online: https://insideevs.com/news/450548/sae-j2954-wireless-charging-standard/ (accessed on 20 April 2022).
109. Huang, A.; Kim, D.; He, Q.; Zhang, H.; Zhu, Y.; Kim, H.; Fan, J. Optimal Matching Reactance Design and Validation in Wireless Power Transfer System for Electric Vehicle Based on SAE J2954-RP. In Proceedings of the 2020 IEEE Wireless Power Transfer Conference (WPTC), Seoul, Republic of Korea, 15–19 November 2020; pp. 174–177. [CrossRef]
110. Rahman, M.; Rahman, F.; Rasheduzzaman, A.; Shahriyar, M.F.; Tanseer Ali, M. Magnetic Resonance Coupled Wireless Power Transfer Analysis For Electric Vehicle. In Proceedings of the 2021 3rd Global Power, Energy and Communication Conference (GPECOM), Antalya, Turkey, 5–8 October 2021; pp. 28–33. [CrossRef]
111. ElectronicsNotes. A4WP Wireless Charging—Details and Specifics about the A4WP Wireless Charging System Developed and Promoted by the Alliance for Wireless Power. Available online: https://www.electronics-notes.com/articles/equipment-items-gadgets/wireless-battery-charging/A4WP-wireless-charging.php (accessed on 20 April 2022).
112. Singh, D.V. Inductive Wireless Charging Is Now a Thermal Design Problem. Available online: https://www.electronics-cooling.com/2017/01/inductive-wireless-charging-now-thermal-design-problem/ (accessed on 20 April 2022).
113. Jang, B.; Hejazi, A.; Rad, R.E.; Qaragoez, Y.M.; Ali, I.; Pu, Y.; Hwang, K.C.; Yang, Y.; Lee, K.Y. A 15-W Triple-Mode Wireless Power Transmitting Unit with High System Efficiency Using Integrated Power Amplifier and DC–DC Converter. *IEEE Trans. Ind. Electron.* **2021**, *68*, 9574–9585. [CrossRef]
114. Niu, S.; Yu, H.; Jian, L. Thermal Behavior Analysis of Wireless Electric Vehicle Charging System under Various Misalignment Conditions. In Proceedings of the 2020 IEEE 4th Conference on Energy Internet and Energy System Integration (EI2), Wuhan, China, 30 October–1 November 2020; pp. 607–612. [CrossRef]
115. Niu, S.; Yu, H.; Niu, S.; Jian, L. Power loss analysis and thermal assessment on wireless electric vehicle charging technology: The over-temperature risk of ground assembly needs attention. *Appl. Energy* **2020**, *275*, 115344. [CrossRef]
116. Simonazzi, M.; Sandrolini, L. Conducted Emission Analysis of a Near-Field Wireless Power Transfer System. In Proceedings of the 2021 IEEE 15th International Conference on Compatibility, Power Electronics and Power Engineering (CPE-POWERENG), lorence, Italy, 14–16 July 2021; pp. 1–6. [CrossRef]
117. Patil, D.; McDonough, M.K.; Miller, J.M.; Fahimi, B.; Balsara, P.T. Wireless Power Transfer for Vehicular Applications: Overview and Challenges. *IEEE Trans. Transp. Electrif.* **2018**, *4*, 3–37. [CrossRef]
118. Marinescu, A. Current Standards and Regulations for Wireless Battery Charging Systems. In Proceedings of the 2021 7th International Symposium on Electrical and Electronics Engineering (ISEEE), Galati, Romania, 28–30 October 2021; pp. 1–6. [CrossRef]
119. Wang, W.V.; Thrimawithana, D.J.; Neuburger, M. An Si MOSFET-Based High-Power Wireless EV Charger With a Wide ZVS Operating Range. *IEEE Trans. Power Electron.* **2021**, *36*, 11163–11173. [CrossRef]
120. Gear, S. How Does Wireless EV Charging Work? Available online: https://www.slashgear.com/791589/how-does-wireless-ev-charging-work/ (accessed on 10 May 2022).

121. Jeschke, S.; Maarleveld, M.; Baerenfaenger, J.; Schmuelling, B.; Burkert, A. Challenges in EMC Testing of EV and EVSE Equipment for Inductive Charging. In Proceedings of the 2018 International Symposium on Electromagnetic Compatibility (EMC EUROPE), Amsterdam, The Netherlands, 27–30 August 2018; pp. 967–971. [CrossRef]
122. Böttigheimer, M.; Maier, D.; Parspour, N.; Noeren, J.; Walter, R. Validation of the Design of an 11 kW Inductive Charging Prototype on a New Test Bench for WPT-Systems. In Proceedings of the 2018 IEEE Wireless Power Transfer Conference (WPTC), Montreal, QC, Canada, 3–7 June 2018; pp. 1–4. [CrossRef]
123. Boettigheimer, M.; Parspour, N.; Zimmer, M.; Lusiewicz, A. Design of a Contactless Energy Transfer System for an Electric Vehicle. In Proceedings of the PCIM Europe 2016, International Exhibition and Conference for Power Electronics, Intelligent Motion, Renewable Energy and Energy Management, Nuremberg, Germany, 10–12 May 2016; pp. 1–7.
124. Jafari, H.; Moghaddami, M.; Olowu, T.O.; Sarwat, A.I.; Mahmoudi, M. Virtual Inertia-Based Multipower Level Controller for Inductive Electric Vehicle Charging Systems. *IEEE J. Emerg. Sel. Top. Power Electron.* **2021**, *9*, 7369–7382. [CrossRef]
125. Musavi, F.; Eberle, W. Overview of wireless power transfer technologies for electric vehicle battery charging. *IET Power Electron.* **2014**, *7*, 60–66. [CrossRef]
126. by Kiranmai Momidi, C.D. Wireless Electric Vehicle Charging System (WEVCS). Available online: https://circuitdigest.com/article/wireless-electric-vehicle-charging-systems (accessed on 10 May 2022).
127. Nimje, A.A.; Panwar, A.B.; Gupta, A.; Tanwar, S. *Capacity Estimation of Electric Vehicle Aggregator for Ancillary Services to the Grid*; Springer: Singapore, 2019; Volume 206, pp. 235–257.
128. Lecluyse, C.; Minnaert, B.; Kleemann, M. A Review of the Current State of Technology of Capacitive Wireless Power Transfer. *Energies* **2021**, *14*, 5862. [CrossRef]
129. Kline, M.; Izyumin, I.; Boser, B.; Sanders, S. Capacitive power transfer for contactless charging. In Proceedings of the 2011 Twenty-Sixth Annual IEEE Applied Power Electronics Conference and Exposition (APEC), Fort Worth, TX, USA, 6–11 March 2011; pp. 1398–1404. [CrossRef]
130. Kodeeswaran, S.; Nandhini Gayathri, M.; Kannabhiran, A.; Sanjeevikumar, P. Design and Performance Analysis of Four Plates Capacitive Coupler for Electric Vehicle On-Road Wireless Charging. In Proceedings of the 2021 24th International Symposium on Wireless Personal Multimedia Communications (WPMC), Okayama, Japan, 14–16 December 2021; pp. 1–6. [CrossRef]
131. Kodeeswaran, S.; Nandhini Gayathri, M. Performance Investigation of Capacitive Wireless Charging Topologies for Electric Vehicles. In Proceedings of the 2021 International Conference on Innovative Trends in Information Technology (ICITIIT), Kottayam, India, 11–12 February 2021; pp. 1–6. [CrossRef]
132. The state-of-the-arts of wireless electric vehicle charging via magnetic resonance: Principles, standards and core technologies. *Renew. Sustain. Energy Rev.* **2019**, *114*, 109302. [CrossRef]
133. Samal, S.K.; Kar, D.P.; Sahoo, P.K.; Bhuyan, S.; Das, S.N. Analysis of the effect of design parameters on the power transfer efficiency of resonant inductive coupling based wireless EV charging system. In Proceedings of the 2017 Innovations in Power and Advanced Computing Technologies (i-PACT), Vellore, India, 21–22 April 2017; pp. 1–4. [CrossRef]
134. Menchaca, A.; Duke, C.; Gelfer, D.; Vang, P.; Xiong, V.; Arbabi, A.; Badall, I.; Ortiz, J.; Badawy, M. Novel Load Independent Control Structures for a Resonant LCC EV Wireless Charging Converter. In Proceedings of the 2020 IEEE Energy Conversion Congress and Exposition (ECCE), Detroit, MI, USA, 11–15 October 2020; pp. 1534–1539. [CrossRef]
135. Regensburger, B.; Sinha, S.; Kumar, A.; Maji, S.; Afridi, K.K. High-Performance Multi-MHz Capacitive Wireless Power Transfer System for EV Charging Utilizing Interleaved-Foil Coupled Inductors. *IEEE J. Emerg. Sel. Top. Power Electron.* **2022**, *10*, 35–51. [CrossRef]
136. Vinod, M.; Kishan, D.; Harishchandrappa, N.; Reddy, B.D. Comparative Analysis of Symmetrical and Asymmetrical Phase Shift Control Strategy for Resonant Wireless Inductive Charging System. In Proceedings of the 2021 IEEE International Power and Renewable Energy Conference (IPRECON), Kollam, India, 24–26 September 2021; pp. 1–6. [CrossRef]
137. Trivedi, M.; Kakkar, R.; Gupta, R.; Agrawal, S.; Tanwar, S.; Niculescu, V.C.; Raboaca, M.S.; Alqahtani, F.; Saad, A.; Tolba, A. Blockchain and Deep Learning-Based Fault Detection Framework for Electric Vehicles. *Mathematics* **2022**, *10*, 3626. [CrossRef]
138. Huang, P.; Verma, A.; Robles, D.J.; Wang, Q.; Mukherjee, P.; Sun, J. Probing the cooling effectiveness of phase change materials on lithium-ion battery thermal response under overcharge condition. *Appl. Therm. Eng.* **2018**, *132*, 521–530. [CrossRef]