energies

Review

Electric Vehicle Charging Modes, Technologies and Applications of Smart Charging

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Abstract: The rise of the intelligent, local charging facilitation and environmentally friendly aspects of electric vehicles (EVs) has grabbed the attention of many end-users. However, there are still numerous challenges faced by researchers trying to put EVs into competition with internal combustion engine vehicles (ICEVs). The major challenge in EVs is quick recharging and the selection of an optimal charging station. In this paper, we present the most recent research on EV charging management systems and their role in smart cities. EV charging can be done either in parking mode or on-the-move mode. This review work is novel due to many factors, such as that it focuses on discussing centralized and distributed charging management techniques supported by a communication framework for the selection of an appropriate charging station (CS). Similarly, the selection of CS is evaluated on the basis of battery charging as well as battery swapping services. This review also covered plug-in charging technologies including residential, public and ultra-fast charging technologies and also discusses the major components and architecture of EVs involved in charging. In a comprehensive and detailed manner, the applications and challenges in different charging modes, CS selection, and future work have been discussed. This is the first attempt of its kind, we did not find a survey on the charging hierarchy of EVs, their architecture, or their applications in smart cities.

Keywords: charging techniques; modes of charging; charging technologies; scheduling; key technologies

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Citation: Ahmad, A.; Khalid, M.; Ullah, Z.; Ahmad, N.; Aljaidi, M.; Malik, F.A.; Manzoor, U. Electric Vehicle Charging Modes, Technologies and Applications of Smart Charging. *Energies* **2022**, *15*, 9471. https://doi.org/10.3390/en15249471

Academic Editor: Balakumar Balasingam

Received: 3 November 2022
Accepted: 28 November 2022
Published: 14 December 2022

1. Introduction

Transportation resources play an essential role in managing environmental pollution. The air pollution caused by CO_2 emission in internal combustion engine vehicles (ICEV) has been drastically increased. Keeping in view the catastrophic effects of climate change, the development of an environmentally friendly transportation system has become a goal of researchers and the automobile industry. Therefore, the idea of developing and commercializing electric vehicles (EV) has gained the interest of the people. Due to these reasons, the majority are switching from ICEV to EV to reduce CO_2 and particulate emissions which are driving the EV transportation industry [1,2]. According to the recent studies from the Centre for "Solar Energy and Hydrogen Research", the demand for EV accounted for a global market is more than 740,000 EV in early 2015. In the coming 50 years, the number of EVs is expected to increase to 2.5 billion [3–5]. The fast-increasing ratio of EVs invites both challenges and opportunities [6,7]. On one hand, the high load because of the integration of EV into the smart grid raises concern about the possible impact to the voltage stability, operation cost and frequency excursion at the transmission and generation side. On other hand, EVs will be used as a new energy storage system that can serve many purposes. Sufficient energy storage in batteries of EVs suggested static versus mobility charging infrastructure and the most extensive application with microgrids is bidirectional charging and discharging [8,9]. However, in bidirectional charging during off-peak hours, EVs can charge the battery and store the electricity from the microgrids. Where in peak hours, EV can transfer the stored energy back to microgrids to complete the demand of the other EVs user [10–12].

As a major component, EV includes a battery that takes a long time to charge. Therefore, with the increase in EVs, proper charging infrastructure along with scheduling technique, placement of CS, providing charging management to static and mobile EV [13], is needed. In static charging management, EV is charged at home or in parking a lot, where mobile EV charging needs smart processes (where and when to recharge, how to communicate with CS, how to schedule EV charging). A few EV and EV charging related terms are described below [14].

Centralize vs. Distributed Charging: In centralized charging management, EV is charged with the help of a third party global controller (GC), wherein distributed charging each EV individually selects a CS with the help of local information, On board Unit (OBU) and installed map [15]. Further details are provided in Section 3.

Online and Offline Charging Scheduling of EV: Online charging scheduling refers to the real-time scheduling of EV. In the element of online charging, scheduling includes event-driven, system time, causal information, random data, knowledge of future data and objectives. Where in offline charging scheduling is the day ahead management of EV charging requests [16,17].

Charging scheduling of statics vs. Mobile EV: Mobile EV charging scheduling needs mobility parameters, including the current location of the EV, status of charge of EV, destination and route of the EV. In static charging, scheduling EV is considered as the stationary body [18,19].

Some different techniques of charging scheduling have been proposed such as heuristic algorithm [20,21], greedy algorithm [22], ant colony optimization [23], random selection, first come first server and so forth. These algorithms understand and create a charging pattern based on user behaviour.

1.1. Motivation

Technological advancements in the automobile industry are compelling more people to adopt the usability of EVs. This daily increase in number will eventually result in petrol/diesel supply and demand competition in the future. Moreover, ICEV is considered a key player in environmental pollution due to the emission of CO_2, and other emissions [24]. Environmental and energy considerations forced researchers and engineers to an alternatives such as conventional vehicles with green energy sources [25]. EVs were invented in 1834 with Britain, Americans and French starting the production of EVs at the end of the 19th century [26]. Limited travelling range and battery limitations vanished the EV from the market in the period of 1930–1970. In 1976, the USA launched Hybrid Electric Vehicle (HEV) and made commercial availability of EV in 1998 with the feature of no component failure [27].

However, following commercial availability, several problems hindered the competition of EV with Conventional Vehicles (ICEV) such as infrastructure availability for large scale charging stations, more recharging time and sophisticated energy resources for recharging [28–30]. Moreover, charging management, uncoordinated and insecure interaction between EV and CS and load balancing on CS and some others [31–33]. Research on EVs is surveyed to find optimal smart charging management techniques for electric vehicle recharging and with control of EV charging distributed energy resources.

1.2. Electric Vehicle

EV is advanced automobile vehicle, the same as other types of vehicles. The key difference is that the EV is based on advanced electric propulsion (power converter, electric motor and energy source) which is aimed not only to reduce noise and air pollution but also to reduce the dependencies on the fuel of transportation system [34,35]. From an energy perspective, the development of EVs can offer a secure, comprehensive and balanced energy option that is efficient and environmentally friendless and offer various kind of renewable energies. Therefore, EVs will have the potential to have a great impact on energy, the environment and transportation as well as hi-tech promotion, new industry creation, and economic development. According to this broad definition, EV may include Hybrid Electric Vehicle (HEV), Battery Electric Vehicles (BEV) and Fuel Cell Electric Vehicles (FCEV) which is summarized in Table 1, and detailed discussion is available in [36–40].

Table 1. Summary of BEV, HEV and FCEV.

Types of EV	**Battery EV**	**Hybrid EV**	**Fuel Cell EV**
Actuation	Electric motor drive	Electric motor and internal combustion Engine	Electric motor drive
Power System	(1) Battery (2) Ultracapacitor	(1) Battery (2) Ultracapacitor (3) ICE generating unit	Fuel Cell
Source of energy and	Charging Station	(1) Gas Station (2) charging station	Hydrogen, Gasoline and Ethanol
Feature	(1) No emission (2) Now satisfied driving range (3) Under development phase (4) Costly (5) Environment friendly	(1) less emission (2) Driving range is long (3) Complex architecture	(1) No emission (2) Satisfied driving range (3) Not commercially available (4) Too much expensive

1.3. Previous Survey Papers on Electric Vehicle Smart Charging Management

Some previous survey papers regarding EV smart charging management is given below.

- Yadlapalli and Aljaidi et al. [41,42], describe in detail efficient energy management mechanisms and optimization technique for charging station placement for the reliability of EV.
- ElGhanam et al. [43], have focused on Vehicular communication, communication requirement and technologies for the purpose of efficient charging management.
- Nimalsiri et al. [44], have discussed in detail the coordination of EV in centralizing manner for charging and discharging of EV batteries to efficiently manage the supply of power voltage.
- Jawale et al. [45], have focused on EV charging systems, different charging technologies and mechanisms of controlling CS for reliable recharging of EV.
- Rahman et al. [46], present opportunities of gird regarding issues via distributed environment in detail.

In the above mentioned surveys lack some major things regarding smart charging management of EV, which is present in this survey.

1.4. Why Chose Smart Charging of EV

EV grasp the attention of the people (user), research scholars and industry. Therefore, it is essential to make a review on smart charging of EV for the sake of understanding the core concept. Hence, the survey describes the communication concept in two ways including vehicle-to-grid and grid to vehicle operations. In addition, not only focuses on monitoring aspect and reliable communication but illustrate the desirable impact of a centralised and distributed charging mechanism, real time communication aspect and load balancing among CS in smart charging. The aim is to refer EV to optimal CS. However, key issue in recharging of EV is long duration of time. Therefore, the charging scheduling per unit price adjustment and demanded time of charging (peak hours and off-peak hours) scheduling should also be employed for considering both mobile and static EV to improve performance and quality of generating power and energy.

1.5. Contribution of This Survey

In this survey, the basic ideas of smart charging management of EV are focused on with an overview of some EV advanced charging technologies. Following are the major contributions of this survey.

- Firstly, present a comprehensive overview of updated articles regarding charging mode and management techniques of EV.
- A thorough discussion on communication framework, communication model and communication network infrastructure for EV charging management system is presented.
- A complete overview of charging technologies, system architecture and communication architecture of EV is highlighted.
- Furthermore, comprehensive knowledge about major parts of EV is discussed in detail.
- Finally, applications of EV, open research challenges in advanced development of EV and its charging management are highlighted in detail.

1.6. Paper Organization

The remaining paper is structured as followed: Section 2 presents a comprehensive overview of updated studies regarding smart charging management of EV. Section 3 discussed in detail "parking mode and on-the-move mode" with charging management technique (Centralized vs. Distributed charging) and clarifies which one is better. Then, we present the P/S communication framework, push and pull mode for the purpose of communication in EV charging management. Furthermore, a discussion is made about the existing studies related to EV fleet management and the advanced essential part of EV development that aims to understand the difference between purpose build EV and converted EVs. Charging scheduling of EV is discussed in detail under global and distribute control manner considering both static and mobile EV. At the end of Section 3 we present a major application of EV smart charging management. In Section 4 we described open research challenges for the future direction followed by the conclusion in Section 5. The big picture of this survey for understanding and clarity is given in the organization chart as shown in Figure 1.

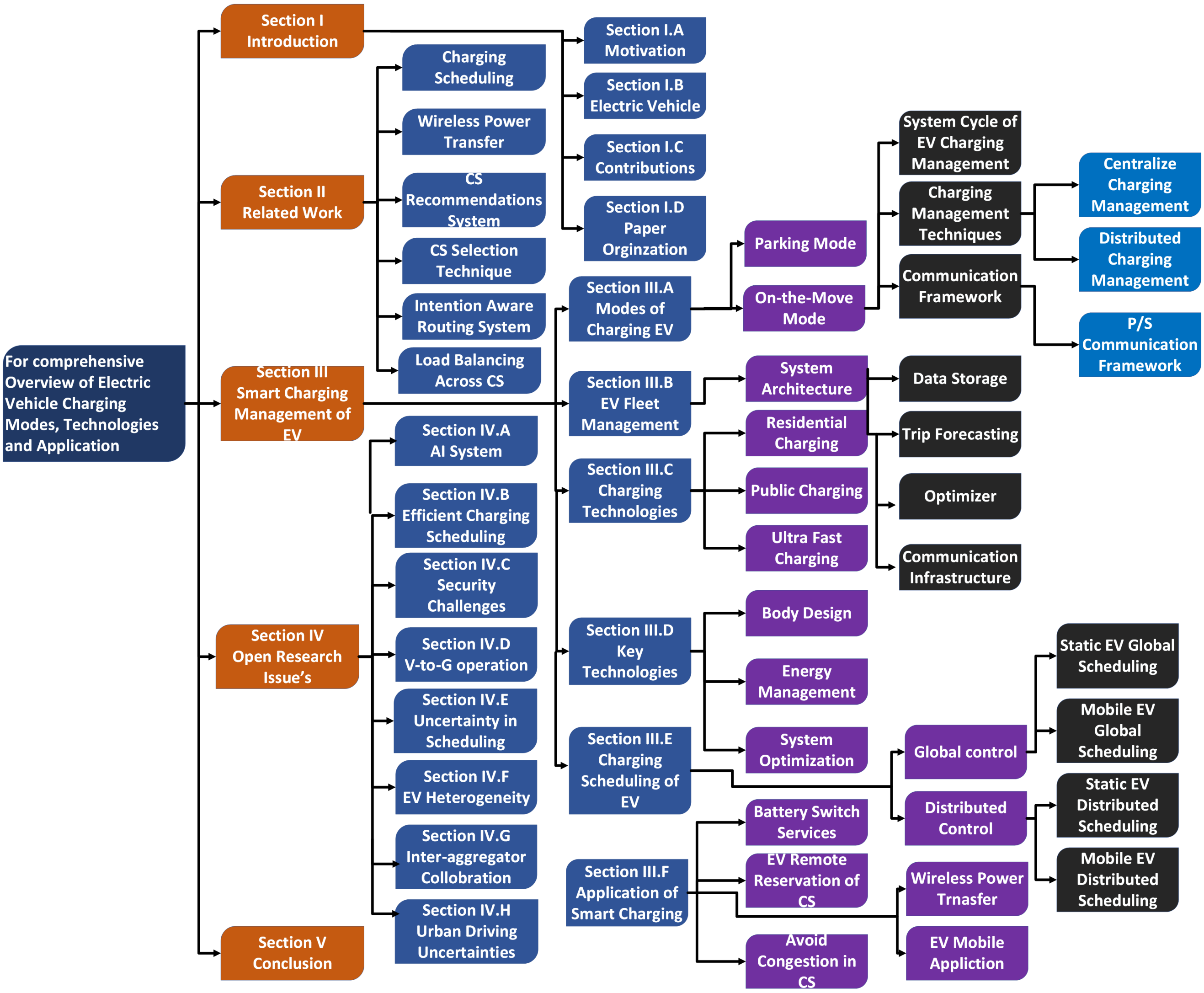

Figure 1. Organization of the Survey Paper.

2. Related Work

According to our literature study the work done on EV smart charging are focused upon essential parameters including charging schedules [47], wireless power transfer [48], charging station recommendation system [49], CS selection techniques [50], and charging methodologies of EVs [51].

However, in existing work regarding smart charging management of EV few major works is illustrated below in detail. The aim to deliver for sake the understanding the extensive evaluation of smart charging under different charging mechanisms.

From the last two decades, the CS selection problem in on-the-move mode has gained the interest of researchers from the commercial perspective. Rehman et al. in [52], proposed an advanced smart management system (SMS) for managing EV battery recharging, distributed energy source and the EV. Moreover, balance the impact of EVs on the grid/CS, and increase the satisfaction of EV users in recharging services (reduce waiting time). In [53], the author proposed the "real-time smart load management system" to control several types of EV traffic while charging. However, considering fast CS in the proposed work to encapsulate as a record the demand of each fast CS. In addition, proposed an efficient model for the entire network to analyze the power flow of the generator and each fast CS. In results of these two models minimized the total, generation cost of energy and reduce energy loss. The number of EV is rapidly increase day-by-day. Therefore, it is essential to make advanced efficient charging mechanism. Hence, Aljaidi et al. [54], proposed a charging scheme namely "Reinforcement Learning-based Assignment "and an efficient algorithm based on Q-learning. The aim is to assign EV to optimal CS when it needs to recharge the battery, reduce charging and travelling cost and overloading on the smart grid. At the end, the author shows that the proposed work efficiently minimizes the total cost by comparing with greedy algorithm and some more. D. Aggeler et al. [55], focused on power electronic (PE) infrastructure and enable fast charging process depending upon battery and vehicle type. However, EV technologies are continuously updated by the automobile industry engineers such as, the battery technology now take fuel equal time on recharging. Thus, proposed scheme is able to recharge the battery in 10 min and claimed that it will be sufficient for 100km approximately. In addition, study the influence on grid by placing fast CS in Sweden.

Furthermore, Shun-Neng Yang et al. [56], focus on the problem of optimal CS selection for battery recharging. Therefore, two types of basic algorithm are proposed based on local and global information to select a CS for EV users. The EV user shares basic information regarding charging parameters via mobile communication network. This information leads to a selection of the selected CS with minimum distance and waiting time. In [57], the author proposed intention aware routing system for EV. The proposed system enables a vehicle to compute a routing policy and select a CS or route which have the shortest distance and minimum waiting time. Computing routing policy computation results in the best charging options for EV. Jarvis et al. [58], consider the enhancement of EV in future and predict that when the EV development is increasing the load on CS among networks is also going to increase. Moreover, illustrate that the impact on low voltage charging of randomly arriving vehicles on CS, on smart grid, measure the influence of entire network voltage and congestion in the distributed network are investigated. Efficient and optimal charging station placement position are difficult to diagnose for EV recharging to recharge its battery at a reasonable cost and in driving range. He, Jia et al. [59] proposed a programming model considering two levels. In the first level is to optimize the place for CS and maximize the use of that path of CS while in second level select the route for vehicle which have less congestion and vehicle reaches to CS in reasonable and sufficient energy to minimize risk and waiting time. In result shows that the driving range of EV has a significant impact on CS placement position in this problem. Zhiyong Tian et al. [60], proposed the "real-time charging station recommendation system" for EV on the basis of analysis of taxi driver recharging behaviour and CS condition information. The proposed system is doing work via GPS data mining, to reduce the extra time of the EV user in the CS while recharging the battery. Yue Cao et al. [61], proposed a communication framework for the purpose of disseminating CS information to EV. The proposed communication framework is based on vehicle-to-vehicle (V2V) communication when the EVs are in an on-the-move mode to easily select a CS for recharging the battery.

Furthermore, Emmanouil S. Rigas et al. [62], work on the problem of urban EV overcrowding in the CS while recharging the battery. The author proposed a system to ensure that load in the treated CS is according to the desired limit and minimize the disturbances of the EV user. Furthermore, they proposed a novel solution that EV and CS are self-interested nodes that aims to minimize the impact on their regular schedule and increase their regular profit. Junming et al. [63], proposed Intention Aware Routing System (IARS) which is embedded in the EV navigation system. However, that aim to predict congestion (waiting time) in the CS and compute the efficient route for the EV user while recharging the battery. The summary of related work is shown in Table 2.

Table 2. Summarize Table of Related Work.

Papers	Authors Reference Number	[47]	[48]	[49]	[50]	[51]	[52]	[53]	[54]	[55]	[56]	[57]	[58]	[59]	[60]	[61]	[62]	[63]
Checking parameters	Charging Scheduling Techniques	Yes	No	No	No	No	Yes	No	No	No	Yes	No	No	No	Yes	No	No	No
	Wireless Power Transfer	No	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No	No	No	No
	CS Selection Technique	No	No	Yes	No	No	No	No	Yes	No	No	Yes	No	No	No	No	No	No
	Smart Charging Management System	No	No	No	No	Yes	Yes	Yes	Yes	No	Yes	Yes	No	No	No	No	No	No
	Load Balancing	No	Yes	No	No	No	No	Yes	No	No	No	No	Yes	Yes	No	No	No	No
	Charging and Discharging	No	No	No	No	No	No	No	Yes	No	No	No	No	No	No	No	No	No
	Fast Charging	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	CS Selection using local and Global Information	No	No	Yes	No	No	No	No	Yes	No	Yes	No	No	No	No	No	No	No
	Intention Aware Routing System	No	No	No	Yes	No	No	Yes	Yes	No	No	Yes	No	No	No	No	No	No
	Impact of Charging Power on Grid	Yes	No	No	No	No	Yes	No	No	No	Yes	No	Yes	No	No	No	No	No
	Forecasting Load Profile	No	No	No	Yes	Yes	No	No	No	No	No	Yes	No	Yes	No	No	No	No
	CS Recommendation System	No	No	No	Yes	Yes	No	No	No	Yes	Yes	No	No	Yes	No	No	No	No
	Communication Framework	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Smart Grid Congestion Management	No	No	No	No	Yes	No	No	No	Yes	No	Yes	Yes	No	No	No	No	No

3. Smart Charging Management of EV

Smart charging management of EV generally consists of EV, CS, Global Controller (GC) and Road Side Units (RSUs) as nodes, communicating with each other during charging management of EVs. A SCMEV has some basic applications in smart charging management such as load balancing [64], identifying route [65], and identifying generating power/energy [66]. The combination of these nodes with applications in one network concludes a multi-functional network [67]. Limitations of structure nodes of SCMEV, like where to deploy CS [68], range between RSUs [69], communication range between nodes and so forth, hinder its management. Load balancing across CS is challenging for SCMEV for the reason of a large number of vehicles with a limited number of CSs.

According to [70], there are approximately 16.5 million EV is manufactured and delivered to different countries worldwide according to the analysis of the International Energy Agency (IEA). While the number of CS across the world is estimated 1.8 million. The number of CS in Mumbai and Delhi in India is 107 and 229 respectively, Sydney in Australia has 65 CS, Japan has 924 and Bangkok has 398 CS. While in Houston and New York in US has 578 and 2418 CS respectively, Paris has 2047, Berlin has 1161, Ruhr has 2080 and London has 8959 CS is calculated. However, according to the above data about CS and outlets, CS is very less as according to vehicle. Thus, because of less number of CSs and the problem of uncoordinated recharging of EVs in peak demand hours EV is loaded on CSs. Thus, because of less number of CS and jointly considering the problem of without pre-planning and un-coordinated charging of EVs have arisen some major problems such as unacceptable voltage fluctuation, problems of mismanagement and unbalancing load across CS. To handle this problem one solution is to increase power generation, but for avoiding power fluctuation this is a cost-effective solution. An alternative solution is to coordinate charging plans continuously with CSs to use power efficiently [71].

Typically, vehicles and CS coordinate through Vehicle to Grid (V2G) and Grid to Vehicle(G2V) Interactions, of which G2V is unidirectional (power flow only from the grid to vehicle) [72–77] and V2G is bidirectional (power flow from both side,but not simultaneously) in nature [78–82]. Typically all nodes of smart charging management architecture are grouped into a network, of which each node gathers and deliver their information to the GC via wireless communication links using "ETSI TS 101 556-1 and ETSI TS 101 556-3" communication standards [83,84]. The transaction cycle along with communication standards is illustrated in Figure 2.

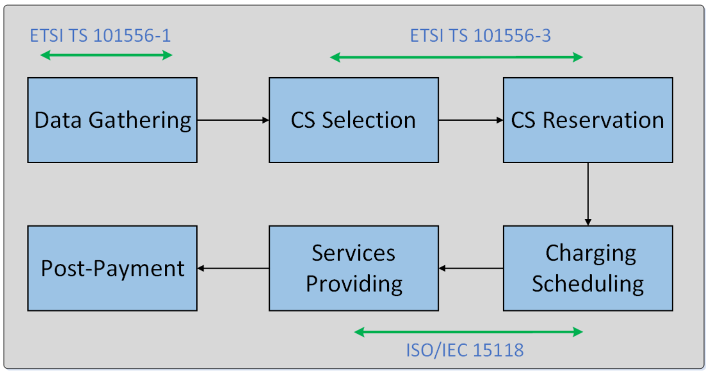

Figure 2. Transaction Cycle of Energy Management.

GC is responsible for gathering information from other nodes of the network through either single-hop or multi-hop communication nodes. The GC sends the collected information to interested nodes of the network such as EV, CS and RSU.

Indoor and outdoor are two types of scenarios in EV charging management. In the indoor scenario, EV is in parking mode, where there is only one charging outlet and one EV. Furthermore, in an outdoor scenario EV is in on-the-move mode, where multiple nodes are involved in charging management. These two scenarios are discussed below.

3.1. Modes of Charging EV

In this subsection, a succinct overview of the most popular modes of charging EV is provided. Over the last decade, most of the research contributions have addressed various aspects of charging EV typically, including scheduling for charging and discharging of EV [85], wireless power transfer (WPT) for EV [86], appropriate route selection [87], uni-directional and bi-directional charging strategies for re-charging EV [88], and so on. However, some of the most commonly used modes of charging (parking and on-the-move modes) EV are discussed below.

The basic communication service and architecture model of SCMEV are illustrated in Figure 3.

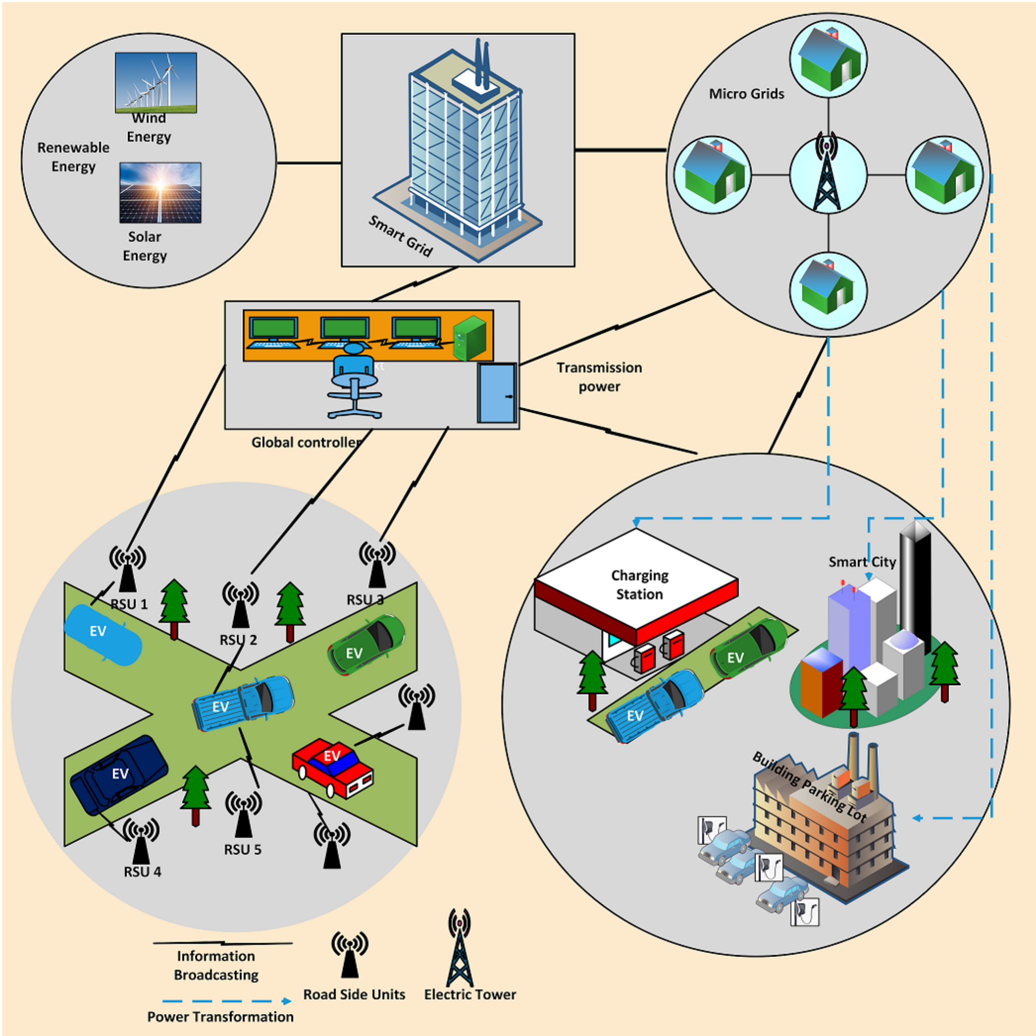

Figure 3. Communication and Service Architecture Model.

3.1.1. Parking Mode

In parking mode, the vehicle is already parked at home, CS or in the parking lot. The majority of EV owners can re-charge their battery of vehicles overnight at home using AC level 1 or AC level 2 charging equipment. Moreover, the charging and discharging scheduling operation of EV is coordinated with other home appliances and charge vehicles at night because of the lower load of electricity. Typically, peak demand hours is suitable to discharge the batteries of EV. However, EV starting and shut-downing is free of cost [89]. More detail on the parking mode of charging EV is available [90,91]. However, the brief overview is given as:

Real Time Smart Load Management of EVs at CSs: For the purpose of controlling a number of EV at CS proposed Real-Time Smart Load Management (RTSLM) strategy [92]. RTSLM strategy enables multiple PEV recharging activities at CS. Moreover, the slot will be allocated to the decided EV (whose battery will be charged) along with when and where as soon as possible in real-time. Thus, RTSLM strategy results in achieving reliability while recharging the battery, avoiding power loss and overloading at CS [93].

Time-of-Use (TOU) Price: Typically, in the light of high demand for electricity, proposed TOU price method for a regulated market in [94]. However, TOU price is a method of controlling EV load at CS and is also important for supply power and demand-side management. Moreover, the TOU price method enables EVs to adjust recharging time, reduce cost and fill fewer demand hours reducing the number of peak hours [95–98].

Scheduling and Controlling: The charging and discharging scheduling of EV totally depends on normal, fast and medium charging technologies. However, CS has its own constraints with different duration. The advantage is balancing and controlling in peak demand hours to avoid overload on electricity generation [99].

3.1.2. On-the-Move Mode

Multiple mobility aspects are taken into account while battery recharging in charging management of on-the-move mode as vehicle is on the move. Mobility aspects include the trip history of EV, departure and arrival time of EV at CS and selection of CS. Considering these mobility aspects makes the charging management more realistic in on-the-move mode. Moreover, mobile EV is either plan their charging schedule under the control of a central aggregator or may it plan to charge their vehicle in a distributed manner. The charging plan of EV in movable positions has been studied in a few articles.

Route Selection: In charging planning of EV in on-the-move mode, route selection is considered as an important parameter by researchers to minimize energy loss and maximize energy harvesting with appropriate route selection [100].

Range Anxieties: Range anxieties are considering the tension between the current SOC of mobile EV and cost from the current position to optimal/selected CS. The new strategy of coordinated charging is proposed in [101], as a solution to range anxieties. Coordinated charging enables efficient battery recharging and minimizes travel costs while planing battery recharging. However, coordinated charging take decisions based on the reading history of the remote terminal unit (RTU) power gird. CS is then referred to EV, for battery recharging, after collecting real-time information including SOC and location of the EV [102].

Deployment of BSS and CS: Deployment of CS and BSS, providing either battery switch service or plug-in charging, within the driving range of EV is also considered in parameters of charging management of mobile EV. Moreover, beside the capabilities of CS also to handles load in peak demand hours when a number of EV arrives at CS [103].

System Cycle of EV Charging Management in On-the-Move Mode

The system cycle of on-the-move EV charging management is illustrated in Figure 4 [104–106].

- Driving Phase: Typically, in the driving phase mobile EV is travelling on the road with a satisfactory level of charge and accessing the charging information from the opportunistic encounter RSUs.
- Charging planinng Phase:: When mobile EV charge level is reached to define the minimum threshold of charge, it needs to search CS to recharge the battery. However, in the driving phase the access information from the RSUs, used EV driver and run selection technique locally.
- Charging Reservation Phase: In the reservation phase EV driver has done individually its CS selection, which then publishes its reservation to the global controller. However, EV CS selection and charging reservation are aggregated and cached by RSU.
- Charging Scheduling Phase: When EV reach at the selected CS, the using charging scheduling policy when recharging the EV battery is first come first serve. However, the main difference between the charging planning and charging scheduling phase is: The charging planning phase is run when EV is in a movable position and the charging scheduling phase is run when EV reach to CS for re-charging the battery.
- Battery Charging Phase: EV commences its driving phase (returns to travelling) after its battery gets full recharge at the selected CS through plug-in-service.

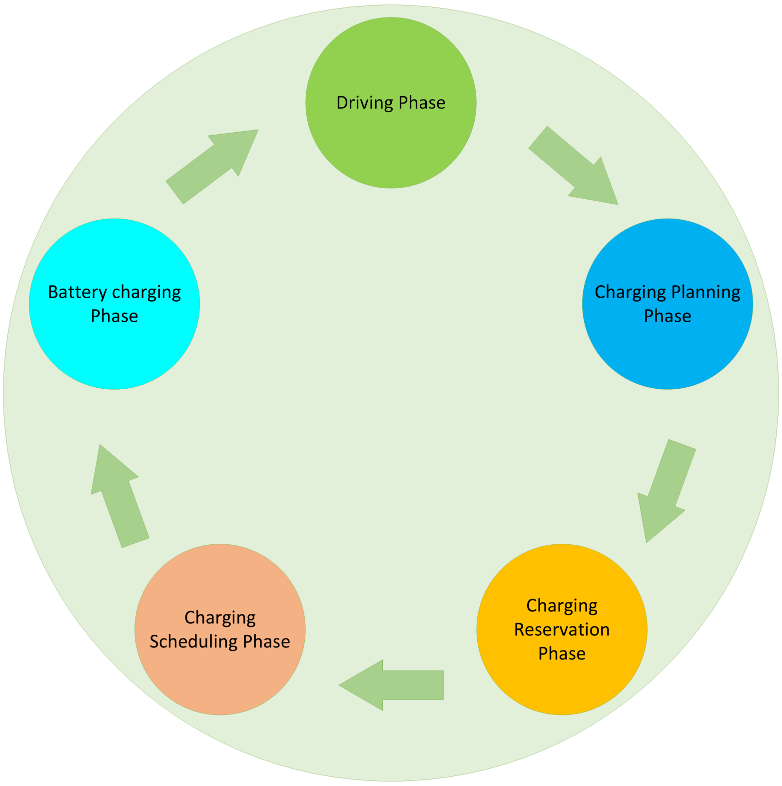

Figure 4. System cycle of EV in on-the-move mode charging management [107].

Charging Management Technique's in On-the-Move Mode

Prior to the introduction of charging management techniques in EVs, increase power loss, distributed charging source overload, decrease lifespan of RSUs and so forth were to occur frequently as a result of charging mismanagement [108,109]. To resolve this mismanagement issue, different studies were done to propose charging management. Centralised and distributed charging management techniques came as a result of these studies. In the next section, the details of these studies are discussed, which minimized power loss and load on distributed charging source [110].

Centralize Charging: In centralised charging management, when EV SOC reaches its defined minimum threshold, the EV driver shares its electric parameter with GC i.e., current SOC, maximum capacity of the battery and average speed of the vehicle. In response, GC then monitors the total number of CS in the network and executes centralised charging management. GC compiles CS list and selects the appropriate CS for recharging EVs battery. Thus, the aim of centralised charging management is to reduce waiting time while recharging the battery, avoid congestion in CS and reduce power loss. Moreover, because of communicating with the GC much privacy concern is aroused in centralizing charging management such as, location, ID and SOC will be released [111].

Distributed Charging: In distributed charging management, each EV individually selects a CS for recharging the battery rather than collaboration with the third party. Typically, each EV can install an Onboard Unit (OBU) then through GPS and the installed map in the OBU the EV driver can search for a CS for recharging the battery. Moreover, CS is selected through local information such as the location of the EV, CS in a radio coverage area, and SOC of the EV. After collecting the above information, the optimal selection of CS for EV is the responsibility of OBU to compile the list of reachable CS across the network and the preferred efficient one. Basically, for the purpose of CS selection three types of the algorithm is used locally, namely shortest first CS, longest first CS and randomly select CS. However, based on local information CS selection, the OBU cannot estimate the waiting time in the CS. Thus, for the purpose of obtaining global information, the OBU can communicate with the CS via wireless communication to minimize waiting time at

CS [112]. Hence, distributed charging is more secure/fewer privacy issues as compared to centralize management.

For more detail, on centralised and distributed management, refer to [113–115] and [116–118], respectively.

Communication Framework for EV Charging Management in On-the-Move Mode

Published Subscribe Communication Paradigm: The P/S communication paradigm allows a subscriber to show their interest and subscribe to the event which is generated by the publisher in order periodically. The information about the event is represented by the entitled "Event" and the process of transmission of information is represented by the entitled "Notification". However, the fundamental communication model Figure 5, for P/S service totally depends on a single service called Event Notification service. Event notification provides a basic service of the model namely storage and management service, responsible for subscription and transmission of events. In communication model event notification services act as a mediator between publisher and subscriber. In this communication model, publishers and subscribers act as consumers and producers of events.

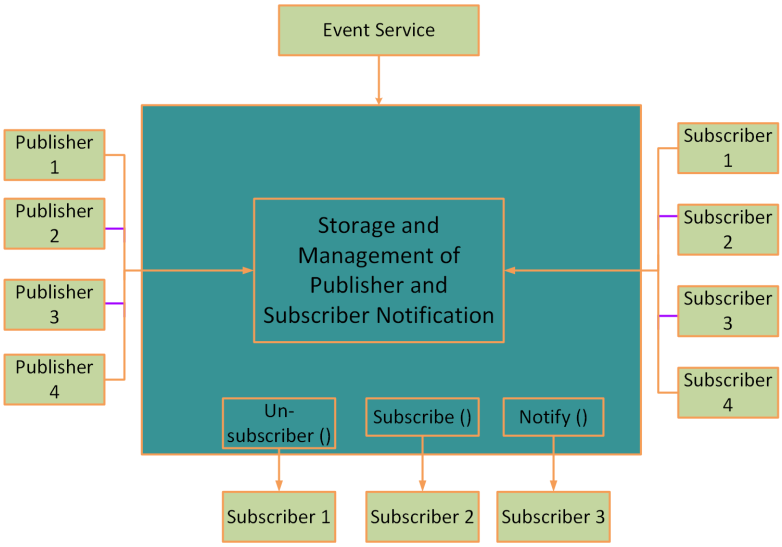

Figure 5. P/S Communication Model.

Moreover, when EV user like the published event service and want to register their interest, used a Subscribe operation. However, the information about the subscription is stored in the event service. For generating an event, the typically publisher used an operation namely Publish operation and for terminating a subscription typically calling an unsubscribe operation. After generating the event, this is the responsibility of "Event Service" to transmit the information message to each "subscriber" to show their interest. Moreover, the Publisher is also able in this communication model to advertise their future plan event by the operation namely "Advertise" operation [119].

Published Subscribe Communication Framework for On-the-Move EV Charging Management: P/S Communication framework is topic based communication paradigm. However, on-the-move EV charging management it comprises of EV, CS, RSU and GC as entities. Moreover, every entity can subscribe to information of their interest via P/S communication framework [120]. The communication network infrastructure is illustrated in Figure 6.

- Electric Vehicle (EV): EV is in contact with RSU continuously to access the information about CS such as, ATC and price per unit charge and so forth. Each EV have SOC, when EV current SOC is below or equal to the minimum thresh hold of charge. The EV can select a CS as its charging plan on the basis of received information about the CS from the encounter RSU.

- Charging Station: CS is placed at different locations and aims to facilitate EV for re-charging the battery via plug-in charging technology. Particularly, CS publishes it's local condition information (ATC, No.of parked EV at CS and their charging times) periodically, to facilitate EV and GC. GC can subscribe to this local information for the purpose of calculating ATC.
- Roadside Units (RSUs): RSUs are also located at different locations in this communication network infrastructure. Aims are to transfer the charging information from CS to EV and from EV to GC. Moreover, RSUs have the ability to obtain, cache and published information about each CS which is in include in the network. RSU passes information when it receives a request query regarding charging from a mobile EV.
- Global Controller (GC): It administered the charging regarding information of each CS via centralize manner. It can perform estimation based on CS current situation and charging reservation of EV by obtaining available time of charging of particular CS. However, this operation are mainly used for mobile EV.

Moreover, distributed charging management is also handled via P/S communication framework. Where EV takes decides where and when to recharge the battery from the opportunistic encounter RSUs. Two communication modes are proposed for disseminating the information about CS to EV, namely Push and Pull mode [121], where RSUs are able to cache the information and allow asynchronous communication. More detail about the placement of RSUs in the communication infrastructure is available in [122].

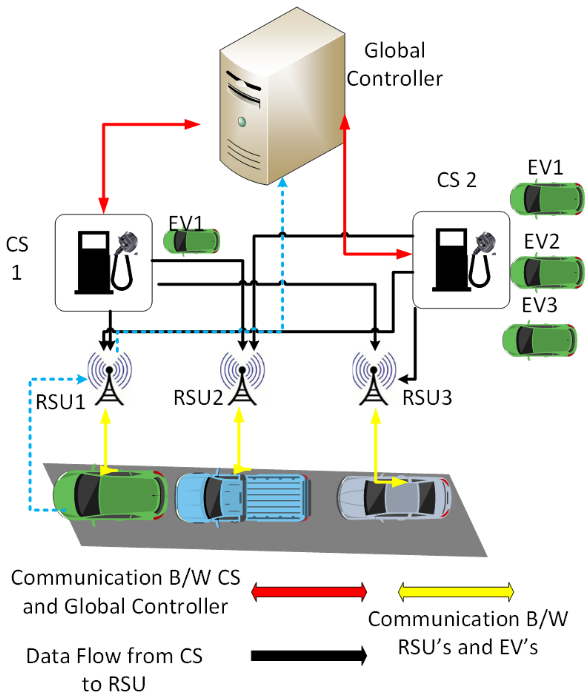

Figure 6. Communication Network Infrastructure of EV Charging System.

Overview of PUSH and PULL Mode

- Push Mode: In Push mode, CS have a responsibility to share periodically its current reservation, charging queue of EV and price of time charging with nearest RSUs. Typically, this information is disseminated to and received by the EV, which forwards subscription query to the local RSU for recharging the battery. EV has received the information when it comes under the range of the RSU. Under the push mode RSU has no facility for caching the historical information about the CS. Thus, the communicating client (EV) cannot receive any information from the RSU, if the CS has currently not published any information [123].

- Pull Mode: Similar to push mode in pull mode, CS publishes its information periodically with the nearest RSUs in the network infrastructure. The key difference in pull mode is, RSU is able to store the CS transfer information as a historical record. When a mobile EV comes under the defined range and sends the subscription query to that RSU, then RSU will facilitate it with the latest fresh information.
  It's worth noticing, when new information is received in this mode the RSU will replace it with obsolete information. The range of radio coverage distance is to define the value for both modes. When the EV current distance is less than or equal to that value, then the RSUs will communicate with the EVs via WiFi or cellular network [123]. For understanding and memorizing the summary of smart charging of EV is shown in Table 3.

Table 3. Summarize Table of Smart Charging Management.

Summarize Table of EV Smart Charging				
Factors	**Descriptions**	**Application**	**Safety Aspect under ISO 26262**	**Failure Aspect under ISO 26262**
Safety in public place	Excellent	Congestion detection and avoidance	Hardware and Software tested periodically	Centralize system failure
System Failure	Relate to overloading on the gird	Route Selection toward CS	Reduction of risk	Random hardware and software fault occurrence
Compatibility	Convenient	Vehicle coordination and assistance application	Hazard free analysis and risk assessment	Occurrence of error in scheduling running
Complexity	Huge	Battery Switch Service	Automotive safety integrity	costly and time consuming corrective actions
Frequency control while charging	In Ultra Fast charging	Remote Reservation	Secure communication architecture	Automotive function maintenance is critical
Controlling strategies	Time of use prices Encourage to charge in Valley filling Save power for peak hours	Charging scheduling	Support error detection mechanism	Security vulnerabilities
Performance	Excellent	Wireless Power Transfer	Function safe system	Low carbon emission need separate function safety
Energy flow	Vehicle to Grid and Grid to Vehicle	Efficient Security	Function safe management architecture	Costly architecture
Architecture	Centralize and Decentralize	EV mobile application		
Objective	Minimize charging cost Minimize power loss Usage of renewable energy	Real time smart charging management		
Charging Technologies	Residential charging Public charging Ultra Fast charging	Generate necessitate level of power or energy		
Power transfer techniques	Plug-in charging Wireless power transfer	Event storage system		

3.2. EV Fleet Management

If a fleets of EV is properly managed, then EV users might be increased. Thus, for the purpose of integration and managing the fleet of EVs, the electric grid needs bits of intelligence to monitor the recharging battery of vehicles for the purpose of improving efficiency [124]. The following issues are addressed in the EV fleet management by an aggregator.

- CS Backup Power: Plug-in EV needs to recharge its battery to an appropriate level for a trip plan, therefore the selected CS must have sufficient energy when EV needs recharging.
- Minimize the Charging Cost: The energy sources may apply variable charging prices for recharging the battery. However, with price change as a function of the load on the grid, the provision of sufficient energy at all reasonable costs is necessary at each price.
- Load Handling: Considering a large number of vehicles in localising CS for a long period of time. However, to handle the long queue or bottleneck appropriately to save time while recharging the battery.

Moreover, for the purpose of EV fleet management in a geographically distributed environment, the author in [124], proposed the fleet operator (FO). The FO facilitates EVs with multiple services such as providing charging service, managing the fleet of EV charging and others which is shown in Figure 7. Typically, an alternative name used for FO in the literature has EV "virtual power plant", "EV aggregator" and EV "charging services provider" [125,126]. The system architecture of EV fleet management is discussed in detail below.

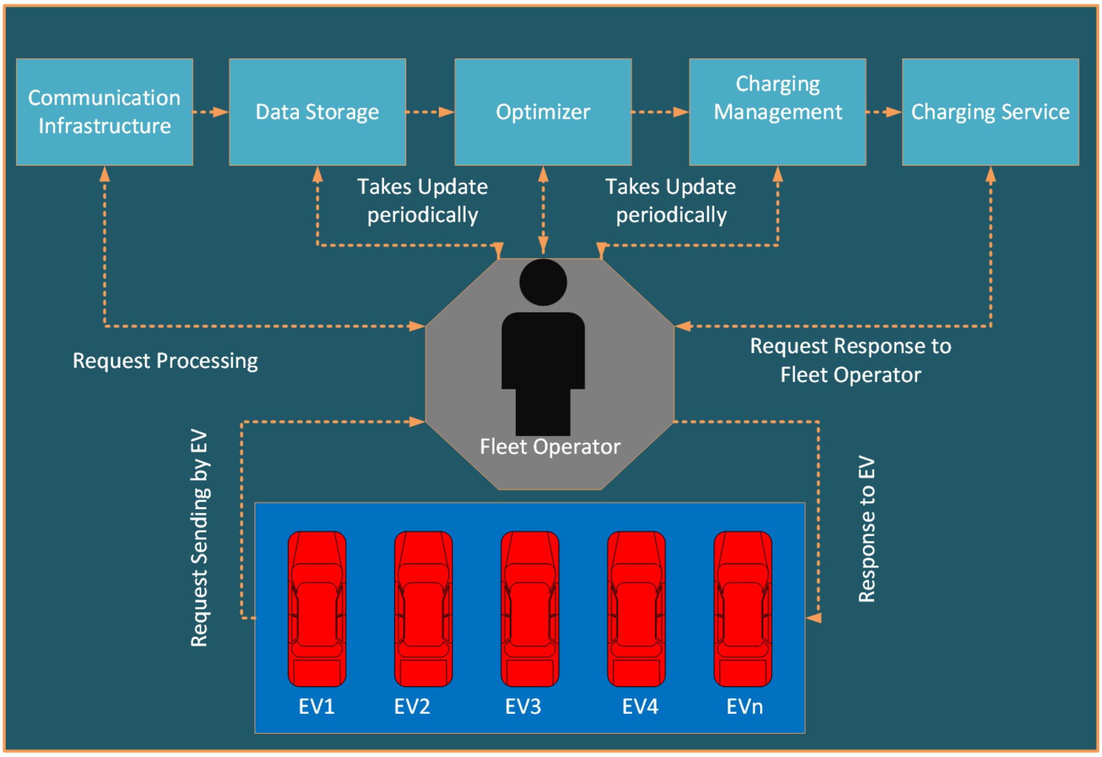

Figure 7. Fleet Operator and Operations.

3.2.1. System Architecture

In the system architecture of EV, FO has four parameters named as data storage, trip forecasting, optimization, and communication infrastructure [127]. The integration of all of these makes the system architecture which is discussed below in detail.

Data Storage

For EV fleet management it is important to store a considerable amount of data to perform fleet management appropriately. Records regarding trips data, billing information of EV and end-user etc. are required by FO for future prediction about EVs charging and it needs to be stored. Also, it may need weather forecasting information for the purpose of wind and solar generating power prediction. The gird and CS status information, and the communication between EV and VPP will be needed to store in the storage system [128,129]. Thus, all of this information feeding in the storage device is an independent task. Moreover, the data either be fed periodically or maybe push in an asynchronous form.

Trip Forecasting

This parameter of the system is responsible to predicate according to the plan trip, how much energy is needed for EV. However, the charging management of EV and avoiding overcharging is depended on the state of charge/energy of the EV. The EV driver accepts that the current SOC is sufficient for the trip or for the trip which is occurring in the next plan. Also, complete charging of the battery may be costly sometimes because of CS load. Therefore, it is recommended and beneficial to charge EVs according to what is needed for the current trip plan [130]. However, this battery demand of EVs for the decided trip needs excellent estimation which will be done according to the history record stored in a data storage device.

Hence, for each trip, the following features of the trip must be noted.

- Initial position of trip: A timestamp when travelling is starting.
- Final position of trip: A timestamp when travelling is ended.
- SOC when a trip starts: Status of charge/energy of EV when a travelling starts.
- SOC when a trip end: Status of charge/energy of EV when a trip is ended, means that the remaining energy level after reaching a destination.
- Destination at the end of trip: The location where the physical EV reaches finally.

All of these information must be needed for good estimation and to avoid extra energy charging.

Optimizer

In overall system architecture the optimizer is the core parameter. The first objective of the optimizer, it will invoke the trip forecasting to obtain the trip estimation of the EV means, i.e., when to recharge the battery and how much charge it will require. The second objective of the optimizer is to forecast the power generation i.e., the power available in the CS is enough for the vehicle according to the planning period or not. The third objective of the optimizer is to minimize the overall charging cost by producing the exact amount of power to avoid extra power generation. The problem formulation (Linear and Quadratic) of the optimization is given in the [131], with comparison. Moreover, in result showed that the linear formulation is better as compared to a quadratic formulation for the scheduling of the optimization.

Communication Infrastructure

Typically, for controlling and operating the distributed environment infrastructure and EV, there is a need of Communication Infrastructure (CI). However, the CI must be reliable, support maximum throughput, provide security and importantly economical. Moreover, the CI also has an interface with the power system (PS) and with the PS market stakeholder. However, at the time of fleet management, the FO gathers data and discusses it such as, pricing per unit charge, grid constrain and grid status. The communication infrastructure and its requirement are discussed in detail in the [132,133].

3.3. Charging Technologies

In [134], ABB (Asea Brown Boveri) proposed three main categories of charging namely, residential charging, public charging and fast/ultra-fast charging). However, each of these charging technologies has their own services & limitations which is discussed below and shown in Figure 8.

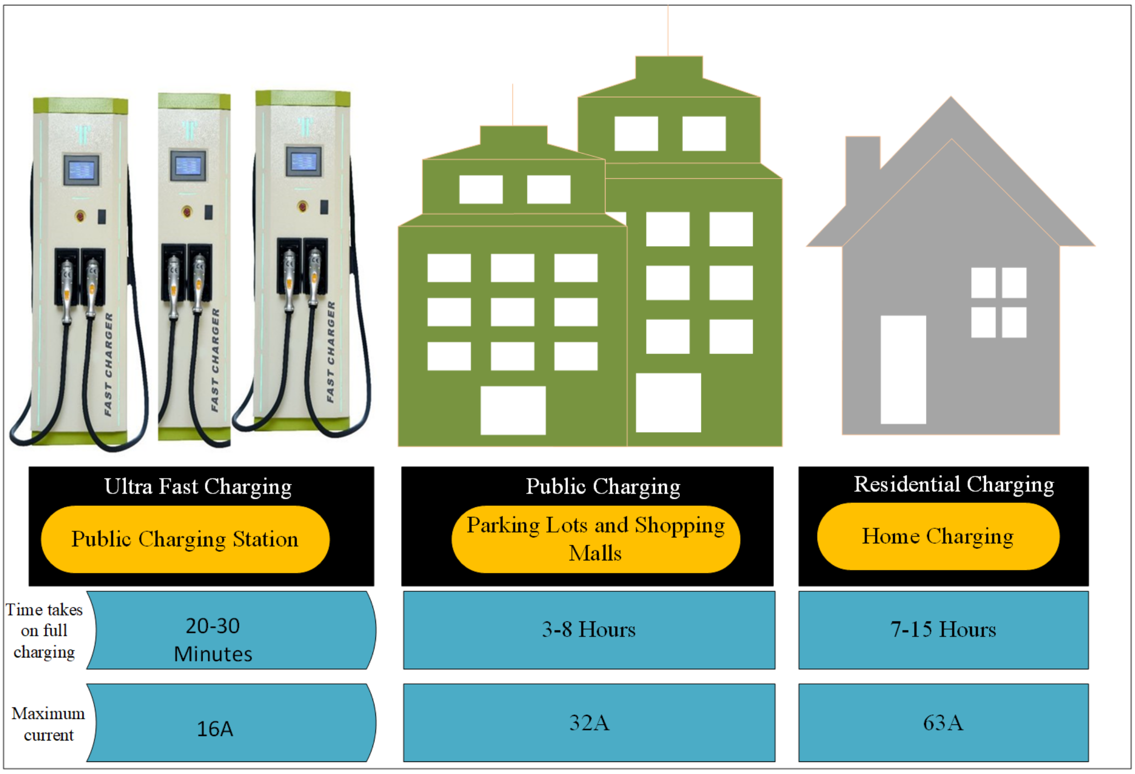

Figure 8. Charging Technologies and its Feature.

3.3.1. Residential Charging Technology

Residential charging technology, also known as home charging technology, provides power at a single-phase AC line with 50/60 Hz. Recharging time under this charging infrastructure is around eight hours [135]. It is preferable to start charging at night to minimize charging costs as CS has less load in night. Efficient charging power, battery life preservation and less installation cost are some of the noticeable features of this technology [136–140].

3.3.2. Public Charging Technology

Public charging technology flows the power from a "three-phase AC line at 50/60 Hz". These charging poles are secure, safe and well-suitable for the public environment and it is available in a shopping mall and parking lots. In this charging infrastructure, the EV can recharge the battery in a few hours. Moreover, the electronic payment system is available as a self-service in the charging pole in different forms. Installation of this charging technology has a higher cost than residential because of technology differences i.e., this system has upgraded technology [141].

3.3.3. Ultra Fast Charging Technology

In ultra fast charging technology direct current is fed in the EV and set the variable voltage level in the range of 50–700 Vdc to satisfy the EV and its battery type. Moreover, it will take time equivalent to fuel filling on re-charging the battery of EV and offer low charging efficiency as compared to residential and public charging technology. Furthermore, the corresponding charging station installation cost is high and available on highways and in smart cities [142]. The Summary of charging technologies is given in Table 4.

Table 4. Summary of Charging Technologies.

Charging Technologies	Parameter of Charging Technologies						
	Specific Connector for charging	Charging Time	Charging Type	Maximum Current	Impact of Grid/CS	Connector Type	Installation Cost
Residential Charging	No	7∼15 h's	AC	16 A	Less	Nil	very Less
Public Charging	No	3∼8 h's	AC	32 A	Medium	BS EN 62196-2 (J1772)	1000 to 2000
Ultra Fast Charging	Yes	Fuel Equal Time	DC	63 A	High	BS EN 62196-2 (Mennekes)	Undefined

3.4. Key Technologies for Charging Management of EV

Information technology [143], electrical technology [144], automotive technology [145], and chemical technology [146], are considered as key technologies of EV. For simplicity and contemplation, in this subsection describe some basic technologies namely body design, energy management and system optimization [147,148]. The combination of all of these technologies plays a successful role in the development of EV.

3.4.1. Body Design

Under the body design of EV have two approaches, the first one is conversion ICEV to EV and the other one is a purpose-built EV. In conversion of ICEV to EV have replaced some specific equipment by electric motor, power converter and battery [149]. The advantage of this approach is that, it is done in less economy and adjust with existing chassis. However, the problem in ICEV is highly weighted and as compared to EV high center of gravity (CG) which can affect the stability of EV. That's why most of the EV are purposed with built EV. As compared to the conversion approach the purpose-built EV have a number of advantage because the engineers are free at the time of development and integrate all key technologies same as EV demand to work efficiently. For purpose-built EV, weight-saving design, low drag coefficient body design and low rolling resistance concept is some design concept through which the performance of EV (range, speed and grade-ability of the vehicle) can improve, automatically. Use of lightweight material for manufacturing of parts (upper pillar, sill, floor, wheelhouse, bumper, suspension tower) will be a weight-saving design. Provision of smooth, speedy and long-range drive on a single charge of battery is subjected to low drag coefficient design as it is helpful in reducing the aerodynamic resistance. Therefore, in this design low rolling resistance tires are recommended as they play a vital role in controlling a high-speed vehicle [150].

3.4.2. Energy Management

As compared to ICEV, the EV has limited driving capacity. The driving capacity of the EV can be improved easily, if the energy stored in the EV is utilized efficiently. Therefore, an "energy management system" (EMS) is needed to enhance the utilization of energy/power, which takes input from various subsystems of the EV with the help of sensory inputs [151,152]. Sensors will be deployed to check the voltage rate of smart grid and CS while recharging and discharging of battery EV, the remaining charge of the EV, vehicle speed, inside and outside air temperature and also senses the external climate environment. It will then utilize this subsystem information for minimizing energy usage.

The EMS can perform the following function.

- Monitor the history and diagnose the effect on the energy source (battery).
- Proposed the charging according to vehicle electric motor.
- Adjust the light's brightness according to the external environment to increase the usage of energy stored in EV.
- Monitor the SOC of the vehicle.
- Produce energy while driving for a subsystem of EV i.e., battery.

Also, the coordinated structure of EMS with the navigation system could be helpful in planning an efficient energy route, appropriate selection of CS for re-charging [153].

To conclude, it is apparent that EMS has multi-discipline functionalities and can manage/maximize the use of stored energy in the EV.

3.4.3. System Optimization

EV is the integration of multidisciplinary field, and technologies and have a complex architecture. Thus, the performance of the EV can be affected by these multidisciplinary filed. For the purpose of this integration and system-level optimization checking, computer simulation is the one and most important technology through which optimization for cost reduction and improve performance could be carried out. EV simulation helps the developer to minimize the time at system-level optimizations and decrease the cost of designing and testing during the development phase [154–157].

3.5. Charging Scheduling of EV

In smart charging management of EV one of the major things is the charging scheduling of EV. Charging scheduling aims in management to address issues in real-time charging of EV, demand and its impact on the smart grid. Address uncertain events occurring in future, manage load profile of CS and EV, improve frequency regulation, renewable energy source power generation efficiently use and transmit to micro grids. In this section, we discuss in detail work on charging scheduling of EV in term of global control and distributed control charging scheduling, static vs. mobile EV and objective of charging scheduling respectively. The classification of charging scheduling is shown in Figure 9.

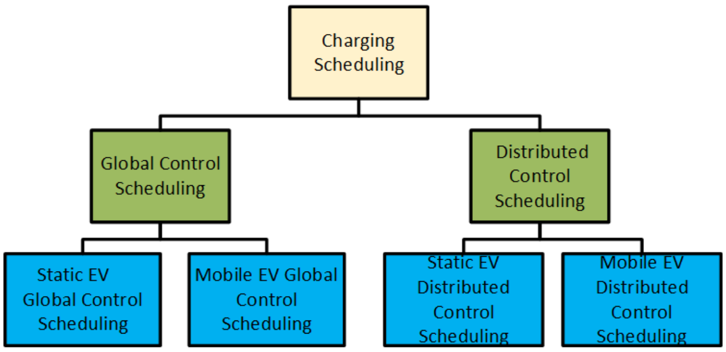

Figure 9. Classification of Charging Scheduling.

3.5.1. Global Control

Under the global control charging scheduling mechanism, each requested EV charging scheduling is optimised by the GC or central aggregator (CA). The CA can collect the information from the requested EV for the purpose of identifying the requirement of EV via communication. The EV can only share data concern to its electric parameters with CA. The CA along with EV is in contact with smart gird and micro girds to use efficient energy transmission of renewable energy source. The flow of energy process is shown in Figure 10. However, the global control scheduling mechanism is able to select optimal CS for the vehicle because all electric parameter has available to it. The main objective to achieve form the global control is minimised charging cost, optimal selection of CS, minimising power loss, use efficient production of renewable energy source and maximize number of charge EV.

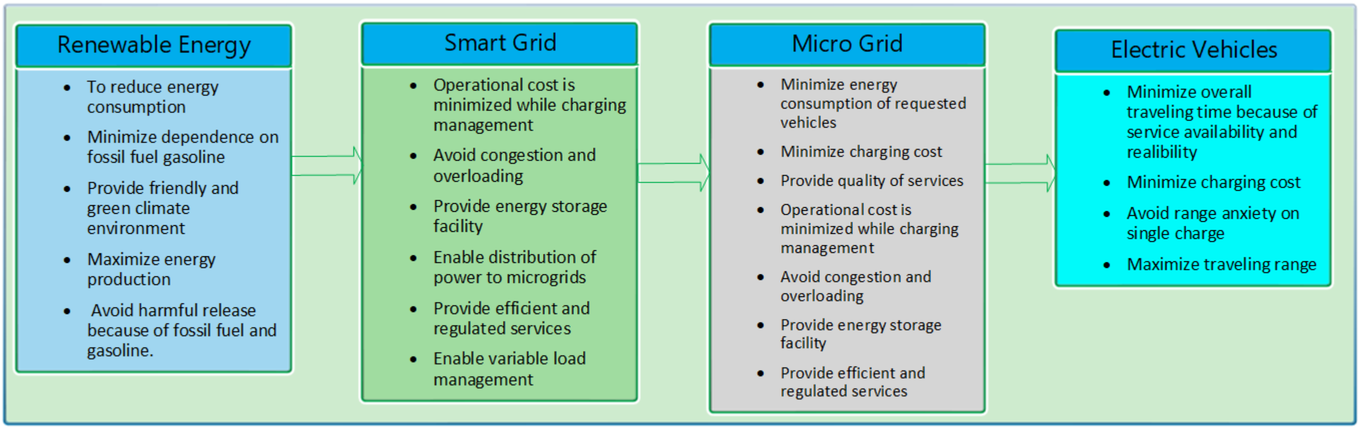

Figure 10. Flow of Energy.

3.5.2. Distributed Control

Under distributed control scheduling mechanism, each EV is taken decision self-regarding to charge EV or not and where to charge. In such cases, requested vehicle share with CA its charging objective like charging price and frequency and own comfort zone. Upon this CA make decision and prefer appropriate CS to vehicle. This is possible only in distributed control. However, if any requested vehicle share insufficient information with CA in result it may schedule and achieve sub-optimal CS. The objective of distributed manner is minimizing dependency on GC and charge a huge number of vehicle because of self regarding decision.

3.5.3. Static EV Global Scheduling

Han et al. [158], proposed charging algorithm base on peak hours energy consumption periods price predication. Where each and every CS are informed aggregator in real time the price of energy via wireless communication. The aim of the proposed algorithm to find efficient time for re-charging the battery. If the algorithm is found the cost of energy is grater then the thresh hold price of the user preferred, the charging process is delayed until efficient charging time and price is not determine. However, in result the load is distributed in different time period automatically and the cost of energy and energy consumption in peak hours of the day is efficiently reduce by this scheme.

Sortomne et al. [159], studied the impact of plug-in HEV on distributed charging management performance including overloading in CS, increasing and decreasing power quality and regulation of voltage in peak hours and in off-peak hours. In the solution of all these factors for efficient management, the author proposed an optimal charging scheduling algorithm and coordination mechanism. The proposed algorithm is based on the relationship among different parameters such as load factor in CS, grid losses in a distributed environment and load variance. However, the aim of the proposed algorithm is to increase the profit, reduce power loss and voltage fluctuation of the smart grid. In addition, the problem of the coordination of plug-in HEV with smart grid is also addressed to schedule the charging plan effectively and minimize time loss.

Wu D. et al. [160], proposed another charging scheduling algorithm for aggregators to dispatch efficiently energy to microgrids and minimize energy cost of plug-in EV. The algorithm operates on the base of a regular charging profile to predicate the demand of the coming day and determine the day-ahead scheduling for each plug-in EV in centralised manner. In conclusion purchase, the required need of electricity/energy and dispatching it to the individual plug-in EV it a reasonable cost. Therefore, the impact of the proposed algorithm reduces overall power loss of the coming day of the grid maximize the profit because of efficient management.

3.5.4. Mobile EV Global Scheduling

Yang, Yu et al. [161], proposed real time smart grid load management algorithm for plug-in EV to minimize grid overloading and congestion and increase grid co-ordination reliability with requested EV. Such charging parameters are considered for proposed real time scheduling algorithm including arriving and departure of EV and price of energy of different time period of grid and CS. The charging of EV is start priority base according to propose algorithm. The aims is minimize charging cost and energy loss of the grid.

Su, Wencong et al. [162], have studied municipal parking spot and proposed scheduling algorithm for a large number of EV. The term considered for the scheduling algorithm is arrival time of EV , SOC, and maximum expected re-charging time of battery. The proposed work is simulated in term of statistical analysis using available transportation data. In term of mobility of EV formulate expected arriving, charging and departure time of pulg-in EV. The objective of the proposed work is increase the SOC for future plan trip by considering price of energy per unit, maximum battery capacity and current SOC of requested EV.

Lee, Junghoon et al. [163], work on integration of vehicular network and smart grid and proposed scheduling algorithm using genetic and heuristics approach for mobile EV to minimize load on each CS. When EV SOC is reached to the minimum threshold, send a request to the aggregator for battery re-charging along with its current SOC and location, and arrival time. Upon receiving new request the CS verify that, along with already submitted request I'm able to satisfy the new requested vehicle in term of minimum waiting time and provide sufficient level of voltage. The result is communicated with the requested vehicle. Upon receiving the result the driver of the vehicle is to decide recharge battery in selected CS or send a request to another CS.

3.5.5. Static EV Distributed Scheduling

Gan, Lingwen et al. [164], have studied in detail the distributed charging and proposed algorithm for plug-in EV to achieve satisfactory level of result in night valley. The objective of the proposed work is minimize charging rate at night valley for the requested vehicle. The proposed algorithm monitor in each iteration broad-coasting of the grid operator and note the price per unit and along with this the charging profile of EV in term of price of re-charging battery.

Richardson et al. in [165], proposed a CS selection mechanism for plug-in EV by considering multiple characteristics for satisfaction of user including SOC, affordable price and minimum charging time. The aim is to maximize user satisfaction in define demand constraint for battery re-charging.

Ardakanian et al. in [166], used optimization tool namely convex optimization to select optimal CS for plug-in EV for re-charging the battery. The proposed work is simulated against un-coordinated charging of plug-in EV. The result shows that the negative impact of plug-in EV is reduce. Using decentralize control the algorithm is also proposed for CS. The requested vehicle share electric parameters with the aggregator multi time and takes decision to where to charge EV. For the purpose of information sharing the communication framework is also proposed.

3.5.6. Mobile EV Distributed Charging Scheduling

The author proposed in [167], distributed charging algorithm for plug-in EV in order to minimize loss of grid energy and flatten load across the total of number of CS. The Plug-in EV charging process and algorithm is run on the base of current situation/condition of the power system. The parameter include in the formulation of the algorithm is total number of requested EV, waiting time of each slot in CS, charging cost at current time and the total time for each vehicle according to current situation and net load is calculated. The aim is to minimize charging and operating cost and load balancing. The aim is to minimize charging and operating cost and load balancing across the number of CS along with this decide efficiently that, the requested vehicle in mobile position (need of recharging vehicle) is to facilitate to recharge the battery in coming CS or it continue driving and move toward the next CS to efficiently charge the battery without waiting in queue. The decision is always in binary value.

Hamidi et al. [168], have observed price in a CS which remain constant in different charging periods. In response of these proposed efficient charging algorithm by considering decentralize manner. The charging cost of the battery and demand of power/energy in different periods are observed for both single and multi EV by aggregator. However, after arriving mobile EV to CS, put the plug of charger in vehicle, set the expected time, SOC and voltage of charging power within the system for recharge the battery. The algorithm is run by relations of these parameters to reduce the cost of recharging all the time. The presented algorithm namely heuristic algorithm.

Qureshi et al. [169], have studied issues in charging management of EV including increasing cost of re-charging the battery route selection to selected CS, selection of appropriate CS. In response of all of these issues proposed efficient charging scheme and scheduling algorithm for plug-in EV namely EV "Intelligent Energy Management and Charging Scheduling System". The aim is to provide efficient energy management services and facilitate the driver to take decision of re-charging the battery via communication with CS. The proposed scheme also proposed a security mechanism for protecting data from any kind of malicious activity.

3.6. Application of Smart Charging of EV

Generally, EV smart charging applications comprises of two types of applications such as monitoring and tracking. Monitoring application is used for analyzing, supervision and carefully operating of CS and smart grids in real-time. In contrast, tracking application is used for the prediction of power generation changes and generating in event notification in network infrastructure. Existing some monitoring application includes, congestion detection and avoidance at CS [170], route selection toward selected CS [171], vehicle coordination and assistance application [172], while traveling EV support application (e.g, local map install in OBU and road uncertainties warnings) [173,174], ease of accessing anytime event storage application [175], charging scheduling [176,177] and remote reservation application [107]. In tracking application includes, follow SOC and give alert to vehicle drive (vehicle needs to recharge battery) [178], generating necessitate level of charge at smart gird [179], in real-time traffic tracking at CS [180] and so forth.

Concise discussion on some of the other applications is presented below.

3.6.1. Battery Switch Services

Battery switching is a process that provides automated switch platform in which a drained battery is switch by a fully charge battery with in few minutes i.e., 4–5 min. After switching the depleted battery, it is placed in CS for recharge, after that it can be used for other EV. For the purpose of enabling this fast charging technology, it is necessary for each CS (which provided battery switching service) to maintain a number of fully charged batteries every time to facilitate EV users.

3.6.2. EV Remote Reservation of CS

In remote reservations, while travelling, EV publishes its information to selected CS via RSUs, when it is on the status of recharging the battery. Once CS received the reservation information about vehicle then CS calculates and updates its current conditional status such as increased number of reservation requests, decrease number of available batteries and expected waiting time at CS. However, Because of asynchronous communication in the remote reservation process, CS publish its information according to the standard of ETSI TS 101 556-1 and EV publish it's reservation using the standard of ETSI TS 101 556-3. It is worth notifying that caching information in this remote reservation requires the use of pull mode.

3.6.3. Avoid Congestion and Minimize Waiting Time in CS

As compared to gas and fuel station in EV CS have a minimum waiting time. For the purpose of this proposed algorithms in [181], based on local and global information. For the selection of CS the EV installs OBU and GPS-based navigator then the installed map in OBU, EV will be guided via GPS for the selection of CS. This CS selection is based on local information (location of EV and CS and remaining electricity), but using local information the OBU can not estimate waiting time in the CS. In the solution of this global information(total No, of EV in CS) is provided to OBU from global controller selection (GCS) via mobile computing to select the least loaded CS and save time while re-charging.

3.6.4. Wireless Power Transfer (WPT)

Is a technology used for new technological devices re-charging like cell phones, bio-medical implanted devices and EVs. This technology avoids physical connection between the charging nodes and device i.e., cell phone and charger, EVs and source of re-charging. WPT system comprised of two circuits (primary and secondary) and a number of nodes including battery, transmitting and receiving coil, sensor, electric grid and micro-controller. While WPT charging, the primary circuit transfer the energy and the secondary circuit receives the energy which produced and transfer from the primary. It is to be worth notifying that the receiver coil is to be specifically aligned to the transmitting coil in a short distance.

3.6.5. EV Mobile Application

As compared to traditional vehicles EV have mobile applications. EV driver/owner can plan trips through the interaction with communication infrastructure, finding out the position of CS on the route and reserving a slot in advance for re-charging the battery. As result, the EV driver can drive comfortably, without any fear that the battery can run out of energy.

4. Open Research Issues

Apart from many advances in EV technology, there are still areas which need improvements and invoke the researchers to find out the solution of the challenges and issues. Some of these issues are discussed below:

4.1. Advance Integrated System

The incorporation of green energies i.e., solar and wind along with sophisticated and up-to-date charging technologies (battery switching, wireless and plug-in charging technology) can be integrated into P/S system, which requires more computation. Deployment, maintenance and management of this advanced integrated system (P/S system) in smart cities having a greater degree of semantic heterogeneity of events is a challenging task.

4.2. Efficient Charging Scheduling

Most EV users follow a certain trip pattern based on job routines etc. which define their trip routes and can be recorded as history. These records help the aggregator in providing efficient charging scheduling to the user at multiple locations which comes in user trip route. While travelling, mobile vehicles may face traffic issues like congestion areas, unplanned accidents, traffic jams etc. Therefore communicating in real-time of charging system with mobile vehicle needs to be efficient for better charge scheduling. Therefore, integrating work on charging management with existing mobility works is a challenging task, as the integration of both demands robust design.

4.3. Security Challenges

Along with technical challenges in the smart charging management of EVs, security challenge is of great importance. These challenges comprise providing security at both user (EV) and source (CS) level. Information regarding EVs/user must be kept private and secure during inter-aggregator collaboration. Also, communication between EVs and CSs must be made secure as malicious information can be forwarded by the anonymous group to EVs and CSs for manipulation and unwanted events. These provoking malicious attacks could also leak users' profiles which also needs to be secure.

4.4. Vehicle-to-Grid Operation

Vehicle to the grid allows transmission of power in both directions i.e., from vehicle to grid and from grid to vehicle. Typically, at CSs depleted batteries of EVs are charged in real-time which takes time and invokes congestion at CS due to a limited number of ports. Instead, it can be solved with heterogeneous/homogeneous battery switching, which allows only replacement time of 4–5 min. The residual energy in the replaced depleted battery could be sold back to EV for time-saving and better management.

4.5. Inter-Aggregator Collaboration

In distributed manner, it is essential to mange a vaster number of the requested vehicle to achieve satisfactory result while travelling. However, a service-oriented framework is proposed by [182], which rely on aggregator as a solution, in which end-user will subscribe to the aggregator and provision of facilities will be on aggregator when and where needed. Simultaneous facilitation to different EVs at many locations requires inter-aggregator collaboration. Research and investigation of this collaboration is provoking challenge for researchers.

4.6. Uncertainty in Scheduling Process

Bidirectional power flow allows charging and discharging of the battery. Studying the effect of discharging on batteries life and incorporating this effect in optimization problem solutions is of great interest among EV researchers and engineers.

4.7. EV Heterogeneity

Each EV is designed by the manufacturer for one or a few types of battery and is only compatible with them. For this, CS must have availability of the different types of batteries that can replace for number of EVs heterogeneously. An algorithm designed and different types of batteries available at CSs, for facilitating heterogeneous EVs, is an interesting problem to be addressed.

4.8. Cost Optimization Model

Along with the deployment of CSs and Vehicle to Grid (V2G) operations from a technical perspective, there is need of business model, accounting for price adjustment (variable for peak and normal hours) with more profit benefiting both end users and aggregator.

4.9. Urban Driving Uncertainties

Selection of CSs in urban areas with traffic accidents/jams will have variable mobility i.e., slow in a congested area and fast in the open area. This difference will affect the reservation of CSs and will have uncertainty at both CSs and EVs side. Optimizing solutions to this complex issue is of great interest among engineers and researchers.

5. Conclusions

This survey paper is intended to review the different charging management techniques. Among them, the smart charging management technique is considered the optimum management technique. A P/S communication framework is employed for this management technique. Real-time smart charging management is introduced in on-the-move charging mode for market regulation in peak hours with price adjustments. A fleet operator is introduced for EV fleet management to encourage a greater number of people to use EVs. Along with other technical issues, security is also of concern and importance in EVs. This survey revealed distributed management systems as more secure and private than centralized approaches. This survey also discusses the key factors that could improve EVs, such as body design, energy management, and system optimization. It was also revealed from the study that improvement in technical aspects of EVs like decentralized charging, mobility issues, heterogeneous battery switching and security can put EVs in good competition with conventional ICEVs and HEVs. An integrated review of homogeneous and heterogeneous battery switching technologies, plug-in charging technologies, and charging assessments of various types of EV and their impact on the smart grid. The work regarding these is left for future review.

Author Contributions: Conceptualization, A.A. and M.K.; methodology, validation, A.A., Z.U., M.K. and N.A.; formal analysis, N.A., M.A., F.A.M. and U.M.; investigation, A.A., N.A., M.A., F.A.M. and U.M.; writing—original draft preparation, A.A., Z.U. and M.K.; writing—review and editing, A.A., N.A., M.A., F.A.M. and U.M.; supervision, M.K. and Z.U. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: Not applicable.

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

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