An Overview of EV Charging Infrastructure

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ABSTRACTS:

Electrical vehicles are a promising new transportation innovation, according to current trends. A barrier to the acceptance of electric vehicles will be the absence of convenient charging facilities. Other problems include grid voltage irregularities, overuse of the grid's current capabilities, and a mismatch between supplies and consumption in the electrical network. This study examines the effects of EV fast charging points on the current power grid as well as possible solutions to these problems. This document offers a categorization and analysis of the positioning of charging stations, the scheduling of charging activities, and the overall charging architecture scenario. The problems, prospects, present research trends, conclusion, and future scope are also included in this chapter.

KEYWORDS: Coordinated Charging, Charging Planning Model, Charging Scheduling, Charging Station, Electric Vehicle, and Renewable Energy Sources.

1. INTRODUCTION

The nation's public transit industry is largely responsible for the nation's socioeconomic prosperity. About 25% of all Carbon dioxide produced by the burning of fossil energy is attributable to the automotive industry. Electric vehicles (EVs) are a favorable choice for decreasing harmful emissions, which can enhance the quality of air and lessen the negative consequences of ICE-based automobiles. An automobile that operates completely or partially on electricity is referred to as an electric car. The system is classified into 4 groups based on the method of functioning, including A battery-electric car only uses electricity to operate. On-board batteries provide it with power. A car that uses both electricity and fuel is known as a plug-in hybrid electric automobile. Before the combustion engine (the engine that runs on gasoline) begins, the car is propelled for a portion of the distance by its electric motor. If the distance is short, it might only utilize electricity. By powering an electric generator that recharges the car's battery, a range extender is a gasoline auxiliary power unit (APU) that increases the range of a battery-electric vehicle. A fuel cell electric vehicle (FCEV) is an electrified device that utilizes a fuel cell to operate its onboard electric engine, often in combination with a tiny battery or ultracapacitors. To produce electricity, fuel cells in cars typically use pressurized hydrogen and oxygen from the air. Several of the difficulties involved in organizing the transit system and the charging infrastructure are similar. Both systems demonstrate how need and production are interconnected, and how delay develops when need outpaces availability. The absence of adequate EV charging infrastructure that can fill the role of and contend with the current refueling stations is also another barrier to the widespread deployment of EVs. Consideration of electric vehicle charging infrastructure is covered in this chapter.

There are *5 sections* in this article. Introduction, a correlation of the different types of EV charging technologies systems, a review of the latest trend from *42 journal articles*, the current EV charging market situation, and a conclusion are all included.

1.1. Electric Vehicles Charging Infrastructures

Electric vehicle charging infrastructure (EVCI) is the technology that makes it possible for using electric automobiles (e.g. charging stations). EV recharging service providers are focusing on providing more advanced and reliable e-mobility recharging options to support the development of a virtual environment that connects vehicles, structures, and services. Mini EV recharging strategies are required for EVs to satisfy their goals either now or in the long term. These alternatives need to ensure quick, on-demand recharging in addition to a dependable connection. Three charging levels are determined by voltage level and are compared in **Table 1** shown below.

Table 1: Performance comparison of various charging levels

Levels of Charging		Level 1		Level 2	Level 3
Parameters					
Nature of charging		Slow		Semi fast	Fast
Charger position		On-board		On-board	Off-board
Voltage (V)	**Standard**	US	120	240	208 - 600
		EU	230	400	208 - 600
Current (A)	**Standard**	US	12	17	100 - 200
		EU	20	32 (80)	400
Charging period (hours)	**Standard**	US	4 - 11	2 - 6	0.4 - 1
		EU	11 - 36	2 - 3	0.2 - 0.5
Provider interaction		Convenient store.		Advanced EVSE.	Dedicated EVSE.
Power levels (kW)	**Standard**	US	1.4	4	50
		EU	1.9	8 - 19.2	100
Vehicle technology		EVs (5 -49 kWh).		EVs (2.5 – 48 kWh).	EVs (18 – 49 kWh).
Usage		Domestic.		Private, and Public.	Commercial.

The three main elements of the power storage technology at the EV CS are the battery, the power conversion equipment, and the software (CS). Now let's examine these in greater depth:

- **Battery:** Lithium-ion batteries, which include cells, packs, and battery management systems (BMS) to regulate the recharging procedure of the battery, make up the majority of the batteries at EVCS.
- **Power Conversion System:** Inverters, casing, and thermal protection (HVAC) for batteries are all parts of the power conversion technology for the EVCS. The battery is maintained at a specific temperature by these parts working together.
- **Software:** Software for EV recharging is part of the structure for EV recharging. It helps e-mobility suppliers and managers of charging ports handle EV CS and its clients. Recharging software makes it easier to handle EV chargers at CS (web- or mobile-based). The software used for EV recharging has several crucial features, such as the ability to incorporate and control the charger, analyze data instantly, display real-time meter readings, collect payments, keep tabs on pricing, control clients, and far more.

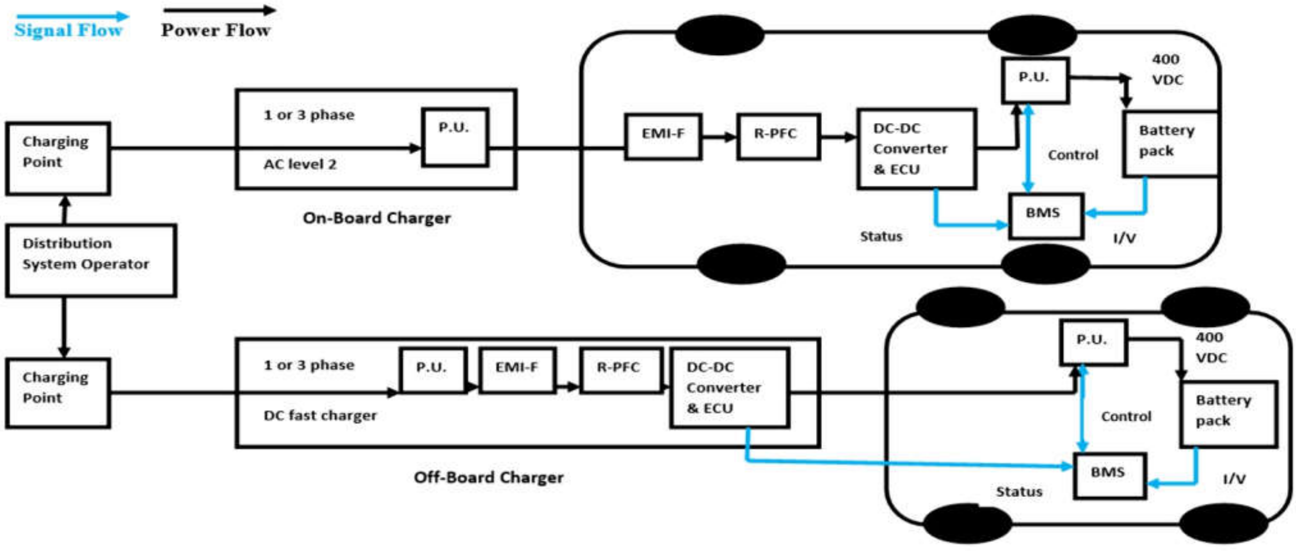

Fig. 1: Electric vehicle charging structures of Onboard, and off-board charging.

Figure 1 illustrates on- and off-board charging systems. The protection unit (P.U.), electromagnetic interference filter (EMI-F), power factor correction unit (R-PFC), electric vehicle control unit (ECU), and battery management system (BMS) are all identified.

Figure 2 illustrates charging methods. Inductive transfer of power (IPT), also known as wireless power transmission (WLPT), and conductive power flow control, sometimes known as wired transferring power, are the two basic classes under which the EV charging infrastructure is divided (WPT). Both have advantages and disadvantages relative to one another. These are further divided into on-board and off-board recharging topologies. While the ESS and EV charger technologies are placed inside the EV at onboard recharging stations, the EV does not have an off-board recharging network.

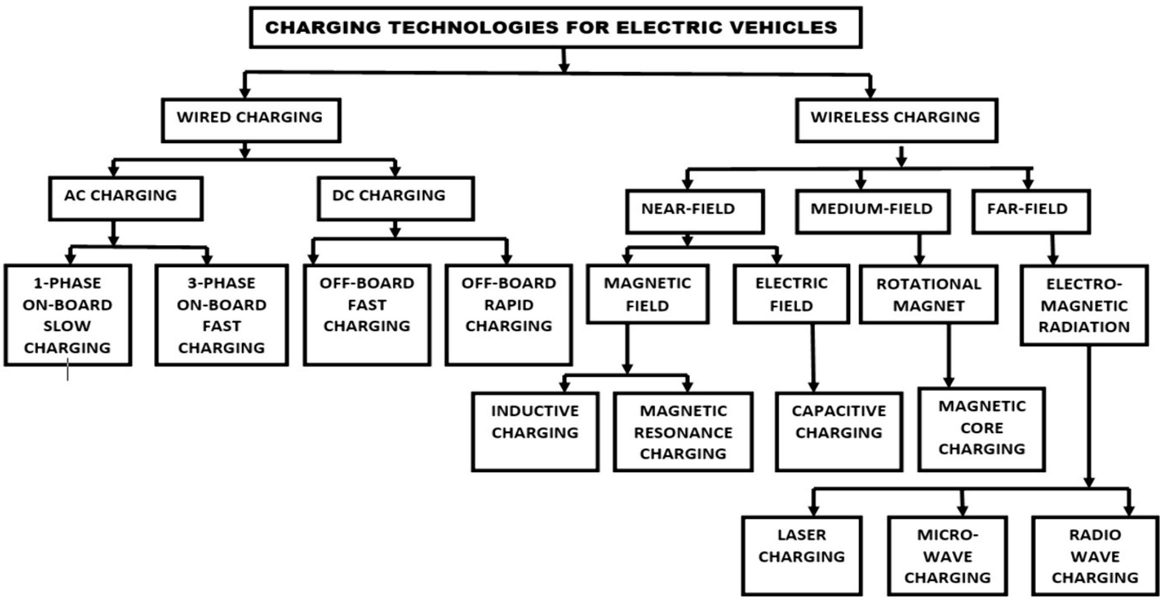

Fig. 2: Classification of electric vehicle charging technologies

- Conductive recharging requires a direct metal-to-metal interface between the power system and the EV in require to transfer energy. This method of recharging is very dependable and efficient. On-board and off-board charging facilities are categorized as having conductive chargers. Due to restrictions on mass, area, dimensions, and price, onboard chargers are built into electric vehicles. However, the power level of these categories of chargers is constrained. Off-board EV chargers, on the other hand, are not constrained in terms of dimension, weight, or area because they are located in public car parks such as those at hospitals, malls, and colleges and are not a necessary component of EVs.
- To transmit energy from the grid to the EV, inductive or wireless chargers use the IPT, or mutual induction, concept. In contrast to conductive chargers, it doesn't call for any physical interaction between the power grid and an EV. However, because of the mismatch of the energy transfer coils, inductive chargers are generally less effective. Inductive chargers are divided into three groups: static inductive chargers, dynamic inductive chargers, and quasi-dynamic inductive chargers. Static inductive chargers have two coils; one is within the charger or outside the EV, and the other coil is a crucial part of the EV. Both coils are correctly aligned to generate maximum effectiveness. With the help of versatile inductive recharging, the EV can be recharged while in motion. This charging method involves constructing on the roadways dedicated recharging tracks that can recharge the EV while reducing range concerns and ESS capability (often motorways). An EV is recharged when employing quasi-dynamic inductive charging each time it stops for a small period, like at a traffic light.

2. COMPARATIVE ANALYSIS OF VARIOUS TYPES OF CHARGING TECHNOLOGY

There are various charging architectures are there such as an ac/dc/dc converters in which vehicles to the grid and vice-versa power flow that place by including the property of renewable energy, & battery energy storage integration with medium energy density, second is multiport with common ac bus in which vehicles to the grid and vice-versa power flow that place with low energy density, third is without transformer only with dc bus in which vehicles to the grid and vice-versa power flow that place by including the property of renewable energy, & battery energy storage integration with high energy density, fourth is without transformer and dc bus in which vehicles to the grid and vice-versa power flow that place by including the property of renewable energy, & battery energy storage integration with high energy density, and with matrix converter in which vehicles to the grid and vice-versa power flow that place by including the property of battery energy storage integration with low energy density.

In **Table 2 - 4**, different cable, wireless, and dc quick charge technologies are compared and explored in turn.

Table 2: Comparison of several wired charging methods

Model	Country	Battery			Charging Criteria			
		Type	Voltage (V)	Capacity (kWh)	Current (A)	Power (kW)	Charging speed	Charging time (h)
Smart Fort Wo ED	France	Lithium-ion	275 - 375	16.9	10, & 30	2 - 7	Slow	7 - 8
Hyundai Ioniq EV	South Korea	Lithium-ion	230 - 340	27.5	30	2.9 – 49.9	Moderate	1 - 13
Mitsubihi iMiEV	Japan	Lithium-ion	355	16	32	2 - 25	Fast	1 - 3
Kia Soul EV	South Korea	Lithium-ion	220 - 340	31	10 - 125	2 - 99	Moderate	1 - 11
Tesla Model 3	USA	Lithium-ion	235 - 355	74	100 - 300	2.9 - 115	Moderate	1 - 8
Tesla Model S	USA	Lithium-ion	450 - 500	100	30 - 400	3.5 - 155	Fast	0.5 - 3
BMW i3	Germany	Lithium-ion	340 - 355	27 - 35	30	3.0 - 49.9	Fast	1 - 6
Nissan Leaf	Japan	Lithium-ion	360	35 - 40	16, & 32	2.8 - 102	Fast	0.5 - 5
Toyota RAV4	Japan	Nickel Metal hybrid battery	225 - 390	40 - 43	25, & 125	3.0 - 49.9	Slow	3 - 16

Table 3: Comparative analysis of various wireless charging technology

Company	Country	Technology level	Model	Charging Criteria					
				Field range	Type	Energy transfer tech.	Maximum Efficiency (%)	Power level (kW)	Maximum Frequency
Conductix -Wampfler	Italy	Public demonstration	Perpetual	Near field	Inductive	Electromagnetic field	70	59.9	30 kHz
Qualcomm halo	UK	Public demonstration	Stationary/ dynamic		Magnetic resonant		80	6.5 - 7.5	20 kHz
ORNL	US	Prototype	Stationary/ dynamical		Capacitive	Electric field	92	2.0 - 3.0	20 kHz
KAIST	South Korea	Public demonstration	Perpetual/dynamic		Magnetic resonant	Electromagnetic field	85	3 - 99	20 kHz
MIT WiTricity & Delphi	US	Commercial Kit	Stationary		Inductive		90	3.0 - 3.5	145 kHz
Evatran	US	Commercial Product	Dynamical		Magnetic resonant		90	3.3	80 kHz
Columbia university	Columbia	Prototype	Static	Medium field	Mechanical	Mechanical force	85	1 - 3	20 kHz
JAXA	Japan	Prototype	Perpetual	Far-field	Laser	Electromagnetic field	35	1 - 5	7.4 GHz
Kyoto	Japan	Prototype	Stationary		Microwave		55	10 - 30	2.45 GHz
Tesla	USA	Prototype	Static		Radiowave		80	5 - 20	30 GHz

Table 4: Comparative analysis of DC fast charging technology

Company	ABB	TRITIUM	PHIHONG	TESLA	EVTEC	ABB
Type	Terra 53	Veefil-RT	Integrated-type	Supercharger	Espresso & charge	Terra HP
Supported protocol	CCS type 1.0 CHAdeMO 1.0	CCS Type 1-2 CHAdeMO 1.0	GB/T	Supercharger	SAE Combo-1 CHAdeMO 1.0	SAE Combo-1 CHAdeMO 1.0
Standard	IEEE 2030.1.1	IEC 62196-3	IEC 62196-3	-	IEEE 2030.1.1	IEC 2030.1.2
Input voltage (V)	400 - 480	350 - 450	360	380 - 480	380 - 420	400
Output voltage (V)	200 - 500	150 - 450	200 - 750	50 - 420	170 - 500	150 - 900
Output current (A)	120	125	240	320	300	375
Power (kW)	45	50.5	110 - 125	130	145	340
Peak efficiency (%)	95	90	93	90	92.5	96
Volume (L)	750	490	590	1050	1580	1900
Weight (kg)	390	160	220	590	390	1320
Time to add 200 miles	65 min	71 min	30 min	25 min	24 min	10 min

3. RESULT & DISCUSSION

3.1. Recent trends overview of EV CS

This chapter suggests an ongoing, movement, spatial EV allocation approach (SEAA) inside a dynamic wireless charging system (DWCS) coordinating (COORD) approach as an alternative to offline, day-ahead charging demand (CD) scheduling [1]. Every unit in the suggested configuration (CNFG) provides a wireless EV charger using a modular multilevel converter grid interconnected (MMGIC) architecture [2]. The study suggests a thorough research and designing instrument for EV infrastructure (EV CI-PAT) that includes solar power (SP) production for small-scale projects for the installation of EVCS [3]. This research uses a Net Logo agent-based strategy to precisely simulate human aggregation behavior and its impact on the load demand caused by the recharging of EVs [4]. This chapter proposes and elaborates a Python-supervised co-simulation for a day-long harmonic assessment of EV recharging [5]. To create interaction amongst EVs, this study suggests a decentralized EV charging control (DEV-CCA) method that may be implemented by the current onboard devices (ECUs) [6]. To size DWC facilities taking into account EV's location-routing, power dispersion network (PDS) losses, and transport network traffic, this article offers a long-term probability scenario-based mathematical formula as well as a Mixed Integer Non-Linear Programming (MINLP) prototype [7]. Magnetic coupling allowed for the DWC recharge between coupled EV(s), and the Charge State Estimator (CSE) was utilized as an untrained machine learning approach to determine each EV's current charging condition [8]. Using the parallelism between mobility needs and the heat equation as applied by the Finite Element Method analysis (FEM), a novel approach to locating EV's CI is provided in this research [9]. In this research, we present an IoV-based platform that incorporates the installation and planning of mobile recharging stations in smart transportation networks (ITS) [10]. The charge planning presented in this work uses multiple aggregators and integrates cooperative EV charging (CEVCS), real scenarios with variable energy purchasing (VEP), and cancellation fees [11]. In this research, a smart Recharging suggestion technique and a supportive framework for mobile edge computing (MEC) are developed [12]. We offer a two-stage approach to offer and size a wide-scale (LS) DC rapid charging unit (FCS) system for the expected energy demand and that reduces the installation costs in order to (DC) [13]. This study offers a holistic model for very-short term hybrid market rate predicting (HMPFM) and Data Clustering Methods (DCT) to increase the predictability of both non-spike and spike wholesale market rates [14]. The goal of this work is to comprehend the possible advantages of a straight V2V charge-sharing feature and MIN energy usage restriction by studying this allocation issue explicitly in a provider non-intrusive situation (without modifying their mobility) (ECL) [15]. This article suggests a real-time smart charging protocol (RT SCA) that can be coupled with a Corporate & Industry (C&I) EVSE host via Building Power Management (BEMS) or with the company back offices through the Advanced Metering Infrastructure (AMI) [16]. In this study, they suggest a blockchain-based network for charging-connected EVs that is confidential and does away with third-party systems [17]. For the connected EV CS architecture and energy DN, a multi-objective, multi-stage collaborative methodology is developed in this research [18]. The system layout and usage administration (MNGT) program for EV CS is proposed as a bi-level MINLP optimization program in this research [19]. The Random-In-Window (RIW) idea, which includes two versions for long-range (LR) and short-range (SR) EVs—fixed rate recharging (RIW-FR) and variable rate charging (RIW-VR)—is proposed and examined in this study [20]. In order to protect the safety of EV clients, they offer Block-EV, a blockchain (BC) based effective CS selection method [21]. To increase the estimation accuracy when investigating a wide state space for refinement, we suggested a redesigned metaheuristic method using three speedup strategies [22]. The current solar (SP) aided level-2 EVCS is governed by a Type-1 vehicular connector, and this article illustrates its architecture considerations and practical application [23].

To examine the recharging frequency and shared recharging degree for the CS, a Non-deterministic Polynomial (NP) framework and an agent-based approach is created [24]. This scheme framework is designed on the A-IoT and utilizes blockchain and dispersed ledger techniques, along with other components, to create a framework that can be used for energy buying and selling, predicting future assessment, sequence-dependent setup governance that is best suited, and immediately allocating power exchanges [25]. The stock for public EV recharging with heterogeneous CS using a time-based invoicing method is the main topic of this research [26]. Effectively install a chargeable network to address the issue, we suggest a multicriteria-oriented strategy in this study, like Lazy Greedy with Direct Gain (LGDG) and Lazy Greedy with Effective Gain (LGEG) [27]. This research suggests a costing structure for CSs in regions with a lot of alternative energy sources. On a test platform created employing actual statistics from the Dublin road system, the pricing technique is assessed [28]. In this article, researchers investigate the recharge issue in a linked-wise CS EV-based automated transit scheme [29]. In this chapter, we examine the effects of such assaults on both dishonest and sincere EVs [30]. In this research, they present an EV charging/discharging procedure that refers to a multi-queueing system with an EVSE (Electric Vehicle Supply Equipment) selection method [31]. The vehicle-to-grid (V2G) procedure described in this study was based on a fleet of EVs that are joined to a decentralized power network via a network of CS [32]. This study examines a bidirectional single-phase, three-level stacked neutral-point-clamped (3L-SNPC) converter for CS scenarios, which, determines the direction of the power flow (PF), can operate as either a rectifier or an inverter [33]. By utilizing our suggested traffic flow-based recharging demand forecasting software, a unique adaptive dynamic wireless CS (ADWCS) is developed that allows mobile EVs to be charged by sustainable wind power [34]. The optimized scheduling of EVs' charging/discharging is developed in this research utilizing the Multi-Objective Particle Swarm Optimization (MOPSO) optimization method with the goal of maximum shaving, valley filling, and flattening the base load curve [35]. In this paragraph, three charging methodologies current (CC), multistage constant current (MSCC), and CCCV algorithm—are used to show the correlation between the charging methodologies in use by EV chargers, the state of charge (SoC) of the batteries, and the harmonic current disturbance produced during the charging process [36]. This study seeks to meet the needs of EV customers while achieving effective planning of the charging period for EVs, minimizing any detrimental network effects [37]. In this chapter, a plan for recharging EVs is put out [38] that takes into account both the specific needs of each EV and the facility's total financial situation.

In a linked traffic-electric network (TEN), this chapter undertakes a multidisciplinary study on the integrated design approach of EV CS [39]. In the study, the information management that transmits waiting time forecasts to customers from the system is connected with the billing need [40]. The material currently available on charging architecture frequently relies on obsolete notions about charging behavior, such as everyone getting access to home chargers and the "Liquid-fuel" mental model [41]. Singh *et al.* [48] presented an extensive review of modern optimization strategies for coordinated EV control in super-smart power grids, highlighting algorithmic efficiency and system reliability. Bindeshwar and Dubey [49] examined distributed power generation planning using EVs, addressing technical challenges and future opportunities. Dubey *et al.* [50] proposed a comparative framework for analyzing DGs and EVs in power DS, while their later study [51] emphasized AI-based techniques for improved DG–EV integration and grid performance. Yadav *et al.* [52] developed a GA–RBF hybrid model to predict EV penetration and its impact on DS. Singh *et al.* [53] contributed a chapter on grid integration of EVs, focusing on charging technologies and infrastructure optimization. Dubey *et al.* [54] analyzed the global scenario of DGs, and Dubey [55] investigated electromagnetic interference effects on network performance. Further, Dubey *et al.* [56] offered a comprehensive review on EV and DG planning, and another study [57] explored the role of EVs in super-smart grids with communication-based control systems.

Dubey *et al.* [58] introduced cognitive intelligence for smart grid management, while their IEEE work [59] reviewed recent developments in energy storage technologies. The group also analyzed advancements in RES [60] and applied decision tree algorithms for evaluating hybrid EV battery charge states [61]. Their studies on automation [62], EV planning trends [63], and solar power scenarios [64] demonstrated broad expertise in sustainable energy systems. Research by Dubey *et al.* [65] explored AI-based MPPT techniques, and Singh *et al.* [66] discussed AI's role in optimizing fuel cell performance. Dubey *et al.* [67,68] examined 5G, 6G, IoT, and Green IoT technologies for intelligent and eco-friendly network operations. In emerging applications, Dubey *et al.* [69] reviewed blockchain technologies for healthcare data privacy, and their Wiley chapter [70] presented advanced trends in EV planning and hybrid vehicle systems. Collaborative works, including textbooks on *Electrical Vehicle Engineering* [71] and *Electrical Machines* [72], contributed to technical education. Additional publications by Dubey *et al.* [73,74] reviewed transformer health monitoring, microgrid switching, and energy management strategies, while the most recent study [75] proposed a hybrid PMLP–PSVM–MLR model for optimizing EV charging, collectively showcasing continuous contributions to AI-driven power systems, smart grids, and renewable energy advancements.

Table 3 (a): Analysis of EV CS scheduling

Ref. No.	Title	Objective	Component	Drawback	Operational Factor	Methodology	Upcoming Plans	ROC
1.	Regarding the COORD of the EV recharging needs in a DWCS system.	MIN is the load fluctuation caused by EV recharging.	EV DWCS.	A small number of DWCS lanes.	Greater than 44% lessens the peak-to-average power ratio.	SEAA.	A large number of DWCS lane analyses.	3
2	MMGIC load rebalancing for large-scale, cordless EV CI without transformers.	Minimize the copper volume and profile.	EV CI.	Low current rating.	After 0.1 s, the intra-arm rebalancing is possible by re-establishing the second harmonic infusion.	MMGIC topology.	Increased current rating of the system.	7
3	EV CI scheduling and optimization using dynamic behavior.	MAX economic benefits.	EV CI, and SP.	Uncertain, and dynamic policies.	Draw current up to 30 A and voltage between 208 and 224 V.	EV CI PAT.	Deep learning was used.	3
4	Accumulated behavior modeling for EV charging load using agents.	Performing sensitivity analysis.	EV.	Data is not so favorable.	Energy in the study ranges from 81 to 57 kW.	An agent-based approach using Net Logo.	Fuzzy membership functions can be used.	23
5	Co-simulation in Python under supervision for a day-long harmonic analysis of EV recharging.	Harmonic emission of a CS.	EV.	Simulation time is large.	Take 2 hours for simulation.	Python.	AI-based techniques.	2
6	DSRC system-based new DEV-CCA in LV DN.	Voltage enhancement and recharging power management.	EV, and DN.	Cost analysis ignores.	The amount of energy usage is 78 kW to 45 kW.	DEV-CCA.	Economic benefits of implementing DEV-CC	1
7	Optimum placement and configuration of a wireless EV CI taking into account traffic and DN.	Cost MIN.	EV CI.	Less accurate.	45% of the total cost reduction.	MINLP.	GA.	1
8	A trustworthy sensor architecture that enables MLT-based variable wireless connectivity for EVs.	Power transfer.	EV.	Latency is there.	The most practical distance where the two EVs can transmit the most power is 1.5 meters apart (s).	MLT.	Expand the suggested paradigm to an EV environment that is diverse.	4
9	Dynamical system for FEMA's design of the EV's CI.	Utilization capability.	EV CI.	City-based.	15000 CS location,	FEMA.	Country-based analysis.	3
10	CI installation and planning in ITS on an IoV basis.	MIN travel distance and charging costs.	CI.	Theoretical Approach.	The ideal price is $7,599.	MINLP, and IoV-based scheduling scheme.	V2G technology was used.	5
11	During variable energy procurement and EV cancellation occurrences, multi-aggregator CEVCS.	Profit MAX.	EV.	Customer choice is missing.	Less than 1% cancellations.	CEVCS.	Willingness factors include.	9
12	A decentralized, time-based suggestion for EV recharging.	MAX communication efficiency.	EV.	Less accurate.	The number of fully charged EVs has decreased from 500 to 300 due to parking restrictions.	MEC.	Multidisciplinary research on ICT is achieved by the incorporation of PN.	6
13	EV FCI demand-aware scheduling.	MIN deployment cost.	EV FCI.	The negative impact of FCS is missing.	Cost reduction by 11%.	Queuing Theory.	Look into the potential harm that LS FCSs may cause.	5
14	DCT and unique HMPFM for EV CS applications.	Improve the accuracy of the wholesale electric price prediction.	EV CS.	The effect of ESS is missing.	The Mean Absolute Percentage Error is 16.11%.	HMPFM-DCT.	Local EV CS probabilistic OPT issue with DESS involvement.	4
15	spatial-temporal direct V2V CS synchronization that is non-intrusive.	MIN ECL.	V2V CS.	Cost analysis is missing.	The suggested matching methods provide a further 80–90% ECL reduction.	Matching algorithms.	Examine the cost using the suggested V2V CS.	8

Table 3 (b): Analysis of EV CS scheduling

Ref. No.	Title	Objective	Component	Drawback	Operational Factor	Methodology	Upcoming Plans	ROC
16	At locations other than residences, RT intelligent recharging of EVs can reduce consumption charges.	Request a price decrease.	EV CS.	A battery system is missing.	For a 30 % EV saturation rate, significant retail, & monthly consumption rates imposed by EVs can be decreased by 20–35 %.	RT-SCA, and BEMS.	Station hosts install battery systems to further reduce demand charges.	13
17	An anonymized blockchain-based recharging mechanism for EVs is called EV-chain.	The suggested system's validity, safety, and secrecy.	EV CS.	Less accurate.	10% security level enhancement.	BCT.	AI-based technology.	26
18	Cooperative stochastic scheduling of the power DN and EV CS.	MIN the investment & operation costs.	EV CS.	RES integration is missing.	The computational cost is 1374s/100 iterations.	FISK's stochastic traffic assignment model, and MOEA/D algorithm.	EV CS integrated with RES.	21
19	Designing the charge stations and utilizing the facilities in a hierarchy.	Maximize the money made by EV recharging.	EV CI.	Less accurate.	The cost of charging has risen by 38.21%.	Bi-level MINLP.	Compare with benchmark technique.	4
20	To lessen the impact of LR EV recharging on older distributing transformers, use VDSCS.	Greater intelligence in recharging will reduce the effect on the grid.	EV CS.	When charging, LR EVs use about 30% more power than SR EVs.	EV saturation levels are as high as 59.9% for LR EVs and 69.9% for SR EVs.	VDSCS-RIW strategies.	Energy consumption mitigation.	6
21	Block EV: A quick and secure way to choose CS for EVs.	Improved scalability.	EV CS.	Low level of security.	Less BC transaction and storage overhead.	BC-based efficient CS selection protocol.	Introducing the privacy-preserving aspect.	7
22	MAX the dimensions and placements of solar-assisted EVCS in metropolitan areas.	Improve the computation efficiency.	EV CS, and SP.	Less accurate.	Once the dimension of the SP with EV is at the MIN can the restrictions be satisfied when is equivalent to 0.4	Metaheuristic schemes.	Adjusting charge requirements using a probabilistic approach.	5
23	System design and realization of an SP EV CS.	Enhance economic development.	SP EV CS.	Expensive.	In this case, it is 0.93. Since it was 0.72, the PFC adjusted it.	Buck converter.	EVs CS with RES.	16
24	Solving location problem for EV CS—A sharing charging model.	MIN is the total vehicle service distance.	EV CS.	Small system analysis.	The chosen CS's recharging frequencies sustain a range of 4 to 7 percent.	NP model.	Large system analysis.	8
25	BC-based intelligent CS MNGT system platform.	Decrease the contractual capacity's CS penalty price by 58%.	CS MNGT.	Less accurate.	Profit will rise by 2.3%, and EV consumers' recharging expenses will drop by 10%.	AI-based-decentralized charging algorithm.	The reliability of the software platform is verified using a real virtual 945 power plant (VPP).	1
26	Game with a hierarchy for connected EV public CS with time-based billing.	MAX has its revenue.	EV CS.	A stability analysis is missing.	The weight factor is 0.2.	BCD algorithms.	Think about CS profitability, EC contentment, and PS stability together.	5
27	Concurrent OPT of CS deployment and recharging pile assigning allow for effective EVCI installation.	MAX the pile's capacity for service.	EVCI.	Expensive.	Improve the utilization rate by 10%.	LGDG, and LGEG.	Cost analysis.	7
28	Variable EV recharging price technique taking highway traffic into account to support RES.	MAX the highway CS's operating effectiveness.	EV charging price.	Less accurate.	Wind energy usage reached 82.97 percent in MAX, and solar energy reached 59.50 percent.	AI-based-charging pricing methodology.	Moderation in system performance takes place.	6

Table 3 (c): Analysis of EV CS scheduling

Ref. No.	Title	Objective	Component	Drawback	Operational Factor	Methodology	Upcoming Plans	ROC
29	A location-aware alternative to games theory-based CS for connected EVs.	MAX revenue.	EVs charging.	No RT analysis.	SOC is increased by almost 17.2%.	Stackelberg game model, and game theory.	Include a range of discharging possibilities in the design.	6
30	Detection of lying EVs in charging coordination using DL.	Fast operating detectors.	EVs charging.	A detector is unable to detect the new attack.	The detectors have a low rate of false alarms and better detection accuracy.	Non-dominated sorting GA.	Evaluated the detector on new attacks.	1
31	A unique queue-based MNGT mechanism for EV charging and discharge.	Utilize the PEV BESS to organize the operations for EV recharging and EV discharging.	EVs.	Less accurate.	ES strategy saving ratio has a peak-to-off-peak occupancy efficiency of 81 percent.	EVSE selection approach.	EV recharging and discharge plans are integrated into a global EV guiding network.	14
32	V2 aggregator to support power grid and reduce EV charging cost.	Cost MIN.	EV charging cost.	Short-time analysis.	By employing the suggested V2G method, recharging expenses are decreased to a mean of £0.34 per day with V2G versus £1.49 per day without V2G.	Advanced energy supervision approach.	Include the aging simulation from a lengthy study.	25
33	Neutral-point-clamped converters for EVCS that are bilateral and 3 levels high.	MIN current and voltage stress.	EVCS.	Less accurate.	The PF inverting also needs about 8 cycles of the network voltage.	3L-SNPC.	PID controllers.	2
34	Integrating RE to maintain low carbon pollution for rapidly recharging EVs.	CO2 pollutants and system costs are subtracted.	EVs charging.	The charging pad design is missing.	The total reduction in carbon footprints is 63.7 percent.	ADWCS model.	Optimum CNGFG of the recharging pads to boost the effectiveness of transferring power.	4
35	Optimum EV CS distribution with an intelligent charging/discharging strategy.	Cutting back on electricity expenditures and PL.	EVCS.	Less accurate.	The DSO's overall value in the SCDM phase is $4.4*10^7$.	MOPSO.	GWO.	6
36	Impact of the SoC on EV CS harmonic distortion.	PQ enhancement.	EVCS.	The harmonic effect is missing.	THD is 33%.	CC, MSCC, and CCCV charging approach.	Evaluate how the harmonic aggregation.	4
37	Ranked approach for the technical and financial improvement of higher absorption EV charging.	Cost MIN.	EVs charging.	Less accurate.	MAX energy consumption can be reduced by 48.9%.	PSO.	AR-IFC proposed strategy, and PSO.	1
38	Routing of energy for a CS that takes EV users' happiness into account.	EV users' economic profits will increase.	EVs charging.	Complex.	The minimum annual electric bill is 8.59 percent.	Single-leader, multi-follower Stackelberg game.	GA.	2
39	EVCS and linked TEN master plan is integrated.	For linked TEN, an overall optimum scheduling approach.	EVCS.	Less accurate.	In very little than a minute, all MILP scenarios are addressed.	MILP.	PSO.	23
40	CI for EVs should be sized and placed optimally under knowledge transfer.	Waiting time analysis.	EV CI.	Less practical.	Predicted efficiency measures, 0.5 minutes of wait period efficiency.	Queuing theory.	Including a more sophisticated recharging behavioral model.	1
41	Effects of recharging habits on energy requirements and BEV CI requirements.	Charging behaviors analysis.	BEV CI.	-	It could be necessary to have a slow charger for between 30 and 150 BEVs.	Large-scale agent-based simulation, and Liquid-fuel mental model.	AI-based model.	1
42	The effect of plug-in behavior on the adaptability of the EV recharging load in terms of space and time.	Evaluation of charging behavior.	PHEVs CS.	Less accurate.	EV customers have the most ability for peak mitigation (up to 80%) and load sharing when they charge when their SOC is below 30%. (up to 80 percent).	Agent-based model.	Research into (potential) traffic flows, regulated recharging, and reward creativity.	1

4. MARKET SCENARIOS:

- The market for EV chargers was estimated to be worth USD 6.99 billion in 2021 and is projected to grow to USD 63.97 billion by 2030, with an impressive growth rate of 27.9% from 2022 to 2030.
- ABB, Robert Bosch, Siemens, Delphi Chroma ATE, Aero-environment, Silicon Lab, Chargemaster PLC, Schaffner, and POD Point are the leading players in the EV charger industry.
- India has 2,700 public charging points and 5,500 recharging connectors by the end of 2022. As per Counterpoint Research, there will probably be 10,000 public charging points throughout the nation by the end of 2025.
- A collaborative analysis by the Indian Venture and Alternate Capital Association (IVCA), Indus-law, and EY predicts that by 2027, there will be 100,000 charging stations, which will be able to meet the demand of the anticipated 1.4 million EVs that would on the road.
- The marketplace for EVs in India was worth USD 1.399 billion in 2021; it is anticipated to increase to USD 112.88 billion in 2029, rising at a growth of 65.92 percent from USD 2.99 billion in 2022.

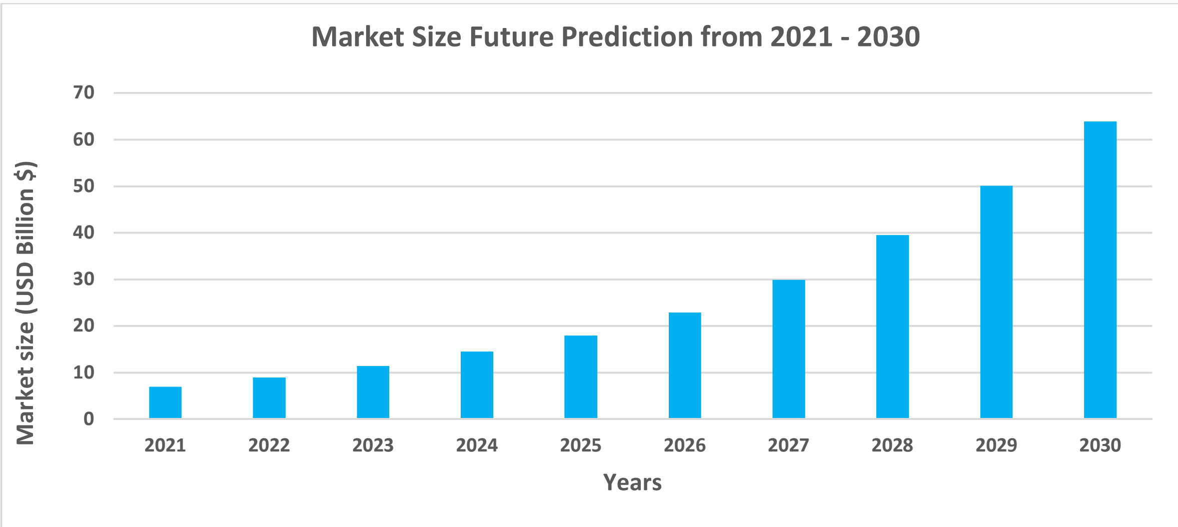

Fig. 4: Market future prediction for electric vehicles charging stations from 2021 to 2030

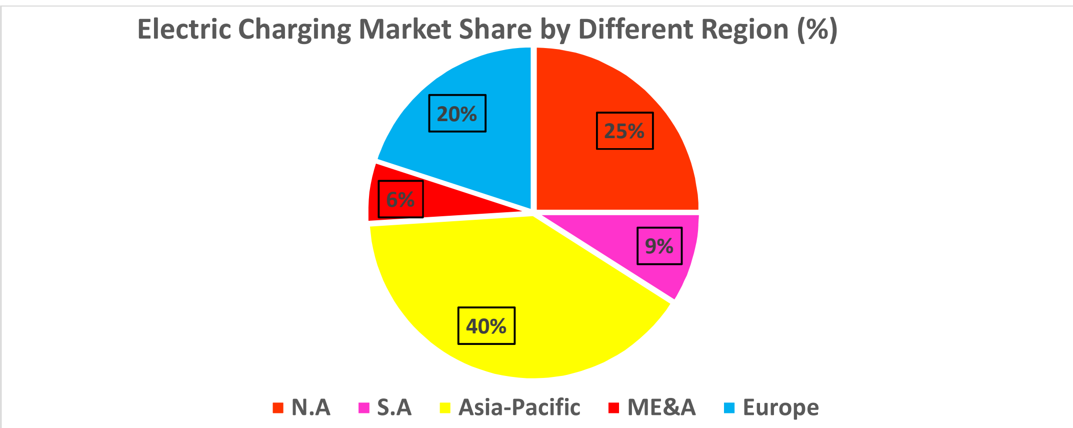

Fig. 5: Electric charging market share by various regions of the world

The industry for EVCS was predicted to be valued at USD 6 billion in the reference period. It is projected to increase at a rate of 45 percent over the ensuing five years, reaching USD 54 billion.

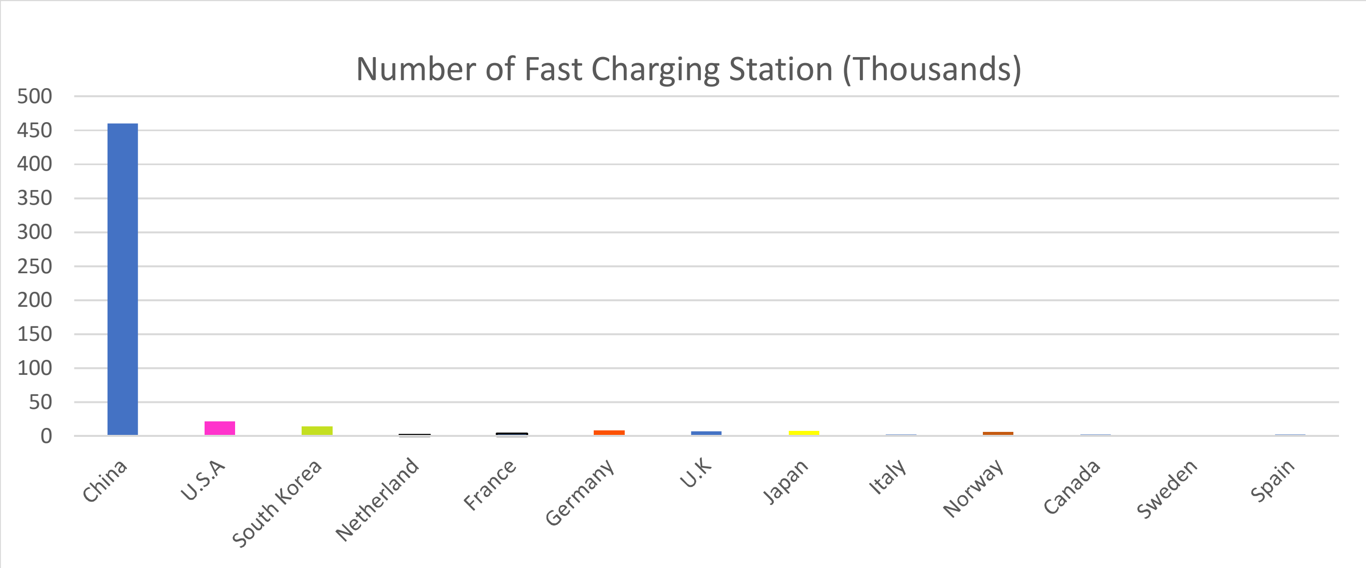

Fig. 6: Number of fast charging stations in various countries (2021-2022)

5. CONCLUSION

The novel EV transportation technology presented in this study is entirely distinct from the IC powertrains now in use. Our trading strategy of EV charging smart metering has several findings that might be drawn. EV recharging requirements affect the transport system as well as the power DS. Many studies have been conducted on the synchronized operation of linked networks to determine the best individual EV routing, traffic flow guiding, etc. The economic factors and social behaviors should also be taken into account, even though the modeling and methods for solving the synchronized operation challenges are the main study priorities. The current research on the topic of establishing the architecture for EV charging mostly concentrates on the location and scaling optimum of several EVCS types, such as FCS, BSS, and WCS. The goal of the design is to satisfy recharging demand at the lowest possible cost; additional considerations could include the safe operation of the power distribution grid, restrictions on traffic flow, or even the interface between connected networks. Investments in EVCS along with RES, ESS, or network strengthening have been researched about the co-planning issue. The issue could be described as a multi-objective instruction set with numerous investment goals, which can be resolved by various tactics.

Future projects might take into account the development of vehicles and modes of transportation, such as shared electric vehicles, fleets that operate on demand, and autonomous electric vehicles. These changes in transportation, when combined with data-driven optimization and machine learning techniques, may present fresh opportunities and challenges for managing the demand for electric vehicle charging, necessitating the development of new techniques for EV infrastructure planning and operation. The advancement of Battery recharging calls for major infrastructure expansion, the incorporation of alternative power supplies, as well as increasing battery technology's power density. Financial theories for open EV recharging should also be established and controlled to enable long-term sustainable growth. In the interim, it is critical to developing the plans, tools, and laws required to handle issues with EV recharging for on-street parking.

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