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A Study on Standards and Charging Infrastructure for Electric Vehicles

***Jinagam Chiranjeevi*[1]*, N. V. A. Ravikumar*[2]**

[1]B. Tech Student, Department of EEE, GMR Institute of Technology, Rajam-532127, Andhra Pradesh, India
[2] Sr. Assistant Professor, Department of EEE, GMR Institute of Technology, Rajam-532127, Andhra Pradesh, India
Email: 21341A0239@gmrit.edu.in [1], ravikumar.nva@gmrit.edu.in [2]

ABSTRACT –

Over the past ten years, one of the primary research fields has been transportation electrification. The market share of traditional internal combustion engine cars is being surpassed by electric vehicles (EVs). There are more charging stations due to EVs' growing popularity. We will learn about the infrastructure and regulations for charging electric vehicles in this. Globally, there are several standards pertaining to EV charging infrastructure. Worldwide, SAE and IEEE are the two main standards that are adhered to. Power, control, and communication infrastructures make up most of the infrastructure needed for EV charging. In this, we pay particular attention to an electric vehicle's charging infrastructure. electricity infrastructure is categorized according on the kinds of electricity utilized, charging circuit accommodations, criteria for physical contact and the direction of power flow. The core component for real-time EV charging monitoring and control is a control and communication system. Mobility, coordination, and control structure may all be used to categorize the control structure of EV charging, which includes EVs, EV charging stations, and the distribution grid. A smart EV charging management system requires an efficient communication system between EVs, electric vehicle supply equipment (EVSEs), and the grid. Wired and wireless communication technologies fall under the category of communication protocols. Ultimately, this study offers insightful information on the ever-changing world of EV standards and infrastructure for charging them.

***Key Words*:** Standards, charging infrastructure, Power infrastructure, Control, and communication, charging stations, wired communication, wireless communication.

1. INTRODUCTION

The accelerated global shift towards sustainable transportation has placed an unprecedented focus on the development of electric vehicles (EVs) as a possible alternative to traditional internal combustion engine vehicles. As the electrification of the automotive industry gains boost, one of the most crucial components underpinning the success of this transition is the establishment of standardized and efficient charging infrastructure for electric vehicles. This report talks about the critical intersection between standards and the charging infrastructure of electric vehicles.

This paper analyses the multifaceted dimensions of charging infrastructure standards, exploring their impact on the development of a reliable and accessible charging network. It further talks about the technological advancements driving the standardization process and the strategies employed by industry leaders and policymakers to streamline the integration of standardized charging solutions. The global transition towards sustainable mobility has gained significant momentum in recent years, with a pronounced shift towards the adoption of electric vehicles (EVs) as a promising solution to mitigate the environmental impact of traditional internal combustion engines. The widespread acceptance of Electric vehicles is notable for their potential to reduce greenhouse gas emissions and their dependence on fossil fuels**,** thereby contributing to the global efforts to combat climate change and improve air quality.

2. LITERATURE REVIEW

Electric vehicles (EVs) have witnessed a surge in market dominance, gradually eclipsing conventional internal combustion engine vehicles. The escalating preference for EVs has led to a proliferation of charging stations, significantly impacting the electricity grid. To mitigate the adverse effects of EV charging and optimize the integration of EVs into the grid, diverse charging strategies and grid integration methodologies are under development.

It introduces the current status of EVs, presenting a comprehensive review of critical international EV charging and grid interconnection standards. Various configurations of infrastructure, encompassing control and communication architectures for EV charging, undergo scrutiny and assessment. Moreover, the paper delves into the study of the electric power market by delineating the roles played by EV aggregators and individual EV owners. It explores diverse optimization and game-based algorithms employed for managing EV grid integration. Special attention is dedicated to evaluating the potential impact of future EV advancements, such as connected vehicles, autonomous driving, and shared mobility, on EV grid integration. Additionally, it investigates how the evolution of the power grid towards the future energy Internet and the integration of EVs would mutually influence and bolster each other.

3. STANDARDS FOR ELECTRIC VEHICLE

Globally, there exists a multitude of standards governing Electric Vehicle (EV) charging infrastructure. In the United States, manufacturers adhere to SAE and IEEE standards, while European manufacturers predominantly follow the IEC guidelines. Japan utilizes the CHAdeMO standards for EV charging, while in China, the Guobiao (GB/T) standard is employed for both AC and DC charging. Published by the Standardization Administration of China, the Chinese National Committee of ISO, and the IEC, GB/T AC charging standards align closely with IEC standards. The IEC and SAE standards are extensively detailed here due to their extensive implementation.

Table 1 lists the international regulatory agencies and the standards they have set to regulate various EV-related issues [1]. Three categories of standardization are identified from the table i.e. safety standards, Electric Vehicle Grid Integration (EVGI) standards, and EV charging component standards. The International Organization for Standardization (ISO), one of the organizations that standardizes EV charging components, focuses on standardizing EVs overall

Table 1

Regulatory organizations and standards associated with EV.

Organization	**Standards**	**Details**
International Electro-technical Commission (IEC), Britain	TC21	Standard for all secondary cells and batteries regarding dimension, performance safety, testing, installation & maintenance.
	TC22	Standard for power electronic systems, equipment and their component design, control, protection, monitoring, and measurement.
	TC64	Standards for installation and coordination of equipment for protection against electric shock due to equipment installation error and high voltage supply. For different types of EDVs
	TC69	Standards related to general charging requirements
	IEC61851	Standards for wireless power transfer (WPT) for EVs.
	IEC61980	Standards for plugs, sockets, and connectors for EV conductive
	IEC62196	
Society of Automotive Engineers (SAE), United States	J2293	EV and off-board EV Supply. Device requirements via the public power grid.
	J1772	Conductive charging standards.
	J1773	Contactless charging standards.
	J2847	Communication standard between EV and utility grid, and off board DC charger.
	J2931	Digital communication standards between EV and utility grid.
	J2954	WPT for EVs.
	J2894	Requirements for power quality and procedure testing for EVs.
Japan Electric Vehicle Association (JEVA), Japan & CHAdeMo (Charge de Move) Association	C601	Charging plugs and receptacles standards.
	D001-002	Battery characteristics for EV are standardized.
	D701-709	Battery testing Introduction.
	G101-105	Standards for Quick charging.
	G106-109	Standard Contactless charging
Institute of Electrical and Electronics Engineers (IEEE)	P1547	Different aspects of grid connection of DERs standards.
	P2100.1	WPT and charging system standardization.
	P2030	Standard for addressing the interoperability of smart grid.
Underwriters Laboratories (UL)	UL2231	Protection devices requirements for EV charging circuits.
	UL2251	Requirement for charging plugs, receptacles and couplers
	UL2202	Charging system equipment requirements.
	UL2594	Supply equipment requiremts.
	UL1741	Specifications for inverter, converter, charge controller and output controllers used in power system
	UL1741 SA	Supplement draft of UL 1741, defining safety requirements of inverters for grid stability.
	UL62109	Safety requirements of inverters used in grid connected photovoltaic systems.
National Fire Protection Association (NFPA)	70	Safety standards for grid integration of DERs.
	70B	Contains safety measures for electrical equipment maintenance.
	70E	The electrical safety standards in workplace.

National Electric Code (NEC)	625 626	Off board charging system safety standarrds, such as conductors, connecting plugs and inductive charging devices. Parking lots requirements for electrified trucks, including conductors etc.
Deutsches Institute fuer Normung (DIN), Germany	43538 EN50620 VDE0510-11	Battery systems specifications. Specification for Charging cable. Li-ion batteries specification and testing procedure.

4. ELECTRIC VEHICLE CHARGING INFRASTRUCTURE

Electric vehicle supply equipment (EVSE) is the basic unit of EV charging infrastructure. The EVSE accesses power from the local electricity supply and utilizes a control system and wired connection to safely charge EVs. In general, the overall EV charging infrastructure comprises power infrastructure and control and communication infrastructure.

4.1 Power Infrastructure in EV charging

The power infrastructure Fig 4 provides an electric circuit or system for power flow between EVs and the grid. It can be classified according to the types of power used, accommodation of the charging circuit, physical contact requirements, and power flow direction. Fig 1 shows the classification of power infrastructure of EV.[1]

4.1.1 Types of power used

EV charging utilizes two primary power supplies: AC (alternating current) and DC (direct current). AC charging varies in voltage and frequency, contingent upon the power system of the respective country. Voltage-wise, AC charging is categorized into Levels 1, 2, and 3, with Level 3 boasting the highest charging voltage. Levels 1 and 2 charging setups can be installed at private locations. However, Level 3 installations necessitate separate wiring and transformers, mandating permission from utility providers, typically found in public charging stations.

Within the same voltage range, DC charging stands out for its swifter charging capabilities and usually accommodates higher power capacities. The latest DC fast charging (DCFC) technology can completely charge an EV in as little as 20 minutes, highlighting its efficiency compared to AC charging methods.

4.1.2 Accommodation of charging circuit

The charging circuit can be integrated in two primary ways: within the vehicle itself (on-board charging) or within a designated charging station (off-board charging), as illustrated in Fig 6. An on-board charger allows EV owners to recharge their vehicle batteries wherever a power supply is accessible. It boasts a compact size, lightweight build, and affordability. However, its limited power delivery capacity to EVs results in longer charging times, potentially impacting driver satisfaction.

Conversely, an off-board EV charger isn't as constrained by weight and size concerns, enabling the facilitation of multiple charging modes, including both slow and fast charging schemes within the same infrastructure. Nonetheless, the installation of off-board chargers can incur higher expenses due to accommodating various charging schemes within a single charging station.

Beyond the on-board and off-board charging options, wireless charging represents a third type of system. In this setup, energizing coils are positioned external to the vehicle, while the receiving coil and converter are housed within the vehicle. This wireless charging method offers convenient power transfer between charging stations and EVs.

4.1.3 Physical contact

Regarding physical contact during charging, charging topologies fall into two categories: conductive and contactless charging. Conductive charging involves a direct physical connection between the power supply and the onboard battery, while contactless charging transfers power without any physical contact.

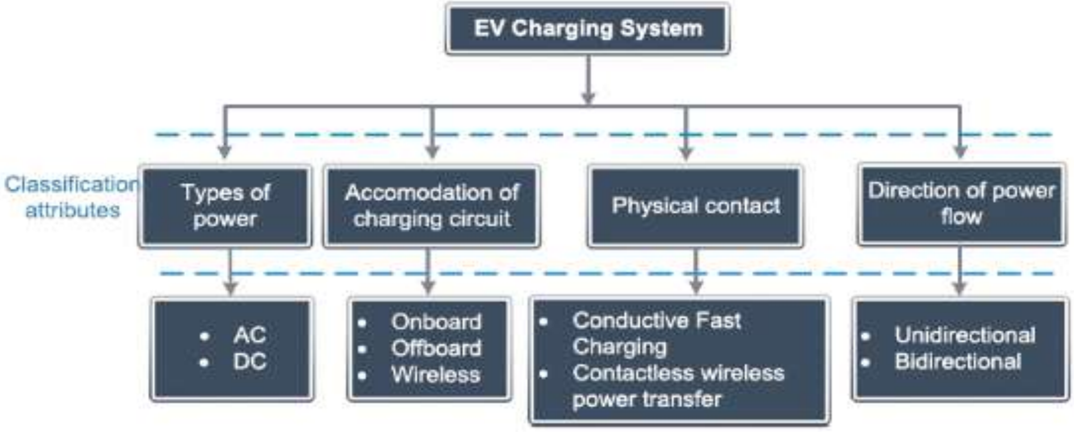

Fig 1. Classification of Power Infrastructure

In contrast, contactless charging systems typically utilize Wireless Power Transfer (WPT) technology to charge the battery. WPT systems can function across various voltage levels (Levels 1, 2, and 3) with power ratings reaching up to 20 KW, boasting

an efficiency of up to 90%. Based on charging technology, WPT can be categorized into four types: resonant inductive, inductive, capacitive, and low-frequency permanent magnet coupling power transfer.

4.1.4. Directional of power flow

EV chargers can be categorized based on the direction of power flow, dividing into unidirectional and bidirectional types. Unidirectional EV chargers employ a diode rectifier and unidirectional DC-DC converter for charging control. Their simplicity makes them easier to control compared to bidirectional chargers. Unidirectional chargers offer benefits such as reduced battery degradation and fewer interconnection complications. However, they lack the capability to provide most grid ancillary services.

4.2. Control infrastructure in EV charging

The core component for real-time monitoring and control of EV charging is the control and communication system. Despite EV charging introducing an extra load demand to the power system, effective scheduling can mitigate peak demand and minimize charging costs. This is achievable through adept management and coordination of EV charging stations connected to the grid, guided by the specific control architecture and communication infrastructure. Fig 2 shows the classification of control infrastructure in EV charging. [1]

4.2.1 Vehicle mobility consideration

Regarding EV charging infrastructure, it can be categorized into static and dynamic charging. Static charging involves the vehicle being parked at a charging station during the charging process. In contrast, dynamic or mobility-aware charging schemes consider various temporal movements, such as vehicle arrival and departure times, trip history, and any unforeseen instances of EV arrival or departure. This approach is more realistic as it considers both spatial and temporal relations of EVs but is more intricate and necessitates advanced control infrastructure.

4.2.2. Charging co-ordination

In the realm of EV charging, two approaches are prevalent: uncoordinated and coordinated charging control. Uncoordinated charging involves EV batteries initiating charging immediately upon plugging in or starting after a user-set fixed delay, continuing until fully charged or disconnected. While convenient, uncoordinated charging exacerbates peak-hour loads, potentially leading to overloads in distribution transformers and cables. This method can escalate power losses and compromise grid reliability. To counteract this, some utility companies offer dual tariffs, incentivizing EV owners with cheaper night rates to alleviate peak loads.

Conversely, coordinated or smart charging optimizes both time and power demand, curtailing daily electricity expenses, voltage fluctuations, line currents, and transformer load surges. A straightforward coordinated charging method involves off-peak charging, scheduling EV charging during periods of minimal grid load. Although this addresses overload issues to an extent, obtaining specific time information from utility providers becomes necessary.

4.3 Communication network for EV charging

An effective communication system between EVs, EVSEs and the grid is necessary for a smart EV charging management

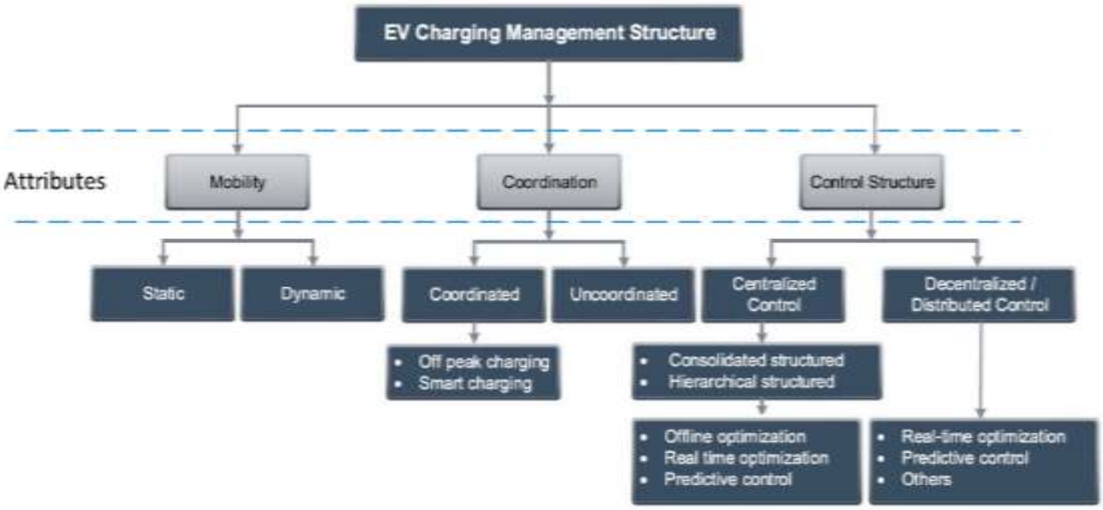

Fig 2. Classification of control infrastructure in EV charging

4.3.1 Wireline Communication

Wireline technologies are well-suited for long-distance data transfer, ideal for EV charging stations spread across expansive urban areas. Optical and Digital Subscriber Line (DSL) protocols also feature prominently in wireline communication systems.

Optical communication protocols boast significantly higher data rates, reaching several Gbps, and offer extended transmission ranges of several kilometers compared to PLC.

4.3.2 Wireless Communication

A comprehensive communication structure necessitates wireless communication, especially for data exchange between vehicles and charging stations. This medium serves as a primary avenue to relay charging status information to EV users. Wireless communication networks are established utilizing Wireless LAN devices in a hierarchical mesh structure to interconnect electrical devices. In the realm of EV grid connection, prevalent wireless communication technologies encompass Zigbee, cellular-Wi-Fi, WiMAX, and satellite networks.

5. CONCLUSION

In conclusion, the investigation into the standards and charging infrastructure of electric vehicles has underscored the critical significance of standardized protocols in facilitating the seamless integration and widespread adoption of electric mobility. The analysis has illuminated the pivotal role of uniform guidelines and interoperable technologies in ensuring the accessibility, safety, and efficiency of charging infrastructure across diverse networks and geographical regions. The evolution of standardized charging solutions is essential not only for addressing the technical complexities of electric vehicle charging but also for fostering consumer confidence and driving the transition towards sustainable transportation alternatives.

As the global community continues to prioritize environmental sustainability and decarbonization, the establishment of robust standards and interoperable charging infrastructure remains a fundamental prerequisite for the widespread adoption of electric vehicles. By embracing a collaborative and forward-thinking approach to standardization, the vision of an integrated, reliable, and universally accessible charging network for electric vehicles can be realized, paving the way for a cleaner, greener, and more energy-efficient transportation landscape.

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