Electric Vehicle Charging Station Challenges and Opportunities: A Review

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***Abstract*—Following the environmental crisis, Electric Cars (EV) are the appropriate substitute for Internal Combustion Engine (ICE) vehicles. However, focusing just on EVs is inadequate since the deployment of these vehicles also necessitates the installation of Electrical Vehicle Charging Stations (EVCS). Because these automobiles run on electricity, installing charging stations involves a number of challenges. Grid overload and load forecasting were once major challenges. The latter pertains to charging station traffic-crowd management and charging time. This paper defines key charging station concepts such as charging station types and levels. Several approaches are offered to address these difficulties, as well as a brief overview of lithium-ion battery charging schemes and the Battery Management System (BMS). The deployment of EVs and the building of EVCS is critical because the Indian government is concentrating on developing a more ecologically friendly ecosystem and as part of its goal to decrease carbon emissions from the transportation sector. This is a straightforward task given that the government has reduced the tax on EVs and granted incentives for charging station construction. As a consequence, this document contains several laws established by the Ministry of Power and the Ministry of Housing (Government of India) that may aid a person in putting up a charging station at their site.**

***Index Terms*—Electrical Vehicle (EV); Electrical Vehicle Charging Station (EVCS); Renewable Energy Sources (RES); Smart Grid; Battery Swapping Station (BSS); Intelligent Transport System (ITS); Vehicle to Grid (V2G).**

I. INTRODUCTION

With the increase in carbon emission, global warming and oil crisis in all over the world a revolutionary change can be identifiedinthefieldofautomobilesintermsofshiftingofICE basedvehiclestoEVs.SinceoilistheprimaryfuelusedinICE vehicles which is the major reason of global environmental crisis, EVs are the best alternative [1]. Apart from being eco-friendly these vehicles can provide other advantages like less moving parts, high starting torque, high power density, good efficiency, etc. by replacing internal combustion engine from electrical motors like DC series motor, brushless DC (BLDC) motor, permanent magnet synchronous motor, induction motors, switched reluctance motor (SRM) [2]. The main power source to these motors is electrical batteries. Themajor challenge for these electrical vehicles is charging of these batteries in minimum time and for which electrical vehicle charging station plays a vital role. Charging station can be of various types depending upon the level of charging [1]. There are various standards codes like Society for Automobile Engineers(SAE),InternationalEnergyAgency(IEA),Institute of Electrical and Electronic Engineering (IEEE), International Electromechanical Commission (IEC) and International Organization for Standardization which provides the guidelines and voltage level to charge the vehicle according to its rated capacity[1].

There are various challenges to deploy Electric Vehicle Charging Station (EVSE). Day by day the numbers of vehicles are increasing on road and that requires more electrical power. This will pressurize the grid to supply more electrical power which can overload the grid and the generation of power will have to increase which if generated using fossil fuels will equally harm the environment as that of ICE vehicles [3]. Apart from that, overloading of grid can cause voltage regulation issue, voltage fluctuation, increase in peak demand, reliability and efficiency of the system will decrease, thermal loading will increase and most important affect can be seen on load forecasting. Load Forecasting is very crucial in the electrical distribution system for determining how muchpower is to be generated by calculating the peak load and base load [1], [3]. But after the deployment of EVs and EVCS, the load forecasting of the system is becoming difficult as calculation ofthevaryingloadisbiggestchallenge.

Byungchul Kim, [4] develop a smart charging architecture between electric vehicle and smart home in which the system is comprises of sensors and processors which can help a lot in vehicle to grid(V2G) technology by setting a communication channel in between. By the help of this technology proper monitoring of the load due to charging of vehicle can be monitored. With the help of V2G technology and Intelligent TransportSystem(ITS)thewaitingtimeatthechargingstation can also be reduced and Dimitrakopoulos.G [5]discussed about the internet of vehicle concept and automatic management algorithm for vehicles in which with the help of Information and Communication Technology (ICT) vehicles, grid and charging station can communicate with each other on the basis of IP- based level. This can help in reduction of traffic congestion and long queue problems at EVCS Charging time of the vehicle is also one of the biggest challenges in the development of the EVs. Lithium ion batteries are used as a storage medium of electrical energy in these vehicles and these batteries use graphite for storing charge. To increase the charge storing capacity of lithium ion batteries silicon is added in graphite layer. Proper charging of the batteries isvery necessary for its long life. Since charging a lithium ion battery is a very sensitive process as overvoltage and overheating can cause a severe problem hence there are various charging strategies like Constant Current, Constant Power, Constant Voltage, Constant Current Constant Voltage and multistage charging [6]. Kodali S and et al. [7] discusses the five level charging scheme of the lithium ion batteries in which five different levels of current as per the voltage limit is used to charge the battery. But while charging these batteries proper monitoring of the State of Charge (SOC) of battery is required which shows how much battery is charged or discharged. For monitoring purpose and smooth operation of process Battery Management System (BMS) is used. BMS not only monitors the charge density and SOC level but it also provide the information of the temperature and failure of each lithium ion cell present in the battery [8], [9], [10]. BMS and SOC level can help in forecasting the load using the Internet of Things (IOT) which can help in overcome the problems of power quality andreliability.

II. ELECTRIC VEHICLE CHARGING STATION

EVCS is a place where the charging of EV takes placewith proper safety, monitoring, conversion system and with high voltage and current for the fast charging. Some of the basic terminologies related to EVCS are.

A. Types of ChargingStation

1) Residential Charging Station: To enter in the era of EV, residential charging station is very important as it will reduce the load on the grid at a great extent. The residential charging of vehicles can be done by drawing less current from the grid which will help the grid to overcome the demand of extra voltage at peak load hours. According to [11] charging of EVs at night hours is the best time to charge a vehicle and is very effective in terms of cost and impact on grid. It reduces the load on grid as it is the base load hours and charging vehicles in night time also reduces per unit cost of electricity. Vehicles can easily charge within 7 to 8 hours by Level 1 charging in residentialchargingstationasshowninTable. I.

2) Parking Charging Station: Charging a vehicle is a time taking process but by utilizing the time while parking a vehicle will reduce the stress on the public charging station as well as on grid. According to National Household Travel Survey, vehicles are parked around five hours in a dayat work place [12]. Apart from work place this facility is also taking place at restaurants, shopping malls, library etc. with proper charging infrastructure policies. Existing parking lotare converted into smart charging parking lot having connectivity with the internet for slot booking and traffic enquiry at parking area[13].MainlyinsuchplaceLevel2chargingisusedhaving bothsinglephaseandthreephaseslot[14].

3) Public Charging Station: The provision of public chargingstationisintroducedtoprovidefastchargingtothevehicles as normal charging takes more time to charge a battery. With the help of various charging topologies and fast charger configuration fast charging is carried out. Mainly in a charging station the charger consists of AC-DC converter at front end and DC-DC Converter at back end. Both the converter is connectedviaDClinkcapacitor[15].

Chargers having high frequency switching rectifiers are made up of MOSFET and IGBT that works on the principle of Pulse Width Modulation (PWM) scheme. PWM scheme provides power conversion with high efficiency and precision and it also control the output voltage by maintaining the power factor near to unity [16]. Due to the presence of power electronics devices charging a vehicle can cause power quality issues like harmonics, voltage imbalance etc. For this the connection of charger by power grid is done by using a filter of good quality which will resist the harmonics to effect the gridaswellasmotorconnectedtovehicle[15],[17].

4) Battery Swapping Station: To overcome the problem of time taken in charging and the urgent requirement of charged vehicle Battery Swapping Station (BSS) was introduced. In a BSS vehicle's discharged battery or battery pack can be immediately swapped by a fully charged one, eliminating the delay involved in waiting for the vehicle's battery to charge. The BSS takes care of the battery life by monitoring it using BMS. It determines the energy density of battery along with the SOC level [18]. There are various challenges while deploying a BSS. Battery design is one of the major issues which can be resolved by designing battery pack in a specific way so that it can easily and rapidly removed from vehicles and so rapidly re-attached. Another challenge is brand compatibility of the battery packs. For this a common standard format can be used by the manufactures so that the interchangeable battery packs can be manufactured for BSS and EVs. There are also battery degradation issue and battery ownership issue which is the main obstacle in the BSS technology.

B. Levels ofCharging

As per various international standards and codes for charging vehicles the level of charging are given in Table I [1].

C. EV ChargingSystem

The EV charging systems can be classified according to the mode of energy transfer such as: conductive charging systems and inductive charging systems.

1) Conductive Charging: This charging system uses direct contact between the vehicle and charger using a cable or connector.Thisisthebasicinfrastructureofthecharging

TABLE I. CHARGING LEVELS [19], [20], [21]

Level of Charging	Phase	Type of Charger	Usage and Location	Power (kW) and current(A)
As per SAE standard for AC and DC charging				
Level 1: Vac= 230V (EU) Vac=120V(US)	Single Phase	On Board	Residential and Office	1.4kW/12A , 1.9kW/20A
Level 2: Vac= 400V (EU) Vac= 240V (US)	Single/Three phase	On Board	Public and Private	4kW/17A , 8kW/32A
Level 3- Fast: Vac:=208-600 V	Three Phase	Off Board	Commercial and Filling Station	50kW , 100kW
DC Power Level 1: Vdc= 200-450V		Off Board	Dedicated Charging Stations	40kW/80A
DC Power Level 2: Vdc= 200-400V		Off Board	Dedicated Charging Stations	90kW /200A
DC Power Level 3: Vdc= 200-600V		Off Board	Dedicated Charging Stations	240kW /400A
As per IEC standards for AC and DC Charging				
AC Power Level 1	Single Phase	On Board	Residential and Office	4-7.5kW/16A
AC Power Level 2	Single/Three phase	On Board	Public and Private	8-15kW/32A
AC Power Level 3	Three Phase	On Board	Commercial and Filling Station	60-120kW/250A
DC Rapid Charging		Off Board	Dedicated Charging Stations	1000-2000kW/400A
CHAdeMO Charging Standard				
DC Rapid Charging		Off Board	Dedicated Charging Stations	62.5kW/125A

station now. It can be On-Board charging or off boardcharging depending upon the level of charging. This type of charging provides better efficiency and almost all the electric vehicle company provides the facility of such charging. Conductive charging systems are currently available in vehicles such as: Nissan Leaf, Chevrolet Volt, Mitsubishi i-MiEV and Tesla Roadster [1],[6].

2) Inductive Charging: A new emerging concept named as inductive charging or wireless charging in which no physical contact or linkage is provided between the vehicle and charger is in growing phase. It works on the principle of the electro-magnetic induction same as the principle of the transformers. [6], [22].The wireless transmission charging is carried out by determining the distance between the primary and secondary coil. Magnetic field is used to transfer energy through thin air The only drawback is that its efficiency and power density is very low as compare to the conductive charging and cost is high [1]. But it is convenient in terms that charging can be carried out without hassles of plugging and unplugging of the heavy charging plugs. Vehicles can be charged irrespective of thesizeandcompatibilityoftheconnector.

By incorporating charging strips at the highway the vehiclescan be charged while driving also. This is called as dynamicwireless charging. Roads that are capable of supplying electricpower to electric vehicle using wireless power technique(WPT) are called electrified roads or charging lane [1], [23].Charging while driving technique will reduce the chargingtime of vehicles at stationary position [1]. This method isongoing at various countries and more researches are going on to increase its efficiency [24].

D. ChargingTime

Charging time is one of the biggest challenge in the EV technology. Recharging time of the battery is higher than refueling time of oil in ICE vehicles. To reduce the charging time there are mainly 5 factors discussed below that affect the fast charging of system [25].

- Size of the battery: The charging time will increase as the capacityorsizemeasuredinkWhwillincrease.Bigger the battery more time it will take to charge the battery.
- State of charge (SOC): SOC of the battery helps to determine whether battery is fully charged, fully discharged or partial discharged and according to that the charging timevaries.
- Maximum charging rate of vehicle: The vehicle can be chargedatamaximumrateofchargeonlyandnotbeyond that. Suppose if the maximum rate of charge of any battery is 22kW than it cannot be charged using a 50kW chargepoint.
- Maximum charging rate of the charge point: The time of charging depends on the rating of outlet where the battery is connected. To charge a battery of 22kW if a 7kW outlet is connected it will charge it in same rate as of7kWthatmeansthechargingtimeincrease[25].

Normally the charging time is 8 hours if the battery is charged from a 7kW charger and it can be used till 60 miles. Table II summarizes the time required to charge a battery of different company vehicle with different rate of chargers. Where, Model I: Nisan Leaf 2018, Model II: Tesla Model S 2019, Model III: Mitsubishi Outlander PHEV 2018 respectively.

TABLE II. CHARGING TIME OF VEHICLE [25].

Model	Battery Capacity (kWh)	Range (miles)	Charging Time(hours)				
			3.7 kW	7 kW	22 kW	43-50 kW	150 kW
I	40	143	11	6	6	1	NA
II	75	238	21	11	5	2	1
III	13.8	24	4	4	4	0.66	NA

III. RECENT TECHNOLOGIES FOR EFFICIENT SYSTEM

Deployment of large number of charging station increases the need of electrical power. So more the power will be drawn from the grid, grid will become overloaded and due to which various power quality issues rises like voltage fluctuation, voltage regulation issue, peak demand issue, reliability and load forecasting. All these issues affect the overall efficiency ofthesystemwhichisnotadmissiblefordevelopmentofEV and EVCS. So to overcome these challenges there are various technologies introduce as:

A. Smart GridTechnology

The problem of uncoordinated power supply and reliability can be minimized to a certain extent by using the smart grid technology. The smart grid set up a communication channel between the grid and the user for proper monitoring of load as per the area [26]. By the implementation of smart grid safe operation of system can be assured as at each feeder the remote terminal units are installed which send the information of any fault condition as well as the usage of power at each feeder. This technique can give prior information to grid about the load so that at generation end smooth generation can be assured and thus no reliability issue takes place [26], [27]. Moreover this technique is also helpful in forecasting loadand linked with the vehicle so that the SOC of a battery can be shared with the grid and according to the SOC percentage the grid can trace the nearby charging station to which feeder the load is going to add [27]. Now, when distributed energy generation is at its peak, smart grid works as an extraordinary techniquetoprovideproperloadandgenerationestimation.

B. Renewable EnergyTechnology

Fossil fuels are the major reason of degradation of environment and these are the major source of electricity generation today. Adoption of more EVs requires more electrical power. So it is not a wise decision to again use these fossil fuels in different manner to fulfill the needs. Renewable sources of energy are the best alternative for charging EVs as these sources will reduce the carbon emission as well as the load on the grid [28], [29]. Among all renewable sources of energy solar energy is the easiest and cheapest form available at various part of the world today. Installing the solar plant at residence level is also easy and safest mode of obtaining electricalpower.Solarpanelscanbeinstalledontheroofofthe public EVCS, shopping malls, office and other places having large surface area so that direct load on the grid can bereduced [28]. Although installing solar plant on roof top is bit costly initially but its running cost is very cheap so it also decreases therunningcostofEVsascomparetoICEbasedvehicles.

C. Vehicle to GridTechnology

To keep the power system balance there should be a balance between the active power and frequency as the overloading and under loading can create an issue of frequency mismatch which can affect the systems stability. So it is recommended to use bidirectional energy flow system where the grid supply power to vehicle and when not in use the vehicle feed the power to the grid. This system is also called vehicle to grid system or V2G system [30]. Statistics says that 90 % of electrical vehicles are idle every day and they can be helpful to meet the high energy demand by supply power back to grid [31]. Automatic generation control (AGC) was introduced to controlthemodernpowernetworktokeepabalanceofvarying load. Traditional AGC regularize generating unit to respondto load fluctuation. With the help of residential small solar plant which is not charging the vehicle at that moment it can be helpful to decrease the load on grid as this generating power can be fed back to the grid. This will be the pure or greenformofelectricalpowerandcosteffectivealso[11],[31].

D. Intelligent TransportSystem

To make the system smarter Intelligent Transport System (ITS) came into picture. This system comprises of sensors, actuators and embedded processor which helps to track the traffic congestion of the particular area. In other words, it set up a communication channel between two or more with the charging station or parking lot. By the medium of internet or mobile network and on-board Geographical Information Systems (GIS), Global Positioning Systems (GPS) and advanced traffic flow modeling techniques this communication can be easily done [5], [32]. The monitoring and control of the process can be done through Internet of Things (IOT). IOT is also helpful in determining the SOC of the EV battery and send this information to the grid so that the proper monitoring of load can be carried out. Apart from that the pre booking of slot at charging station and knowing the status of empty slot can be easily done using this technology [11], [5], [32].This technique made the load forecasting effective and can easily communicate with the renewable sources based generating plant either at home, office, parking lot, shopping mall or charging station [5],[32].

IV. CHARGING TECHNIQUES OF BATTERY

Lithium ion batteries are now days best knownbatteries in terms of energy density and longevity for EVs. These batteries comprise of various cells connected in series andthen in parallel to form a module and various modules are connected in series to form a battery pack. Usage of various cells helps in good maintenance and monitoring of battery [33]. The biggest challenge today is to charge these batteries efficientlyandfaster.Someofthechargingtechniquesare:

A. Constant Current ChargingScheme

In this scheme battery is charged using constant current or uniformly constant current. If more number of cells is associated then this method is not used because this can lead to the issue of cell balancing. Hence, this method is inefficient and can put cells in stress [7]. To implement this method on the lithium ion batteries high current is required which undoubtedly charge the battery faster but in the mean timethe temperature of the battery will rise which can led to thesudden death of the battery. Another reason is that high current will increase the rate of travelling of lithium ion in the graphite layer but if the rate is faster than the ions will not inserted in graphite layer properly and can deposit on the electrodes leads to lithium plating. So extra time is required by lithium ions to get deposit in the layer hence indirectly in increases thetimeofcharging[7],[8].

B. Constant Current Constant Voltage ChargingScheme

In this scheme basically there are 4 modes to charge a battery [7].

- PreChargeMode:Inthismode10%ofbatteryischarged usingfullcurrenttoavoidoverheatingofcell.
- Constant Current Mode: The battery is below 1C rate untilbatteryreaches4.2V.thiswillincreasethevoltage.
- Constant Voltage Mode: The battery is charged at constant voltage of 4.2V until it reaches 100 % SOC. Although battery shows full charge but still there is space required to charge, because of overheating issue of constant current method the battery is than charged with constantvoltage.
- Charge Termination Mode: Termination of charge is carried out using minimum charge current method by monitoring charge current as it reaches 0.02-0.07C the charge isterminated.

Having all these advantages, this method is still not in use so much as it takes lots of time to charge a battery completely.

C. Multistage ChargingScheme

All above mentioned method has drawback of more charging time. But in this method the battery is charged at various current levels and each level has its own voltage limit. Since high current can increase the temperature of the battery this method was introduced [7]. For fast charging of the battery high current is required to charge the battery when internal resistance of the battery is low and decrease the charging current when the internal temperature is high. According to the charging rate and SOC these charging current value and threshold voltage limits are decided. This method can charge batteryfaster,efficientlywithoutharmingbatterylife[9].

V. INDIANCONTEXT

Indian Government is focusing more on reducing thecarbon emission rate and for which it is taking all the necessary steps. India is in one of the top 10 countries having vast automobile market [34]. Hence using more and more oil based vehicle degrades the environment. According to National Electric Mobility Mission Plan (NEMMP) 2020 [35], around 5 to 7 million electric vehicles should be run on road by 2020 which will reduce the carbon emission by vehicle by 1.3%. As per the Indian Government vision of generation of electric power using renewable sources of energy, around 175GW power can beonlygeneratedusingthecleanenergysourceby2022outof which 100GW will be generated only by the solar [36], [37]. This step of government will be so helpful to install more and more charging station and residential charging station without putting any extra load on the grid. Ministry of Power and Ministry of housing and urban affairs provides some of the basic guidelines and standards to install a public charging station [38], [39] asfollows.

1) It is a de-licensed activity that is any person is free to install a charging station. But the person needs to informtheelectricitydistributertotakeproperelectricity connection.
2) Anychargingstationcanobtainelectricityfromanygeneration companyeitherprivateorpublicorbygenerating theirownpowerusingsolarpanelsorwindmillsoretc.
3) At charging station a exclusive transformer is required having a all the safety devices connected at their sub-station or switchgearroom.
4) Adequate space in the station for movement of the vehicles.
5) Propercivilworkandfirefightingworkshouldbedone
6) For deploying public charging station at least 5 chargers of rating given in Table III is necessary. It is not necessary to use only these companies charger given in the table III. Owner can use any connector but it should meet the standards and specification as that of these chargers and provided by BIS standards. According to the number of EVs the number of charging points can be increased but the minimum criteria of at least 5 chargers should befulfilled.
7) As far as the distance is concerned it is recommended to set up a charging station within 3 km range in city and on highways at each 25km there should be a charging station. This distance can be minimized as per thechoice ofinstallingmorestationsbutitshouldnotbemore.

According to the Ministry of Housing (Government of India) in electrical vehicle charging infrastructure, EVSE is very important. EVSE are classified or installed as per the levels of charging of EVs, charging speed and requirement. It is different for private, public and commercial CS [39].

TABLE III. TYPES OF CHARGERS REQUIRED [38]

Charger Type	**Charger Connector**	**Minimum Power (kW)**	**Rated Voltage(V)**	**No. of Charging Point**
Fast	CCS	50	200-1000	1
	CHAdeMO	50	200-1000	1
	Type 2 AC	20	380-480	1
Slow/ Moderate	Bharat DC 001	15	72-200	1
	Bharat AC 001	10	230	3

VI. CONCLUSION

This research investigates the challenges of deploying a charging station in terms of grid overloading, battery charging time, and traffic congestion due by increased waiting time at EVCS. To address these difficulties, many technologies are being investigated. The intended use of these technologies has the potential to enhance the overall reliability and efficiency of the electrical transportation system. This article also goes through several charging processes, since the battery is the most important component of an electric car and must be charged successfully without causing internal harm. Multistage charging is the most prevalent way of quickly charging a battery without causing it to degrade. The deployment of EVs and EVCS is crucial since India is a rising country seeking environmentally sustainable development. Transportation infrastructure is a crucial component determining a country's development. As a result, many concepts and standards are being considered in order to deploy EVCS in India, which may help to bring about a revolutionary transition in the automotive sector. Adoption of all-electric cars may result in major environmental improvements. This will contribute significantly to a more sustainable future. However, before they can be used, authorities must build more charging stations capable of charging batteries faster and utilising renewable energy sources. A lot of research is currently being done to make the whole system more trustworthy.

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