

Status of electric vehicles charging methods

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Abstract

Compared with vehicles powered by fuel, electric vehicles are more efficient in energy saving, emission reduction, and environmental protection. As a result, it is becoming most important with more applications in the transportation sector. As Electric vehicles usage is growing from day to day Electric vehicles (EVs) will become a reality in the future. The time taking the method of charging an EV becomes a major problem to accept the electronic revolution of the automobile industry. In this paper, we have discussed the various charging methods for an Electric vehicle, which also gives us a view of electric vehicle use in today's world. It gives a brief overview of the present and methods recommended for EV charging.

Keywords: Electric Vehicles (EVs), Environment Pollution, E-mobility Revolution, Emission Reduction, EV Charging Technologies.

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1. Introduction

Today, fossil fuels are depleting, which increases the need to supply and adopt sustainable and new eco-friendly alternatives to the internal combustion engine (ICE) based vehicles. Therefore, Electric vehicles (EVs) became widespread, because of low fuel gas emissions and they're less dependent on fossil fuels (Rizvi *et al*, 2018 and Papadopoulos *et al*, 2009). This work discussed the advantages and modeling of EVs. There are many ways of charging an Electric vehicle few methods are discussed below (Hans *et al*, 2009). The first method is conductive charging which again is classified into 2 types DC and AC. The second is an inductive method of charging, which is a wireless charging method; then battery swap method is discussed in which the old battery is exchanged by full charge battery, and then the last method which is the smart charging (Report of McKinsey & Company, Netherlands, 2014). Later we have discussed the problems faced with adoptions of these electric vehicles, then we see its scope in the future and at last conclude that ways of charging our electric vehicle's may change in a few decades, which can be helpful in the widespread of electric vehicles. The benefit of having an EV is that we can charge an Electric vehicle anywhere, and also, it's a type of one-time investment because the cost of charging will be very low (Qualcomm, Dynamic electric vehicle charging, 2017).

Electric vehicles are the future, not because they are better for the environment but because they are just better vehicles and offer many advantages. They have better acceleration and torque, are easy to handle and they have more efficiency than the other vehicles powered by fuel, are quieter, there is no smell, the investment is one time and it is very cheaper to run. We need not have to depend on the oils because every night car is charged and in the morning it's ready to use - just as my mobile and pc. And we need not worry about travel distance. Our daily journeys can be done with this and also which the invention of wireless road charging we can charge it while traveling also. New techniques are coming today which mainly aim to make the battery pack cheaper, lighter, and most efficient. By looking at all these reasons, we can say that electric vehicles are the future of vehicles is electric (Khurana *et al*, 2020.).

2. Modeling of an Electrical Vehicle

The model of an electric vehicle has four parts, which are the body of the vehicle, motor and controller, power converter and battery, and drive cycle source. The battery supplies the power to the motor by the power converter (Cheng *et al.*, 2009.). The generated energy is fed back to the battery through a bidirectional converter which is charged when the vehicle is in braking mode. The body of the vehicle shows the wheels joined by the drive system to the engine. The engine draws energy from the battery of the entire load. This is done with the help of the controller, which tells the load and its needs and after that feedback is given, it then gives controlled signals. Finally, this improves the efficiency of the vehicle (Abulifa *et al.*, 2017.). The general block diagram of the electric vehicle structure is shown in Figure 1.

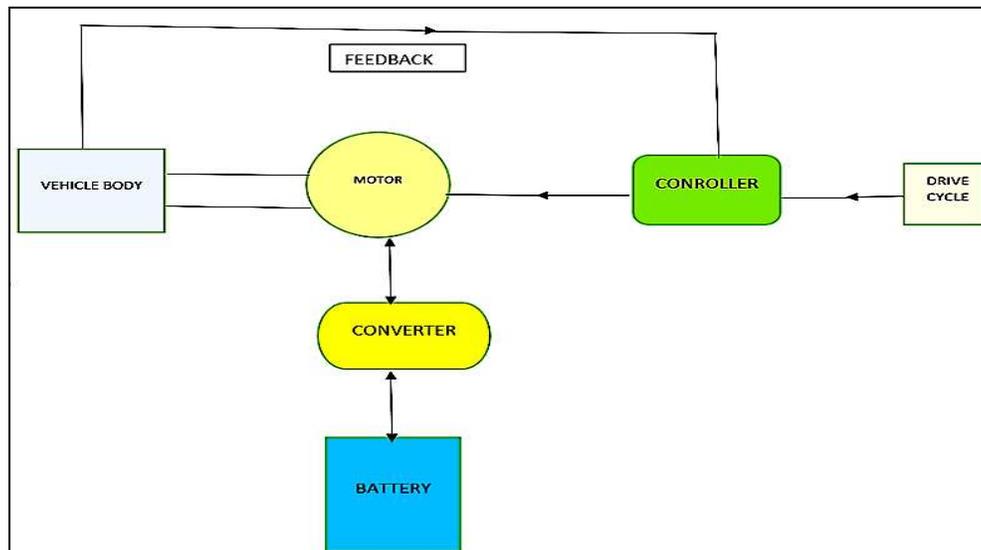


Figure 1. The general block diagram of an Electric Vehicle.

3. EV Charging Methods

The most important part of the electric vehicle battery bank and is needed to charge using various techniques. Various methods are given below:

3.1 Conduction Type

The conduction type of charging can be categorized based on supply types like AC charging and DC charging as below:

A. AC Charging

AC (alternating current) charging or slowing slow charging is the most common method that you do from a home wall box or, if there is no alternative, a household plug point. Inside an electric vehicle, there is a converter that converts power from AC to DC and then supplies it back into the car's battery. It is the most common charging method for electric vehicles today and almost all the chargers use AC power. It's very useful if you have time to charge the electric vehicle overnight it generally takes about 7 hours to fully charge a 40-kWh battery car. An AC charger supplies the EV's onboard charger, and further, it converts the power from AC to DC so the battery can be charged (Yilmaz *et al*, 2012). Space constraints the size of the onboard charging unit. Because of the limited size, the amount of power that can be provided to the battery is significantly reduced. As a result, the charging process is slow (Govt of India Report, 2017). The vehicle receives AC power from the grid via an AC charging station. The AC

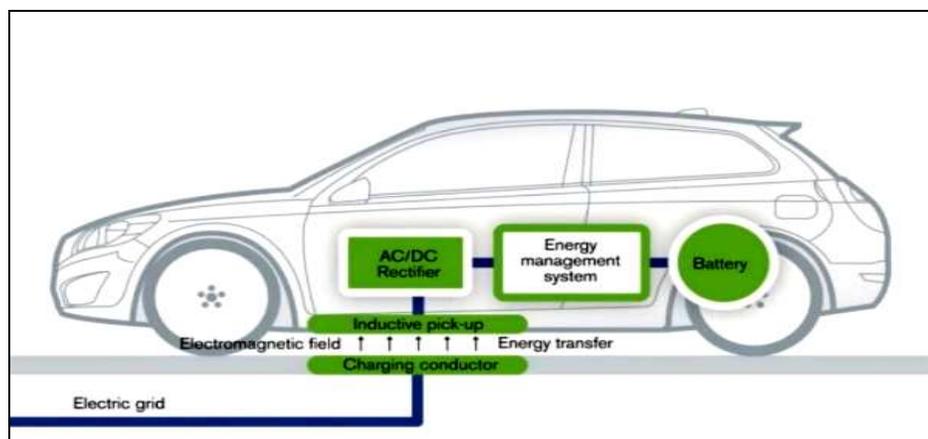
power is converted to DC by the onboard system, which is then stored in the battery. However, the size and weight limits of the onboard charger, there is a limit to the amount of power output. As a result, it will take a long time (Ricaud C *et al.*, 2010).

B. DC Charging

DC charging is used in electric vehicle fast chargers. The power is then converted before entering the vehicle. After conversion, the electricity is fed straight into the automobile battery, bypassing the car's converter (David, 2021). DC fast-charging stations, for example, necessitate the installation of dedicated three-phase power supply equipment that consumes substantially more current than AC charging solutions (Brenna *et al.*, 2020). DC charging has the advantage of being able to be designed for either a high or low charging rate, and it is not limited by weight or size. Outside of the car, off-board chargers allow additional flexibility in terms of the amount of power they can deliver (Wolbertus and van den Hoed, 2020). There are certain obstacles in the way to providing a cost-effective and reliable DC charging service. First, there is the negative influence on the power system, which includes harmonic pollution, high current demand, and on-peak hours that are stacked on top of each other. Second, due to the constraints of the supply network, this method's reliability is limited (Sanguesa *et al.*, 2021). Furthermore, having a large fast-charging model that is more flexible should make electric cars more appealing than they would be otherwise, resulting in an increased level of adoption (Capasso *et al.*, 2014).

3.2 Induction Charging

The energy input from the power source to the electric vehicle via magnetic induction coupling, based on the concept of electromagnetic induction and high frequency, is referred to as an inductive charge. The utilization of two electromagnetically connected coils is the core concept of inductive charging. The primary coil, which is connected to the power network, is pushed on the road surface in a pad-like design. The secondary coil is installed beneath the vehicle, ideally near the bottom and away from the occupants. The AC is rectified within the charging station and changed to high-frequency AC power, which is then transmitted to the car via induction. This technique for charging. Because there is no cable, this way of charging is simple and less untidy than conductive charging. Charging without wires Inductive charging or wireless energy transfer, on the other hand, might assist electric mobility in making a breakthrough. Dynamic induction charging is another option for charging an automobile wirelessly. The coils buried beneath the road emit an electromagnetic field picked up by the vehicles traveling by this technique to charge the cars. The representation of induction charging is illustrated in Figure 2.



(Source: <https://www.motorbeam.com/wp-content/uploads/Volvo-Electric-Vehicle-Cordless-Charging-Technology.jpg>)

Figure 2. The representation of Induction Charging.

3.3 Battery Swapping

An electric car's exhausted battery can be switched with a fully charged one in electric vehicle battery swapping (Ahmad *et al.*, 2020). This eliminates the time spent waiting for the vehicle's battery to charge. When compared to charging stations, battery switching stations provide a solution to all of the anxiety and tension, as each battery swap takes only a few minutes and requires significantly less room for installation. Furthermore, battery changing saves time and vehicle acquisition costs (S Jain *et al.*, 2020). It has the potential to be the most economical alternative for efficient fast charging, especially for commercial fleet operators who experience a high vehicle utilization. Additionally, the integration of re-utilization application of used EV batteries can offer additional sources of revenue in battery swapping stations (BSS). Although some places have already taken steps to incorporate

battery swapping in their EV policies (Mouli *et al*, 2017 and Vellucciet *al*,2012). The representation of the battery swapping method is given in Fig. 3.

3.4 Smart Charging

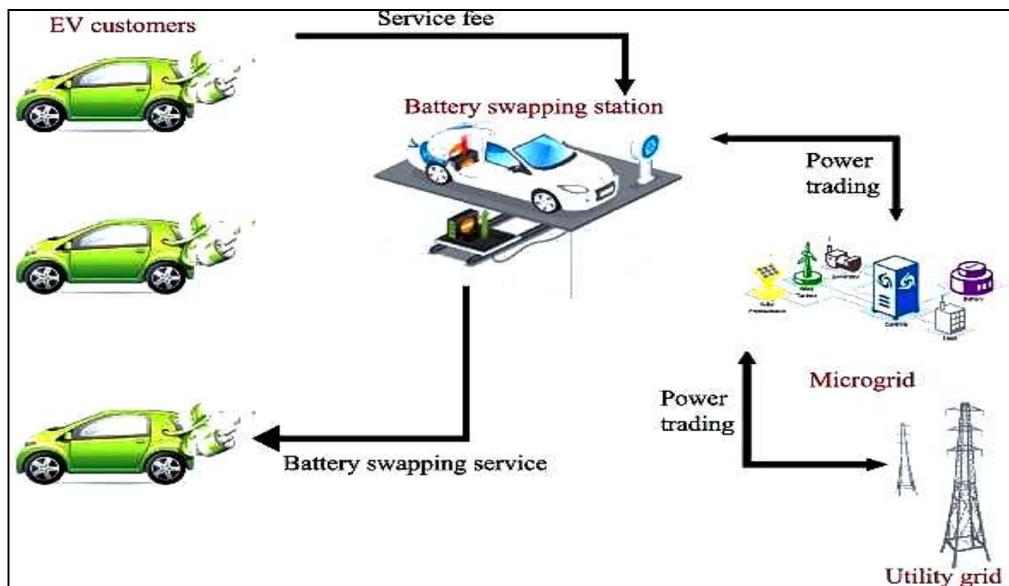
It refers to how intelligently you can manage your electric vehicle charges by connecting them to the grids. Implementation of this technology using software applications makes our work very easy from this technology. The charging stations can easily keep an eye on and manage the use of charging devices to reduce the wastage of energy (Ferreira *et al*, 2011 and Moghaddamet *et al*,2018). The representation of Smart Charging infrastructure is shown in Fig. 4.

4. Electric Vehicle Chargers

Different chargers are available for EV charging at the charging stations and the chargers are designed for 2-wheeler as well as 4-wheeler vehicles. The most commonly used chargers are discussed below-

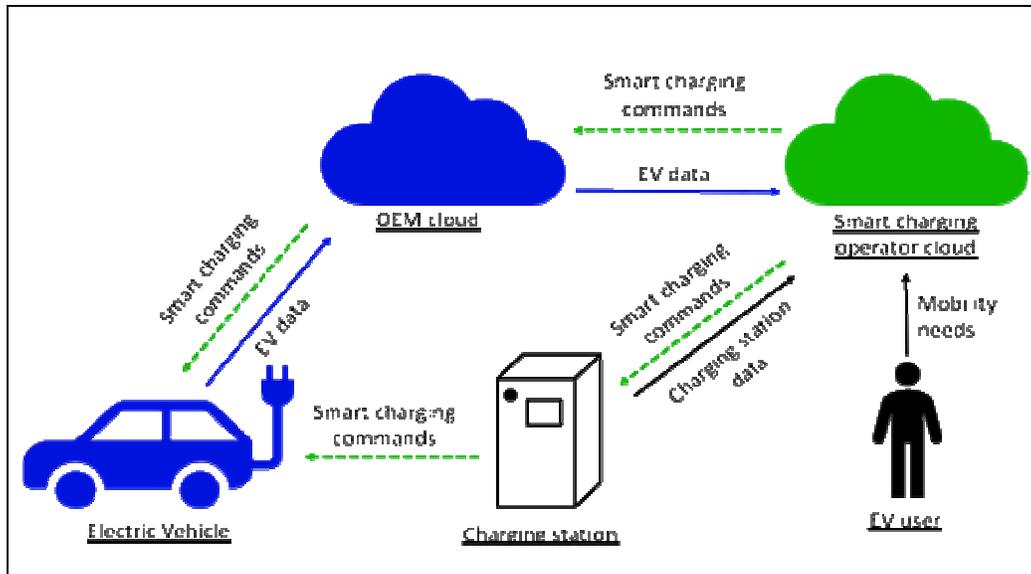
4.1 Combined Charging System (CCS) Charger

The Combined Charging System, usually referred to as CCS is mainly designed for DC fast charging. CCS charging sockets have a shared pin system hence they can be used for both AC and DC. Hence, the charging socket of these types of vehicles is smaller as compared to the space needed for a CHAdeMO socket plus an AC socket. The output from this type of charging is nearly 50KWh and it cost 14 thousand approximately (Pal *et al*, 2021 and Bahrami *et al*, 2020).



(Source: [Error! Hyperlink reference not valid.https://1.bp.blogspot.com/](https://1.bp.blogspot.com/))

Figure 3.The representation of Battery Swapping.



(Source: **Error! Hyperlink reference not valid.**<https://fsr.eui.eu/wp-content/uploads/2020/02/Picture-1-2.png>)

Figure 4.The representation of Smart Charging.

4.2 CHAdeMo Charger

These types of chargers are also used in DC charging. The output obtained and the cost of the charger is almost the same as the CCS charger. It is mostly used for charging 4-wheeler vehicles. During the charging period, the connectors of this charger remain locked and immediately get detached when the charging is stopped. The price of this type of charger is around 13.7 thousand (Anegawa *et al.*, 2011).

4.3 Type 2 ACCharger

It is most commonly used in newly launched vehicles. It is mainly used for the fast charging of 2 wheeled vehicles. The output power is nearly 22kwh and its cost is approximately 1.2 lacs. It consists of a 7-pin connection that makes it easy for connecting to the wall box of every house. The 5 of these pins are larger as compared to 2 other pins. Because these 2 pins are used when required during fast charging mode(Morcos *et al.*, 2000).

4.4Bharat DC-001 Charger

It is suitable for charging vehicles with a voltage is less than 100 volts. This charger cannot handle a current value of more than 200 A in case of fast charging. the output is nearly 15kwh and the cost of this charger is approximately 2.5 Lacs. It is commonly used for charging 4-wheelervehicles. The operating temperature range is 0 degrees to 55 degrees centigrade(Sharma *et al.*, 2020 and Kumar K *et al.*,2021).

4.5Bharat AC-001 charger

This charger is used for 2-wheeler slow charging. The output is nearly 4 kWh from each of the 3 pins of the charger and the cost of this charger is approximately 65 thousand. The rated voltage of this charger is 230 volts. The operating temperature is 10 degrees to 55 degrees centigrade(Sharma *et al.*, 2020).

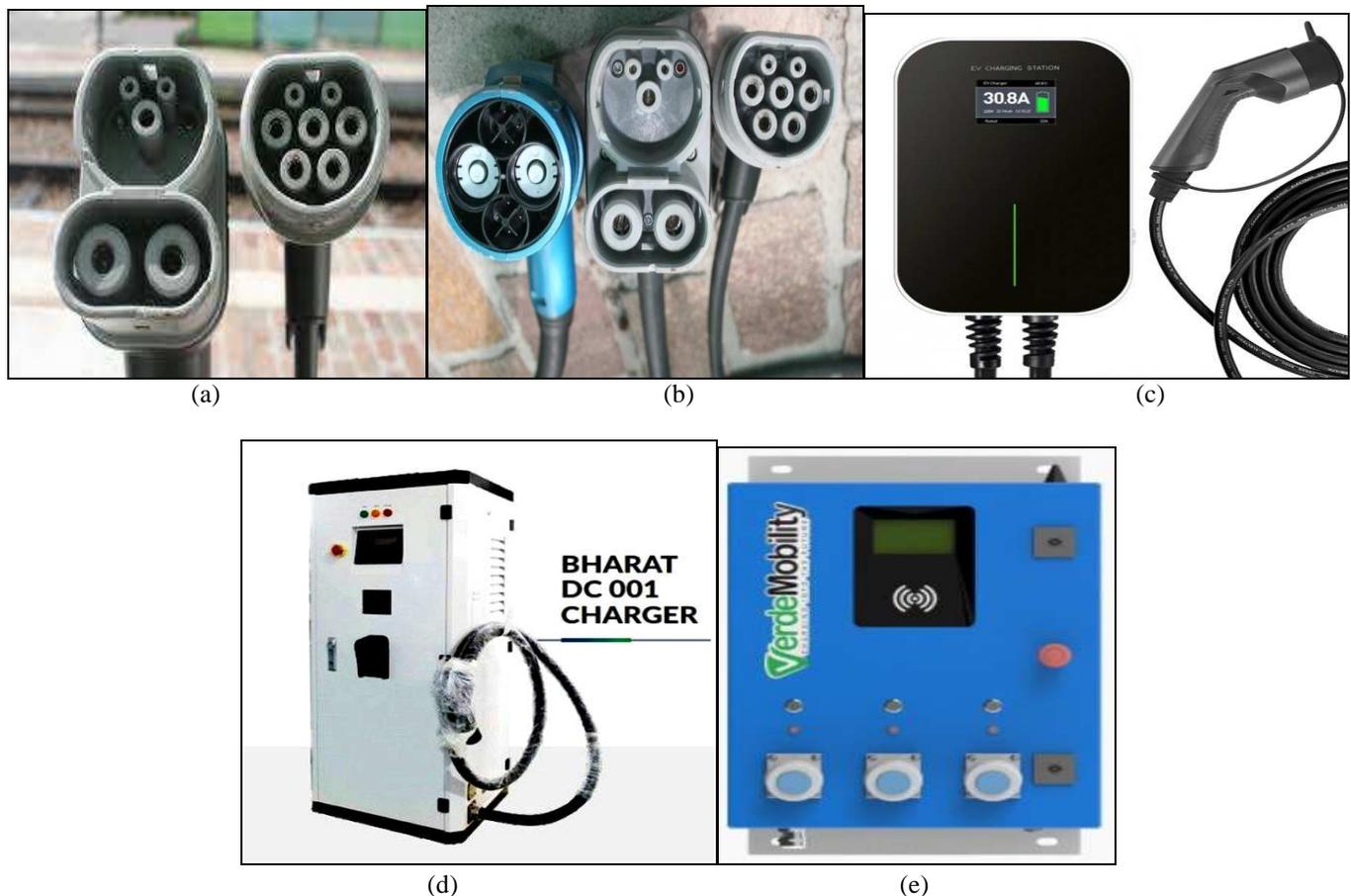


Figure 5. Different electrical vehicle chargers (a) Combined charging system (CCS) charger, (b) CHAdeMo Charger, (c) Type 2 AC charger, (d) Bharat DC-001 Charger, (e) Bharat AC-001 charger.

5. EV Problems in INDIA

Countries like the USA, UK, Russia are more developed in the field of electric vehicles as compared to India. The main reason which can justify this is given below:

It can be seen that in Indian people don't buy vehicles by doing proper research on them. They simply see others and get influenced by them (Kumar *et al*, 2013). The review summary on the development of EV and its charging methods are discussed in Table-1. We can say that this can be the main reason why people are not buying EVs and are not aware of their importance.

- One more reason can be that because EVs are more expensive as compared to diesel and petrol vehicles.
- Due to the no availability of charging stations at various places, like India, it is limited to metro cities only
- Due to fewer promotions of EVs as compared to normal vehicles.
- Due to low sales people are worried about whether to invest their money in buying EVs or not.
- Other factors like low economic ranges, bad government policies, fewer subsidies, and others also lead to low sales (Rupesh *et al*, 2020).

Table-1. Review Summary on development of EV and Its charging methods

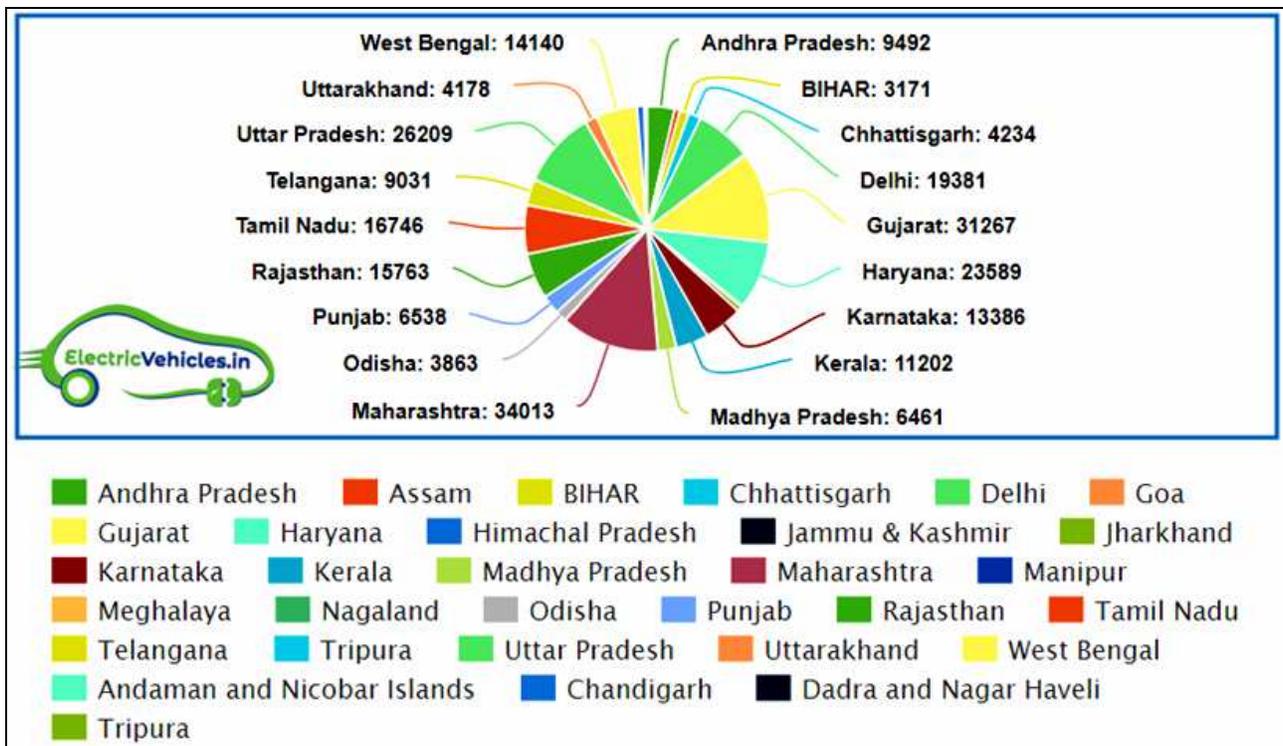
Reference/ Author's Name	Objective	Methodology/work presented	Summary/Outcome
Rizvi, et al.	To study EVs and it's effect on Integration into Power Grid	Here the analysis of the distribution systems with EV is performed.	This paper mainly tells us about the effect of EVs interconnection with the current power system.
Papadopoulos et al.	Energy Management and Power Quality	Bidirectional Charging	Reduction in THD.
Hans et al.	To study the development of Electric Vehicle (EV) charging trends and	AC/DC and charging method studied in the paper	We are still in a long run to develop the most efficient charging for EVs.

	technology		
Qualcomm	Demonstrates the dynamic EV charging.	Wireless charging method	Wireless charging of EV permits vehicles to charge during driving.
Khurana, et al.	The paper aims to find out the factors which affect the growth of EV usage.	Data collection was done through a questionnaire	Study of the advantages and the challenges that people face after launching the electric vehicle (EV)
Cheng et al.	This work presents the idea of working on an EV's battery and studying its components.	H bridge converter is used with intelligent BMS control	We got to know about the various parts and the model of EV.
Abulifa et al.	It presents modeling and simulation of battery for EV	The design of EV battery components and integrating the whole system using Matlab Simulink.	In this study, BEV and its parts are used to simulate to find out energy flow and efficiency.
Yilmaz et al.	To study the charging methods of EVs for commercial use	Different methods of charging like inductive and conductive charging are studied	This paper mainly focuses on inductive and conductive charging methods.
Ricaudet al.	To study the key elements and connection methods for the EV charging system.	Different modes of charging of electric vehicles are studied.	The combination of different modes of charging with different to offer suitable solutions for EV charging.
Herron	To study EV DC Fast Charging standards	Different types of charging methods like – CHAdeMO, CCS, SAE Combo, Tesla Supercharger is studied	PLC protocol based fast charging control system(CCS)
Morris, et al.	To study EV charging by using renewable energy sources	Uni-directional and bi-directional power flow using constant current and constant voltage charging method.	Zero voltage switching and zero current switching charging system.
Wolbertus and van den Hoed	Here we explore the future use of fast charging in EVs	The data collection method is used and then is transformed and analyzed	Through this paper, we got to know that the fast charging method is the main method used for long journeys
Sanguesaet al.	This paper reviews the various developments in EV charging methods.	The battery capacity, the cost, and the advancements of charging methods are shown.	In this paper, we reviewed the various kinds of methods used for EV charging and the advantages of EVs over IC engine
Capasso et al.	It's centered on the assessment of analytical and experimental components associated with the exclusive operation modes of lab power architecture	A DC bus, acquired via AC/DC converter that lets in the various DC electric powered loads connections.	This article introduces the main standards for the design, assembly, and experimental testing of the fast-charging station DC microgrid for plug-in hybrid and all-electric road vehicles.
AhmadFurkan et al.	To study the battery swapping method of charging of EVs and to discuss the problems during the use of it and find solutions to it.	Various techniques of battery swapping and its station's functionality is used to study	This paper discusses the Battery swapping methods of EVs, their advantages over the charging stations, and the main issues related to the Battery swapping method.
S. Jain, et al.	The battery swapping method of charging of EVs is studied and it tells about the current situation of EV charging to discuss the problems during the use of it and find solutions to it	It describes the method which requires less time to complete the entire process because after replacing the vehicle battery, a fully charged battery enters the replacement system and conserves the battery driving time	To appeal to clients in the direction of it swapping is in height called for in recent times in one of the important ways. The technique defined here is a method in which in an automobile a charged battery is replaced with the old one
Mouli, Gautham Ram et al.	To study the future charging methods	Review on different charging scenarios is studied.	It tells about the Smart charging, vehicle-to-grid, solar charging of EVs.
Vellucci et al.	The purpose of this research is to ensure that the inductive charging of EVs can be achieved with the same efficiency as current conductive charging methods and without affecting the safety of people.	Two tests were conducted the objective of the tests was to check the efficiency of transfer of power with the gap of air with no coil misalignment and with a fixed gap.	This project shows inductive charging of EVs can be achieved with the same efficiency as current conductive charging methods and without affecting the safety of people.
Ferreira, et al.	This paper proposes the development of an electric vehicle charging process creation and management system based on the induction process.	Smart charging and weather module is studied here	This paper proposed a smart charging system for electric vehicles, the implementation of the software application will simplify the user experience through connections.
Moghaddam et al.	In this document, we introduce the smart charging method for them, which provides a variety of charging processes, including conductive charging, and device replacement of batteries method.	It presents the conductive charging and device replacement of batteries method.	It shows that today it's very important to find out a way where the people can charge the vehicle at minimum cost so it introduces the concept of partial charging.
Bahrami, Ali	This paper gives us the idea of various types of charging and plugs of Ev	Cases study on EV charging is conducted.	We studied different types of chargers of EVs.
Pal et al.	This paper proposes the various charging methods of an EV.	EV charging infrastructure for rural areas is presented.	At last, it analysis the cost of setting up an EV charging station.
Anegawa	This paper is a study on the	Experimentation of CHAdeMO	It concludes by showing that this charging uses

	CHAdEMo charger.	charging is conducted.	analog and digital signal transmission.
Morcos et al.	The performance of batteries is studied here	Possible battery charging schemes are presented.	Different types of chargers and their performance is shown.
Sharma and Gupta	Bharat DC fast charger is briefly studied.	Simulation of EV charger is studied.	Methods for improving the performance are concluded.
Kumaretal.	To study the charging methods of EVs for commercial use	DC and AC charging are discussed.	The conclusion is that the new technology can be implemented for the better performance of EVs.
Sharma et. al.	Main methods of charging are discussed	Standards for EV fast chargers are discussed.	Various charging methods and their drawbacks are discussed.
Kumar, Praveen, et al.	To study potential need for electric vehicles, charging station infrastructure, and its challenges for the Indian market.	Focused on different challenges and possible solutions for charging infrastructure	It focuses on the various problems related to EV charging and possible solutions.
Kumar, Rupesh, et al.	Study the challenges that India faces by launching the electric vehicle (EV)	Data collected shows us that the challenges that are faced by launching EVs	The study concluded that, given the high price of EVs, insufficient infrastructure, and low buying capacity of consumers in India, the government had taken a good initiative by promoting EV usage.
Broderet al.	The future challenges that India faces by launching the electric vehicle (EV) are studied	It focuses mainly on the problem associated with EV development for future	Electrical vehicles are the best replacement for fossil fuels vehicles in terms of emissions reduction, energy-saving but the infrastructure is not supporting their wide use of it.
Shisheng et al.	Research on the usage of EVs by the residents of Indianapolis	A multiparadigm modeling approach has been used to determine the effects of EVs on the electricity demand sector.	It found the usage of vehicles varied greatly from zone to zone, it creates various charging profiles unique to each of the zones.
Cheng et al.	Development of Electrical vehicles related to battery technology, charger design, motor, steering, and braking are studied.	Different prototypes of electric vehicle technology and its charging are studied.	This paper tells us about the recent developments of electrical Vehicles.
HeHui, et al.	Prospective of the US electrical vehicles used and their effect.	The graph between the Percent of light-duty vehicles (LDVs) recalled by yearly model.	Various points were discussed to build a successful and robust vehicle emission compliance and recall program.
Sanguesa, etal.	Review on EV technology	The graph on battery life evolutions is drawn.	This paper tells us about the challenges faced by electrical Vehicles
Ayob etal.	Review on charging stations of an EV	It presents a review of EV charging standards	This study gives a review of the various types of EV charging.

6. Recent Trends and Future Scope in India

The Automobile Industry of India is currently ranked one of the largest in the world. The mobility requirement may face a drastic change shortly provided to the requirement of 1.30 billion population. The future of EVs in India by 2030 is an interesting question. Taking this aspect, the Government of India is trying to develop the choice of mobility, which is 'shared, connected and electric. It is to be ready for a future where the vehicles will be environmentally friendly and will not be completely reliant on petrol or diesel (Broderet *et al.*, 2009 and He *et al.*, 2018). There is a target for 100 percent EVs in the upcoming 20 years; many people say about 60-70 percent EV conversion till 2040 is a prediction (The main push of EVs production in the future will be because of public transport demand in India – 3-wheelers, 2 wheelers fleet cars, 4-wheelers and E-Buses (Huang *et al.*, 2012; Cheng *et al.*, 2019; Sanguesa *et al.*, 2021 and Ayob *et al.*, 2014). The state-wise sales report of India is represented in Figure 6. Also, the allocation of EV charging stations in India is tabulated in Table 2.



(Source: <https://images.app.goo.gl/rHPoHsbMSUZiEsjeA>)

Figure 6. State-wise sales report of India.

Table 2. Allocation of EV charging stations in India (as of January 3, 2020)

State/Union Territory	No. of EV Charging Stations	State/Union Territory	No. of EV Charging Stations
Maharashtra	317	Meghalaya	40
Andhra Pradesh	266	Madhya Pradesh	159
Telangana	138	Bihar	37
Tamil Nadu	256	West Bengal	141
Kerala	131	Jammu & Kashmir	25
Gujarat	228	Sikkim	29
Delhi	72	Chhattisgarh	25
Rajasthan	205	Assam	20
Chandigarh	70	Uttarakhand	10
Uttar Pradesh	207	Odisha	18
Haryana	50	Himachal Pradesh	10
Karnataka	172	Puducherry	10

(Source: <https://www.india-briefing.com/news/delhi-electric-vehicles-policy-incentives-india-ev-market-20847.html/allocation-of-electric-vehicle-charging-stations-in-india-as-of-january-3-2020/>)

7. The Government Policies for Adoption of EVs

The Indian government has a major role in the widespread of EV and many initiatives have been taken by the government for the adoption of EVs in India. With the support of the government, electric vehicles have started penetrating the Indian market. However, the availability of adequate Charging Infrastructure is one of the key requirements for accelerating the adoption of electric vehicles in India.

In this regard, the Ministry of Power has issued “Charging Infrastructure for Electric Vehicles – Guidelines and Standards” mentioning the roles and responsibilities of various stakeholders at the Central & State levels, for expediting the development of public EV charging infrastructure across the country. Ministry of Power has designated the Bureau of Energy Efficiency as the Central Nodal Agency for the National-level rollout of charging infrastructure in the country. Adequate Charging Infrastructure is one of the key requirements for accelerated adoption of electric vehicles in India. (<https://powermin.gov.in/en/content/electric-vehicle>)

The major policies of the government of India and Ministry of Power for adoption of EVs and also to develop the sufficient charging infrastructure for the available EVs are described under following categories as:

- Due to the policies like FAME 1 and FAME 2, the use of EVs is increasing.
- The Vehicle Scrappage Policy which was announced the which aims to reduce the import of oil in India.
- The PLI scheme for the battery of the EV provides subsidy on manufacturing of the EV battery which costs nearly half of the EV cost.
- Government provides initiatives for purchasing EVs in large quantities.
- Also, for riding an electric scooter no license is needed.
- The provision of subsidies by government for the EV users.
- Specified the standards for the development of EV charging infrastructure.

8. Conclusion

Ways of charging our electric vehicles may change in a few decades, which can be helpful in the widespread of electric vehicles. The benefit of having an EV is that we can charge an electric vehicle anywhere and also, it's a type of one-time investment because the cost of charging will be very low. There are hurdles to the adaptation of EVs by people due to the continuous development of new technologies and limited charging infrastructure available in the markets. The technologies of charging like the battery swap technology used in China, give us hope that new techniques of charging will be available in the future, which will be more efficient than the present charging methods as our auto industries are also electrifying globally. There is still a long way to go in this area. It can be recommended that a more efficient and detailed charging strategy can be explored with financial analysis to determine the most cost-effective charging scenario.

Nomenclature

EV	Electric vehicle
ICE	Internal combustion engine
AC	Alternating current
DC	Direct Current
BSS	Battery swapping stations
CCS	Combined Charging System (CCS)
CHAdemo	Charge de move
FAME	Adoption and Manufacturing of Hybrid and Electric Vehicle

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