A REVIEW ON VARIOUS METHODS FOR CHARGING TOPOLOGY OF ELECTRIC VEHICLE BATTERIES

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ABSTRACT

This paper presents a review on the different types of EV charging method like conventional & advanced methods based on the infrastructure, method of power transfer, power levels, and direction of power flow for charging of electric vehicle batteries. As the demand for EVs continues to grow, the limitations of conventional charging approaches become increasingly apparent, underscoring the necessity for innovative solutions that can unlock new dimensions of efficiency, speed, and reliability in recharging EV batteries. However, electric vehicles face significant charging time, charging methods, and range anxiety challenges. To overcome these challenges, charging technologies for electric vehicle batteries play an essential role. Various types of electric vehicle charging topologies have been discussed in many practical applications. As the demand for EVs continues to increase, the limitations of conventional charging approaches become increasingly apparent, underscoring the necessity for innovative solutions that can unlock new dimensions of efficiency, speed, and reliability in recharging EV batteries.
For charging, the conventional method is being grid-based, usage of solar energy for charging batteries and incorporating vehicle to grid and grid to vehicle power transfer has been identified. Recent methods for EV battery charging are such as Battery Swap Station (BSS), Wireless Power Transfer (WPT), and Conductive Charging (CC) has been studied. In this we analyzed various methods for charging electric vehicle. This provides the research directions for the academic and industrial communities.

Keywords: *EV, BSS, WPT, CC, Battery*

1. INTRODUCTION

As an important energy support system for electric vehicles, the EV charging system provides necessary energy supply for the operation of electric vehicles. It is also an important step in the process of EV commercialization and industrialization.
Based on the standard of whether the charging device is on board or not, the EV charging devices can be roughly classified into portable charger for EV and non-on-board portable EV charger. According to different charging modes, there also exist slow charging, fast charging, power changing, wireless charging, and mobile charging; and different types of electric vehicle charging cables are needed for different charging modes.
Electrical vehicle was marked from 1890 to 1924 with a peak production of electric vehicles in the mid-year of 1912. However, in old days the EV requires continues charging. An electric vehicle can be powered with electricity from extravehicular sources, or it can be powered autonomously by a battery (sometimes charged by solar panels, or by converting fuel to electricity using fuel cell s or a generator). The utilization of electric charging is depended on the location and time of charging of electric vehicle. It can be operated by an electric motor for charging or by other means of charging battery in a vehicle rather than using an internal combust ion engine. Nevertheless, the concept of electric vehicles has been familiar from mid-19's, it has drawn a considerable amount of i nterest in the past decade due to rising carbon footprint and other environmental impacts of fuel-based vehicles. The basic benefit for commercializing EVs will be requiring an installation of charging infrastructure that is easy to approach, easy to use, and reas onable in price. There is an uncertainty in infrastructure if one looks into. The historical growth of electric vehicles is shown in th e fig.1. Electric vehicles are the most efficient form of transportation as compared to other forms. Owing to that next generation v ehicles will be requiring electric drive trains to propel the vehicles. The basic advantage of using electric vehicle is that they are of low maintenance and having less pollution hazards. According to International Energy Forecast, the usage of electric vehicle will be increasing from 3.5 million to 125 million users by 2030.

ELEMENTS OF ELECTRIC VEHICLE

The basic elements of electric vehicle are simple in construction and it consists of battery pack, motor, transmission unit containin g converters and inverters and the most importantly a battery charger. Lead acid, nickel iron, nickel cadmium, nickel metal hydrid e, lithium polymer and lithium iron, sodium sulphur and sodium metal chloride are commonly used batteries for electric vehicles. Among these, the most commonly used battery for electric vehicle is lead acid battery. Controller is used to control the signals fro m battery and control signals give input to motor for running wheel.

2. ELECTRIC VEHICLE CHARGING METHODS

There are various electric vehicle charging methods like conventional as well as advanced charging techniques. Battery exchange, wireless charging, and conductive charging are the three main charging techniques.

There are three common ways to charge an EV are:

1. Conductive charging - AC and DC

2. Inductive charging - Static and Dynamic

3. Battery swap technology

The physical location of the components for converting the power supplied by the grid to that required by vehicle battery can be categorized as onboard and off-board chargers. Onboard chargers are located within the vehicle, and the size and power rating are constrained by the available space within the vehicle. Off-board chargers are located outside the vehicle, and this setup provides more flexibility in terms of the power that can be delivered. Both classes of charging devices must contain control circuits and communicate in real-time with the vehicle battery. This is to ensure that the battery is charged in an optimum way, avoiding any damage to the battery through overcharging. AC charging uses an onboard charger while DC and battery swap use an off-board charger. In case of an inductive charger, a combination of both onboard and off-board chargers is required.

2.1 Conductive Charging

This is the most common charging method right now and it has 2 categories: AC and DC charging.

Fig.2.1 (a) : Conductive Charging- AC

Conductive Charging - AC

Advantages

1. The battery can be recharged anywhere using the AC grid and the onboard EV charger

2. The EV charger can easily communicate with the Battery Management System (BMS) and no additional power electronic converters are needed in the EV charger. This leads to higher performance and lower cost.

Disadvantages

1. AC power has to be converted into DC power in the car, and there is a limitation of the power output for AC charging due to the size and weight restrictions of the onboard charger.

2. AC charging needs a relatively long time due to the relatively lower charging power

DC charging is suitable for high power EV charging, and the power output of fast charges is limited only by the ability of the batteries to accept the charging power.

Fig.2.1 (b) : Conductive Charging- DC

Conductive Charging - DC

Advantages

1. It can be designed with either a high or low charging rate, and is not limited in its weight and size.

2. DC charging with high power requires low charging time.

Disadvantages

1. Higher investment for installation of the charger when compared to AC charging.

2. Adverse impact on power system: high power demand on the grid esp. at peak hours

3. Since the off-board chargers and the BMS are physically separated, reliable communication is important to ensure correct charging conditions.

2.2 Inductive Charging

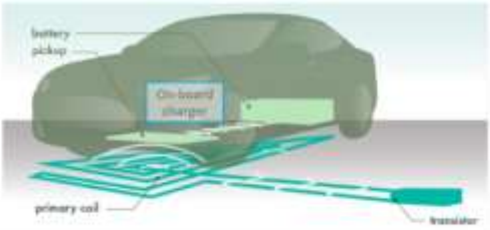

Fig. 2.2 (a) : Inductive Charging -Static

Inductive Charging - Static Charging

The main idea behind inductive charging is the use of two electromagnetically linked coils. The primary coil is placed on the road surface, in a pad-like construction linked to the electricity network. The secondary coil is placed on the vehicle, ideally on the bottom or top of the car. The 50Hz AC power from the grid is rectified to DC and is then converted to a high-frequency AC power within the offboard charger station. Then this high-frequency power is transferred to the EV side by electromagnetic induction. The coils on the car convert this high-frequency AC power back to DC to charge the EV using the onboard charger.

Advantages

1.Convenience

2.Suitable for self-driving cars

And the disadvantages are:

1.High investment

2.Limited space & weight of charge pads

3.Misalignment tolerance between the vehicle and the charge pad

4.Power losses and relatively lower efficiency than conductive charging

5.Electromagnetic radiation exposure

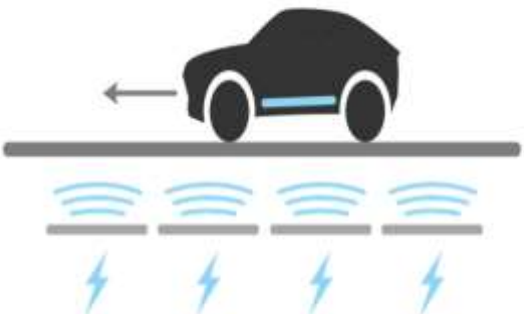

Fig. 2.2 (b) : Inductive Charging -Dynamic

Inductive charging - Dynamic charging

The other way to charge a car wirelessly is called dynamic charging. The coils connected to electric cables which used to provide the power are buried in the road. The coils emit an electromagnetic field that is picked up by vehicles driving over them and converted into electricity to charge the cars.

Advantages:

1.Low stand-in charging time

2.Low battery DoD

3.Smaller battery size

So far the dynamic inductive charging is still in the experimental stage because there are many challenges to standardize it.

The challenges are:

1. The high cost of investment

2. Foreign objects, coil structure changes and coil misalignment on the road

3. Applicability of different car types and universal coil type selection

2.3 Battery swap

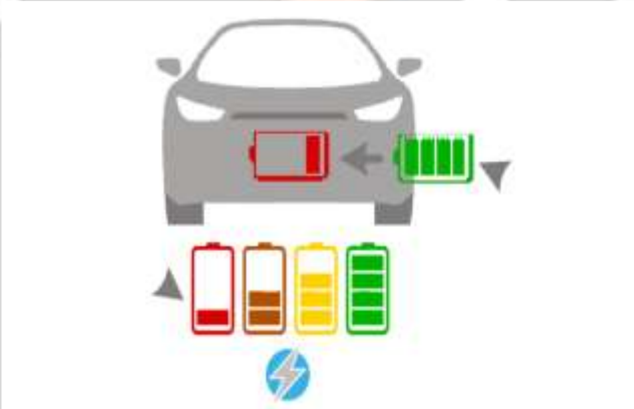

Fig.2.3.1: Battery Swap

The third method of EV charging is a battery swap. It works on the basis of switching out the depleted battery and replacing the same with a full battery. The process involves driving into a battery switching bay and an automated process will position the vehicle, switch out the current battery, and replace it with a fully charged battery. The depleted batteries are charged in the station for later deployment. The system works on the business concept that the EV user owns the vehicle and not the battery. Battery swap requires a foolproof way to estimate the batteries' state of health to check for its usage pattern and to ensure that only authorized vehicles and charging stations can charge it.

Advantages

1.No range anxiety

2.Quick and easy refilling like a combustion engine car tank

3.Longer charging times available for the EV battery compared to fast DC charging

The main challenges to this method are:

1. The requirement of standardized battery interface across multiple car manufacturers.

2. Consumer acceptance of not owning a battery and having to change the vehicle battery.

The comparative analysis of EV charging methods with various aspects are as follows

Table 2.1: Comparison of EV Charging Methods

Battery Powering Methods	**Conductive Charging**	**Inductive Charging**	**Battery Swap**
Infrastructure required	Depending on charging power level but relatively low	High (static) Very high (Dynamic)	High
Battery Ownership	EV's owner owns the battery	EV's owner owns the battery	Enter the EV's owner or charging stations owns the battery
Risk of electric shock	Possible	Safer than CC & BS (static)	Possible
Charging	Charging is fast	Charging is slower (Static)	Fast charging
Cost	Less expensive	Cheaper (static) Most Expensive (dynamic)	Cost effective
Charging Duration	Depending on power level but relatively high	High (Static) Does not matter due to charging in motion (Dynamic)	Very low
Service Time	Relatively Long (AC) Very short(DC)	Relatively Long (static) Very Flexible (dynamic)	Shortest
Battery Size	High	High (static) Lower than other methods(Dynamic)	High
Charging Efficiency	Higher	Lower than CC & BS	Higher
Range Anxiety	Depending on state of charge of battery	Depending on state of charge of battery(static) Lower than the other methods due to charging in motion (Dynamic)	Depending on state of charge of battery
Battery life time	Lowest lifetime (DC)	Longest lifetime (Dynamic)	
Standardization Challenge	Faced with the less difficult challenges	Faced with the most difficult challenges	Faced with the most difficult challenges

EV Charging Methods Classification

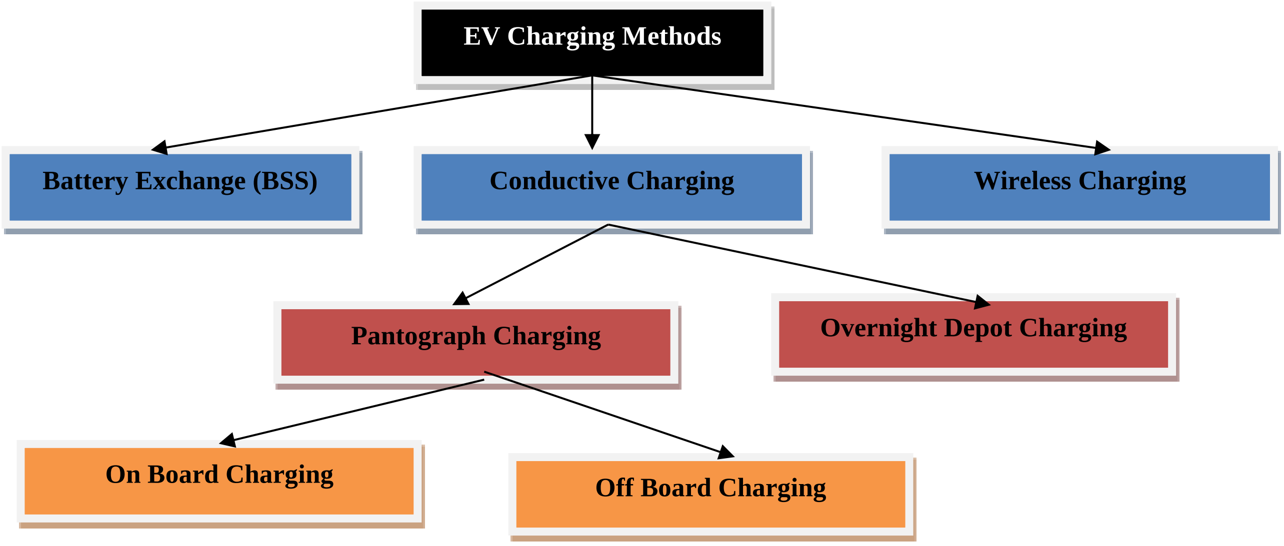

Fig 2.1: Electric Vehicle Charging Methods

There are three common methods of charging a battery; constant voltage, constant current and a combination of constant voltage/constant current with or without a smart charging circuit.
Constant voltage allows the full current of the charger to flow into the battery until the power supply reaches its pre-set voltage. The current will then taper down to a minimum value once that voltage level is reached. The battery can be left connected to the charger until ready for use and will remain at that “float voltage”, trickle charging to compensate for normal battery self-discharge.
Constant current is a simple form of charging batteries, with the current level set at approximately 10% of the maximum battery rating. Charge times are relatively long with the disadvantage that the battery may overheat if it is over-charged, leading to premature battery replacement. This method is suitable for Ni-MH type of batteries. The battery must be disconnected, or a timer function used once charged.
Constant voltage / constant current (CVCC) is a combination of the above two methods. The charger limits the amount of current to a pre-set level until the battery reaches a pre-set voltage level. The current then reduces as the battery becomes fully charged. The lead acid battery uses the constant current constant voltage (CC/CV) charge method. A regulated current raises the terminal voltage until the upper charge voltage limit is reached, at which point the current drops due to saturation.

3. CHALLENGES FACE TODAY: EV CHARGING NETWORKS

With the EV revolution well underway, electric vehicle charging networks need to keep up with demand from manufacturers releasing new cars. They also need to stay on top of the fast-paced technologies and charging architecture found in modern Electric Vehicles. That being said, electric vehicle efficiency is being constantly monitored. With many brands flooding the market for their version of a rapid or home charger, each one faces problems within the network. Sometimes the charge point manufacturers are not to blame.

The main challenges include the high cost of installation, communication between the grid and charge station companies, and the compatibility of chargers. We explore all of these and other issues in depth below to give you a sense of what manufacturers face when installing and running their charge network.

1] Poor charging infrastructure

2] Vehicle-grid interoperability

3] Station performance and downtime

4] Payment method integration

5] Power issues while charging

6] Charging station to network

7] Finding balance between rapid charge points and on-street units
8] Ease of use while charging

EV challenges must be tackled to boost electric vehicle efficiency

Technology and innovation are driving the electric vehicle space with exciting ways to charge, longer-range batteries, and rapid charging capabilities to get users back on the road as quickly as possible. The grid, local governments, and legislation are all falling behind in coming up with a refined way for drivers to charge their EVs.

Limitations on the electric vehicle charging network include the lack of protocol sharing, limited network changes, and the infrastructure to support the high power consumption that some chargers need.

Payment methods in recent times have been a headache for owners too. This needs to change to centralize one method or app to take over the market for all charging networks – making the process much easier. Consumer surveys have proven customers fear not finding a charge point when their range is low, putting them off buying an EV.

However, other consumer surveys show that 40% of EV owners do not have any issues charging. With the right mix of home and highway service station chargers, these issues can be resolved, as long as the funding, infrastructure, and communication exists between the grid, charge point manufacturers, and local governments to legislate the charging network as a whole.

4. Latest Development in EV Charging Technology

Electric vehicle charging technology has seen significant advancements in recent years, with the introduction of several innovative solutions that aim to improve charging times, efficiency, and sustainability. Here are some of the latest advances in EV charging technology:

1. **Wireless Charging Technology**

This innovative technology eliminates the need for cables and plugs, making the charging process simpler and more convenient. Wireless charging uses electromagnetic induction to transfer energy from a charging pad to a receiver coil inside the EV. While wireless charging is slower than cable-based charging, it offers greater flexibility, convenience, and safety, as it eliminates the need for physical contact between the charging port and the charging station.

2. ***Ultra-fast Charging Technology***

Ultra-fast charging stations are designed to deliver a high amount of energy to the EV battery in a short amount of time. These stations can charge an EV battery up to 80% in under 30 minutes, making long-distance travel more feasible and convenient. The latest ultra-fast charging technology uses high-power chargers that can deliver up to 350 kW of power, significantly reducing charging times.

3. **Bidirectional Charging Technology**

Bidirectional charging technology allows EVs to not only consume energy from the grid but also return energy back to the grid. This technology enables EVs to act as energy storage units, making them an integral part of the power grid. Bidirectional charging is particularly useful during peak demand hours. As it enables EVs to supply energy back to the grid, thereby reducing the strain on the grid.

4. **Solar-powered Charging Stations**

Solar-powered charging stations use solar panels to generate clean energy that can be used to power EV charging stations. This technology is environmentally friendly and reduces reliance on the grid, making it an excellent option for remote locations where grid power is not readily available. Additionally, solar charging stations can work with battery storage systems. This is allowing for 24/7 access to clean energy.

5. **Smart Charging Technology**

Smart charging technology uses data and communication technologies to optimize the charging process. This technology can monitor the state of the grid, EV battery capacity, and user preferences to determine the optimal charging strategy. Smart charging technology can also facilitate vehicle-to-grid communication, enabling EVs to send data back to the grid, and receive instructions on when and how to charge.

Advances in EV charging technology are opening up new possibilities for the future of transportation. Bidirectional charging technology has the potential to transform EVs into energy storage units. This is allowing them to provide electricity to the grid during peak demand hours. This technology could revolutionize the power grid. And making it more flexible and responsive to fluctuations in demand. Additionally, wireless charging technology could enable EVs to charge while driving, eliminating the need for frequent stops to refuel.

V. Conclusion

There are various methods for charging electric vehicle batteries like conventional as well as advanced methods. In conventional techniques, there are some charging issues in terms of time, efficiency , cost etc. There are some advanced techniques that overcome all the issues in conventional methods .The latest advances in EV charging technology offer significant benefits for the environment, the economy, and the future of transportation. Technologies such as wireless charging, ultra-fast charging, bidirectional charging, solar-powered charging stations, and smart charging systems are making electric vehicles more accessible, convenient, and sustainable than ever before. These technologies can significantly reduce carbon emissions and create new job opportunities, and reduce reliance on foreign oil imports.

Furthermore, they have the potential to revolutionize the way we think about energy storage and the power grid. They are enabling electric vehicles to act as energy storage units. And supply power back to the grid during peak demand hours. While there are still challenges to overcome, such as the cost and availability of charging infrastructure, the future looks bright for this technology. Because it continues to evolve and improve. With continued investment in research and development, electric vehicle has a bright future in all aspects.

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