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A Comprehensive Review of Electric Vehicle Charging Stations and Battery Technologies

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Abstract: The rapid adoption of electric vehicles (EVs) necessitates the development of efficient and sustainable charging infrastructure, particularly in regions like India, where energy demand and environmental concerns are rising. Aggressive marketing and major aid from the government have been instrumental in accelerating recent technological advancements in the areas of electric power trains and batteries. There has been a significant decrease in the costs associated with the production of batteries over the course of the last three years. Experts predict that EVs will become more important to the car industry in the years to come. As a result of the electric vehicle (EV) conversion scenario and the roll-out timeframe that was specified in 2015, the number of electric vehicles (EVs) surpassed one million in October of 2018, as shown by the evidence. Through the implementation of several legislation, the government of the United States of America has created an incentive for the public sector to provide infrastructure for charging electric vehicles. This article provides comprehensive information about the different types of electric vehicles (EVs), including details about their charging stations and battery technologies. It also delves into hybrid electric vehicles (HEVs), exploring their unique characteristics, advantages, and potential drawbacks. Additionally, the article highlights the advancements in EV infrastructure, such as charging networks, and discusses the environmental and economic impacts of adopting electric and hybrid technologies.

Introduction

Electric vehicles are gaining popularity because they emit less pollution and are less reliant on fossil fuels. By integrating smart grid charging stations with distributed renewable energy sources, energy efficiency and carbon reduction can be achieved [4]. It is possible to have a micro grid that is both linked to the grid and separated from it, where various sorts of loads make local use of energy sources. However, widespread adoption of high-capacity EV charging stations increases demand for charging infrastructure, which in turn increases demand on the power grid [5]. Power converter topologies and local renewable energy sources are used to help people who have trouble using a lot of energy. Tesla and Nissan are two of the companies that make electric cars. They build the infrastructure for charging stations. As a result, electric vehicle charging stations that use renewable energy cut charging costs and emissions while improving the synchronization of the utility grid [6].Combining the use of renewable energy sources with smart grid technology to electrify charging stations increases power conversion efficiency and decreases emissions.

Locally used by various loads, micro grids may function in either grid-connected or islanding modes, and they consist of a network of distributed energy sources. Various energy sources and storage technologies comprise the micro grid. However, the burden that is placed on the power system increases in tandem with the number of electric vehicle charging stations. Because of this, an increasing number of individuals are driving electric automobiles. Here, the right power converter topologies used in combination with nearby renewable energy sources solve power consumption problems.

Electric Vehicle types

The electric car (EV) can either receive all its power from electricity alone, or it can have an internal combustion engine (ICE) to provide extra power. The most basic type of electric cars (EVs) is those that get their power from batteries alone. Other types can use a variety of energy sources, though. These are what are called hybrid electric cars (HEVs). HEVs were inspired by Technical Committee 69 of the International Electro technical Commission (IEC) focusing on Electric Road Vehicles. [7]. HEVs are cars that use more than one type of energy source, store, or converter. This is possible as long as at least one of these energy

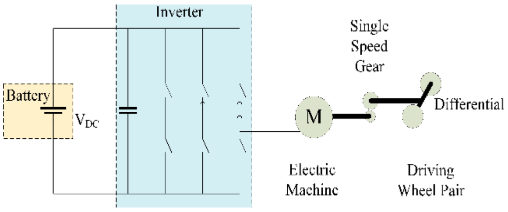


Figure 1: BEV configuration [3].

Sources can turn into electricity. Because of this idea, HEVs can be put together in a lot of different ways, such as with internal combustion engines (ICE) and batteries, batteries and flywheels, capacitors and batteries, fuel cells and batteries, and many more. In response, terms such as HEVs, UCAEVs, and FCEVs began to be used to describe vehicles that combined electric motors with internal combustion engines (ICEs)[8]. If you follow this guideline, electric cars could be called f. The use of these terms has become widely accepted.

- Hybrid Electric Vehicle (HEV)
- Plug-in Hybrid Electric Vehicle (PHEV)
- Fuel Cell Electric Vehicle (FCEV)
- Battery Electric Vehicle (BEV)

EVs whose only power source is a battery are called BEVs? Because BEVs can only use the energy saved in their battery packs, the range of these vehicles is closely related to the size of their batteries. Best models can go much farther, from 300 to 500 km [9]. Most of them can go between 100 and 250 km on a single charge. These numbers change depending on how and what you drive, the weather, the road conditions, the type of battery, and how old it is. When the battery pack is empty, it takes a lot longer to charge than it does to fill a regular ICE car. For example, fully charging batteries can take up to 36 hours [10]. There are tasks that take much less time, but none of them are as quick as filling up a gas tank. The charger's configuration determines the charging time, how much power it has, and how it is configured. The pros of BEVs are that they are easy to build, drive, and maintain. Therefore, they are fine for the environment because they don't make any noise or GHG. Electric power gives you high torques right away, even when you're going slowly. Because of these benefits and the fact that they have a limited range, they are great for use in cities. These days, the Nissan Leaf, Teslas, and some Chinese cars are some of the best-selling BEVs.

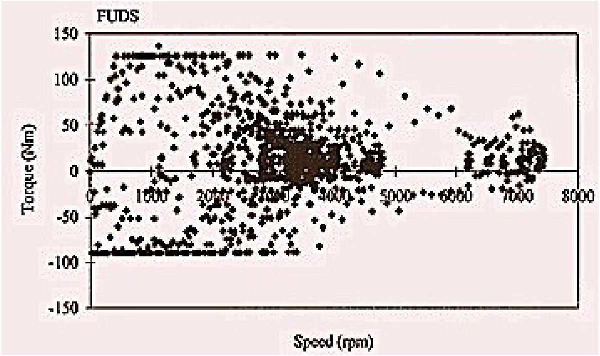


Figure 2: Federal Urban Driving Schedule torque-speed requirements [2].

A. Hybrid Electric Vehicle (HEV)

A combination of an electric power train and an ICE is what propels a hybrid electric car. As we'll see in a little, these two components may take several forms. When electricity demand is minimal, a hybrid vehicle's electric propulsion system kicks in. In low-speed settings, like urban areas, it's great since it cuts fuel usage by turning the engine off entirely when it's not in use, as when there's traffic. Reduced emissions of greenhouse gases are another benefit of this feature. If the hybrid electric car needs extra speed, it switches to the internal combustion engine. The two power trains may work together to boost efficiency. A common method for reducing or eliminating turbo lag in turbocharged cars like the Acura NSX is to install a hybrid power system. By providing speed boosts when required and bridging the gaps between gear changes, it increases performance. Regenerative braking is an additional energy recovery mechanism that certain hybrid electric vehicles (HEVs) use, while internal combustion engines (ICEs) are able to recharge the batteries.

Hybrid electric vehicles (HEVs) are ICE cars that supplement their ICE's performance and fuel economy with an electric power train. In order to get article traits. The use of HEV configurations is widespread among automakers.

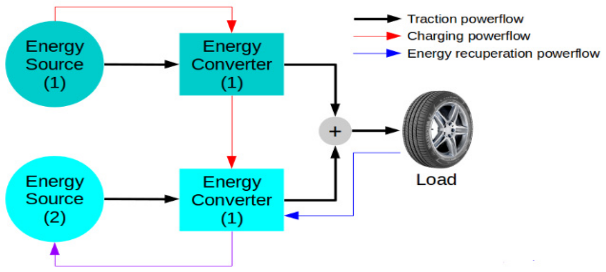


Figure 3: HEV basic operating principle [6].

B. Plug-in Hybrid Electric Vehicle (PHEV)

A greater all-electric range was a need for HEVs, which led to the development of the PHEV concept [7–12]. HEVs combine the advantages of electric propulsion with those of ICEs. However, a PHEV relies only on energy for traction. This means that these vehicles need larger batteries compared to HEVs. The PHEV initially operates in "all electric" mode, meaning it relies only on energy for propulsion. The ICE is summoned charge battery when the battery pack is almost empty. Here, the ICE is used to enlarge the region. When compared to HEVs, PHEVs have the advantage of being charge their batteries directly from grid. PHEVs can also utilize regenerative brakes. Compared to HEVs, PHEVs can run mostly on energy. This means they leave less of a carbon footprint. The costs of using them go down because they use less gas.

C. Fuel cell electric vehicle (FCEV)

Fuel cell cars, which are another name for FCEVs, are sometimes used. These cars' main parts are called fuel cells, and they get their name from the chemical processes they use to make energy [13]. FCVs run on hydrogen are optimal for this procedure. One reason for this is the fact that these automobiles are sometimes referred to as "hydrogen fuel cell vehicles." FCVs transport hydrogen in high-pressure tanks. Getting oxygen from the air that is drawn in from the outside world is another part of the process that makes power. There is an electric motor that moves the wheels, and the fuel cells send power to the motor. Some storage devices, like batteries and super capacitors, can be used to keep extra energy [14–16]. Batteries are used for this in FCVs that are sold for business use, like the Honda Clarity and the Toyota Mirai. Once FCVs start making electricity, they only make water as a waste product. This water comes out of the car through the tailpipes. One good thing about these cars is that they can make their own electricity, which doesn't give off any carbon dioxide. This makes their carbon footprint even smaller than that of any other electric car. Additionally, these automobiles are very practical since they can be refueled in the same time it takes to fill up a conventional car at a gas station. Possibly the most important benefit these cars offer right now is this. The chances of these cars being used in the near future are higher because of this [2, 17].

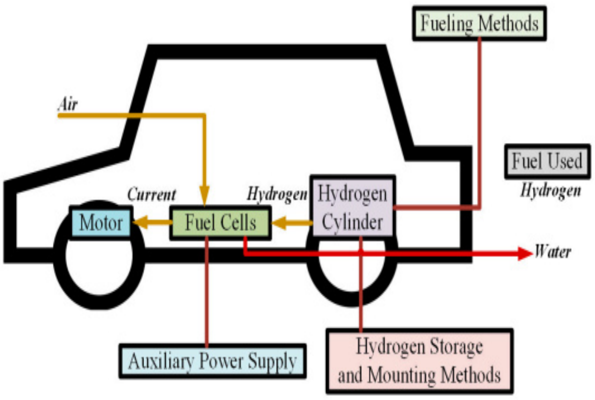


Figure 4: FCEV configuration.

EV Charging Framework and Standards

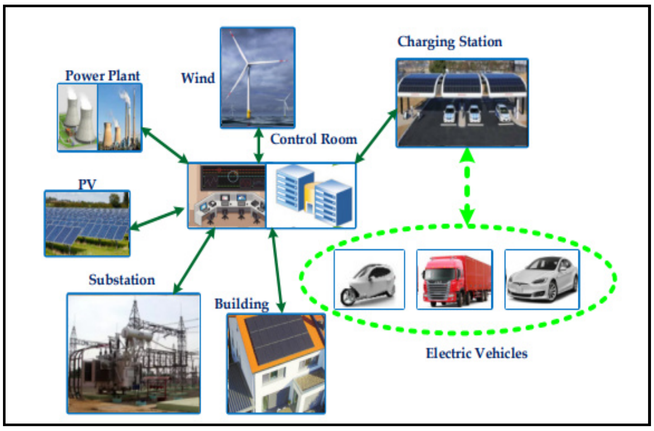


Figure 5: An EV-charging stations as part of the micro grids infrastructure.

Micro grid systems, whether AC, DC, or hybrid, are often used for automobile charging purposes. The charging station is powered by high-voltage alternating current or direct current. The charger regulates voltage to charge electric vehicle's battery. There are several power output ratings available for electric car chargers for you to choose from.

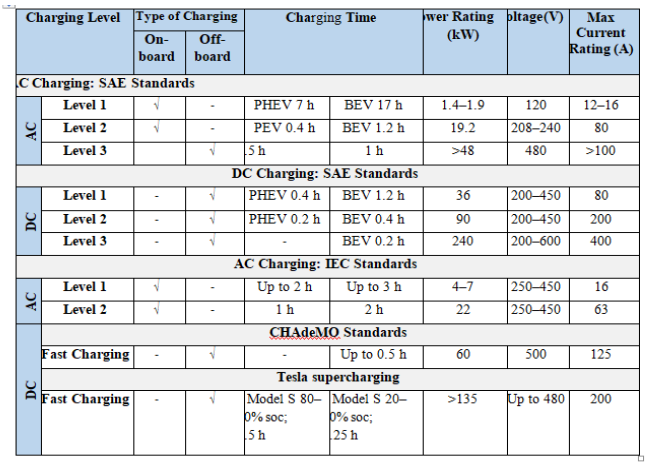
Battery packs, usually storing many kilowatt-hours of energy, are charged by electric car charging systems after the conversion of power from AC to DC or from DC to a different level. Electric cars use direct current (DC) power to recharge their batteries. The charging current, Ich, generates a distinct voltage, Vev.

$$P_{ch} = V_{ev} * I_{ch}$$

Thus, the energy supplied to the EV battery pack E_{ch}during a T time

$$E_{ch} = \int_{0}^{tch} P_{ch}\, dt$$

Table 1: Comparison between EV charging levels and international standards.



Charging Level		Type of Charging		Charging Time		wer Rating (kW)	oltage(V)	Max Current Rating (A)
		On-board	Off-board					
C Charging: SAE Standards								
AC	Level 1	√	-	PHEV 7 h	BEV 17 h	1.4–1.9	120	12–16
	Level 2	√	-	PEV 0.4 h	BEV 1.2 h	19.2	208–240	80
	Level 3		√	.5 h	1 h	>48	480	>100
DC Charging: SAE Standards								
DC	Level 1	-	√	PHEV 0.4 h	BEV 1.2 h	36	200–450	80
	Level 2	-	√	PHEV 0.2 h	BEV 0.4 h	90	200–450	200
	Level 3	-	√	-	BEV 0.2 h	240	200–600	400
AC Charging: IEC Standards								
AC	Level 1	√	-	Up to 2 h	Up to 3 h	4–7	250–450	16
	Level 2	√	-	1 h	2 h	22	250–450	63
DC	CHAdeMO Standards							
	Fast Charging	-	√	-	Up to 0.5 h	60	500	125
	Tesla supercharging							
	Fast Charging	-	√	Model S 80– 0% soc; .5 h	Model S 20– 0% soc; .25 h	>135	Up to 480	200

Because EVs are so widely used, several worldwide charging methods and standards have varying charging capacities. Chargers for electric vehicles are classified as either AC or DC.

Battery in EV

In order to choose the right battery, you need to think about its energy density, weight, and cost as well. Electric bikes and mopeds with a short range need less battery power than electric cars, which need a lot more. For the majority of electric cars, lead-acid batteries have been used because they are well-known, easy to get, and cheap. Battery technology has changed a lot since the 1990s, and there are now a lot of different types of batteries. As a result of their better efficiency, lighter weight, faster charging times, more power output, longer lifespan, and less environmental impact when they are thrown away, lithium-ion batteries and their derivatives have become more popular in recent years. The following four battery types are often utilized in EVs today:

1) Lead Acid

2) Nickel Cadmium (NiCd)

3) Nickel Metal Hydride (NiMH)

4) Lithium-ion (Li-ion)

A. Lead Acid

Chemistry: Lead-acid batteries use a chemical reaction involving lead dioxide and metallic lead to generate electrical energy.

Application: Commonly used in automotive starting, lighting, and ignition (SLI) batteries for vehicles, as well as in uninterruptible power supplies (UPS) and backup power systems.

Advantages: Relatively low cost, high surge current capability, and availability in various sizes and capacities.

B. Nickel Cadmium (NiCd)

Chemistry: Nickel-cadmium batteries use nickel hydroxide and metallic cadmium as electrodes, with potassium hydroxide as the electrolyte.

Application: Historically used in portable electronics, such as cordless phones, power tools, and early laptop computers, but gradually being replaced by newer battery technologies.

Advantages: High discharge rates, long cycle life, and resilience to overcharging.

C. Nickel Metal Hydride (NiMH)

Chemistry: Nickel-metal hydride batteries use a hydrogen-absorbing alloy instead of cadmium, with nickel oxyhydroxide as the positive electrode and a potassium hydroxide electrolyte.

Application: Commonly used in portable electronics, such as digital cameras, handheld gaming devices, and hybrid electric vehicles (HEVs).

Advantages: Higher energy density compared to NiCd batteries, no toxic cadmium content, and reduced memory effect.

D. Lithium-ion (Li-ion)

Chemistry: Lithium-ion batteries use lithium compounds as the active material in both electrodes, typically lithium cobalt oxide for the positive electrode and graphite for the negative electrode.

Application: Widely used in consumer electronics, electric vehicles (EVs), energy storage systems, and portable electronic devices.

Advantages: High energy density, lightweight, long cycle life, and minimal self-discharge.

Future Scope

The quality of an electric car's batteries has a direct effect on how long it can go. According to these characteristics, we looked at a lot of different types of batteries. We also talked about the technologies that could be used in the future, like graphene, which is thought to be a good way to store more electricity and charge faster. The electric car could also benefit from this kind of technology, gaining more range. This could help drivers and users get used to the cars.

Batteries with more capacity will also lead to faster and more powerful charging modes, as well as higher wireless charging methods. It's also possible that making a universal electric car connector could be useful. When it comes to the future of Smart Cities, electric cars will play a big role, and having flexible charging options that can be customized to meet the needs of each person is very important to their success. Batteries and Smart City standards are going to change the way things work in the future, so the BMS should think about that.

Very High-Power Charging The condition of an electric car's batteries has a direct effect on how far it can go. We looked at a lot of different types of batteries based on these features. Many new technologies, such as graphene, were also talked about. It's expected to be a great way to store more electricity and charge it faster. Also, the electric car could benefit from this kind of technology because it could have more range. This could help both drivers and those who use cars get used to them.It will also be easier to charge faster and more powerfully, and use wireless charging that is faster. Creating a universal electric car hookup could also be good. To make Smart Cities work in the future, electric cars will play a big role, and having charging options that can be customized for each person is very important. Batteries and Smart City standards will change how things work in the future, and the BMS should think about this.

Wireless Charging. The technology has been used in a number of countries, but it hasn't yet been made available to the public in the United States, and its market potential isn't clear.

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