International Journal of Research in Engineering, Science and Management
Volume 4, Issue 3, March 2021
https://www.ijresm.com | ISSN (Online): 2581-5792

Emerging Trends in Electrical Vehicle and its Charging Station

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***Abstract*: With the increasing requirement in green technologies, Electric Vehicles have proven to be the best solution for transportation to reduce greenhouse gas emissions. The conventional electrical vehicle drivers are still reluctant in using such a new technology, mainly because of the time duration (4-8 hours) required to charge the electric vehicle batteries with the currently existing Level I and II charging station. For this reason, Level III fast- charging stations capable of reducing the charging duration to 10-15 minutes are being designed and developed. This paper focuses on the design of a fast-charging station for electric vehicle, in addition to the electrical grid, two stationary energy storage devices flywheel energy storage and a super capacitor is being used. Power electronic converters used for the interface of the energy sources with the charging stations are designed. The design development also focuses on the energy management that will minimize the battery charging time. Battery charging by solar power instead of Grid power brings new evolution in Electrical vehicle charging system. Installation of solar rooftop system on charging station will move one step ahead toward green energy in which Surplus power can be also fed to Grid by Net-metering.**

***Keywords*: Batteries, Charging station, Electrical vehicles, Net metering.**

1. Introduction

The key objectives of the EV policy are to reduce primary oil consumption in transportation, facilitate customer adoption of electric and clean energy vehicles, encourage cutting edge technology in India through adoption, adaptation, and research and development, improve transportation used by the common man for personal and goods transportation, reduce pollution in cities, create EV manufacturing capacity that is of global scale and competitiveness, facilitate employment growth in a sun-rise sector. An electric car is an automobile that is propelled by one or more electric motors, using energy stored in rechargeable batteries. Charging an electric car can be done at a variety of charging stations, these charging stations can be installed in both houses and public areas.

Categories of charging station,

- Residential charging stations
- Charging while parked (including public charging stations)
- Fast charging at public charging stations

Types of charging station,

- Level (120 Volts)-One-Charging
- Level (240 Volts)-Two-Charging
- DC (480 Volts) -Fast-Charging

2. Components of Electrical Vehicle

In Electrical Vehicle, Engine of a conventional IC Engine Car is replaced by an Electrical Motor and the fuel tank is replaced by the Battery Pack. The Battery Pack and Motor contributes to about more than 50% of the total cars weight and the price. So major parts are:

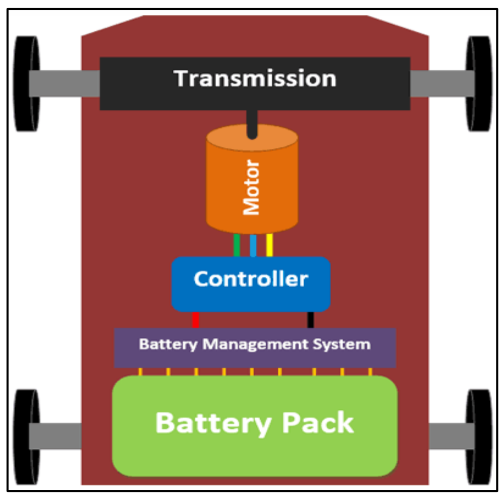

Fig. 1. Parts of electrical vehicle

A. Battery Pack

Batteries are the fuel source for Electric Cars. The voltage rating of the cells (per cell) will be anywhere from 3.7V for a lithium battery and a maximum of 12V for Lead-Acid batteries. But this voltage is not enough to run an electric car. The Tesla for example has a battery pack voltage of 356 Voltas and even for a normal electric bi-cycle we need a minimum of 36V So, to get this higher voltage from 3.7v lithium cells, battery packs are used which are formed by combining more than one battery together. When two batteries are connected in series their voltage ratings are added and when two batteries are connected in parallel their Ah rating is added.

B. Battery Management System (BMS) Controller

Once the system Voltage and Ampere hour (Ah) rating is obtained by combining various modules in series and parallel

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configuration this set-up should be placed inside the EV. But it is not so easy; the reason is -its complexity. Lithium cells are unstable in nature and any mishap like short circuit or excess charging or discharging can make their batteries get very hot leading to fire or explosion. So, the voltage, current and temperature of each cell should be monitored during the charging and discharging procedure. This monitoring circuit is called Battery Management system. Every BMS measures three parameters of the battery- Voltage, current and Temperate of the cell. It constantly compares these values with safety limits and disconnects the load if they exceed the threshold values.

C. Motor

There are many types of Motors used in EV and the one used for Scooters and bikes is totally different form the one that is used in cars. The commonly used ones that are BLDC motors, Brushed DC motors and AC Induction Motor.

D. Transmission unit

All cars have gears, including electric cars. However most electric cars do not have nor need a multispeed transmission due to the high torque available over a very wide range of motor speeds. Generally, the electric motor is always connected to the drive wheels through a fixed ratio reduction gear.

3. Types of Electric Vehicles

There are three types of electric vehicle: Battery Electric Vehicle (BEV), Plug in Hybrid Electric Vehicle (PHEV) and Hybrid Electric Vehicle (HEV).

A. Battery Electric Vehicle (BEV)

It Runs entirely using an electric motor and battery, without the support of a traditional internal combustion engine, and must be plugged into an external source of electricity to recharge its battery. Like all electric vehicles, BEVs can also recharge their batteries through a process known as regenerative braking, which uses the vehicle’s electric motor to assist in slowing the vehicle, and to recover some of the energy normally converted to heat by the brakes. Most have ranges of 80 to 100 miles, while a few luxury models have ranges up to 250 miles. When the battery is depleted, it can take from 30 minutes (with fast charging) up to nearly a full day (with Level 1 charging) to recharge it, depending on the type of charger and battery. Advantages are No emissions, no gas or oil changes, Ability to conveniently charge at home, Fast and smooth acceleration, Low cost of operation - about $30 a month. Disadvantages: are Shorter range than gasoline vehicles, although most people drive well within the range of today’s BEV and could rent a hybrid for the rare long trips., Slightly more expensive than their gasoline equivalent although the gasoline savings pay off the difference in typically 2-3 years.

B. Plug-in Hybrid Electric Vehicle (PHEV)

It uses an electric motor and battery that can be plugged into the power grid to charge the battery, but also has the support of an internal combustion engine that maybe used to recharge the vehicle’s battery and/or to replace the electric motor when the battery is low. Because Plug-in Hybrids use electricity from the power grid, they often realize more savings in fuel costs than tradition hybrids electric vehicles (HEV). Advantages are Longer range than BEV, Less gas consumption than gas only vehicle, Fewer emissions, Very simple mechanics, less to go wrong. Disadvantages are Produces tailpipe emissions, Needs gas and oil changes, More expensive to operate than Battery Electric Vehicle (BEV) but less than traditional Hybrid vehicle (HEV). PHEVs run on electricity for shorter ranges (6 to 40 miles), then switch over to an internal combustion engine running on gasoline when the battery is depleted. The flexibility of PHEVs allows drivers to use electricity as often as possible while also being able to fuel up with gasoline if needed. Powering the vehicle with electricity from the grid reduces fuel costs, cuts petroleum consumption, and reduces tailpipe emissions compared with conventional vehicles. When driving distances are longer than the BEV, PHEVs act like hybrid electric vehicles, consuming less fuel and distances are longer than the all-electric range, PHEVs act like hybrid electric vehicles, consuming less fuel and producing fewer emissions than similar conventional vehicles. Depending on the model, the internal combustion engine may also power the vehicle at other times, such as during rapid acceleration or when using heating or air conditioning. PHEVs could also use hydrogen in a fuel cell, biofuels, or other alternative fuels as a back-up instead of gasoline.

C. Hybrid Electric Vehicle: Hybrid Electric Vehicles (HEVs)

It has two complementary drive systems: a gasoline engine with a fuel tank; and an electric motor with a battery. Both the engine and the electric motor can turn the transmission at the same time, and the transmission then turns the wheels. HEVs cannot be recharged from the electricity grid – all their energy comes from gasoline and from regenerative braking. Advantages are Longer range than BEV, Less gas consumption than gas only vehicle. Fewer emissions than gas only vehicle. Disadvantages are Still produces emissions, Complex mechanics – Gasoline + Electric. Expensive to operate (8-10 times more expensive than BEV) but less than traditional gasoline vehicle. No ability to conveniently charge at home.

4. Charging Stations Categories

An electric vehicle charging station, supplies electric energy for the recharging of plug-in electric vehicles—including electric cars, neighbourhood electric vehicles and plug-in hybrids electric vehicles.

Charging stations fall into three basic categories:

- *Residential charging stations:* An EV owner plugs into a standard when he or she returns home, and the car recharges overnight. A home charging station usually has no user authentication, no metering, and may require wiring a dedicated circuit. Some portable chargers can also be wall mounted as charging stations.
- *Charging while parked:* A commercial venture for a fee or free, offered in partnership with the owners of the parking lot. This charging may be slow or high speed and encourages EV owners to recharge their cars while they take advantage of nearby facilities. It can include

parking stations, parking at malls, small centres, and train stations (or for a business's own employees).

- *Fast charging at public charging stations:* These have rating more than 40 kW, capable of delivering over 60-mile (97 km) of range in 10–30 minutes. These chargers may be at rest stops to allow for longer distance trips. They may also be used regularly by commuters in metropolitan areas, and for charging while parked for shorter or longer periods.

For charging at home or work, some electric vehicles have converters on board that can plug into a standard electrical outlet or a high-capacity appliance outlet. Others either require or can use a charging station that provides electrical conversion, monitoring, or safety functionality. These stations are also needed when traveling, and many supports faster charging at higher voltages and currents than are available from residential EVSEs. Public charging stations are typically on-street facilities provided by electric utility companies or located at retail shopping centres, restaurants and parking places, operated by a range of private companies.

The charging time depends on the battery capacity and the charging power. In simple terms, the time rate of charge depends on the charging level used, and the charging level depends on the voltage handling of the batteries and charger electronics in the car. The U.S.-based SAE International defines Level 1 (household 120V AC) as the slowest, Level 2 (upgraded household 240 VAC) in the middle and Level 3 (super charging, 480V DC or higher) as the fastest. Level 3 charge time can be as fast as 30 minutes for an 80% charge, although there has been serious industry competition about whose standard should be widely adopted.

Charge time can be calculated using the formula:

Charging Time [h] = Battery Capacity [kWh]/Charging Power [kW]

Table 1
Typical charging time for 100Km of BEV

Charging time for 100 km of BEV range	Power supply	Power	Voltage	Max. current
6–8 hours	1 phase	3.3 Kw	230 V AC	16 A
3–4 hours	1 phase	7.4 kW	230 V AC	32 A
2–3 hours	3phase	11 kW	400 V AC	16 A
1–2 hours	3 phase	22 kW	400 V AC	32 A
20–30 min.	3 phase	43 kW	400 V AC	63 A
20–30 min.	DC	50 kW	400–500V DC	100–125 A
10 min.	DC	120kW	300–500 V DC	300–350 A

For normal charging (up to 7.4 kW), car manufacturers have built a battery charger into the car. A charging cable is used to connect it to the electrical network to supply 230-volt AC current. For quicker charging (22 kW, even 43 kW and more), manufacturers have chosen two solutions:

i. Use the vehicle's built-in charger, designed to charge from 3 to 43 kW at 230 V single-phase or 400 V three-phase.
ii. Use an external charger, which converts AC current into DC current and charges the vehicle at 50 kW.

The typical charging time for 100Km of BEV is as shown in table 1.

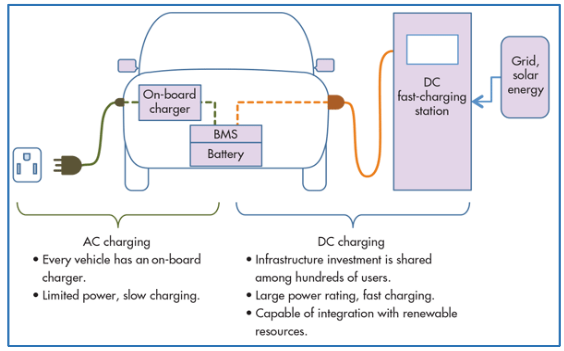

Fig. 2. Block diagram of electric vehicle charging station

5. Fast Charging Battery

Batteries are typically classified as primary and secondary batteries. The primary batteries are non-rechargeable batteries. They need to be discarded once they discharge. They normally have a long shelf life and are used for portable electronic devices. They include Alkaline batteries. Secondary batteries are rechargeable batteries. They are used as storage devices for electrical energy. Their charge retention period is poor resulting in poor shelf life. They include the Lead-acid batteries, Ni-Cd batteries and the lithium ion batteries. Lithium ion batteries have a high power/energy density and low weight/ volume. They have very high efficiency and are expensive. The overall performance and reliability of an advanced battery system depends largely on the chemistry used in the cell. Nanophosphate is an engineered nanoscale material with specific structural and chemical properties designed to maximize the performance of lithium-ion batteries. Hence, Lithium ion batteries are the key candidates for wide range of applications. One of the challenges is the time it takes to recharge the battery Researchers at U.S, Department of Energy Argonne National Laboratory have discovered a new mechanism to speed up charging of Lithium ion batteries used for electric vehicles. By exposing the cathode to a beam of concentrated light (white light) the battery charging time can be lowered by a factor of 2 or more. Currently, it takes 8 hours to charge an electric car. In this photo assisted technology, the electrodes are placed in a transparent container that allows concentrated light to illuminate the battery electrodes during charging. It is found that during charging, white light would interact favourably with the typical cathode material Lithium Manganese oxide. It is a semi conducting material known to interact with light. While absorbing the photons during charging, the element manganese in Lithium Manganese oxide changes its charge state from trivalent to Tetravalent. This result in more oxidized metal centers and the ejected lithium are created due to light and voltage bias. The ejection of lithium ions is faster due to photon excitation which effects faster charging without degrading the performance and cycle life. This discovery / finding can have a huge impact on battery-only electric vehicle and bring a disruption in the automobile industry.

6. Fast Charging Station

The fast charging module can be built on the principle of DC to DC charging.

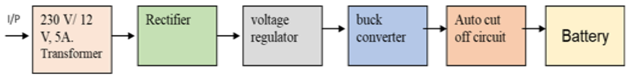

Fig. 3. Block diagram for fast charging module

230VAC supply is given to the input of step down Transformer 230 V/ 12 V, 5A. Transformer has 240V primary windings and center tapped secondary winding. This Power is supplied for circuit board. The sec12 V is given to the rectifier. So 12 VAC is converted in to 12 VDC. Then the 12 VDC supply is given to the voltage regulator which maintains the voltage of a power source within acceptable limits. Such a device is widely used in motor vehicles of all types to match the output voltage of the generator to the electrical load and to the charging requirements of the battery. Then we can connect buck converter in the circuit. The buck Converter circuit consists of the switching transistor, together with the flywheel circuit (Dl, L1 and C1). When the transistor is on, current is flows through the load via the inductor L1. The action of any inductor opposes changes in current flow and also acts as a store of energy. In this case the switching transistor output is prevented from increasing immediately to its peak value as the inductor stores energy taken from the increasing output; this stored energy is later released back into the circuit as a back e.m.f. as current from the switching transistor is rapidly switched off. The buck converter is a form of DC to DC converter that can take an input directly from a DC source. In this circuit buck converter did not reduce voltage, the voltage remain same it convert 12 VDC to 12 VDC. However, the DC applied to the Buck Converter is obtained, it is then converted to a high frequency AC, using a switching or 'chopper' transistor, driven by a (usually pulse width modulated) square wave. This results in a high frequency AC wave, which can then be re-converted to DC in a much more efficient manner than would be possible in the circuits described in Power Supplies to the battery or module. Then the supply is given to the auto cut off circuit. The auto cut off circuit is circuit used to protect the battery from the overcharging, high voltage and low voltage, when the battery fully charged then this circuit automatically cut the power off and protect the battery from the overcharging. The auto cut off circuit is designed for EV batteries. Battery used in the electric vehicle should have long life and need to be run without any fault so we have to protect it and make sure about not getting damage by the overcharge. The output supply from the auto cut off circuit is given to the battery for charging. The battery charge with 12-volt dc input and the 5Amp current. During the charging the battery takes upto 2.5Amp current for charging. With constant 12 VDC. The battery we are testing for charging is 14.6 volt and has capacity of 8000 mAH lithium ion battery. After certain testing it was observed that time taken for charging the battery was 12 minutes. Thus our purpose of fast charging is fulfilled.

7. Conclusion

Potential users of plug-in electric vehicles often ask for public charging facilities before buying vehicles. Furthermore, the speed of public charging is often expected to be similar to conventional refueling. For this reason, research and political interest in public charging focus more and more on fast charging options. By using Fast charging module, we can reduce charging time to 10 to 15 min from Hrs. Moreover, solar rooftop system can be installed on charging station roof. This will move one step ahead toward green energy in which Surplus power can be also fed to Grid by Net-metering.

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