

Review on Electric Vehicle Charging Technology

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ABSTRACT: Due to increase in fuel crises and Greenhouse gases, Government and automotive plane to promote electric vehicles, as electric vehicles are eco-friendly mode of transportation. EVs batteries are the key of both range and cost of the vehicles. Range anxiety has become an issue which has led to re-think refueling similar to conventional gasoline stations. In order to provide better performance in terms of range of the vehicle many possible solutions come into picture. This paper provides charging of electric vehicles which has been characterized into three levels i.e. Standard, Fast and Superfast Charging. Also in this paper All electric vehicles (AEVs) and Plug in electric vehicles (PEVs) has been discussed.

KEYWORDS: Electric vehicles, conventional gasoline stations, All electric vehicles(AEVs), Plug in electric vehicles (PEVs).

I.INTRODUCTION

Due to increase in fuel crises and environmental concerns around the world, Government as well as automotive manufacturers have developed various strategic plans to promote electric vehicles (EVs). But as electric vehicles come into picture people always led to think about range as well as refueling similar to that of combustion vehicles. Range performance can be surge by various ways, but can also be enhanced by fast charging infrastructure which enable user to charge vehicles frequently [4], Fast charging infrastructure will be more economic than increasing batteries. Batteries can also be charged at resident with level 1(120V) and level2(240V)c

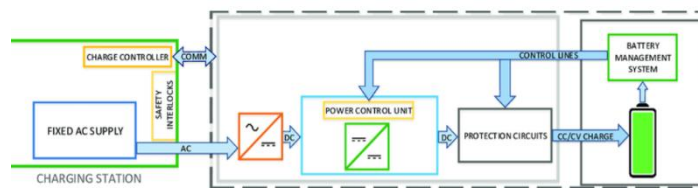


Fig 1. AC on board charging configuration

If the vehicles are equipped with on-board charging they are capable of drawing power of 1.92 Kw and 19.2 Kw for level1 and level2 from mains they take 8h to add 200 miles of range, the another one is off board charger which is located outside the vehicle [1].

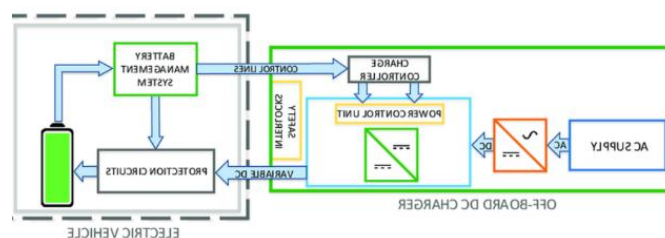
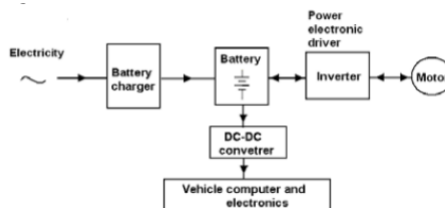


Fig 2. DC Off board charging configuration

A 50Kw Dc charger provide 200km of range within 60min. while 350Kw take only 10 min.Charging of EVs has been classified into three levels by U.S Department of energy. Level 1 is Standard charging while level 2 is Fast-charging and level 3 is Super-fast charging. Level 1 is having charge power between 5Kw while 2 is having charge power between 5Kw to 50Kw and level 3 having charge power above 50Kw [1]

Key components in EVs

Electric vehicle is simple in structure. The key components is shown in fig. the battery is the main energy storage the battery charger is to convert the electricity from main to charger the battery. The other electronic components in a vehicle can be supplied to the battery through DC-DC converter that step down the voltage from the battery pack to lower voltage such as 5V-20V.



Key components of electric vehicle

Motors

There are a number of motors available for electric vehicle: DC motors, Induction motor, DC brushless motor, Permanent magnetic synchronous motor and Switched reluctance motor.

Batteries

The battery is the main energy storage in the electric vehicle. The battery in-fact governs the success of the electric vehicle [5]. Recently there are massive works being reported in battery development. The battery such as Li-ion is now being used by new generation of electric vehicle. The danger of the instability of the battery has been studied by many reported. It seems that the LiFePO4 type is preferable because of its chemically stable and inherently safe. Other Li-ion such as LiCoO2, LiMn2O4 and Li(Ni1/3Mn1/3Co1/3)O2 may has the thermal and overcharge concern

Lithium-ion Battery

By significantly reducing expensive cobalt content per battery pack while increasing nickel content and still maintaining superior thermal stability. As the new cathode technologies are applied tolithium-ion batteries the cost continues to decrease. The producers intend to employ a ratio of 80% nickel to 10% manganese and 10% cobalt. It’s estimated that EVs will be cheaper than traditional gasoline-powered vehicles when lithium-ion batteries cost \$100 per kilowatt hour. Bloomberg New Energy Finance forecast lithium-ion battery pack prices will continue to fall as little as \$73 kWh by 2030[6].

Charging level	Voltage level	Maximum power (Kw)	Charging time
Level 1	120V AC	3.7	10-15 hrs
Level 2	220V AC	3.7-22	3.5-7 hrs
Level 3	200-600V DC	<200	10-30 min

Table 1. Charging power levels [1].

II.CHARGING CONNECTORS

2.1 AC Charging Connectors:

Depending on EVs, power levels of chargers.

A typical connector has two and larger pins and few smaller pins. Two types of connectors have been discussing below.

2.1.1 Type 1 Connector

This connector is used specifically for AC single phase charging and has a round configuration. It has 5 pins in which two AC lines two single lines and 1 protective earth path and voltage rating is 120V – 240V it has current capability up to 80V

2.1.2 Type 2 Connector

This connector is capable for both AC and DC charging the maximum voltage for single phase is up to 230V with current up to 80V. and three phase maximum rating of 400 V at 63A

2.2 DC Charging Connector

DC fast chargers are rated between 50kw to 500kw depending on manufacturer this DC fast charger are implemented off board. It is having high power capability due to which control stage become bulkier and expensive because of which they are implemented off-board. The other reason is being of safety concerns Five connectors have been discussed below

2.2.1 Combo 1 and Combo 2

This connector is compatible with both AC as well as DC charging this connector are capable of handling up to 350A at voltage ranging from 200V to 1KV. Maximum power handling capacity is 350KW

2.2.2 Tesla DC connector

Feature of this connector is that it uses same pin for both AC and DC charging. Also offer adaptor that makes connector compatible. This connector offers power level up to 120Kw.

2.2.3 T connector

This connector having nominal voltage range of 750V to 1 Kw, it can deliver current up to 251A. This connector communicates with onboard power management system.

III. BATTERY CHARGING METHODS

There are several different strategies employed when recharging EV batteries battery charging strategy refers to magnitude of current used during charging [2]

3.1 Constant voltage

In this type of charge, the charging voltage is maintained maximum at voltage that should be applied to certain type of battery while the charging current slowly decreases as the full battery charge is approached.

3.2 Constant current

This charging method applies a constant current as battery voltage builds up to its full charge value. Even if constant current applied is within the rated current, the constant current to battery can easily cause overheating and damage [2]

3.3 Constant Current-Constant Voltage

Also referred as “Voltage controlled charging”, it is common approach to a battery charging where a charger applies a constant current until battery reaches a predefined voltage potential [2]. It is traditional method of charging a battery, the CC-CV method has been further modified to include multiple constant current step

3.4 Current limit

As the charging take place a layer of electrodematerial starts to grow and through which Li+ ion now need to defuse thus slowing down overall charging rate.it is well known that Li-ion batteries are damaged when upper voltage is exceeded, due to occurrence of chemical reaction. Special precautions are needed to maximize the charging rate and to ensure that battery is fully charged and thus avoiding overcharging.

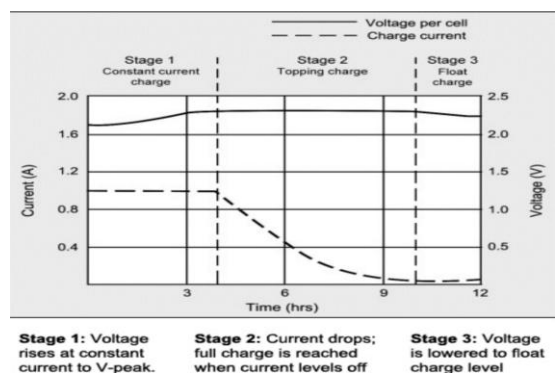


Fig.3 Acceptable battery current during charging

3.5 C-rate

Charge and discharge rate of battery are governed C-rate. The capacity of battery is commonly rated at 1C, meaning that a fully charged battery should provide 1A for 1 hour and the same battery discharging at 0.5C should provide 500 Ma for 2 hours.

Losses at fast discharged reduces the discharge time. Table of C-rate and service time is shown below

C-rate	Time
5C	12 min
1C	1 h
0.5C	2 h

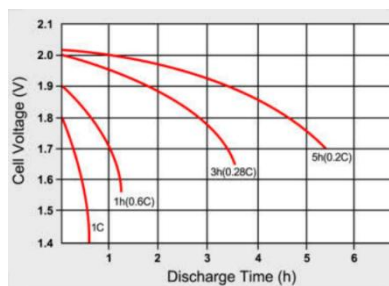


Fig.4 Discharge curve of lead acid as function of c rate

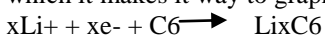
Charging data

The feed produced is converted into charging sessions by observing state change per charging time. Some session turns out to be very short, indicating either user-error or communication error, other error last for days indicating user leaving their car plugged in long after having reached full charge, or some other type of communication error [3].

Therefore, data is filtered to only include charging sessions between three minutes

Kinetics of electric vehicle battery [2]

During charging of LiCoO₂ at cathode Li⁺ desolvate from electrolyte and crosses into solid electrolyte interface from which it makes it way to graphite material in half cell reaction which is given as



at the counter electrode Li⁺ ion de-intercalates from the LiCoO₂ material eventually resulted in

a solvate Li⁺ electrolyte

during discharge, the Li⁺ charge transfer process reverses. The process $Li_xC_6 \rightarrow xLi^+ + xe^- + C_6$ occurs at carbon electrode which act as an anode.

each of this process has an intrinsic reaction rate. The rate of the reaction is fundamentally driven by excess potential applied to the electrochemical system in form of voltage the relation for applied chemical potential is reflected for voltage is given by

$$G_{\Delta} = nFE$$

G_Δ is excess chemical potential

F is faradays constant

n is no of electron exchanged

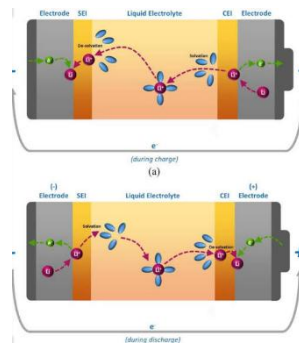


Fig.5 Li+ charge transfer process during charge and discharge [2]

IV. BATTERY THERMAL MANAGEMENT

A significant amount of heat can be generated while a battery is charged and thermal management is critical for Li-ion batteries. Without sufficient cooling the cell can be damaged and significantly reduce battery life [2].

There are two main problems caused by temperature. First one is high temperature during charge and discharge leads to possibility that temperature will exceed permissible level and decrease battery performance ideally Li-ion battery operates between 15° to 40° for optimal battery performance temperature below 15° is acceptable as discharge battery produce its own heat [2]. During extreme heating, electrolyte between electrode can melt, leading to reduction in power delivery, internal short circuit that destroy battery and can cause explosion

Thermal management may be active or passive and can be divided into three categories based on medium

4.1 Air cooling

Air cooling allows direct contact with battery cell, relatively having lower maintenance as well as lower cost but air flow on the cell isn't the most effective method for removing heat, it is difficult to maintain the uniformity of temperature within a cell or within cells[2].

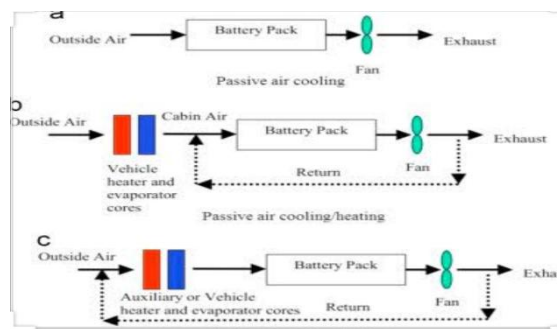


Fig.6 Air cooling system

Cooling in these can be based on simple system that uses fans and ducts. This type of cooling is being used in Kia soul and Nissan E-NV200. Air cooling system in Kia soul has been shown in fig below

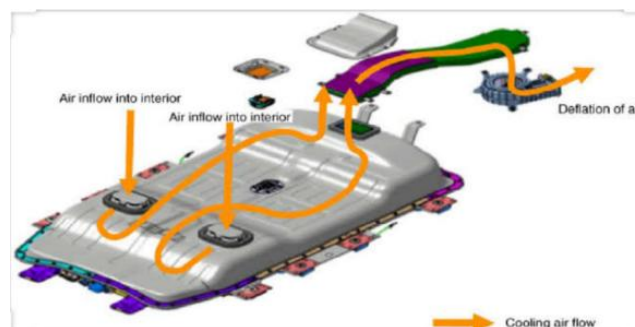


Fig.7 Cooling system in Kia soul

4.2 Liquid cooling

It is another method that is being used. But this system requires more maintenance and components due to which its costs is more than air cooling as components in this system are more there are two types of fuels that can be used in liquid cooling system, [2]

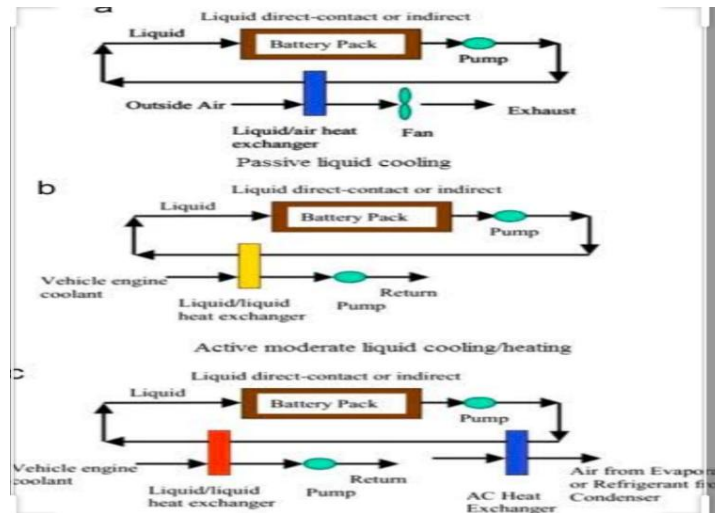


Fig.8Liquid cooling system

water and glycol solution in indirect liquid cooling, and dielectric mineral oil in direct liquid cooling, in indirect liquid cooling having lower viscosity and higher heat capacity this system uses circulating fluid and a radiator and are widely used in tesla, BMW Hyundai and Renault.

V. SMART CHARGING TECHNOLOGY

Smart charges allow the charging power to be controlled along with the charging time and the direction of flow. By this electric vehicle can be made more sustainable by solar and wind generated power. The peak power demand can be fulfilled by utilizing these storage systems [1]. The V2x technology allows the power from the battery to flow from a vehicle to home, building

5.1 Applications

1. local load balancing- If smart charger detects that the load of the power from other power has reduced the charging power can be increased in a controlled way and if demand of the local load increases the power of the charger is reduced in order to balance the load. Smart charger can be sequentially activated with priority or with adjusted power.
2. Renewable energy utilization- The charging power of the car can be adjusted according to the availability of renewable resources may be wind or solar energy
3. peak shaving- With implementation of proper control strategies, electric vehicles can be charged when there is extra energy from renewable source and that energy can be again given back to the grid [1].
4. Grid back up- electric vehicle can act as backup power generation in the feature. If there is a failure of grid for short period of time electric vehicle can be used to power up the local loads thus provide emergency power during outage.
5. Battery swapping- it is the concept of switching of the depleted battery and replacing with fully charged one. This process is done by taking the car to battery switching bay where the car automatically aligned and the old battery is swapped with new one.

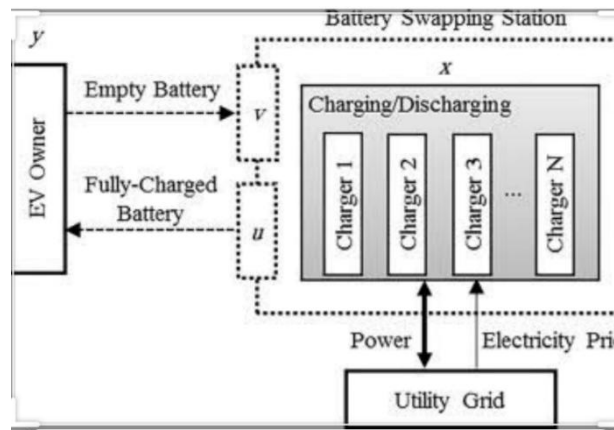


fig.7 Battery Swapping Technology

VI. CONCLUSION

This paper presents a review of charging technology. Explained issues related with charging as well as charging methods and types of charger has also been discussed. Problem related to heating in batteries can be resolved by battery thermal management which has been explained in this paper, also due to stimulus package announced by government it will encourage the increase adoption of EVs, leading to a more sustainable energy feature.

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