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# A STUDY ON CHARGING INFRASTRUCTURE AND THE TOPOLOGIES OF FAST CHARGING TECHNIQUES IN ELECTRIC VEHICLE

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**Abstract—** Over the last few years, the popularity of Electric Vehicles (EVs) has drastically increased, in the transportation industry. In EVs, charging of batteries play a vital role equivalent to refilling of petrol fuel in conventional vehicles. It is essential to develop high power charging infrastructure similar to the existing petrol fuel stations, because of the growing fleet of a new generation EVs. Hence, the development of fast charging infrastructure and fast charging techniques are getting more research focus because it can swiftly recharge the EV battery and extend the range. It is important and need of the time that EV battery charging times need to decrease to the range of 5–10 min, make EV battery charging to compete with petroleum-based transportation. This paper studies various charging infrastructures and the levels of charging for EV and presents DC fast charging techniques.

**Keywords—** BEV, EV, Fast Charging, PEV, PHEV

## I. INTRODUCTION

At present, due to the reduction or even depletion of non-renewable resources, environmental pollution and global warming, the demand for clean energy is constantly rising as in Jensen et al. (2016). The manifestation, in the automotive industry, is that electric vehicles are attracting more and more attention and have broad prospects for development. EVs have been a documented solution for future transportation, and persist to become extensively accepted as the technology develops and economic viability becomes a truth. EVs offer minimised pollution, significant efficiency (energy savings) through enhanced fuel economy, and helps to have a larger variety of fuel choices for transportation Vasiladiotis et al. (2015). EVs comprise a number of drive train and energy storage modules. The battery pack typically uses Li-ion cells (in the range of 400 V) and is managed and monitored by a battery management system (BMS) and charged via an on-board AC/DC converter module as in Miao et al. (2019). A DC/AC inverter uses the high voltage of the battery to drive the electric motor; it is also used for regenerative braking, putting energy back into the battery pack. A DC/DC converter is needed to connect the high-voltage battery to the conventional 12 V automotive network as in Waltrich et al.

(2012). One of the concerns most often raised as hindering the move to an EV is range anxiety. The first is the range provided by the vehicle's battery. Typically, even low-range EVs cover the average daily commute comfortably, but the realities of life mean that the range can be perceived as limited when unexpected additional trips or detours are factored in Bingham et al. (2012). The vehicle's battery management system (BMS) is at the heart of this challenge and has the potential to significantly reduce both aspects of range anxiety. However, this leads to the area where the EV driver's anxiety is really focused: charging infrastructure. This is the second issue, making sure that 'energy' can be topped-up as easily as fossil-fuel vehicles today as in Gomez et al. (2003). Plenty of infrastructures are fine but, unless it provides close to a full charge in a time frame similar to a full tank of fuel, this is an impediment to mobility. This paper studies various charging infrastructures and the levels of charging for EV and presents DC fast charging techniques.

The deployment of plug-in electric vehicles (PEVs) and the fraction of vehicle miles traveled that are fueled by electricity (eVMT) depend critically on charging infrastructure as in Tesla (2019). PEV charging infrastructure is basically different from the existing petrol fueling infrastructure. PEV infrastructure should be found in a various locations such as residence of PEV owner, workplace, parking lots of café, shopping place, and Bus stand, airports, Highways etc. Various types of charging options are available, from level 1 AC chargers that use 230V AC electric circuits that are present in almost every construction to DC fast chargers as in Rodriguez et al. (2012). The charging rate also varies from slow (time-insensitive) charging to fast (time-sensitive) charging. The infrastructure categories are ranked in order of importance for increasing PEV deployment and eVMT. Charging time is not a main consideration in today's level 1 and level 2 AC charging infrastructure technologies, which are typically used. But charging time is an significant consideration in DC fast chargers as in Trivedi et al. (2018). Level 1 and level 2 AC chargers are used to charge all PEVs, and DC fast chargers are used to charge most battery electric vehicles (BEVs). In the future, It is necessary to change and prepare plug-in hybrid electric vehicles (PHEVs) might also to

use DC fast chargers, as PHEVs can use their internal-combustion engines (ICEs) to circumvent the need to charge as in Anderson et al. (2018), Dickerman et al. (2010), Yan et al. (2016).

## II. CATEGORIES OF EV CHARGING INFRASTRUCTURE

Charging Infrastructure in EV is classified into two major categories. They are:

1. Home /Workplace
2. Public

The Public infrastructure is further divided into four categories. They are:

1. Intracity AC
2. Intracity DC
3. Intercity DC fast
4. Interstate DC fast

In general, the charging Infrastructure will fall under four levels of charging. They are: Level 1, Level 2, Level 3 and Wireless charging. Level 1 is standard charging that has a charge power less than 5 kW, Level 2 is fast-charging that occurs between 5 kW and 50 kW, and Level 3 is super-fast charging that is greater than 50 kW. Level 1 and Level 2 charging contain onboard electronic converters allowing for AC energy transfer. Level 3 charging contains off board charger because of its high power charging levels. This is due the requirement of complex power electronic circuits which makes it impractical to carry them on board due to size constraints. In order to reduce the mass of on-board electronics, Level 3 charging usually conveys the power to the vehicle as DC. Electromagnetic waves are used in wireless charging system to charge EV batteries. In wireless charging system, charging pad connected to a wall socket and a plate attached to the vehicle.

The Fig. 1 shows the various types of charging Infrastructure and their levels of charging. The details of Home/ work place and public charging Infrastructure are as follows:

### A.Home/ work place charging Infrastructure

Home/ work place charging is a paradigm shift in refueling behavior for drivers accustomed to refueling quickly at petrol stations. Many find home charging more convenient than refueling at public stations. A small household outlet may charge as slowly as 1.2 kW. The home private chargers are generally used with 230V/15A single phase plug which can deliver a maximum of up to about 2.5KW of power. Home charging under level 1 category will add 8 km of range to the EV per hour. This charging can be simply done just like charging the mobile phone using plug. Similarly Home charging under level 2 category will add 42km of range per hour and typically take 3-4 hours for full charge. The electric

vehicle supply equipment (EVSE) supplies AC current to the vehicle's onboard charger which in turn converts the AC power to DC allowing the battery to be charged. For charging outside the home premises, electric power needs to be billed and payment needs to be collected as in Wang et al. (2017). The power drawn by these chargers may need to be managed from time to time. Merits: Homes are the most important location for charging infrastructure. For the residents of apartments, lack of access to charging infrastructure is a demerit in this home charging infrastructure that need to overcome for development of PEV deployment.

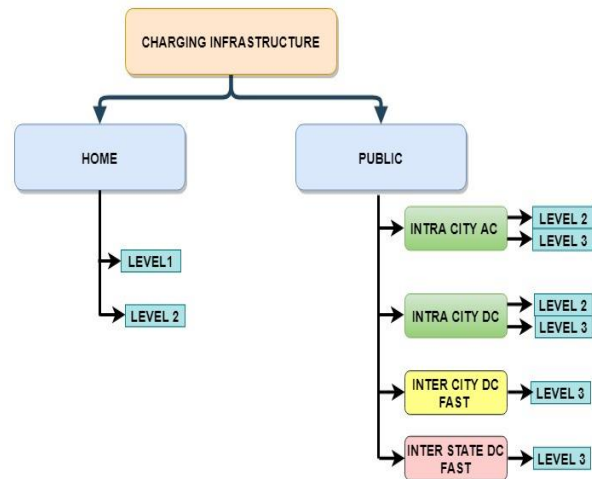


Fig. 1. Types of Charging Infrastructure

### B. Public Charging Infrastructure

Public charging infrastructure is publicly accessible and is located on land owned by the public. Fast charging should be more distributed along the highways for long-distance journeys. In principle, there are two options: (1) Public slow charging (AC) infrastructure is built where there is parking availability (parking lots, buildings or on-street-parking) nearby the home of PEV users for charging overnight (or close to work for charging during work time), or (2) public DC charging hubs are built in city centers and used similarly to today's fueling stations. The latter requires high grid connection power and high investment but will probably be profitable in the long-term.

- Intracity AC Charging Infrastructure

Intracity AC Charging Infrastructure uses Level 1 AC chargers. Level 1 AC chargers offer about 5-10 km of operation per hour of charge. If charging time is not a key concern, then Level 1 AC chargers will be preferred to use and it is optimal to install the places like airports and Bus/railway stations, where people park their vehicles for extended periods. Level 1 AC chargers can also easily be installed using accessible 230 V outlets. Level 2 AC chargers are more preferred for places where vehicles are regularly parked for just an hour or two, such as at temples, parks, shopping areas,

museums, libraries, and hotels. It is the attractive method for businesses to draw customers, if these types of chargers have been installed at the parking area of those locations.

- Intracity DC Fast-Charging Infrastructure

The majority of the fast charge infrastructure is installed within cities and their metro areas, though DC fast chargers are regularly considered for passageway travel, such as between states or cities. According to the PEV type, the impact of intracity DC fast-charging infrastructure varies. As range extension or range confidence is required for Long-range BEVs, it will use fast charging minimally within cities. Conversely, charging BEVs at a DC fast charging station would permit them to attain a complete battery charge more swiftly than home charging; those who do not have a place to charge at residence, this choice might be precious to a long-range BEV owner.

- Intercity and Interstate DC Fast-Charging Infrastructure

The DC fast chargers accessibility in highway roads which connects cities and states will ease the local travel for limited range BEVs and facilitate extensive distance journey for long range BEVs. DC fast chargers are preferred to use primarily for range extension like journey between cities where stops to charge might be difficult; hence DC fast chargers receive less usage preference for BEV between cities than within cities. The least preferred kind of infrastructure for PEVs is Interstate DC fast chargers because it will not (or cannot) be used by PHEVs and will be difficult for limited-range BEVs.

From the discussion, it is inferred that the most preferred EV charging infrastructure by the drivers' everyday usage is home and workplace charging infrastructure; intracity infrastructure will be relatively less preferred. Intercity and interstate charging would, in that scenario, enable long-range BEVs to take longer trips with relative ease. Vehicle manufacturers, especially those focused on BEVs, are building intracity, intercity, and interstate DC fast-charging infrastructure. Hence nowadays DC fast charging techniques are getting importance in the EV industries for deployment of fast charging infrastructure. The following section will detail the DC fast charging Techniques.

### III. DC FAST CHARGING TECHNIQUES

A crucial part of the operation of the EVs is the recharging of their battery pack. This process can be carried out in two different ways: conductively or inductively as in Khaligh et al. (2012), Kouro et al. (2012). The first charging method uses electrical contact between the charge port of the vehicle and the charger connector to transfer the energy into the battery pack. The second method uses wireless energy transfer through electromagnetic field coupling, eliminating the plug-in cord. DC fast-charging EVSE (440-V AC input to the EVSE) enables rapid charging at sites such as heavy traffic corridors and public fueling stations. A DC fast charger can add 90 to 150 km of range to a PEV in 20 minutes. Fig. 2 shows the DC fast charging schematic

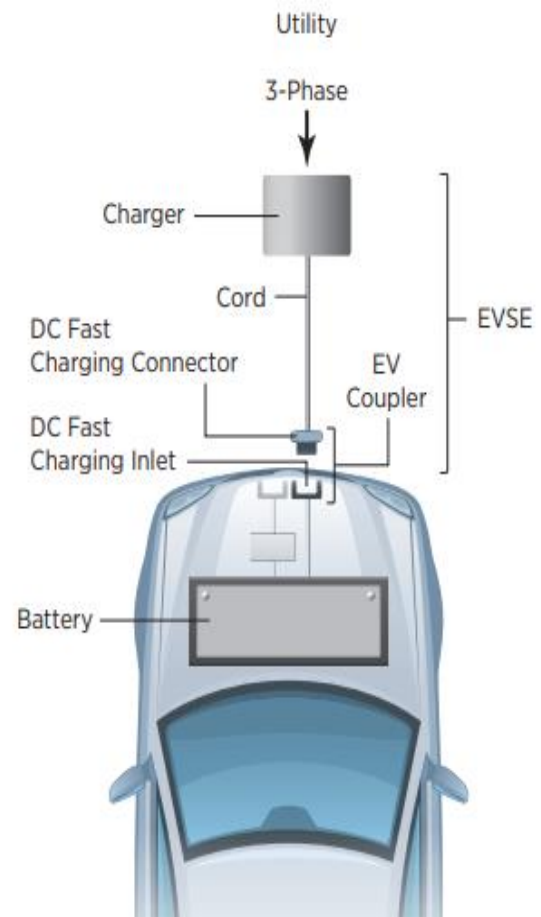


Fig. 2. DC fast charging schematic.

Emerging battery charging technologies that accept higher charging rates and several thousands of charging cycles makes fast charging a realistic possibility.

There are two standard fast charging architecture namely Common AC bus and DC bus architecture. The first uses the secondary windings of the step-down/isolation transformer as an ac bus, where each load is connected to the bus via independent ac-dc stages. The second uses a single ac-dc stage in order to provide a common dc bus for all the loads of the system. Fig. 3 and Fig. 4 illustrate Common AC bus and Common DC bus fast charging architecture.

Common AC bus is the preferred architecture for AC distribution networks to enable the energy management and flow between the charger systems, the energy storage and the grid. In this structure, each charging unit has its own rectifier stage that is connected to a common ac coupling point in the secondary windings of the step-down transformer. This architecture represent a simpler concept because it has been used for years, and well-developed standards and technologies are available.

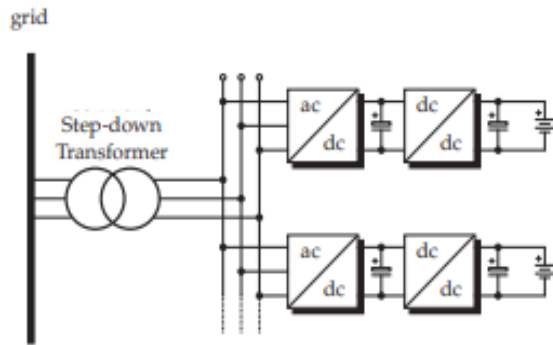


Fig. 3. Common AC Bus Architecture

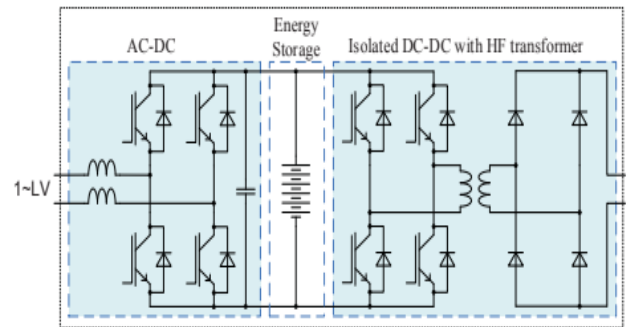


Fig. 5. General Fast Charging Circuit

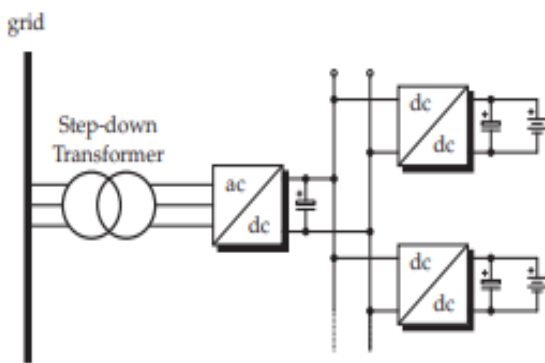


Fig. 4. Common DC Bus Architecture

However, the presence of several battery chargers, with independent rectifier stages and inherent low power-factor operation, may produce unwanted harmonic effects on the utility grid, particularly for high power fast chargers. Moreover, the cost of several converter units with lower power ratings is higher than that of a single high-power converter unit, due the need of several filter sets, control stages and sensors. In addition, in the case of having distributed generation units in the station, such as PV or fuel cells, or even the usage of energy storage systems, which generate energy at dc, will also require their independent AC-DC stage, thereby further increasing the number of the conversion stages in the system and, consequently, the cost and complexity of the system.

New developments in distributed energy resources and renewable energy are leading to increased interest in DC energy distribution. DC common bus feeds several battery chargers and provides a more flexible structure, which can easily integrate distributed renewable energy conversion systems, or energy storage devices, since these systems are essentially DC. Fig. 5 shows commonly used fast charging topology which uses AC-DC rectifier and DC-DC converter along with energy storage as DC link.

- Wireless Charging

Wireless charging is Inductive charging and it is a wireless solution which is being researched for EV charging, both for static charging and dynamic charging, while the vehicle is driving. As can be seen in Fig. 6, by driving an EV over a large charging coil, a coil within the EV can couple to the charging coil, allowing power to be transferred through the magnetic coupling of the two coils. This method has the advantage of simplicity and convenience, e.g., at charging stations and dynamically during driving, safety for the driver (as they won't have to electrically plug the vehicle into the grid), and eliminates the need for the correct charging plug.

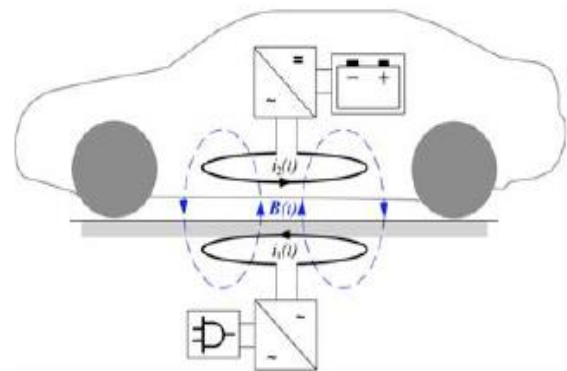


Fig. 6. Inductive Wireless Charging

#### IV. CONCLUSION

The paper studied the types of charging infrastructure and the topologies of fast charging techniques in Electric Vehicle. Charging Infrastructure in EV is classified into two major categories and are: Home/Workplace and Public. The Public infrastructure is further divided into Intracity AC, Intracity DC, Intercity DC fast, and Interstate DC fast. DC fast charging techniques are getting importance in the E vehicle industries for deployment of fast charging infrastructure. Common AC



bus and Common DC bus are the classification of Fast charging Techniques. The paper concludes by presenting commonly used power electronics circuit used in DC fast charging Techniques and the latest wireless inductive charging techniques

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