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A Comprehensive Review of Electric Vehicle Charging Station Topologies

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***Abstract* - Electrified cars are on track to become a critical component of the transportation business over the next several years. As a result, the charging infrastructure should be designed concurrently. The many approaches and strategies for electric car charging systems are presented in this study. Fast charging stations with solar PV integration, predictive controllers based charging stations, PV-assisted EV fast charging stations, MPPT Algorithms for Solar PV based Charging Stations, and Multiport Converter based EV Charging Stations are all discussed in this article. This report will be beneficial to future researchers and students who are interested in working on solar pv based quick charging stations for electric car design.**

***Keywords* – Electric Vehicle, Charging Station, Fast Charging, MPPT.**

I. INTRODUCTION

Since the last decade, electric cars (EVs) have become increasingly popular. The prgressive depletion of fossil fuels such as crude oil, coal, natural gas, and heavy oil, which are sought by the expanding populations of industrialised and emerging nations, is driving up demand [1]. Electric cars have become a class that is further divided into Hybrid Electric Vehicles (HEVs)2 and Plug-in Hybrid Electric Vehicles (PHEVs)3 due to continual efforts and pioneering research initiatives in the Battery Management System (BMS) for applications in EVs. Although the majority of EVs currently on the market are both HEVs and PHEVs, the desire for PHEVs is clearly higher. This is owing to the fuel flexibility provided by these cars, which can run on both traditional fuels like petroleum and gas as well as electric power stored in a battery (energy storage device).

The word "electric vehicle" is used in this document to refer to any mode of transportation that employs rechargeable batteries, such as cars, buses, motorbikes, and trucks. The rise in electric vehicle numbers has created a new problem: increased grid power consumption. Decentralizing power generation, such as incorporating renewable energy local sources into charging infrastructure, is one effective way to mitigate the effects. Liu et al. [2] report on the connection between renewable energy and EV charging problems in the presence of smart grid technology to address this problem.

II. DIFFERENT SCENARIOS OF CHARGING EVs

There can be four different scenarios for charging of EVs.

2.1 Uncontrolled Charging or the end-of-travel charging:

This is a common charging arrangement for an electric vehicle parked at home. It does not require any sophisticated control technology to determine how and when charging takes place. Furthermore, it provides no information on user behaviour or incentives, such as time of use rates (ToU). Based on a standard residential 110/120 volt 20 Ampere circuit with a continuous rating of 1.8-2.0 kW, a constant charging rate of 1.4 kilo Watt (kW) is assumed for this application. Even with this slow charging pace, a fully charged battery takes about six hours to charge.

2.2 Delayed Charging:

This is similar to end-of-trip charging, however it only starts charging after 10 p.m. In this instance, a timer, either in the car or in the charger, is required to manage power use. ToU may be used with just a small increase in infrastructure. Because of the current incentives for off-peak energy consumption, utility firms are more likely to choose this situation. Residential consumers can get ToU prices from a variety of utility companies, including Xcel Energy. The charging rate is 1.4 kW, which is identical to the uncontrolled charging scenario described above.

2.3 Off-Peak Charging:

In this scenario, all charging takes place overnight in residential areas, with the goal of providing the most efficient, low-cost charging possible since car charging may be regulated directly or indirectly by a local utility provider. The car would respond intelligently to a real-time pricing indication in the event of indirect control. For maximum system optimization, the charge rate is raised to 3.2kW during off-peak charging. This is higher than the continuous charge rate of a typical residential circuit, and it implies that 240 V/40 Ampere level 2 chargers are used for 20% of all charging. The charging period is estimated to be roughly six hours.

2.4 Continuous Charging or Publicly available electricity charging:

This scenario is identical to the end-of-trip charging scenario, but it assumes that the electric car is charging at a public charging station. Vehicles are charged anytime they are stationary for more than an hour, even though charging during off-peak hours is recommended. This is an example of uncontrollable charging as well. The utilisation of this charging profile peaks twice a day, usually in the morning and evening.

III. ELECTRIC VEHICLE CHARGING STANDARDS

The Society of Automotive Engineering (SAE), the CHAdeMO association, and the International Electro-technical Commission are three major organisations that seek to standardise electrical characteristics of EV charging stations across the world (IEC). Aside from these organisations, Tesla Motors, the world's leading electric vehicle manufacturer, establishes its own standards for its Model S, Model X, and Roadster electric vehicles.

Every organisation listed above offers a variety of charger standards that function with both AC and DC power. The SAE, for example, has been working on standard J1772, which divides electric vehicle chargers into three levels [5]: Level 1, Level 2, and Level 3.

i) Level 1: The charger is built-in and delivers DC voltage with a maximum current of 80 A and a power output of 40 kW.

ii) Level 2: The charger gives a DC voltage of up to 200 A with a maximum output of 90 kW.

iii) Level 3: The charger is disconnected from the board. With a maximum capacity of 240 kW, the charging station delivers DC electricity straight to the battery through a DC connection.

Level 3 chargers are all considered fast chargers. CHAdeMO and the International Electrotechnical Commission (IEC) suggested various power and current requirements for DC rapid charging. A quick summary of power and current level evaluation for electric car DC charging standards is presented in table 1 for additional information.

Table 1: EV Charger categories

Standard	**Level**	**Max Current Rating (A)**	**Max Power Rating (kW)**
SAE	DC Level 1	80	40
	DC Level 2	200	90
	DC Level 3	400	240
CHAdeMO	DC Fast Charging	125	62.5
IEC	DC Fast Charging	400	100-200
Tesla	DC Super Charger	340	136

IV.DIFFERENT CAHRGING STATION TECHNOLOGIES

4.1 Fast charging station:

Pablo Garca-Trivio [3] and his colleagues presented a rapid charging station that included a solar (PV) system, an energy storage system (ESS), and a link to the local grid. The FCS can operate as a stand-alone system for the most part, with occasional grid support, thanks to this arrangement. The voltage management of the common medium voltage DC (MVDC) bus, to which all the energy sources are linked, is used to regulate them. As a result, the PV system, the ESS, or the grid are employed to supply the energy required by the EVs, depending on their voltage.

Two 48kW fast charging units (FCU) are used in the EV FCS under investigation (Fig. 1), which may be powered by a PV system, a Li-ion battery pack (ESS), or the grid. According to the IEC 61851-1, this FCS is classified as "Mode 4, DC level 2." For managing the power balance between them and the MVDC bus voltage, all of the FCU's components are linked to a 1500V DC voltage (MVDC) through DC/DC converters. A DC/AC converter and a transformer are used to connect to the grid.

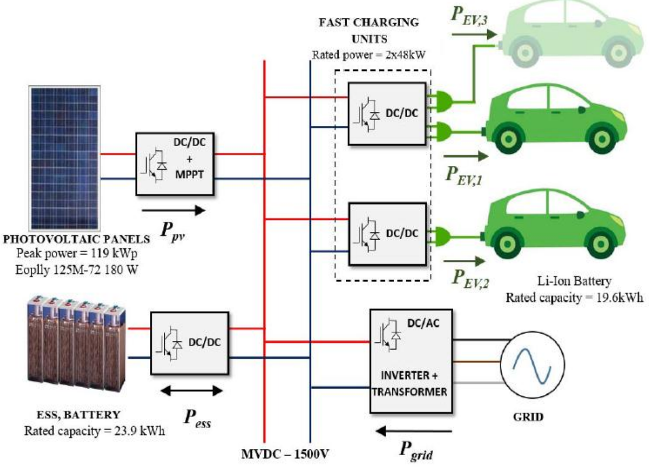


Figure 1: Configuration of the EV FCS

4.2 Cascaded High Frequency AC Link System

The creation of high-power electric vehicle (EV) fast charging stations (EVFCSs) that are directly connected to the medium-voltage (MV) grid is a possible method for reducing EV charging time. The charging station's cascaded-high-frequency-link (CHFL) technology offers an isolated power electronic interface between the station's low voltage (LV) DC bus and the three-phase MV AC power network. A high/medium frequency transformer is used in the CHFL system to offer isolation and a high stepping-up ratio. The enormous number of active switches is the system's biggest drawback.

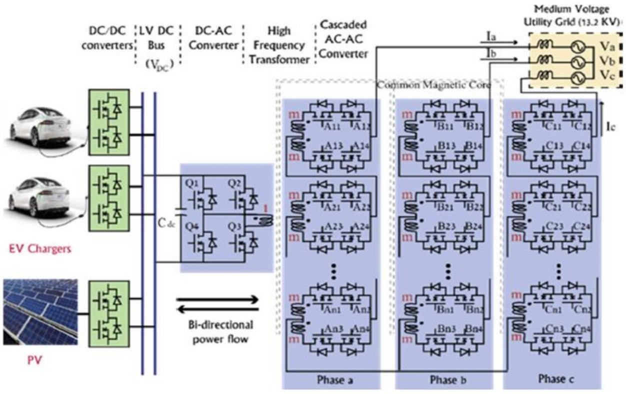


Figure 2: General Block diagram of CHFL system

The CHFL system is depicted in block diagram form in Figure 2. A half-bridge matrix converter is used in the cell topology. There is no dc connection in the CHFL system with this cell architecture. As a result, it qualifies as a CHFACL system. For n cells, the secondary windings of the transformer are 2n. As seen in fig. 2, each cell is coupled to two secondary windings. The primary winding and one of the secondary windings of the transformer have a turns ratio of 1: m. The PV modules are linked to a VDC LV DC bus (this voltage reference is derived using the maximum power point tracking (MPPT) technique shown in [5]. When the duty cycle of a single phase inverter is 50%, the voltage at the transformer primary side is –VDC for 50% of the periodic time and VDC for the balance of the periodic time. For half of the periodic time, the voltage at one of the transformer's secondary windings' terminals will be (-m.VDC), and for the remainder of the periodic time, it will be (m.VDC). Because each cell operates in a bi-polar manner, it can output either (m.VDC) or (–m.VDC). The cell may convert the HF voltage to a low frequency voltage component by adjusting the timing of realisation of these two voltage levels.

4.3 PV-Grid Charging System:

Several elements that impact the CS yield are linked to the coupling of a photovoltaic-grid system (PVGS) and an electric vehicle charging station (EVCS) [6]. External inputs, like as weather data, geographical position, and the daily rated power of the CS [7], are deemed crucial to complete the design. A charging station architecture was presented by A. HASSOUNE et al [12], as shown in Fig. 3. PV array, EVs, and BSB are all connected to a DC bus; the diagram depicts both DC and AC buses.

The PV system is linked to the DC bus through a DC/DC boost converter that uses an MPPT algorithm to extract the maximum power from the PV system. The buck/boost converter connects the BSB to the DC bus, converting the battery's low voltage to the bus voltage. Buck converters are solely used to charge EVs using a variety of charging modalities linked in parallel to modalities linked in parallel to PV/BSB. Each charging station has a Human Control Panel (HCP) with information such as the battery's State of Charge (SOC), time to load, battery capacity, and power necessary to achieve the specified SOC. Another parameter is the vehicle's business name/model in order to correctly adapt the appropriate charging mode and establish the priority level to load when insufficient power is detected at the CS.

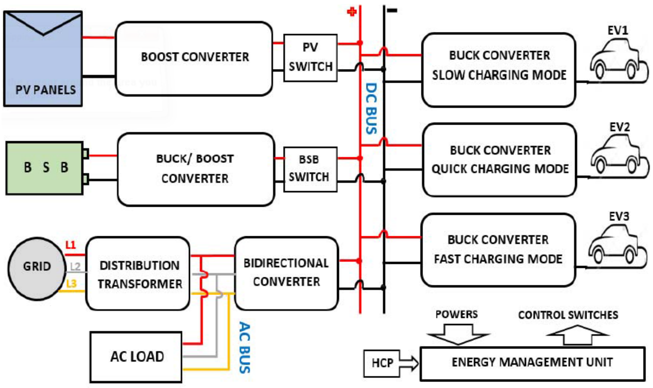


Figure 3: PV-Grid Charging System

4.4 Fuzzy Logic Controlled Charging System:

Pablo Garca-Trivio [11] and colleagues introduced a new decentralised charging station control approach based on a medium-voltage direct-current (MVDC) bus. These charging stations are part of a microgrid that includes a PV system, a battery energy storage system, a local grid link, and two rapid charge units. The referenced decentralised control approach based on fuzzy logic, which includes the state of charge of the battery energy storage system as a control variable, is the primary contribution of their study. This control contains two independent fuzzy logic systems (one for the battery energy storage system and the other for the grid), initial state-of-charge of the battery energy storage system, and number of EVs connected to the charging station.

A DCM based on separate fuzzy logic controllers is aimed to replace this type of control. This structure allows each component to function independently without knowing the state of the rest of the system, removing the theoretical and practical limitations of power supply dependability and facilitating large-scale generator access [13].

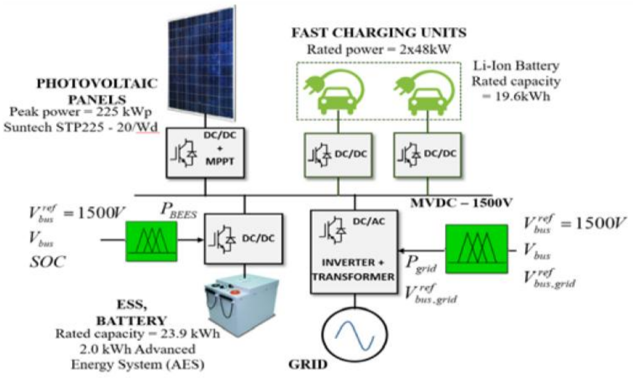


Figure 4: Fuzzy Logic Controlled Charging System

4.5 Wireless Electric Vehicle Charging

Typically, electric vehicle systems are made up of a number of modules that work together to provide the vehicle's high power and track stability. The charging mechanism is connected to the bulk of these components. In this context, dynamic wireless power transfer is a viable solution for addressing electric car range anxiety while also lowering onboard battery costs. In addition, the status of the vehicle, whether it is moving or not, determines various characteristics such as vehicle speed and coil receiver sizes and diameters.

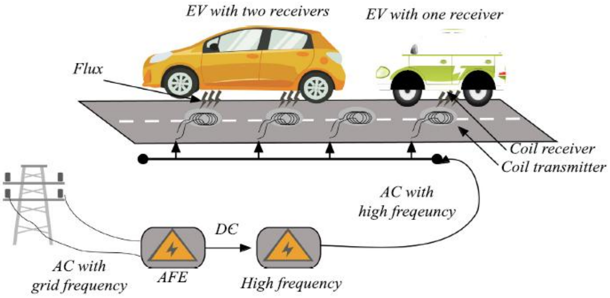


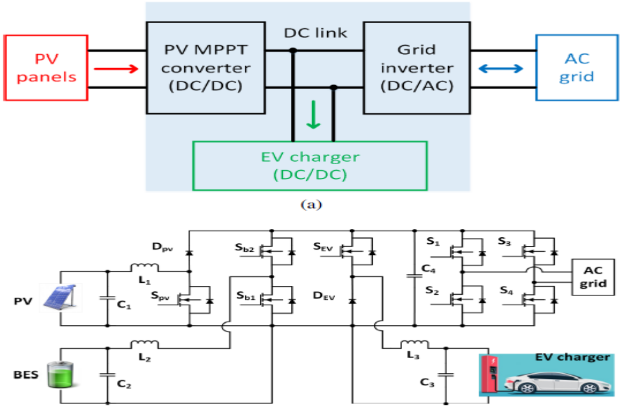
Figure 5: Wireless EV Charging System

The system is divided into two components, one for the road and the other for the car. The permanent portion on the road is known as the transmitter. The moving receiver is the second component, which is located beneath the vehicle. The two parts are separated by a vacuum, and each portion has its own electronic system. The transmitter block produces a high-frequency alternating magnetic flux.

As shown in Fig. 5, the transmitter section is mounted on the road and connected to a series of electrical components that provide flexibility between the receivers and the AC power supply. It shows the original energy AC power linked to the active front end (AFE) converter, which generates a programmable DC voltage. A power factor corrector (PFC) block is added to this area of the transmitter block to maintain grid stability by monitoring the reactive power coming from the source to the transmitter.

4.6 Multiport EV Charging Station

All three power sources, including PV and EV charger unidirectional sources, and AC grid bi-directional source, are connected through three independent converters in the traditional architecture of DC bus charging station with PV integration figure 6.



(a)

Figure 6: Multiport EV Charging System

One more bi-directional power source BES shares the same DC bus in the proposed DC bus charging station figure 6. The BES is used to keep the DC link voltage stable and balance PV power surpluses and shortages figure 6. The purpose and operation modes of this setup may be explored in depth as follows.

V to EV (mode 1)

In this mode, the switches Spv, Sb1, and Sb2 are turned off while SEV is turned on. Therefore, PV directly delivers power to the load.

Mode 2: BES to EV

BES is discharged to the EV load when Spv and SEV are turned on while Sb1 and Sb2 are turned off.

PV to BES (Mode 3)

BES is charged from the PV surplus energy when Sb2 is turned on and Sb1, Spv, and SEV are turned off.

PV to BES, Grid to EV, and PV to Grid are the other modes.

Table II summarises the operational principles of various modes like as PV to BES, grid to EV, and PV to grid. Table II: EV Charging Operating Modes

S_{pv}	**S_{b1}**	**S_{b2}**	**S_{EV}**	**Power flow**
OFF	OFF	OFF	ON	PV to EV
OFF	OFF	ON	OFF	PV to BES
ON	OFF	OFF	ON	BES to EV

-	ON /OFF	OFF/ ON	ON	Grid to EV
OFF	OFF	OFF	OFF	PV to Grid

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CONCLUSION

This study examined multiple energy transfer types, charging levels, and procedures, as well as the current global standards for EV charging, to offer a better knowledge of EVCS technology. There is a comparison and explanation of the many components of the charging stations. To summarise, the photovoltaic charging structure is growing increasingly complicated as additional functions are added into the system, necessitating sophisticated controls in each block as well as real-time station management.

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