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Introduction to Electric Vehicle Fast-Charging Infrastructure

1.1 Introduction

The electric vehicles (EVs) are an absolute necessity due to the rapid degradation of fossil fuels and they are free from environmental pollution during their operation. In a conventional vehicle, petroleum products like petrol or diesel, or gasoline are used as a fuel for transportation. Similarly, in EVs, energy stored in the batteries is used as fuel for transportation. So, batteries in the EVs are to be recharged whenever the battery state of charge (SoC) indication is low or on a need basis by a charger or charging equipment. The charging equipment used to recharge the batteries in EVs is called as electric vehicle supply equipment (EVSE) [1, 2]. An EVSE is placed in a charging station, and it receives the electric power supply from DC or AC supply system and supplies the DC power to recharge the renewable energy storage system (RESS) or simply batteries in the EVs. The typical single-line diagram (SLD) of a charging station is shown in Figure 1.1.

The IEC 61851-1:2017 [3] classifies the EVSE in a charging station into the following types:

1) Characteristics of power supply input

The EVSE is classified based on the grid supply system used to power the EVSE,

- EVSE connected to AC grid power supply system
- EVSE connected to DC grid power supply system

2) Characteristics of power supply output

The EVSE is classified based on the type of current it will deliver to the EV,

- AC EVSE
- DC EVSE
- AC and DC EVSE

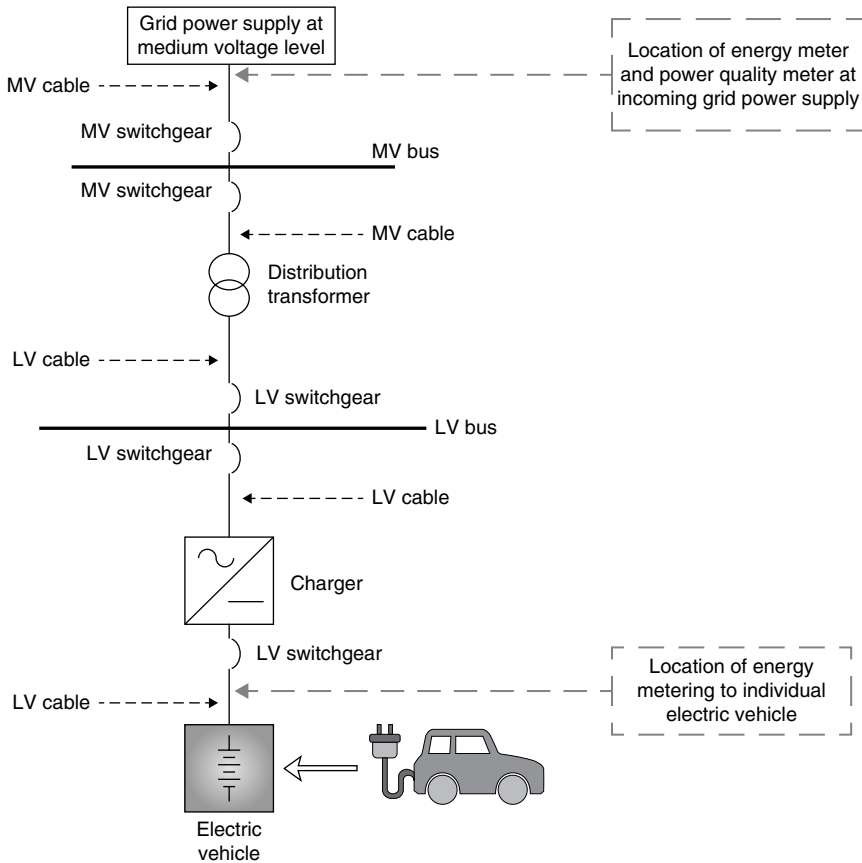


Figure 1.1 Typical SLD of a charging station. MV, medium voltage.

- 3) Based on the type of electric connection method
 - Plug and cable connected
 - Permanently connected
- 4) Based on environmental conditions
 - Indoor
 - Outdoor
- 5) Based on access to the EV users
 - Locations with restricted access
 - Location with non-restricted access
- 6) Based on the mounting method
 - Stationary EVSE equipment
 - Non-stationary EVSE equipment

- 7) Based on protection against electric shock
 - Class I equipment
 - Class II equipment
- 8) Based on charging modes
 - Mode 1
 - Mode 2
 - Mode 3
 - Mode 4

These charging equipment are generally classified into AC charging and DC charging based on where the actual conversion of AC to DC takes place. In AC charging method, the actual conversion of AC to DC takes place inside the EV or onboard. The different types of AC chargers available in the markets are listed in Table 1.1.

In the DC charging method, the actual AC to DC conversion takes place outside of EV (i.e. inside of EVSE) or off-board. The different types of DC chargers available in the markets are listed in Table 1.2.

Also, based on the time taken to recharge the battery to 100% SoC, EVSE is classified into slow charging and fast charging. In the slow charging method, it will take six to eight hours or above to recharge the battery to 100% SoC. This slow charging method is also called overnight charging. In the fast-charging method, EVs are recharged at a higher power rating charger and usually, it will take

Table 1.1 List of AC chargers.

S.No	Charger type	Connector/Socket	Maximum power output
1	Type 1	Yazaki socket	Up to 7.4 kW (32 A, single phase)
2	Type 2	Mennekes socket	Up to 44 kW (63 A, three Phase)
3	Type 3	Grand socket	Up to 22 kW (32 A, three Phase)

Table 1.2 List of DC chargers.

S.No	Charger type	Maximum power output	Communication protocols
1	CHAdeMO	Up to 400 kW DC charging (1000 V, 400 A)	Control Area Network (CAN) for communication between EV and EVSE
2	GB/T	Up to 237.5 kW DC charging (950 V × 250 A)	CAN for communication between EV and EVSE
3	Tesla super charger	Up to 135 kW DC charging (410 V × 330 A)	CAN for communication between EV and EVSE

15–30 minutes to recharge the battery up to 80% SoC [2]. So, the fast-charging method is a widely adopted method to recharge EVs used for commercial purposes including freight transfers. Based on the location of the charging process carried out, charging stations are also classified into residential/home charging and public charging. Residential charging is widely used by EVs owner because recharging is economical at home (i.e. energy cost is less). It normally uses slow chargers to recharge the battery and EVs owner charge their vehicle mostly during the night-time [4]. On the other hand, public charging stations (e.g. charging station at shopping mall, cinema theater, highway, etc.) allow EV users to recharge their vehicle outside the residential premises. The public charging station generally employs DC fast chargers to recharge EV batteries in lesser time to avoid the waiting period.

This chapter discusses the fast-charging infrastructure as a public charging station to recharge an electric vehicle.

1.2 Fast-Charging Station

A charging station is like a fuel stop or a petrol station situated in most of the public places in and around the city and highways. It has off-board chargers of high-power rating and is used to recharge the EV batteries with DC current in lesser time duration. The advancements in battery technologies that allow higher charging rates and higher charging cycles make the fast charging a realistic possibility [5–7]. The SLD of typical fast-charging station is shown in Figure 1.2.

The main elements of any fast-charging station are

- 1) Power grid or grid power supply
- 2) Power cables
- 3) Switchgear
- 4) Transformer
- 5) Energy meters and power quality meters
- 6) Fast chargers
- 7) Plugs and connectors

1.2.1 Power Grid or Grid Power Supply

The power grid is the main source of power supply to the connected loads (including EV loads and other auxiliary loads) of a fast-charging station. Generally, the grid power supply is provided by the distribution company (DISCOMs) in medium voltage level (e.g. 11, 22, or 33 kV based on the particular country voltage level). Some places, where the charging station loads are less, DISCOMs provides the grid power

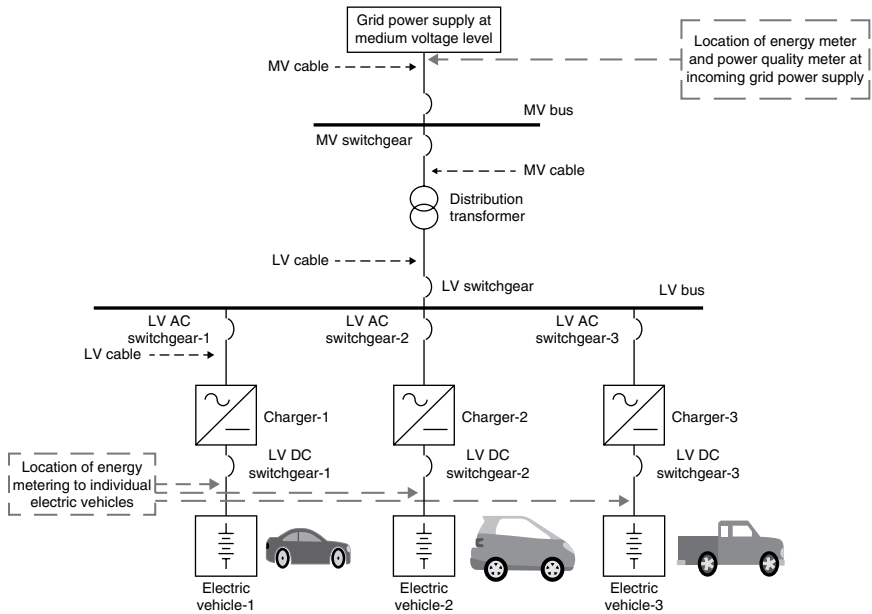


Figure 1.2 Typical SLD of a fast-charging station.

supply at low voltage level (e.g. 400 or 415V) and it does not require the dedicated transformer powered by grid power supply at the medium voltage level.

1.2.2 Power Cables

The power cables are used to carry the electric power from one place to another place. In fast-charging station, power cables are used between the power grid supply source to distribution transformer (medium voltage side), distribution transformer to low voltage switchgear (low voltage side), low voltage switchgear to fast charger (input AC side), and fast charger (output terminal) to EV batteries (DC cables).

The power cables between the EVSE (fast charger DC output terminal) and EV shall comply the technical requirements of IEC 62893 Charging cables for electric vehicles for rated voltages up to and including 0.6/1 kV including the test requirements/methods.

IEC 62893-1 gives the general requirements of the cables for Mode 1–3 (AC charging) [8] and Mode 4 (DC charging). Some of the requirements of IEC 62893-1 related to DC charging are as follows [1, 9]:

Conductor: Plain or tinned annealed copper comply with Class 5 of IEC 60228

Number of cores: Two core cable and three core cable

Table 1.3 Maximum allowed operating voltage limit.

Rated voltage of cable U ₀ /U (kV)	Max allowed operating system voltage	
	DC	
	Conductor to earth	Conductor to conductor
300/500 V	410 V	820 V
450/750 V	620 V	1240
600/1000 V	900 V	1800 V

Power cores 0.6/1 kV: 10–95 mm² for two and three cores (for DC)

Voltage: The nominal voltage and its maximum allowed operating voltage is listed in Table 1.3.

Preferred color for DC cables:

- ❖ Two core cable: No preferred color requirements
- ❖ Three core cable: Green and yellow, no preferred color for other cores

Insulation material:

- ❖ Power cores: Compound of EVI-2
- ❖ Pilot, control, and any other additional cores: EVI-1 or EVI-2

Metallic screen (optional): Braid of plain or tinned copper wire

Sheath: Compound of EVM-1, EVM-2, or EVM-3

IEC 62893-4-1 gives the technical requirements of the cables for mode 4 DC charging without use of a thermal management system are as follows [10]:

Rated voltage: 1.5 kV DC

Power cores: 4–150 mm² for two or more cores

Auxiliary power cores (optional): 2.5–6 mm² – two cores

Temperature sensor cores (optional): Minimum size is 0.5 mm²

Conductor: Plain or tinned annealed copper comply with Class 5 of IEC 60228

Number of cores: Two core cable and three core cable

Preferred color for DC cables:

- ❖ Two core cable: No preferred color requirements
- ❖ Three core cable: Green and yellow, no preferred color for other cores

Insulation material:

- ❖ Power cores: Compound of EVI-2
- ❖ Pilot, control, and any other additional cores: EVI-1 or EVI-2

Table 1.4 Recommended use of cables without thermal management for EV charging.

S.No	Code designation	Cable type	Recommended use	Application	Remarks
1	62893 IEC 126	EVM-1	Mode 4 as per IEC 61851-1	Indoor and outdoor	—
2	62893 IEC 127	EVM-2			
3	62893 IEC 128	EVM-3		Outdoor	Used only for outdoor applications because it will release the halogen content during fire

Metallic screen (optional): Braid of plain or tinned copper wire

Sheath: Compound of EVM-1, EVM-2, or EVM-3

The recommended use of cables without thermal management for EV charging is listed in Table 1.4.

IEC 62893-4-2 gives the technical requirements of the cables for mode 4 DC charging with thermal management system are as follows [11]:

Rated voltage: 1.5 kV DC

Power cores: 16–150 mm² for two or more cores

Auxiliary power cores (optional): 2.5–6 mm² – two cores

Temperature sensor cores (optional): Minimum size is 0.5 mm²

Conductor: Plain or tinned annealed copper comply with Class 5 of IEC 60228

Number of cores: Two core cable and three core cable

Preferred color for DC cables:

- ❖ Two core cable: No preferred color requirements
- ❖ Three core cable: Green and yellow, no preferred color for other cores

Insulation material:

- ❖ Power cores: Compound of EVI-2
- ❖ Pilot, control, temperature sensor, and auxiliary power cores: EVI-1 or EVI-2

Metallic screen (optional): Braid copper with minimum 80% optical coverage

Tubes: Fluid-filled tubes should be made resistant to the media used as a coolant.

It has to withstand an aging of 120 °C temperature for 168 hours in dry air. If the tube is also used as an insulator and it has to comply the requirements of EVI-2.

Sheath: Compound of EVM-1, EVM-2, or EVM-3

Liquid coolants: The coolant type used in the cable shall be specified by the manufacturer of the system. It has to satisfy the test requirements of IEC 62893-4-2.

Table 1.5 Recommended use of cables with thermal management for EV charging.

S. No	Code designation	Cable type	Recommended use	Application	Limitations	Remarks
1	62893 IEC 129	EVM-1	Mode 4 as per IEC	Indoor and outdoor	During the normal operating conditions,	—
2	62893 IEC 130	EVM-2	61851-1 with thermal management system		the cable maximum surface voltage should not exceed 60°C	
3	62893 IEC 131	EVM-3	Mode 4 as per IEC 61851-1 with thermal management system	Outdoor		Used only for outdoor applications because it will release the halogen content during fire

The recommended use of cables with thermal management for EV charging is listed in Table 1.5.

1.2.3 Switchgears

The switchgears are the protection and control equipment used to make and break the circuit by means of automatic or manual operation in the event of electric faults and/or any maintenance activities. Generally, in fast-charging stations, switchgears are used at medium voltage level (i.e. distribution transformer high voltage side), low voltage level (i.e. distribution transformer low voltage side, individual outgoing feeders to fast chargers and auxiliary loads), and output of fast chargers (DC supply) to the EV.

Each EVSE to EV circuit/feeder is protected by a circuit breaker complying IEC 60947 and a residual current device (RCD) of type A or type B for a rated residual operating current not more than 30 mA, as required by IEC 60364-7-722.

1.2.4 Distribution Transformer

A distribution transformer is an electromechanical device that is used to step down the voltage without changing the frequency. In a fast-charging station, distribution transformers are used to transfer the electric power at a medium voltage level (e.g. 11 kV) to a low voltage level (e.g. 415V). The size/rating of the distribution transformer should be selected based on the respective fast-charging station power demand. The number of distribution transformer requirements depends on the reliability aspects of the charging station. Refer to Chapter 6 for more details.



Figure 1.3 Typical distribution transformer.

The typical distribution transformer is shown in Figure 1.3.

1.2.5 Energy Meters and Power Quality Meters

The energy meters are used to measure the energy consumed by the charging station from DISCOMs. Generally, this meter will be installed at the interconnection point (i.e. point of common coupling – PCC). The actual billing for energy consumed by the charging station is based on this meter reading. The technical requirement for this meter will depend on the country grid code (transmission code or distribution code). Generally, an energy meter with 0.2S class accuracy is used for billing purposes.

Fast chargers in the charging station are used to recharge the batteries in the EV. It means, energy is transferred from the charging station to the batteries in the EV. The EV user has to pay for the actual energy that is used to recharge the batteries. Hence, one more set of energy meters installed at the output side of the fast charger or an inbuilt feature of energy metering in the fast charger is used for billing purposes.

The power quality meters are used to measure the various power quality characteristics (like voltage sag, voltage swell, interruption, transients, harmonics, flicker, rapid voltage change, etc.) of the fast-charging station during their operation. Generally, this power quality meter will be installed at PCC. The charging stations



Figure 1.4 Typical fast charger.

are receiving the grid power supply from DISCOMs and it has to maintain the grid code requirements (including power quality requirements) of the country. This power quality meter is used to check the compliance of the charging station with respect to grid code power quality requirements. As per IEC 61000-4-30, the technical requirements of a power quality meter for compliance checking/verification shall be Class A.

1.2.6 Fast Chargers

The fast chargers are used to recharge the EV batteries in a lesser time duration. It converts AC into DC (rectifier) and increases or decreases the output DC voltage to recharge batteries (as a DC–DC buck/boost converter). The power rating of DC fast chargers is typically in the range of 50–150kW for light motor vehicles and more than 150kW for electric buses and heavy motor vehicles.

The typical fast charger is shown in Figure 1.4.

1.2.7 Plugs and Connectors

The plug and connectors are used to connect the EV to the fast charger, i.e. it establishes the temporary connection between the EVSE and EV during the charging period. The IEC 61851-1 describes the three different methods of connection between the EV and EVSE [3].

Method 1: The connection between the EV and EVSE with a cable and plug attached permanently to the EV as shown in Figure 1.5 [3].

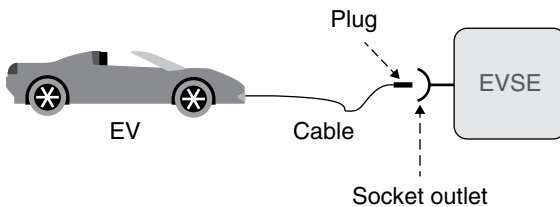


Figure 1.5 Connection between the EV and EVSE with a cable and plug attached permanently to EV.

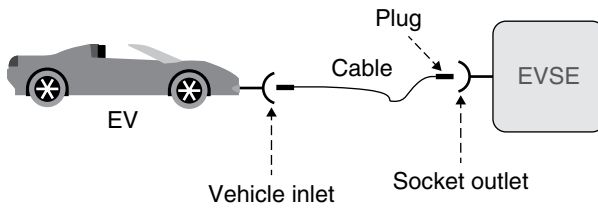


Figure 1.6 Connection between the EV and EVSE with detachable/removable cable assembly at both EV and EVSE end.

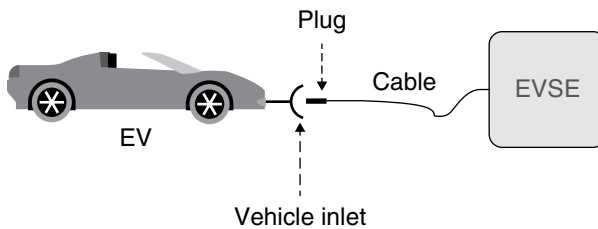


Figure 1.7 Connection between the EV and EVSE with a cable and plug attached permanently with EVSE.

Method 2: The connection between the EV and EVSE with detachable/removable cable assembly at both EV and EVSE end as shown in Figure 1.6 [3].

Method 3: The connection between the EV and EVSE with a cable and plug attached permanently with EVSE as shown in Figure 1.7 [3].

In the mated position (i.e. connection established between the plug and socket outlet), the connection shall comply with the minimum requirements of IPXXD as per ISO 20653.

The requirements (electrical and mechanical) for connection between an electric vehicle and EVSE for plugs, socket-outlets, vehicle inlets, and vehicle connectors are covered in IEC 62196 (all parts) [12, 13].

The requirements specified by IEC 62196-3 are applicable to mode 4 charging as per IEC 61851-1, for the rated voltage up to 1500V DC and current up to 250A, rated voltage 1000V AC, and current up to 250A. The vehicle couplers specified in IEC 62196 are applicable to an ambient temperature from -30°C to $+50^{\circ}\text{C}$ and are intended to connect with copper or copper alloy cable.

The preferred operated voltage rating as per clause 5 of IEC 62196-1 is listed in Table 1.6 [12].

The preferred rated current rating as per clause 5 of IEC 62196-1 is listed in Table 1.7 [12].

Table 1.6 Preferred operated voltage rating.

S. No	Rated operating voltage range (V)	Nature of voltage (AC/DC)	Remarks
1	0–30	AC	Only for control or signal purpose
2	100–130	AC	—
3	200–250	AC	—
4	380–480	AC	—
5	600–690	AC	—
6	480	DC	—
7	600	DC	—
8	750	DC	—
9	1000	DC	—

Table 1.7 Preferred rated current.

S. No	Preferred rated current (A)	Remarks
1	5	—
2	13	—
3	16–20	—
4	30–32	—
5	60–63	—
6	70	—
7	80	Only for DC
8	125	—
9	200	Only for DC
10	250	—
11	400	Only for DC
12	500	Only for DC
13	600	Only for DC
14	630	Only for DC
15	800	Only for DC

The DC charging connector types are generally classified as follows:

- 1) CCS-combo 1 (used in the United States)
- 2) CCS-combo 2 (used in Europe)
- 3) CHAdeMO connector (used globally for cars manufactured by Japanese automakers)
- 4) Tesla DC connectors (AC as well as DC)
- 5) DC connector based on the Chinese standard GB/T

The combined charging system (CCS) connectors are also called hybrid connectors because they are built-in connectors for AC and DC charging. In fact, they derive from Type 1 and Type 2 connectors for AC load which are now referred to as Combo 1 and Combo 2, respectively.

It uses the SAE J1772 load input and adds two more pins underneath [14]. It “combines” the SAE J1772 connector with the high-speed charging pin. The CCS is the accepted standard in North America and was developed and approved by the Society of Automotive Engineers (SAE). Most car manufacturers are using the CCS standard in North America, including General Motors, Ford, Chrysler, Dodge, Jeep, BMW, Mercedes, Volkswagen, Audi, Porsche, Honda, Kia, Fiat, Hyundai, Volvo, smart, MINI, Jaguar Land Rover, Bentley, Rolls Royce, and others [15].

1.2.7.1 CCS Combo 1 Connector

The combo 1 vehicle connector is derived from a Type 1 AC connector and retains the ground pin and the two signal pins (pilot control and proximity pilot). Additionally, two additional DC power pins are at the bottom of the connector for fast charging. On the vehicle input, the pin configuration is the same as the type 1 AC connector at the top, while the bottom two pins are used for DC charging.

Similarly, the CCS combo 2 connectors are derived from the Type 2 AC connector, which holds the ground pin and both signal pins (Control pilot and proximity pilot), and the two DC power pins are added to the bottom of the high-power DC charger.

In this type of DC charging, power line communication (PLC) is used in both combo 1 and 2. PLC is a technology that carries data for communication on existing electric power lines which is used simultaneously for power transmission as well.

1.2.7.2 CHAdeMO Connector

CHAdeMO connector is developed by the Japanese utility Tepco and almost all DC fast chargers in Japan used the CHAdeMO connector. Unlike CCS combo 1 and 2, CHAdeMO connectors do not share part of the connector with the

SAE J1772 input, so they require an additional CHAdeMO input on the car. This requires a larger charging port area to accommodate two separate charging sockets [17].

It has three power pins and six signal pins for its operation, and it uses the CAN (controlled area network) protocol for communication between the vehicle and EVSE (charger).

CAN communication is a robust vehicle communication standard designed to allow microcontrollers and devices to communicate with each other in real-time without a host computer.

1.2.7.3 Tesla Connectors

Tesla superchargers in United States use their own connectors, while their European variant uses the Type 2 connector.

1.3 Fast-Charging Station Using Renewable Power Sources (RES)

The EVs are charged through the fast-charging station as public charging infrastructure. These EV charging loads are added additional to the existing distribution system loads in many locations, and it requires the additional distribution network infrastructure. Also, it increases the power as well as energy demand of the distribution system. In order to reduce the power demand due to EV charging and environmental pollution problems, renewable energy sources are locally used to generate the power and integrated with the fast-charging station. In other words, all EVs have a benefit over environmental pollution, i.e. carbon emissions from the EVs are zero. Certainly, there are carbon emissions at some point in the overall energy conversion process whenever fossil fuels are used to generate electricity for recharging the EVs. In order to avoid carbon emissions throughout the EV operation, renewable energy sources like solar PV systems, wind energy conversion systems, hydropower, biomass, or fuel cells are preferred to generate the electricity of EVs.

The integration of renewable-powered fast-charging stations along with an energy storage system (ESS) reduces the power demand of the distribution grid to a greater extent during the large penetration of EV charging stations. Another important advantage of using RES will reduce the operational cost (i.e. cost of energy consumed from DISCOMs). Generally, the RES integration into a fast-charging station can be done in two ways.

- 1) Integration of RES at AC bus of the fast-charging station.
- 2) Integration of RES at DC bus of the fast-charging station.

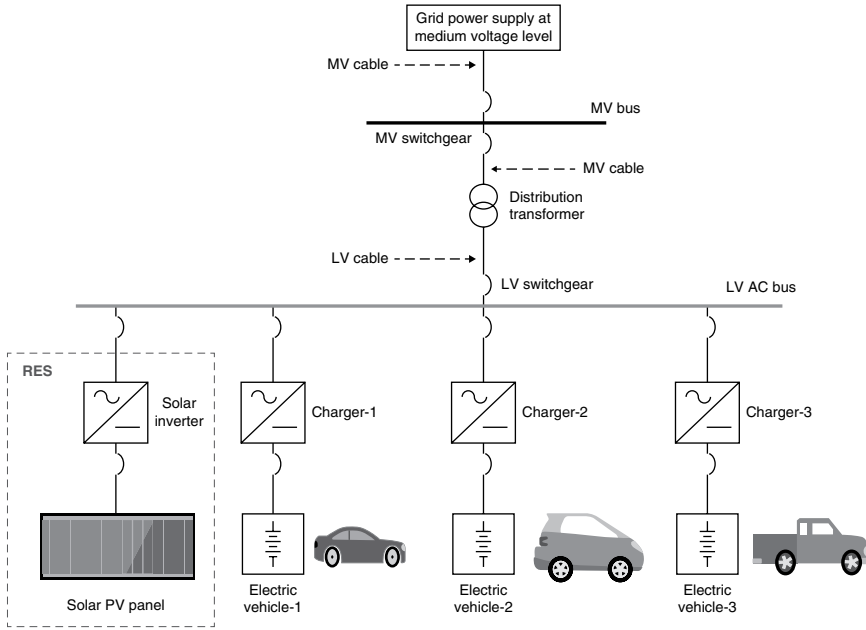


Figure 1.8 Integration of RES at AC bus of the fast-charging station.

The typical Integration of RES at the AC bus of the fast-charging station is shown in Figure 1.8. The solar PV system (one of the RES) is integrated into the LV AC bus through the solar inverter (solar inverter will convert the DC supply into AC supply).

The typical integration of RES at the DC bus of the fast-charging station is shown in Figure 1.9. The electricity generated by solar PV systems and batteries of EV charging is on DC supply. Hence, the integration of RES directly into the DC bus shall reduce the energy loss in DC to AC conversion in solar inverter and AC to DC conversion in EV charger.

The ESS is also used in some fast-charging stations along with RES. It is used to store the energy whenever the solar power generation is higher than EV charging loads or whenever the DISCOMs electricity tariff is less during the off-peak hours. The energy stored in the ESS is used to recharge the EV batteries whenever the solar power generation is lesser than the EV charging loads or whenever the DISCOMs tariff is high during peak hours. The typical Integration of the battery energy storage system (BESS) at the DC bus of the fast-charging station is shown in Figure 1.10.

This configuration shares the common DC bus for all the sources and loads (EVs) in a fast-charging station. The energy management system (EMS) plays an

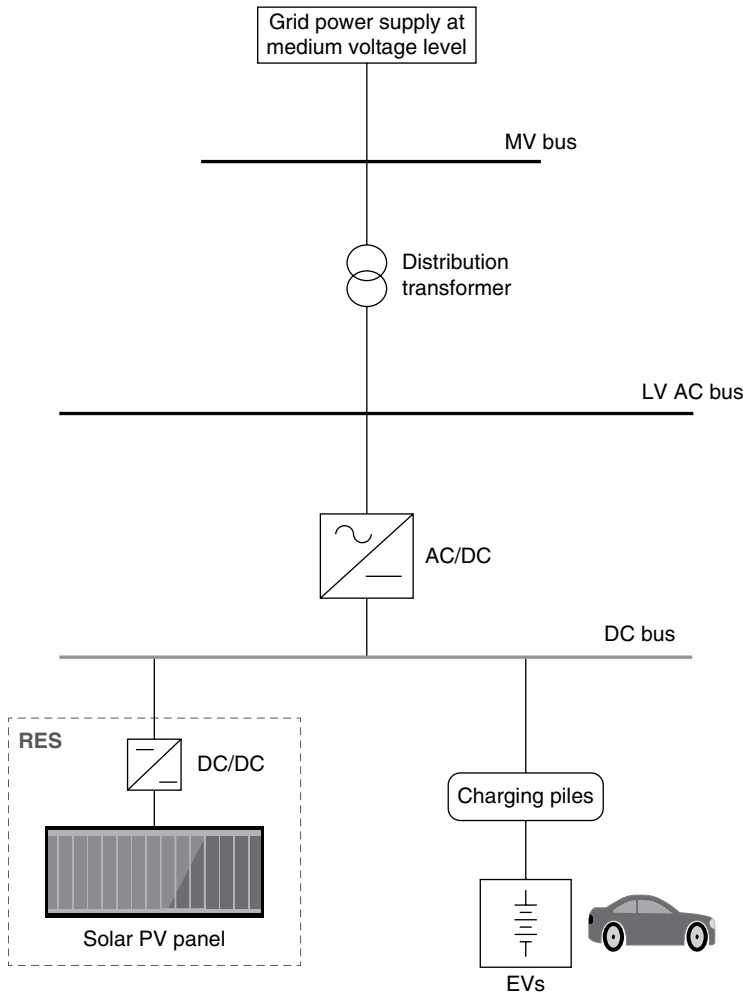


Figure 1.9 Integration of RES at DC bus of the fast-charging station.

important role in optimal power scheduling and power management. The EVs are charged by the power from the solar PV system during the solar generation time (typically 07:00 a.m.–17:00 p.m.). If the solar generation is higher than the EV charging load demand, excessive generation is used to charge the BESS. Whenever the solar generation is lesser than the EV charging load demand, BESS is used to meet the EV charging load demand in addition to the solar power generation. If BESS storage is not sufficient, then the grid power supply is used to meet the EV

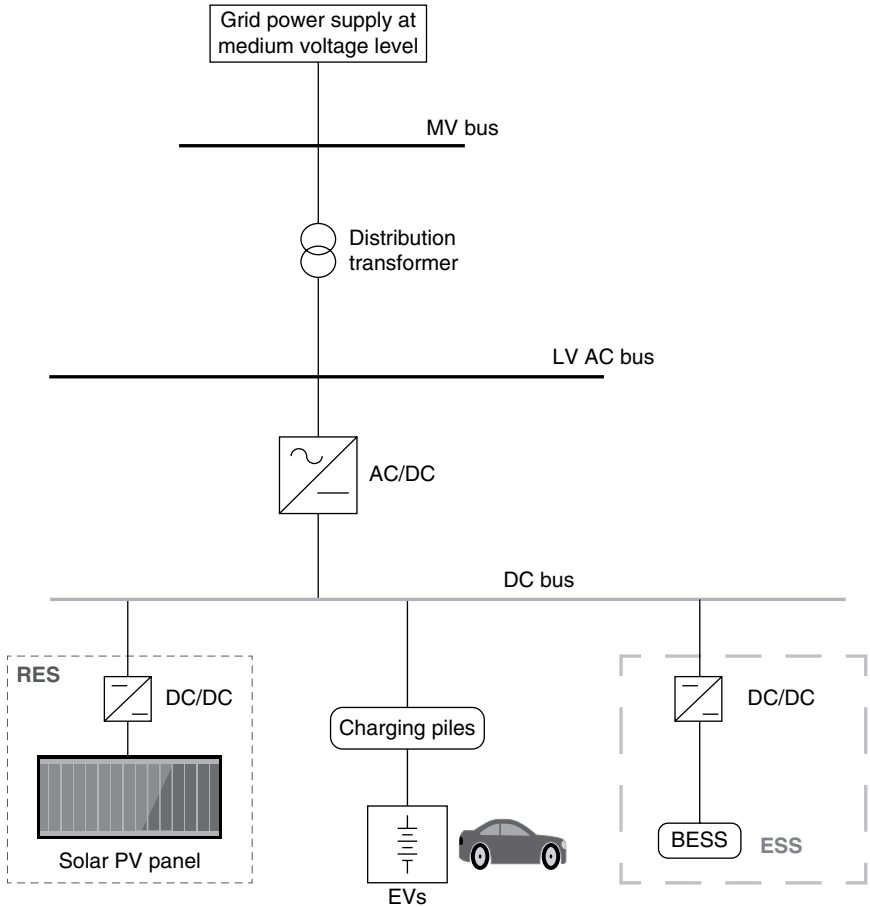


Figure 1.10 Integration of BESS at DC bus of the fast-charging station.

charging loads. The EMS will take care of the entire power and energy management of the fast-charging station.

1.4 Digital Communication for Fast-Charging Station

Digital communication is required between the EV and EVSE for safe and trouble-free recharging. Digital communication is defined as the digitally encoded information exchange between the EV and EVSE. The typical

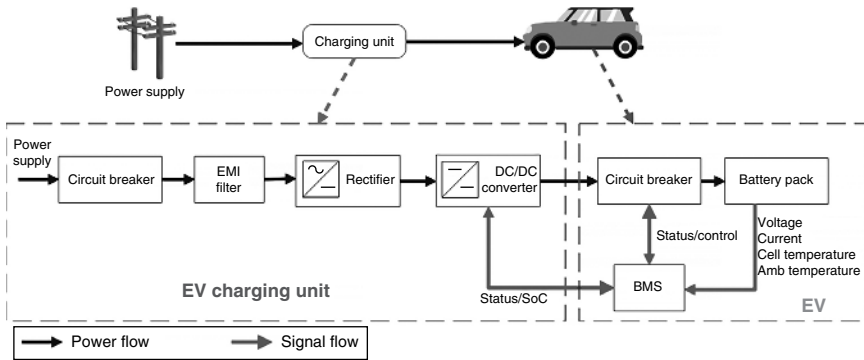


Figure 1.11 Block diagram of the recharging function of the fast-charging station.

block diagram of the recharging function of the fast-charging station is shown in Figure 1.11.

Digital communication is used between the EV and EVSE for information exchange. It is used to send and receive the information/data between EV and EVSE about the battery SoC, temperature, etc., while recharging. The digital communication requirements as per IEC 61851-1 for various charging modes are as follows:

- ❖ Mode 1, mode 2, and mode 3: Digital communication between EV and EVSE is optional
- ❖ Mode 4: Digital communication between EV and EVSE shall be provided as per IEC 61851-24

As per IEC 61851-24, two types of digital communication architectures shall be used,

- ✓ Control Area Network (CAN): Using the dedicated circuit for data communication using CAN protocol as per ISO 11898-1.
- ✓ Homeplug Green PHY: Using the control pilot line.

Some of the information exchange between the EV and EVSE through digital communication as per IEC 61851-24 is as follows:

- Voltage request for the controlled voltage charging (CVC) system
- The current request for the controlled current charging (CCC) system
- Maximum rated voltage of DC EV charging station
- Maximum rated current of DC EV charging station
- Maximum voltage limit of EV

- EV minimum current limit, only for the controlled voltage charging (CVC) system
- Zero current confirmed
- Charging stopped by the user
- EVSE real-time available load current
- Loss of digital communication

1.5 Requirements for Fast-Charging Station

In order to perform safe and reliable charging, both electric vehicles and EVSE (chargers) have to meet certain technical requirements as provided by IEEE Std 2030.1.1-2021 [19]. Some of those requirements are listed below.

- ❖ During the charging period, both the vehicle and EVSE (charger) shall confirm they are physically and/or electrically connected to each other.
- ❖ The EVSE (charger) shall have the feature to detect circuit isolation, short circuit in the circuits, and ground faults.
- ❖ The EVSE (charger) shall have the feature of overvoltage protection function.
- ❖ If the protective conductor is disconnected between the vehicle and EVSE (charger), the charger has to stop charging (charging process) within 10 seconds.
- ❖ If the communication between the vehicle and EVSE (charger) is interrupted, the charger has to stop the charging process.
- ❖ The EVSE (charger) shall have the earth leakage current detection and automatic disconnection function to avoid the electric shock.
- ❖ It has to provide the status of the charging process to users.
- ❖ When the connector is disconnected or not connected to the vehicle, the EVSE (charger) shall have the feature of not supplying the voltage that is unsafe to the human.
- ❖ During the charging process, it has to prevent users from touching/accessing the live parts or electrically energized parts.
- ❖ The EVSE (charger) shall have protection against overload and short circuit of both incoming AC circuit as well as charger internal circuit.
- ❖ After the disconnection of the vehicle from EVSE, the voltage between any accessible conductive parts (it includes the connector, charging cable, and any grounding parts) is reduced to less than 60 V within one second or less.
- ❖ A communications interface must be used to transfer/exchange the data between the vehicle and EVSE for charging control.

Table 1.8 Chargers and their ratings.

S.No	Charger type	Charger connectors	Rated voltage (V)	Number of charging points/Number of charging guns
1	Fast charging	CCS (min 50 kW)	200–1000	1/1 CG
		CHAdeMO (min 50 kW)	200–1000	1/1 CG
		Type-2 AC (min 22 kW)	380–480	1/1 CG
2	Slow/Moderate charging	Bharat DC-001 (15 kW)	72–200	1/1 CG
		Bharat AC-001 (10 kW)	230	3/3 CG of 3.3 kW each

In India, any public charging infrastructure must meet the minimum technical requirements stated by the Central Electricity Authority (CEA). They are:

- Every charging station must have an exclusive or dedicated transformer with all related substation equipment including safety appliances.
- It should have 33/11 kV lines/cables and associated equipment along with all the line termination and metering tools, etc.
- It must have adequate space for charging and entry/exit of vehicles.
- It must have one or more electric kiosks/boards with the installation of all the charger models listed in Table 1.8.
- It must be suitable to install the additional number of Kiosks/Chargers in addition to the minimum number of chargers listed in Table 1.8.
- It must be tie up with at least one online network service provider to enable online or advanced remote booking by EV owners for charging slots.
- Appropriate liquid-cooled cables if high-speed charging facility for onboard charging of fluid-cooled batteries.
- Appropriate climate control equipment for fast charging of batteries to be used for swapping.

1.6 Case Study: Public Fast-Charging Station in India

A charge point operator developed the public charging station with a DC fast charger and AC slow charger for public charging. The charging station receives the electric power supply from DISCOM at 11 kV voltage level and uses the 500 kVA, 11 kV/415 V distribution transformer to power the connected loads. The SLD of the charging station is shown in Figure 1.12.

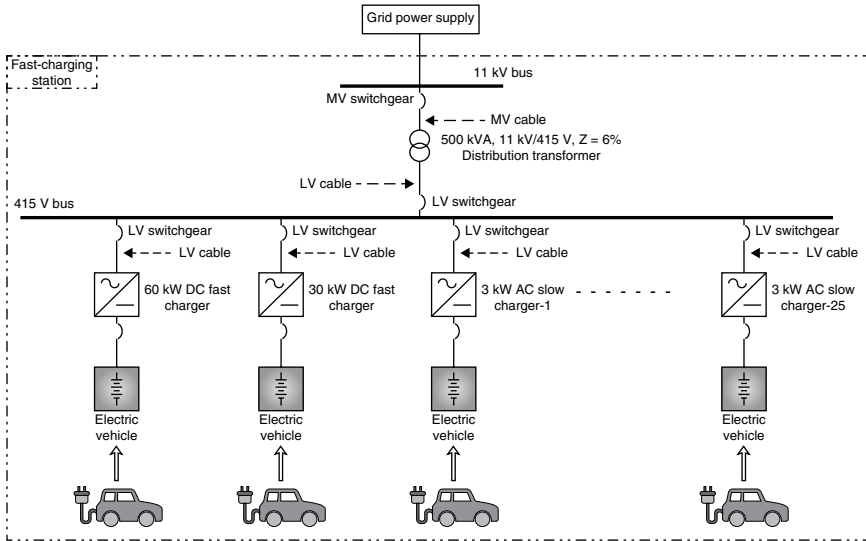


Figure 1.12 SLD of the fast-charging station.

Table 1.9 Chargers used in the fast-charging station.

S. No	Charger type	Power rating (kW)	Number of chargers	Number of charging guns	Installation type	Connection type
1	DC fast charger	60	1	2	Fixed	CCS
2	DC fast charger	30	1	2	Fixed	GB/T
3	AC slow charger	3	25	—	Portable	—

The chargers used in the fast-charging station are listed in Table 1.9.

The chargers (fast charger 60kW, fast charger 30kW, and slow charger 3kW) installation at the charging station is shown in Figures 1.13–1.15, respectively.

The fast charger of 30kW powering the two electric vehicles (i.e. one charging gun is connected to the first EV and the second charging gun is connected to the second EV) is shown in Figure 1.16.

Whenever any EV is coming for charging, the technician or operator person in the charging station connects the vehicle to the charger. In order to begin the charging process, the technician or operator person in the charging station must initiate the



Figure 1.13 DC fast charger 60 kW. *Source:* Courtesy: EXICOM.



Figure 1.14 DC fast charger 30 kW. *Source:* Courtesy: EXICOM.

charging process (i.e. transferring the energy from the charger to EV) by means of scanning the barcode in the mobile or using the RFID card. This method avoids the unauthorized EVs connected to the charger for charging. After the completion of the charging process, the summary of the charging will be sent to EV users through mobile and users have to pay for the actual energy consumption.

The typical charging parameter of a charger during the charging process in the charger display unit is shown in Figure 1.17.

EV users can use the mobile app for prebooking slots available at the charging station for charging services.

1.7 Conclusion

This chapter discusses the various aspects of fast-charging stations like equipment (transformer, charger, connectors, cables, energy meters, etc.),

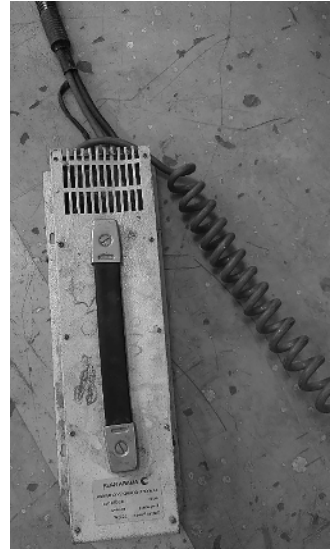


Figure 1.15 AC slow charger 3 kW. *Source:* Courtesy: AMARA RAJA.



Figure 1.16 DC fast charger 30 kW charging two EVs at a time.

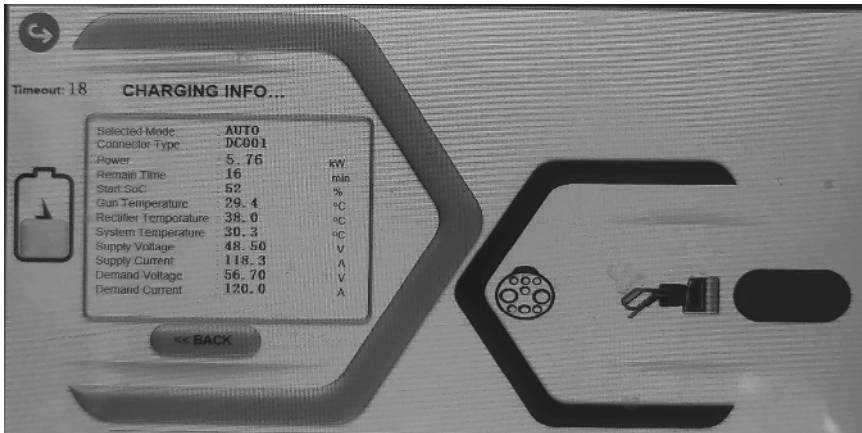


Figure 1.17 Typical charging parameter of a charger during the charging process.

requirements of IEC standards for charging stations, digital communication between vehicle and EVSE, and renewable energy-based fast-charging stations in detail. Also, the requirements of EVSE (fast chargers) for safe and reliable charging as per IEEE 2030.1.1-2021 are discussed.

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Annexure 1 Photos

Figure A1.1 shows the GB/T standard vehicle inlet and coupler. The left one is the vehicle inlet and the right one is the coupler connected to the vehicle inlet.

Figure A1.2 shows the status of the charging process of the charger.

Figure A1.3 shows the installation of a DC fast charger in an outdoor environment. The charger has two charging guns and can able to charge two EVs parallely.

Figure A1.4 shows the charging gun connected to the electric bus.

Figure A1.5 shows the name plate rating of 120kW DC charger.

Figure A1.6 shows the nameplate rating of the EV cable between DC charger and EV.

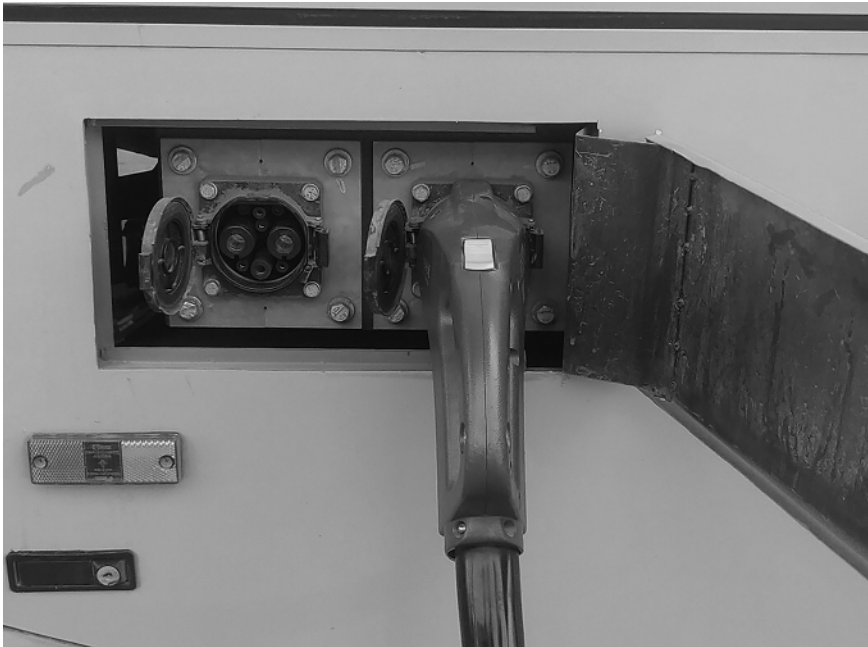


Figure A1.1 GB/T standard vehicle inlet and coupler.



Figure A1.2 Status of the charging process of the charger.

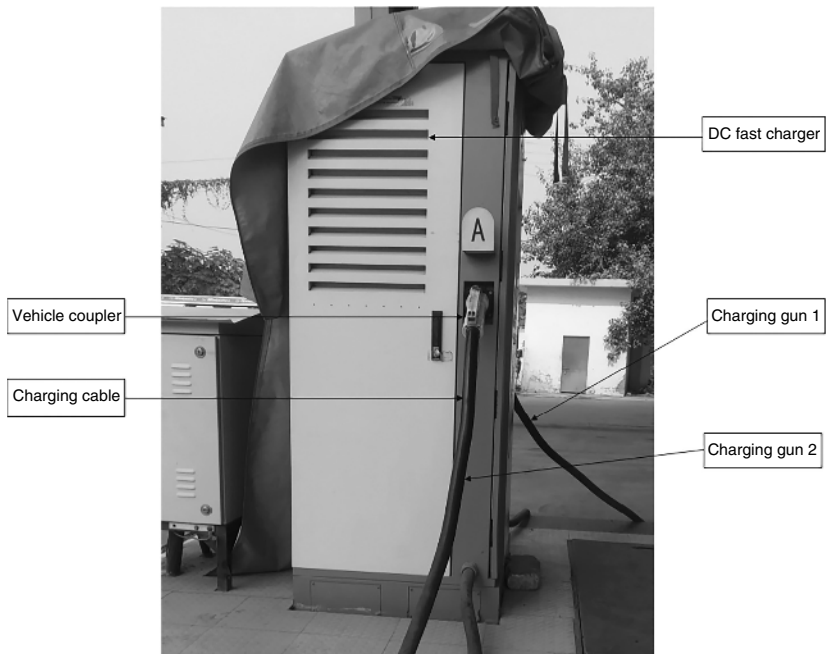


Figure A1.3 Installation of DC fast charger in outdoor.



Figure A1.4 Charging gun connected to the electric bus.

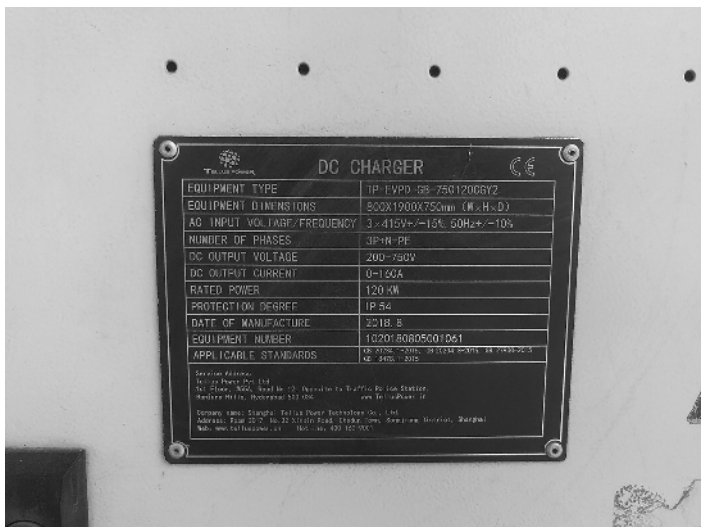


Figure A1.5 Name plate rating of DC charger. *Source:* Courtesy: Tellus Power.



Figure A1.6 Name plate rating of EV cable. *Source:* Courtesy: Guangdong OMG Transmitting Technology Co., Ltd.

