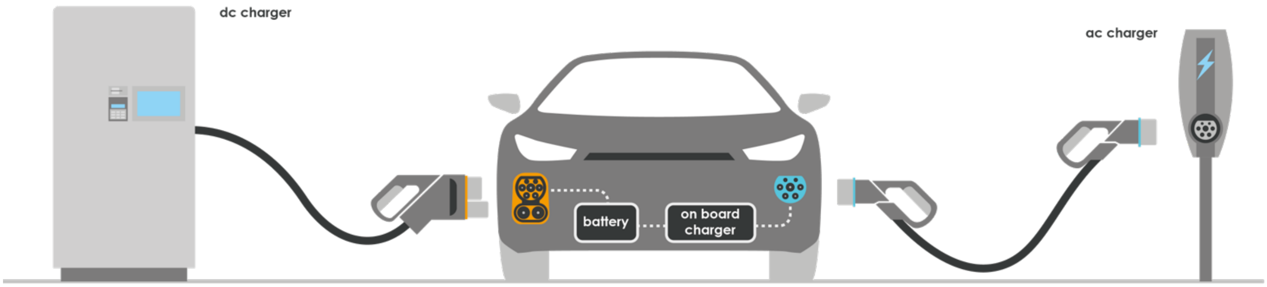
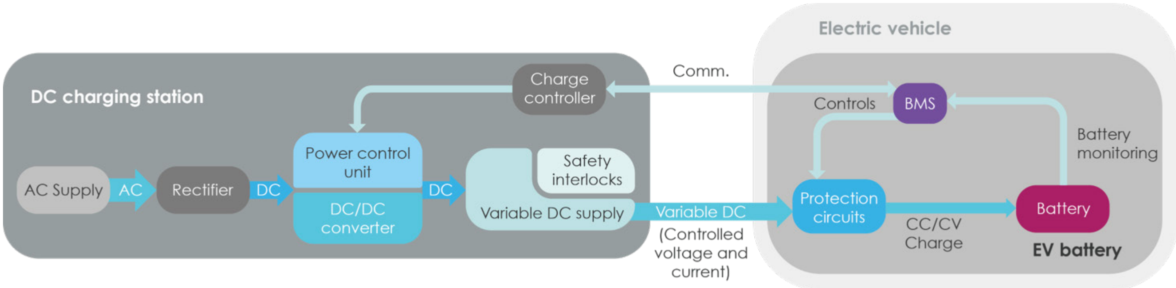
DC charging



DC Fast Chargers supersede Level 1 and Level 2 charging stations and are designed to charge electric vehicles quickly with an electric output ranging between 50 kW – 350 kW.

With high power operation, the AC/DC converter, the DC/DC converter and the power control circuits become larger and more expensive. That is why DC fast chargers are implemented as an off-board charger rather than as an onboard charger so that it does not take up space within the vehicle and the fast charger can be shared by many users.

DC Charger: Operation



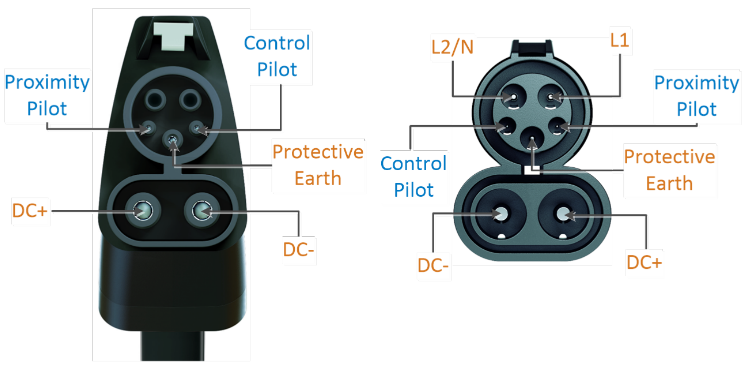
- In the first step, the alternating current or AC power provided by the AC grid is converted into direct current or DC power using a rectifier inside the DC charging station.
- Then, the power control unit appropriately adjusts the voltage and current of the DC/DC converter inside the charging station to control the variable DC power delivered to charge the battery.
- There are safety interlock and protection circuits used to de-energize the EV connector and to stop the charging process whenever there is a fault condition or an improper connection between the EV and the charger.
- The battery management system or BMS plays the key role of communicating with the charging station to control the voltage and current delivered to the battery and to operate the protection circuits in case of an unsafe situation.

DC Charging: types

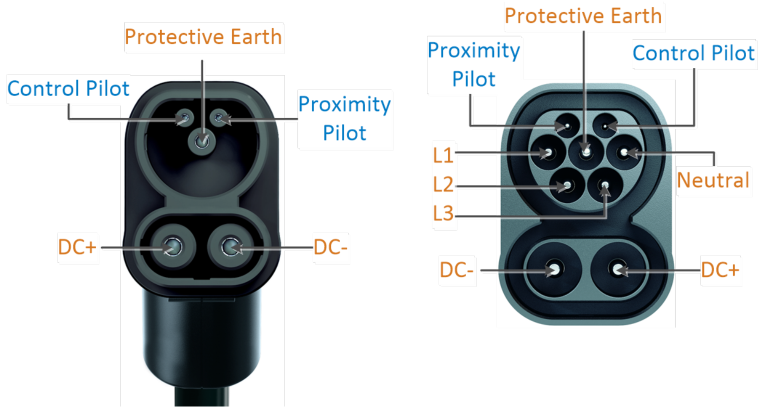
There are five types of DC charging connectors used globally:

1. The CCS-combo 1, which is mainly used in the US,
2. The CCS-combo 2, which is mainly used in Europe,
3. The Chademo connector, used globally for cars built by Japanese automakers.
4. The Tesla DC connector, which is used for AC charging as well
5. And finally, China has their own DC connector, based on the Chinese GB/T standard.

CCS/Combo 1 and CCS/Combo 2



Combo 1



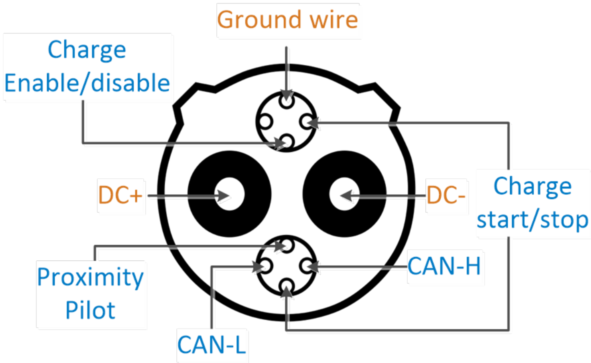
Combo 2

- **Brief History and Usage Information:**
  The Charging Interface Initiative e. V. - abbreviated to CharIN e. V. - is a registered association founded by Audi, BMW, Daimler, Mennekes, Opel, Phoenix Contact, Porsche, TÜV SÜD and Volkswagen. CharIN association is the driving force behind the Combo connector. The key features of the Combined Charging System are the use of a single connector for both AC and DC charging by using separate pins within the same connector. The Combo AC and DC charging connector comply with the IEC 62196-1, IEC 62196-2 and IEC 62196-3 standards. The signalling and communication for AC charging is compliant with IEC 61851-1, 61851-22, and for DC charging with IEC 61851-1, 61851-23, ISO/IEC 15118, the German DIN SPEC 70121 and the SAE J2847/2 standards. So the control pilot has both low-level communication using PWM and high-level communication using power line communication (PLC).
- List of Combo compatible EV manufacturers: http://www.charinev.org/members/.

- **Pin Configuration:**
  Here you see the Combo 1 and Combo 2 vehicle connector is on the left side, and the vehicle inlet is on the right side. The vehicle connector of Combo1 and Combo 2 is derived from the AC Type 1 and Type 2 connector, respectively and retains the earth pin and the two signal pins namely, the control pilot and the proximity pilot. In addition, two DC power pins are added for fast charging. On the vehicle inlet, the pin configuration in the upper part is the same as AC Type 1 and Type 2 connector for AC charging while bottom two pins are used for DC charging.
- **Maximum voltage and current ratings:**
  In general, CCS charger can deliver up to 350 Amps at a voltage of between 200 to 1000V giving a maximum power output of 350 kW. It must be kept in mind that these values are continuously updated to cater to the voltages and power requirements of new electric cars.

For more info, visit https://www.charinev.org

Chademo:



- **Brief History and Usage Information:**

  In March 2010, Toyota Motor Corporation, Nissan Motor Co. Ltd., Mitsubishi Motors Corporation, Fuji Heavy Industries Ltd., and Tokyo Electric Power Company, Inc. had formally established “CHAdeMO Association”. In 2011, the first DC charger in Europe deployed. CHAdeMO has been published as IEC standard (IEC 61851-23, -24, as well as 62196-3) and IEEE standard (IEEE Standard 2030.1.1TM-2015). CHAdeMO is currently used as the DC charging part by all Japanese EV manufacturers. It has the largest global installation base of chargers as of 2017 with 16500 charging points. Further, CHAdeMO was the first DC standard to facilitate V2X via the 1.1 version of the protocol.

  List of Chademo compatible EVs: https://www.chademo.com/products/evs/

  List of Chademo charger manufacturers: https://www.chademo.com/products/chargers/

  List of Chademo V2X chargers: https://www.chademo.com/products/v2x-product/

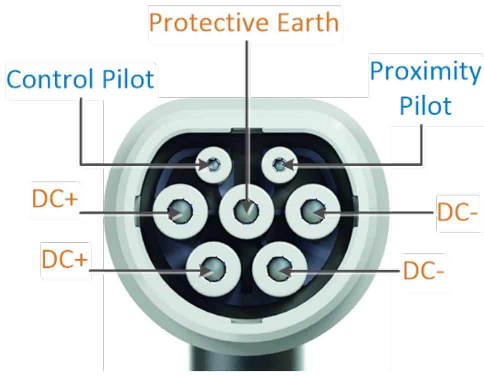
- **Pin Configuration:**

  It is a Type 4 EV connector and has 3 Power pins and 6 signal pins as shown in the figure. Chademo uses the Controller Area Network or CAN protocol in the communication pins for signalling.

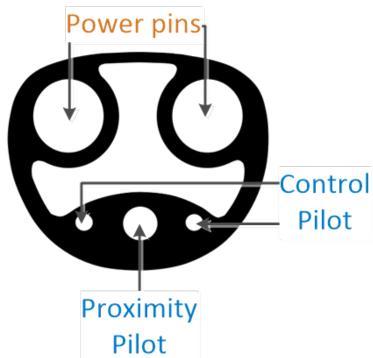
- **Maximum voltage and current ratings:**
  As of now, the voltage, current and power levels of chademo are 50-500V, up to 400A, thus providing a peak power of 200kW. In the future, it is expected that EV charging up to 1000V and 400kW will be facilitated.

For more info, visit [www.chademo.com.](http://www.chademo.com)

Tesla DC chargers:



DC charging in Europe: Type 2 connector



DC charging in USA: Proprietary connector

- **Brief History and Usage Information:**
  Tesla superchargers in the US use their own proprietary charging connector, while the European variant uses the Type 2 connector, but with DC charging built in. The unique aspect of the Tesla connector is that same connector and pins are used for both AC and DC charging. Tesla offers an adapter than help the connector to be used with Chademo DC charging stations.

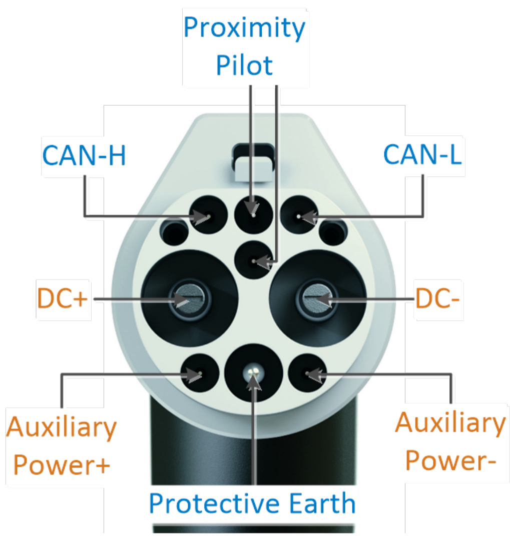
- **Pin Configuration:**

  The Tesla DC chargers like the AC chargers have two signal pins and three power pins - two pins for DC power and one for the earth.

- **Maximum voltage and current ratings:**

  Tesla now offers DC charging up to 120 kW and this is expected to increase in the future.

China GB/T standard:



- **Brief History and Usage Information:**

  China has their own DC charging connector based on the 20234.3-2015 standard and connector that uses a CAN bus for communication. The unique aspect of this DC charger is its ability to charge both the low voltage auxiliary battery and the high voltage traction battery within the electric vehicle.

- **Pin Configuration:**

  It has 5 power pins, 2 for DC power, 2 for low voltage auxiliary power, and

one for earth. This charger has 4 signal pins, two for proximity pilot and two for CAN communication.

- **Maximum voltage and current ratings:**
  As of now, the nominal voltages are 750V or 1000V, and the current up to 250A is supported by this charger.

Limitations of fast charging

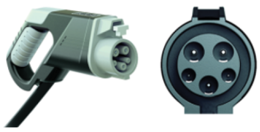
Fast charging is quite attractive in the sense of high power charging with short charging times. But the fast charging power cannot be increased infinitely. That is due to five technical limitations:

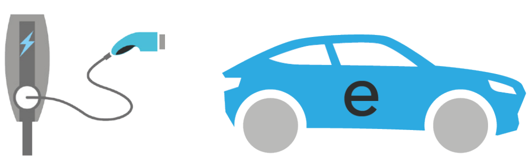
1. Higher charging current leads to higher overall losses both in the charger and in the battery. As the charging currents increases, the effective capacity of the battery decreases as well (for example, as given by Peukert's law).
2. The battery C-rate increases with fast charging and this reduces the battery lifetime due to the heat produced and increased degradation due to the higher temperature.
3. When fast charging a battery, the SOC of the battery can only be reached till 70-80%. This is because fast-charging creates a lag between the voltage and state-of-charge and this phenomenon increases as the battery is being charged faster. Hence, fast charging is typically done in the constant current or CC region of the battery charging and after that, the charging power is reduced in the constant voltage or CV charging.

4. For any EV charger, it is important that the cable is flexible and lightweight for people to use and connect it to the car. With higher charging power, thicker cables are needed to allow more charging current, else it will heat up due to the losses. In the future with currents above 250A, the charging cables would become heavy and less flexible to use. The solution would be to use thinner cables with cooling and thermal management to ensure that cables don't heat up. This is, of course, more complex and costly than using a cable without cooling.

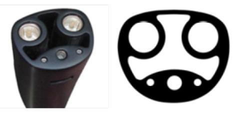
AC and DC charging: Overview

AC Charging plugs

	USA - Japan	Europe	China	
	Type 1  Tesla AC 	Type 2, Tesla AC  Type 3 	Based on Type 2 	



DC charging plugs

	USA-Japan	Europe	USA-Japan-Europe	China
	Tesla DC 	Tesla DC 	Chademo 	GB/T 
	Combo 1: Combined AC & DC 	Combo 2: Combined AC & DC 		

EV chargers: Power Levels

Plug	Pin configuration (Communication)	Voltage, Current, Power
Type 1 (SAE J1772)	3 power pins - L,N,E	1Φ 120V, ≤ 16A, 1.9 kW
		1Φ 240V, ≤ 80A, 19.2kW
Type 2	4 power pins – L1,L2,L3,N,E 2 control pins – CP, PP (PWM over CP)	1Φ 230V, ≤ 32A, 7.4kW
		3Φ 400V, 63A,43kW
Chademo	3 power – DC+,DC-,E 7 control pins (CAN communication)	200-500V, ≤ 400A, 200kW
CCS/ Combo	2 control pins – CP, PP (PLC over CP, PE)	200-1000V DC, ≤ 350A, 350kW
Tesla US	3 power pins – DC+,DC-,E (or) L1,N,E 2 control pins – CP, PP	Model S, 400V, ≤ 300A, 120kW

- USA and Japan have Type 1 AC, Type 4 Chademo DC, Combo 1 AC-DC and Tesla's proprietary AC connector.
- Europe has Type 2 AC, Type 3 AC, Type 4 Chademo DC and Combo 2 AC-DC China has Type 2 based AC and its own DC GB/T connector.
- With respect to car manufacturers, American, European, Korean car manufacturers have adopted CCS/Combo and Japanese car manufacturers have adopted Chademo.
- We have to bear in mind that as EVs are becoming popular across the globe, different countries are coming with their own choice of EV connectors or adopting one of the above connectors types. Further, the power levels are indicated in the tables are being updated by standardisation organization. Hence, this list is indicative and will get changed with time.

List of EV Charging standards

IEC 62196-1/IEC 62196-2/IEC 62196-3: Plugs, socket outlets, Vehicle Connectors, Vehicle-Inlets — conductive charging of electric vehicles
Part 1: General requirements
Part 2: Dimensional compatibility and interchangeability requirements for AC pin and contact-tube accessories
Part 3: Dimensional interchangeability requirements for

IEC61851-1/-21/-22/-23/-24: Electric vehicle conductive charging system
Part 1: General requirements
Part 21-1: Electric vehicle onboard charger EMC requirements for conductive connection to an AC/DC

Part 21-2: EMC requirements for OFF board electric vehicle charging systems (under preparation) supply

Part 22: AC electric vehicle charging station (in future merged with 61851-1)

Part 23: DC Electric vehicle charging station

Part 24: Control communication protocol between off-board DC charger and electric vehicle

ISO/IEC 15118-1/-2/-3: ISO/IEC 15118 – Road vehicles – Vehicle to grid communication interface

Part 1: General information and use-case definition

Part 2 Technical protocol description and Open Systems Interconnections (OSI) layer requirements

Part 3: Physical layer and Data Link layer requirements

Chinese GB/T 20234.1/.2/.3: Connection set of conductive charging for electric vehicles

Part 1: General requirements

Part 2: AC charging coupler

Part 3: DC charging coupler

Fast charging networks

Charging an electric car will be a mix of home charging, destination charging (at work, a supermarket, hotels, etc.), public slow charging and public fast charging. In case of fast charging, fast charging networks on a nationwide scale along highways similar to gasoline stations are the next step. This will ensure seamless travel for long distance travel offering charging in less than 30 min. Estonia, for example, was the first country in the world to build a nationwide EV fast charging network. Several initiatives for statewide and nationwide charging networks have been announced and are in partial/full operation already. A few examples of fast charging networks are:

- Fastned EV charging network, Netherlands, https://fastned.nl/en/
- Tesla supercharging network, https://www.tesla.com/supercharger
- Estonia nationwide charging network, http://elmo.ee/
- Ionity Europe fast charging network, http://www.ionity.eu/ionity-en.html
- Electrify America, https://www.electrifyamerica.com/our-plan
- New Zealand ChargeNet NZ network, https://charge.net.nz/
- Australian Smatric network, https://smatrics.com/en/charging-network

While the above list is not exhaustive, learners can get an idea of the what these networks are, how they stations are spread out and located, what type of chargers they facilitate and what are the charging power levels.