IEC 62196

IEC 62196 is an international standard for set of electrical connectors and charging modes for electric vehicles and is maintained by the International Electrotechnical Commission (IEC).

The standard is based on IEC 61851 which specifies mechanisms such that, first, power is not supplied unless a vehicle is connected and, second, the vehicle is immobilized while still connected.[1]

The IEC 62196-1 definitions for the signal pin and the IEC 62196-1 charging mode definitions have been used in other specifications. Apart from CEEform industrial plugs, the modes were picked up for

- SAE J1772, known colloquially as the Yazaki connector, in Northern America,
- the CHAdeMO connector in Japan and the
- VDE-AR-E 2623-2-2, known as the Mennekes connector, in Europe.

Each of these has been designed for use in an electric vehicle network of charging stations. Other connector types conforming to IEC 62196-1 have been the Framatome plug by EDF, the Scame plug in Italy and the CEEplus plugs in Switzerland.[1]

Public charging stations conforming to IEC 62196 that have a specific socket type (e.g., SAE J1772 or CEEplus) can be used with other plug types by means of adapters – however the current will not be enabled unless an IEC 61851 presence signal pin is connected and the current will be limited to 16 A unless an IEC 62196 charging mode signal is detected that specifies a higher current level.

1 Charging modes

IEC 62196-1 is applicable to plugs, socket-outlets, connectors, inlets and cable assemblies for electric vehicles, intended for use in conductive charging systems which incorporate control means, with a rated operating voltage not exceeding:

- 690 V a.c., 50 – 60 Hz, at a rated current not exceeding 250 A;
- 600 V d.c., at a rated current not exceeding 400 A.

IEC 62196 refers to the charging modes defined in IEC 61851-1 which include:[2]

- “Mode 1” - slow charging from a household-type socket-outlet
- “Mode 2” - slow charging from a household-type socket-outlet with an in-cable protection device
- “Mode 3” - slow or fast charging using a specific EV socket-outlet with control and protection function installed
- “Mode 4” - fast charging using an external charger

IEC 61851-1 documents the pilot signal which communicates the charging requirements by means of pulse width modulation.

1.1 Mode 1

Mode 1 entails the connection of the EV to a standard a.c. mains socket-outlet. Current is limited to 16 A and voltage is limited to 250 V single-phase or 480 V three-phase. Earthing is required.

Mode 1 connectors do not have extra control pins as described by IEC 61851-1.[3]

In some countries including the USA, Mode 1 charging is prohibited. One problem is that the required earthing is not present in all domestic installations. Mode 2 was developed as a workaround for this.

1.2 Mode 2

Mode 2 entails the connection of the EV to a standard a.c. mains socket-outlet using a special cable that has built in control box. The control box ensures, among other things, that current only flows if earth is connected. The Mode 2 connector on the EV end has an IEC 61851-1 control pin.[3] The control box must be in the plug or within 0.3 metres of the plug. The supply side of the cable does not have a control pin.

In Mode 2 the current does not exceeding 32 A and the voltage does not exceed 250 V single-phase, 480 V three-phase.

A possible setup uses an IEC 60309 connector on the supply end of the cable which is rated at 32 A. The cable interacts with the EV to indicate that 32 A can be drawn.[4]

1.3 Mode 3

Mode 3 entails the connection of the EV to electric vehicle supply equipment (EVSE) which implements the control pilot functionality.

Mode 3 connectors have IEC 61851-1 control and signal pins on both ends of the cable. The charging station socket is non-live if no EV is connected. For compatibility, the 32 A plugs of IEC 61851-1 Mode 2 connectors may be used, while fast charging with higher currents up to 250 A require specialized cables enabling the IEC 61851-1 charging mode.[3] The communication wire between car electronics and charging station allows for an integration into smart grids.[4]

1.4 Mode 4

Mode 4 entails the connection of the EV to a d.c. charger which implements the control pilot functionality.

In Mode 4 charging, a.c. mains power is converted in the charging station to d.c. The plug type ensures that only a matching EV can be connected. This mode allows for currents up to 400 A.[3] Mode 4 charging station equipment is generally more expensive than Mode 3 EVSE.[4]

2 Plug types

2.1 IEC 60309

The IEC 62196-1 refers to plugs as specified in IEC 60309 for industrial and multiphase power plugs and sockets.

A number of industry groups have made advancements to add details on specific plugs beyond the existing range IEC 60309 "CEEform" connectors. The CEEform industry connectors are used in many areas while the following plug types from the IEC 62196 annex have been tailored to the usage as automotive chargers. The later IEC 62196-2 contains categorizations on plug types to be used in the charging process. In June 2010 the ETSI and CEN-CENELEC were mandated by the European Commission to develop a European Standard on charging points for electric vehicles.[5] The IEC 62196-2 circulation started on 17. December 2010 and voting closes on 20. May 2011.[2] The standard was published by the IEC on 13. October 2011.[6]

The list of IEC 62196-2 plug types includes:[7]

- IEC 62196-2 "Type 1" - *single phase vehicle coupler* - reflecting the SAE J1772/2009 automotive plug specifications
- IEC 62196-2 "Type 2" - *single and three phase vehicle coupler* - reflecting the VDE-AR-E 2623-2-2 plug specifications
- IEC 62196-2 "Type 3" - *single and three phase vehicle coupler with shutters* - reflecting the EV Plug Alliance proposal

2.2 Type 1: SAE J1772-2009

Main article: SAE J1772

The SAE J1772-2009 connector, known colloquially as the "Yazaki" connector (after its manufacturer), is commonly found on EV charging equipment in North America.

SAE J1772-2009 Plug (Type 1)

In 2001 SAE International proposed a standard for a conductive coupler which had been approved by the California Air Resources Board for charging stations of EVs. The SAE J1772-2001 plug had a rectangular shape that was based on a design by Avcon. In 2009, a revision of the SAE J1772 standard was published that included a new design by Yazaki featuring a round housing. The SAE J1772-2009 coupler specifications have been included to IEC 62196-2 standard as an implementation of the Type 1 connector for charging with single-phase a.c. The connector has five pins for the two AC wires, earth, and two signal pins compatible with IEC 61851-2001 / SAE J1772-2001 for proximity detection and for the control pilot function.

Note that only the plug type specification of the SAE J1772-2009 has been taken over but not the concept of levels found in the proposal of the California Air Resources Board. (The Level 1 charging mode at 120 V is specific to Northern America and Japan as most regions around the world use 220–240 V and IEC 62196 does not include a special option for lower voltages. The Level 3 for DC charging is not applicable to either IEC 62196-2 or SAE J1772-2009.)

While the original SAE J1772-2009 standard describes ratings from 120 V 12 A / 16 A to 240 V 32 A / 80 A the IEC 62196 Type 1 specification covers only 250 V ratings at 32 A / 80 A. (The 80 A version of IEC 62196

Type 1 is considered US-only, however.)[8]

2.3 Type 2: VDE-AR-E 2623-2-2

Main article: Type 2 connector

The connector manufacturer Mennekes had developed

Mennekes/VDE charging station outlet and matching plug

a series of 60309-based connectors that were enhanced with additional signal pins – these “CEEplus” connectors have been used for charging of electric vehicles since the late 1990s.[9][10] With the resolution of the IEC 61851-1:2001 control pilot function (aligned with the SAE J1772:2001 proposal) the CEEplus connectors were replacing the earlier Marechal couplers (MAEVA / 4 pin / 32 A) as the standard for electric vehicle charging.[11] When Volkswagen promoted its plans for electric mobility Alois Mennekes contacted Martin Winterkorn in 2008 to learn about the requirements of the charging equipment connectors.[10] Based on requirement of the industry led by utility RWE and car maker Daimler a new connector was derived by Mennekes.[12] The state of charging systems along with the proposed new connector were presented at the start of 2009.[13] This new connector would later be accepted as the standard connector by other car makers and utilities for their field tests in Europe.[12] This choice was supported by the Franco-German joint council on E-mobility in 2009.[14] The proposal is based on the observation that standard IEC 60309 plugs are rather bulky (diameter 68 mm / 16 A to 83 mm / 125 A) for higher current. To ensure easy handling by consumers the plugs were made smaller (diameter 55 mm) and flattened on one side (physical protection against polarity reversal).[15] Unlike the Yazaki connector, however, there is no latch, meaning consumers have no exact feedback that the connector is properly inserted. The lack of a latch also puts unnecessary strain on any locking mechanism.

Since the IEC standardization track is a lengthy process, the German DKE/VDE (Deutsche Kommission Elektrotechnik / *German Commission for Electronics* of the Association for Electrical, Electronic and Information Technologies) took over the task to standardize the handling details of the automotive charging system and its designated connector published in November 2009 in **VDE-AR-E 2623-2-2**[16] The connector type has been included in the next Part-2 (IEC 62196-2) connector reference as “Type 2”.[12] The standardization process of the VDE plug continues with an extension for high current d.c. loading that will be proposed for inclusion by 2013.[17]

Unlike the IEC 60309 plugs, the Mennekes/VDE automotive solution (German **VDE-Normstecker für Ladestationen** / *VDE standard plug for charging stations*) has a single size and layout for currents from 16 A single-phase up to 63 A three-phase (3.7 kW to 43.5 kW)[18] but it does not cover the full range of Mode 3 levels (see below) of the IEC 62196 specification. Since the VDE automotive connector was described first in the DKE/VDE proposal for the IEC 62196-2 standard (IEC 23H/223/CD), it was also called the IEC-62196-2/2.0 automotive connector before it got its own standardization title. The VDE will formally withdraw the national standard as soon as the international IEC standard is resolved.

There has been criticisms of the price of the VDE connector however by the car manufacturer Peugeot comparing it to the IEC 60309 plugs that are readily available.[19] Unlike field tests in Germany, a number of field tests in France and the UK have taken over the campground sockets (blue IEC 60309-2 plug, single-phase, 230 V, 16 A) that are already installed in many outdoor locations across Europe[19] or weatherproofed versions of their normal domestic sockets. Also the Scame plugin is promoted by a French-Italian alliance mentioning its comparable low price.[20] The Chinese Variant of Type 2 in GB/T 20234.2-2011 has limited the current to 32 A allowing for cheaper materials.[21]

The Association des Constructeurs Européens d'Automobiles (ACEA) has decided to use the Type 2 connector for deployment in European Union. For the first phase the ACEA recommends public charging stations to offer Type 2 (Mode 3) or CEEform (Mode 2) sockets while home charging may additionally use a standard home socket (Mode 2). In the second phase (expected to be 2017 and later) a uniform connector shall be used only, whereas the ultimate choice for Type 2 or Type 3 is left open. The rationale of the ACEA recommendation points to using Type 2 Mode 3 connectors however.[22] Based on the ACEA position Amsterdam Electric has put up the first Type 2 Mode 3 public charging station for use with the Nissan Leaf test drive.[23]

Beginning at the end of 2010 the utilities Nuon and RWE have started to deploy a network of charging poles in Central Europe (Netherlands, Belgium, Germany, Switzerland, Austria, Poland, Hungary, Slovenia, Croatia) using the *Type 2 Mode 3* socket type based on the widely available 400 V three-phase domestic power grid. The Netherlands have started to deploy a network of 10,000 charging stations of this type with a common output of three-phase 400 V at 16 A.

In March 2011 the ACEA had published a position paper that recommends Type 2 Mode 3 as the EU uniform solution by 2017, ultra fast DC charging may only use a Type 2 or Combo2 connector[24] The European Commission has followed the lobbying[25][26] proposing Type 2 as the common solution in January 2013 to end uncertainty about the charging station connector in Europe.[27] There had been concerns that some countries require a mechanical shutter for electrical outlets which the original VDE proposal did not include - Mennekes proposed an optional shutter solution in October 2012[25] which was picked up in the German-Italian compromise in May 2013 which the standardization bodies propose for subsequent inclusion in the CENELEC standard of Type 2.[28]

2.4 Type 3: EV Plug Alliance connector

The EV Plug Alliance was formed on March 28, 2010 by electrical companies in France (Schneider Electric, Legrand) and Italy (Scame).[29] Within the IEC 62196 framework they propose an automotive plug derived from the earlier SCAME plugs (the Libera series) that are already in use for light electric vehicles.[30] Gimélec joined the Alliance on May 10 and a number of more companies joined on May 31: Gewiss, Marechal Electric, Radiall, Vimar, Weidmüller France & Yazaki Europe.[31] The new connector is able to provide 3-phase charging up to 32 Ampere as being examined in the Formula E-Team tests.[20] Schneider Electric emphasises that the “EV Plug” uses shutters over the socket side pins which is required in 12 European countries and that none of the other proposed EV charger plugs is featuring.[32] Limiting the plug to 32 A allows for cheaper plugs and installation costs. The EV Plug Alliance points out that the future IEC 62196 specification will have an annexe categorizing electric vehicle charger plugs into three types (Yazaki’s proposal is type 1, Mennekes’ proposal is type 2, Scame’s proposal is type 3) and that instead of having a single plug type at both ends of a charger cable one should choose the best type for each side — the Scame / EV Plug would be the best option for the charger side / wall box leaving the choice for the car side open. On 22 September 2010 the companies Citelum, DBT, FCI, Leoni, Nexans, Sagemcom, Tyco Electronics joined the Alliance.[33] As of early July 2010 the Alliance has completed the test of products from several partners and the plug and socket-outlet system are made available on the market.[33]

While the first ACEA position paper (June 2010) has ruled out the Type 1 connector (based on the requirement of three-phase charging which is abundant in Europe and China but not in Japan and the USA) it has left open the question whether a Type 2 or Type 3 connector should be used for the uniform plug type in Europe.[22] The rationale points to the fact that Mode 3 requires the socket to be dead when no vehicle is connected so that there can be no hazard that the shutter could protect from. The shutter protection of Type 3 connectors do only have advantages in Mode 2 allowing for a simpler charging station. On the other hand, a public charging station exposes the charging socket and plugs to a harsh environment where the shutter could easily have a malfunction which is not noticeable to the electric vehicle driver. Instead the ACEA expects that Type 2 Mode 3 connectors also to be used for home charging in the second phase after 2017 while still allowing Mode 2 charging with established plug types that are already available in home environments.[22] The impact of some jurisdictions requiring shutters is still being debated.[34]

The second ACEA position paper (March 2011) recommends to use only Type 2 Mode 3 (with IEC 60309-2 Mode 2 and standard home socket outlets Mode 2 being still allowed in Phase 1 up to 2017) being the EU uniform solution by 2017. Car makers should equip their models only with Type 1 or Type 2 sockets – existing Type 3 infrastructure may be connected with a Type2/Type3 cable in Phase 1 for basic charging (up to 3.7 kW). Fast charging (3.7 kW to 43 kW) and ultra fast DC charging (beyond 43 kW) may only use a Type 2 or Combo2 connector (Combo2 is Type 2 with additional DC wires in a global envelope that fits all DC charging stations, i.e. even if the AC charging part was built for Type 1).[24]

The EV Plug Alliance had proposed two connectors with shutters. The **Type 3A** is derived from the Scame charging connectors adding the IEC 62196 pins which is suited for single-phase charging – the connector builds on the experience with the Scame connector for charging of light vehicles (electric motorcycles and scooters).[35][36] The additional **Type 3C** adds additional 2 pins for three-phase charging for usage at fast charge stations.[37] Based on its origin the connector is sometimes referred to as the *Scame Type 3* connector.[38]

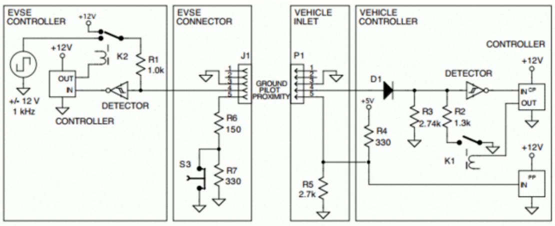
In October 2012 Mennekes has shown an optional shutter solution for its Type 2 socket. In the press material it is shown that some countries chose the Mennekes’ IEC Type 2 connector despite the requirement for shutters on household sockets (Sweden, Finland, Spain, Italy, UK); only France has a decision for the EV Plug Alliance’s IEC Type 3 socket type. The Mennekes shutter is inherently IP 54 safe (dust cover) providing an installation option even beyond IP xxD.[25] After the European Commission has settled on Type 2 (VDE/Mennekes connector) as the single solution for the charging infrastructure in Europe in January 2013, the EV Plug Alliance has asked to include the variant of Type 2 with shutters in the upcoming directive in a hearing of the TRAN Committee in June 2013[39] (which makes the VDE/Mennekes plug a variant implementation of the requirements of IEC Type 3). The Italian standardization body CEI tested the Mennekes shutter proposal (where Italy is a country requiring mechanical shutters) and in May 2013 the Italian and German partners approved it as a compromise solution for Type 2 to be included in the CENELEC standardization of electric vehicle charging connectors.[28]

The EV Plug Alliance was last seen in June 2013 at an EU hearing.[39] The web site was not maintained anymore and in October 2014 it was replaced with a shutdown notice.[40]

2.5 Signal pins

Main article: SAE J1772 Signaling

The function of the signal pins had been defined in SAE



J1772 signaling circuit

J1772-2001 and it had been added to IEC 61851. All plug types of IEC 62196-2 use two additional signals from that standard – the control pilot CP (pin 4) and proximity pilot PP (pin 5) are added to the normal electricity pins for live wires (pin 1, pin 2) and neutral (pin 3) named N (neutral) and PE (protective earth).

The charging station will send a 1000 Hertz square wave on the contact pilot CP that is connected back to the protected earth PE on the side of the vehicle by means of a resistor and a diode. The live wires of public charging stations will always be dead if the CP-PE circuit is open although the standard allows a charging current as in Mode 1 (maximum 16 Ampere). If the circuit is closed then the charging station can also test the protective earth to be functional. The vehicle can request a charging state by setting a resistor – using 2700 Ohm a Mode 3 compatible vehicle is announced ("vehicle detected") which does not require charging. Switching to 880 Ohm the vehicle is "ready" to be charged and switching to 240 Ohm the vehicle requests "with ventilation" charging which does not have an effect outdoors but the charging current will be switched off indoors if no ventilation is available. The charging station can use the wave signal to describe the maximum current that is available from the charging station with the help of pulse width modulation: a 16% PWM is a 10 A maximum, a 25% PWM is a 16 A maximum, a 50% PWM is a 32 A maximum and a 90% PWM flags a fast charge option.[41]

The proximity switch PP is available for the vehicle to describe its input charging capacity to the charging station asking to limit the current. This is done by setting a resistor between the PP and PE wires – adapter cables can use a resistor encoding to define the maximum:[42][43]

The signals use the CP and PP pins with a 12 volt potential from the charger. The analog signal protocol is simple enough to not require any digital electronics. The CP-PE loop is fed through a 1000 ohm resistor from a +12 volt source and grounded through a 2740 ohm resistor to the PE ground at vehicle. Connecting a compatible vehicle drops the voltage at the CP pin to 9 volts; this activates the wave generator. The vehicle activates the charger by adding a parallel 1300 ohm resistor (dropping the voltage to +6V), or a parallel 270 ohm resistor for ventilation (dropping voltage to +3V). A detector in the charger is triggered by the voltage level on CP-PE alone.[44] The PP-PE loop is connected in the plug of the adapter cable specifying the wire cross section; if it is connected through to the vehicle then the it is pulled down with 2700 Ohm and additional resistors in the vehicle charging control can be used to set the current from the charger.

3 IEC 62196-3 – DC Charging

The 2010/2011 voting ballot of IEC 62196-2 does not contain a proposal for DC charging / Mode 4. This is to be found in **IEC 62196-3** published 19 June 2014.[45] The IEC working group for TC 23/SC 23H/PT 62196-3 (max. 1000 VDC / 400 A plugs) has been approved for new work.[46][47][48] Specifications on DC charging have already begun on the national level.

A number of plug types are under consideration for DC charging. The Japanese Chademo plugs have been in use for a number of years already while the common plug type is considered too bulky. China has adopted the Type 2 (DKE) connector adding a mode that puts DC power on existing AC pins. Both of the two connectors use a CAN based protocol between the car and the charging station to switch the mode. In contrast to that both the American SAE and the European ACEA research concentrates on the GreenPHY PLC protocol to plug the car into a smart grid architecture. Both of the latter consider to have a low power / Level 1 configuration where DC power is put on existing AC pins (as specified for the Type 1 or Type 2 plug types respectively) and an additional high power / Level 2 configuration with dedicated DC power pins – the ACEA and the SAE are working on a "Combined Charging System" for the extra DC pins that fit universally.[49][50]

The CHAdeMO specification describes high-voltage (up to 500 VDC) high-current (125 A) automotive fast charging via a JARI Level-3 DC fast charge connector. This connector is the current *de facto* standard in Japan.[51] The SAE 1772 Task Force works on a proposal for DC loading to be published in December 2011[51] The extension of the VDE plug ("Type 2") will be submitted directly to the IEC 62196-2 until 2013.[17] Both China and the SAE consider using the *Type 2 Mode 4* connector for DC charging as well (the Japanese TEPCO plug housing is considerably larger than Type 2).[52]

The VDE has supplied the National Development Plan for Electric Mobility in Germany with the expectation that charging stations for electric vehicles will be deployed in three stages: 22 kW (400 V 32 A) Mode 2 stations are introduced in 2010–2013, the 44 kW (400 V 63 A) Mode 3 stations to be introduced in 2014–2017 and the next generation batteries will require at least 60 kW (400 VDC 150 A) by 2020 allowing to charge the standard 20kWh battery pack to 80% in less than 10 minutes.[53] Similarly the SAE 1772 DC L2 plan is sketched for charging up to 200 A / 90 kW.[51]

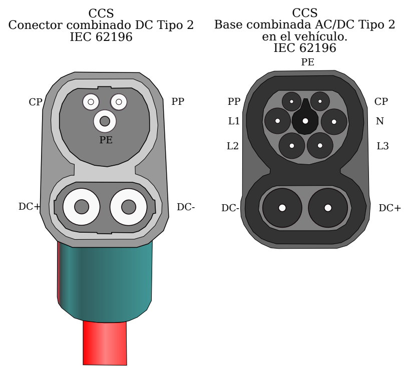
Meanwhile, Tesla Motors introduced 90kW DC charging system called SuperCharger in 2012 for its Model S cars and since 2013 upgraded DC charging system to 120kW DC. Tesla is using modified Type 2 plug for SuperCharger. This modified connector allows for deeper insertion, and longer conductor pins, allowing for greater current. There is no need for additional DC pins because DC current can flow using the same pins as AC current.

3.1 Combined Charging System

While the target to have only one charging connector has been lost in that the world is split on their main grid system with Japan and North America to choose a single-phase connector on their 100-120/240 Volt grid (Type 1) while the rest of the world including China and Europe is opting for a connector with single-phase 230 Volt and three-phase 400 Volt grid access (Type 2). The SAE and ACEA are trying to avoid the situation for DC charging with a standardization that plans to add DC wires to the existing AC connector types such that there is only one "global envelope" that fits all DC charging stations – for Type 2 the new housing is named Combo2.[24]

On the 15th International VDI-Congress of the Association of German Engineers the proposal of a "Combined Charging System" (CCS) was unveiled on 12. October 2011 in Baden-Baden. Seven car makers (Audi, BMW, Daimler, Ford, General Motors, Porsche and Volkswagen) have agreed to introduce the Combined Charging System in mid-2012.[54][55] This defines a single connector pattern on the vehicle side that offers enough space for a Type 1 or Type 2 connector along with space for a two pin DC connector allowing up to 200 Ampere. The prototype implementations for up to 100 kW were shown on the EVS26 in Los Angeles in May 2012.[56] Specifications for DC charging in the IEC 62196-3 draft give a range up to 125 A with up to 850 V.[57]

The seven auto manufacturers have also agreed to



Combo plug for DC charging (using only the signal pins of Type2) and the Combo inlet on the vehicle (allowing also AC charging)

use HomePlug GreenPHY as the communication protocol.[58] The prototype for the matching plug has been developed by Phoenix Contact with the goal to withstand 10,000 connect cycles.[59] The standardization proposal has been sent to the IEC in January 2011.[60] The request to use a PLC protocol for the Vehicle2Grid communication was flagged back in September 2009 in a joint presentation of BMW, Daimler and VW on California Air Resource Board ZEV Technology Symposium.[61] This is competing with the CAN Bus proposal from Japan (including CHAdeMO) and China (separate DC connector proposal) and notably none of their car manufacturers has signed up to the Combined Charging System so far. China had been involved in early stages of the development of the extra DC pins however.[59] A test drive will begin in the fall of 2012.[59]

Volkswagen has built the first public CCS rapid charge station with 50 kW DC in Wolfsburg in June 2013 to support the test drives of the upcoming VW E-Up that is supposed to be delivered with a DC rapid charger connector for the Combined Charging System.[62] Two weeks later BMW has opened its first CCS rapid charge station in support of the upcoming BMW i3.[63] On occasion of the second EV World Summit in June 2013 both a Chademo and a Volkswagen-group spokesperson have pointed out that a concurrency between Chademo and CCS is not required as the additional cost of a dual-protocol rapid charge station is a mere 5% - thus multi-standard DC chargers are being advocated by Chademo, Volkswagen and Nissan.[64]

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5 External links

- “Norme International CEI/IEC International Standard 62196-1” (PDF). International Electrotechnical Commission. 2004. Retrieved 2009-06-07.
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- REMA’s version of the type 2 plug
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- Article on cars21 on the subject

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