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## Technical Note 5

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### Electric vehicle recharging infrastructure for on-road EVs



**Prepared for BAA, Heathrow Airport Limited  
by Sustainable Transport Solutions (STS)**

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# 1 Introduction

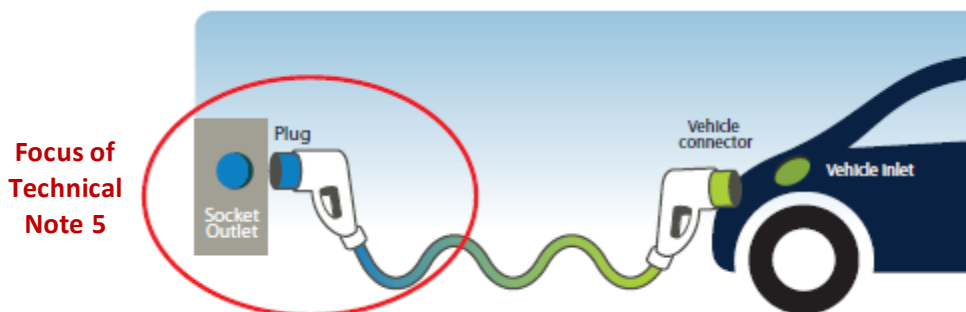
The focus of this Technical Note is conductive<sup>1</sup> electric vehicle recharging infrastructure (also referred to as electric vehicle supply equipment or EVSE) as used for private and commercial on-road vehicles. While the systems used off- and on-board are interdependent, information regarding the vehicle inlet (in which the vehicle connector is located as shown in Figure 1) is not included in detail, but is referred to as required.

As represented in the following Sections, this Note details the most relevant 'Modes', which provide the specifications of the electric supply, and 'Types', which categorise the main socket and plug types currently in use or in development. The document also addresses the compatibilities between Modes and Types, drawing out the combinations already well established or most likely to become a future standard.

## 1.1 Terminology

As shown in Figure 1, conductive couplers connecting EVSE with a vehicle comprise (in most cases), a 'socket outlet' and appropriate 'plug' (supply-side), a cable, and a 'vehicle connector' which is located into the 'vehicle inlet' (vehicle-side).

**Figure 1 Schematic of EV charger socket, plug, cable and connector<sup>2</sup>**



Cable connections can take one of three options: Case A, where the cable is permanently attached to the vehicle (cable has plug but no vehicle connector); Case B, where the cable is not attached to anything (plug and vehicle connector used); and Case C where the cable is permanently attached to the charging station (cable has vehicle connector but no plug).

While most EVSE is supplied by the mains, which is usually three-phase 'alternating current' (AC), batteries need to be charged using 'direct current' (DC). EVSE therefore provides either AC at the socket outlet, the current being rectified (converted to DC) on the vehicle using an 'on-board' charger, or DC at the socket, the current being rectified within the EVSE using an 'off-board' charger.

In general AC chargers, which can be single- or three-phase, provide 'slow' (typically 2-5 kW) or 'fast' (typically 7-24 kW) charging rates, the rate being determined by the EVSE *and* vehicle specifications. As DC chargers are (in general) able to dispense much larger currents, they are often termed 'rapid' or 'quick' chargers (typically 50-100 kW). However, the latest AC units are able to deliver ratings of up to 40-50 kW, and can therefore match the rates more normally associated with DC chargers.

<sup>1</sup> Inductive charging is technically possible and is being developed. However, as few commercial units are currently available, this technology is not included as part of this Technical Note.

<sup>2</sup> Figures 1-5 sourced from: Guide to Electric Vehicle Infrastructure. BEAMA, May 2012. URL: <http://www.beama.org.uk/>.

The time required for a full battery charge depends on both the charging rate (in kW) and the battery capacity (in kWh). Typical charging time for an electric car with battery capacity 24 kWh would be: 8 hours (using a 3 kW 'slow' AC charger), 4 hours (7 kW 'fast' AC), 1 hour (24 kW 'fast' AC), or around 30 minutes for a 80% charge (50 kW 'rapid' DC unit). In practice, any single vehicle will only be able to accept a limited number of charging modes, and/or connect with a limited number of socket types.

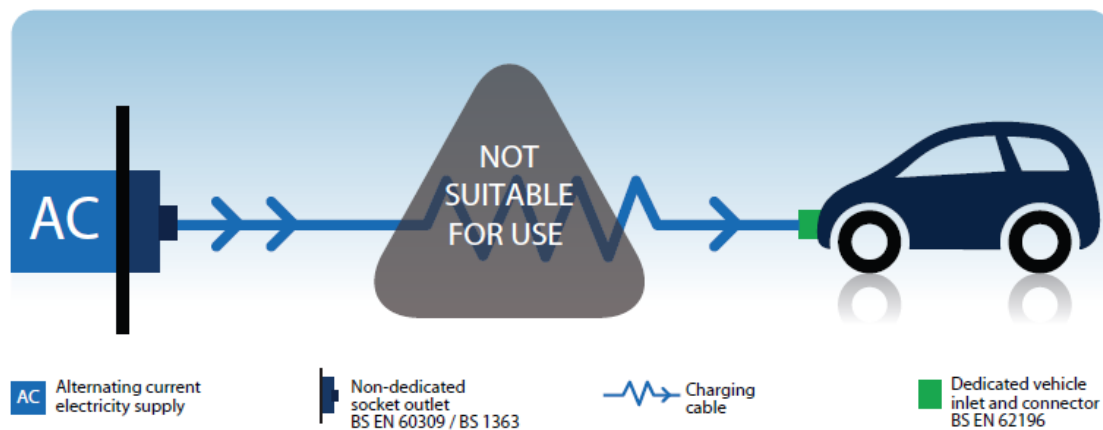
## 2 Charging modes

Charging 'modes' categorise the type of electricity supply available at the socket and are defined in most regards by international standards (eg IEC 62196). In summary, Modes 1-3 provide methods of charging EVs using an AC supply, while Mode 4 provides charging using a DC supply to the vehicle.

### 2.1 Mode 1

Mode 1 charging uses a single or three-phase AC supply, with a maximum permitted current of **16A**. The supply voltage is up to a maximum of 250V for single-phase or 480V for three-phase. The AC is rectified to DC on the vehicle using an 'on-board' charger.

**Figure 2 Schematic of Mode 1 charging**



Mode 1 charging does not require use of a residual current device (RCD), and as such is not generally recommended for public or commercial use. Where Mode 1 is used, either no RCD protection is afforded, or it is assumed that an appropriate RCD is part of the existing electrical supply prior to installation of the EV charging equipment.

Mode 1 facilities are often described as '**slow**' chargers as the current is limited to 16A maximum (EU standard) and 13A maximum in the UK. Typical power ratings are 3kW for a single-phase supply and 10kW for a three-phase 480V industrial supply.

For single-phase, the three socket pins include two power pins and a protective earth. For a three-phase supply, five socket pins are most common including three power pins, neutral and a protective earth. Given the lack of data pins, Mode 1 excludes the possibility of a 'handshake' (a data exchange which enables the vehicle to communicate with the EVSE), which is used on Modes 3 and 4 as a safety feature and to provide a 'smart' charging capability (controlled supply-side).

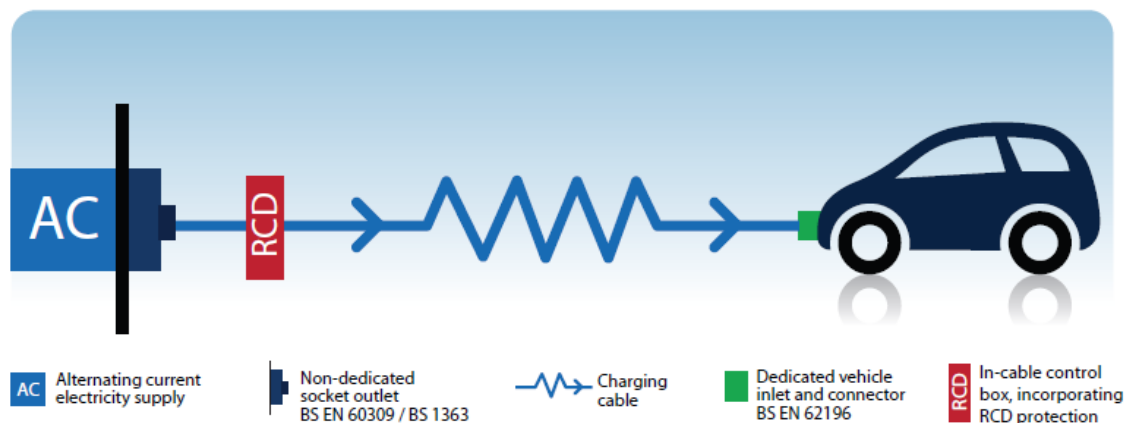
The standard that defines Mode 1 charging parameters is **IEC 62196**, an international standard for a set of electrical connectors and charging modes for electric vehicles. As no 'handshake' is used, Mode 1 does not adhere to IEC 61851, the standard that defines a data link between the charger and the vehicle which can be used to immobilise an EV when on charge or provide 'smart' charging capability.

## 2.2 Mode 2

The main difference between Modes 1 and 2 is the use of a **residual current device (RCD)** which automatically disconnects the AC power supply if an imbalance is detected between the live and neutral components of the supply. While Mode 1 assumes that either no RCD is in use or that an RCD is part of the electrical supply, Mode 2 incorporates RCD equipment as part of the specification.

As with Mode 1, Mode 2 charging uses a single or three-phase AC supply, but with a higher maximum permitted current of 32A. The supply voltage is up to a maximum of 250V for single-phase or 480V for three-phase supply. The AC supply is rectified to DC on the vehicle using an 'on-board' charger.

**Figure 3 Schematic of Mode 2 charging**



As Mode 2 includes an RCD (located within the plug or within 30 cm of the plug), it can be recommended for public or commercial use, but should be considered the *minimum* standard with regard to safety and 'smart' capability. In general, Mode 3 should be adopted wherever costs and operations permit to maximise safety and increase options for intelligent charging regimes.

Mode 2 facilities can be described as '**slow**' or '**fast**' chargers depending on the available power. With a maximum permitted current of 32A, typical power ratings are 7.4kW for a single-phase supply and 24kW for a three-phase 480V industrial supply.

It should be noted, however, that while many EVs are able to connect to a 32A Mode 2 supply, some models only draw 13A and, as a result, only charge at the 'slow' 3kW rate. Some manufacturers also limit Mode 2 charging currents to 10A, so reducing the maximum available power to 2.3kW.

For Mode 2 single-phase, the three socket pins include two power pins and a protective earth. For a three-phase supply, five socket pins are most common including three power pins, neutral and a protective earth. Given the lack of data pins, Mode 2 (like Mode 1) excludes the possibility of a 'handshake' between the vehicle and the supply.

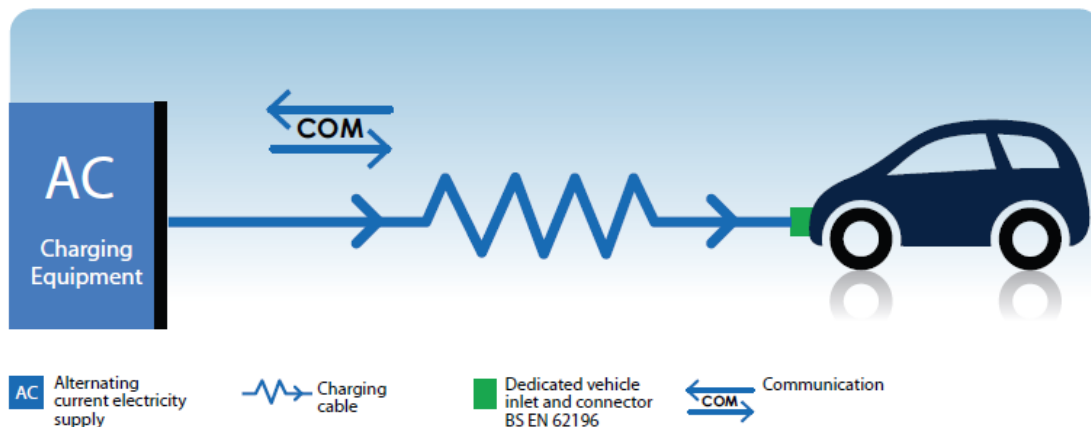
The standard that defines Mode 2 charging parameters is **IEC 62196**, an international standard for set of electrical connectors and charging modes for electric vehicles. While no full 'handshake' is used, Mode 2 does adhere to IEC 61851-1, which requires a control pin on the vehicle side of the cable (the control function being governed by the control box in the cable).

## 2.3 Mode 3

The main difference between Modes 3 and 1-2 is the use of control (data) pins which provide a **'handshake'** between the vehicle and the supply. Mode 3 therefore provides a higher level of safety than lower modes and also provides the capabilities offered by a 'smart' grid (as controlled supply-side). Mode 3 is highly likely to become the future European standard for public access AC EVSE.

As with Modes 1 and 2, Mode 3 charging uses a single or three-phase AC supply, with a maximum permitted current of 32A. The supply voltage is up to a maximum of 250V for single-phase or 480V for three-phase supply. The AC supply is rectified to DC on the vehicle using an 'on-board' charger.

**Figure 4 Schematic of Mode 3 charging**



Mode 3 facilities can be described as **'slow'** or **'fast'** chargers depending on the available power. With a maximum permitted current of 32A, typical power ratings are 7.4kW for a single-phase supply and 24kW for a three-phase 480V industrial supply. (It should be noted that although EVs may be able to connect to a 32A Mode 3 supply, some will continue draw only 13A and, as a result, only charge at the 'slow' 3kW rate.)

Unlike Modes 1 and 2, control and protection functions (including Surge Protective Device and RCD) are permanently installed within the charge point unit which is permanently connected to the AC supply network (mains) at all times.

For Mode 3 single-phase, the five socket pins include two power pins, a protective earth and two control (data) pins. For a three-phase supply, seven socket pins are most common including three power pins, neutral, a protective earth and two data pins. Given the inclusion of data pins, Mode 3 provides the possibility of a 'handshake' between the vehicle and the supply.

The standard that defines Mode 3 charging parameters is **IEC 62196**, an international standard for set of electrical connectors and charging modes for electric vehicles. As a full data 'handshake' is used, Mode 3 also adheres to **IEC 61851** requiring control and signal pins for both sides of the cable. The 'handshake' means that the socket is effectively dead if no vehicle is connected, and the EV can be immobilised when on charge. The data link also enables full 'smart' charging capability.

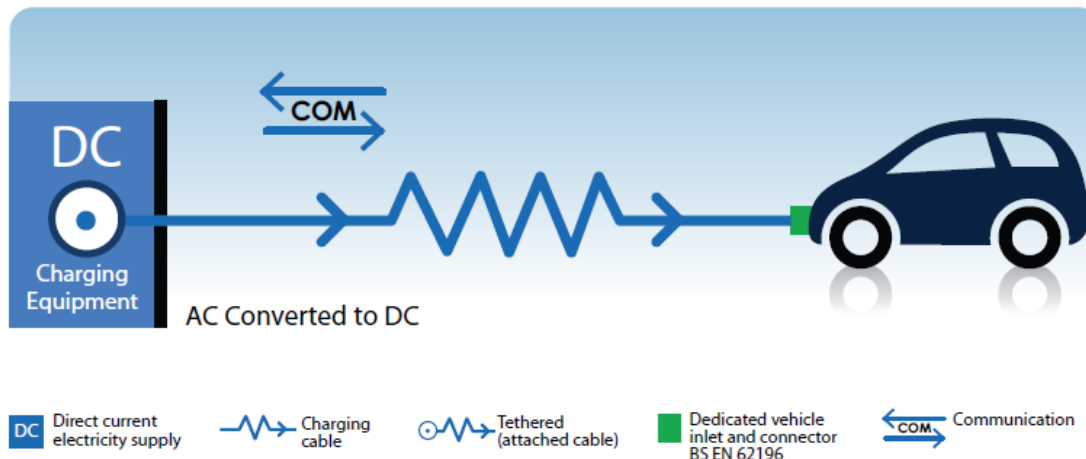
IEC 61851-1 also defines three cases for cable connections: Case A, where the cable is permanently attached to the car; Case B, where the cable is not attached to anything; and Case C where the cable is permanently attached to the charging station. Mode 3 typically uses Case B or Case C options.



## 2.4 Mode 4

The key difference between Mode 4 and Modes 1-3 is the use of an 'off-board' charger which rectifies the single or three-phase AC supply within the charging unit. As a result, Mode 4 chargers provide a **DC supply** at the socket. Mode 4 provides a supply with a maximum permitted current of 1000VDC (typically 500VDC) and current of up to 400A (usually 125A).

**Figure 5 Schematic of Mode 4 charging**



Mode 4 facilities are also described as '**rapid**' or '**quick**' chargers (although some of the latest Mode 3 'fast' units can match many Mode 4 chargers for supplied power). With a current of 125A, typical power ratings are 62.5kW allowing an 80% recharge in around 30 minutes (for a typical electric car).

As with Mode 3, control and protection functions (including Surge Protective Device and RCD) are permanently installed within the charge point unit which is permanently connected to the AC supply network. The standard that defines Mode 4 charging parameters is **IEC 62196**, an international standard for set of electrical connectors and charging modes for electric vehicles.

Mode 4 only operates using the Case C cable option where the cable is permanently attached to the charging station. The plug type ensures that only a matching electric vehicle can be connected. Mode 4 connectors according to **IEC 61851-1** require a range of control and signal pins to ensure operation for fast charging comparable to Mode 3.

## 2.5 Summary

- **Mode 1** is characterised by single or three-phase AC, with a maximum permitted current of 16A. The supply voltage is up to a maximum of 250V for single-phase or 480V for three-phase. As no RCD is included in the EVSE, Mode 1 is not recommended for public or commercial use.
- **Mode 2** uses a single or three-phase AC supply, with a maximum permitted current of 32A. The supply voltage is up to a maximum of 250V for single-phase or 480V for three-phase supply. Mode 2 includes the use of an RCD located within the cable.
- **Mode 3** charging uses a single or three-phase AC supply, with a maximum permitted current of 32A. The supply voltage is up to a maximum of 250V for single-phase or 480V for three-phase supply. As Mode 3 includes a full 'handshake' between the vehicle and the charger, Mode 3 enables full vehicle isolation and 'smart' charging capability.
- **Mode 4** chargers incorporate an 'off-board' charger and provide a DC supply at the socket. The DC supply has a maximum permitted current of 1000VDC (typically 500VDC) and current of up to 400A (usually 125A). Mode 4 includes a full 'handshake' so enabling 'smart' charging capability.

**Table 1 Summary of EVSE charging modes**

MODE	DESCRIPTION	STANDARD	HAND-SHAKE	SUPPLY	CHARGER LOCATION	PHASE	MAX CURRENT	MAX VOLTAGE	MAX POWER	TYPICAL POWER	NOTES
<b>MODE 1</b>	'Slow' charging from a household type AC mains supply WITHOUT a Residual Current Device (RCD)	IEC 62196	No	AC	ON-BOARD	1	16A	250V	4kW	3kW	* On-board vehicle charger (rectifier) converts current from AC to DC * Cannot exceed 16A (EU); generally refers to household supply 13A (UK) * Plug pins are power conductors and protective earth * Does NOT require control pins from the IEC 61851-1 standard (ie. No 'handshake')
						3	16A	480V	13.3kW	10kW	
<b>MODE 2</b>	'Fast' charging using a dedicated AC supply WITH a Residual Current Device (RCD)	IEC 62196	Partial	AC	ON-BOARD	1	32A	250V	8kW	7.4kW	* On-board vehicle charger (rectifier) converts current from AC to DC * Up to 32A so allows faster/safer charging from single/three-phase supply * RCD must either be in the plug or within 0.3m from the plug * Requires a control pin from the IEC 61851-1 standard on the vehicle side, but not needed on supply side, as the control function is governed by the RCD box
						3	32A	480V	26.6kW	24Kw	
<b>MODE 3</b>	'Fast' charging using a dedicated AC supply WITH control and signal pin function extended to the supply-side connection resulting in full 'handshake' that allows integration into a smart grid	IEC 62196 IEC 61851 (handshake)	Full	AC	ON-BOARD	1	32A	250V	8kW	7.4kW	* On-board vehicle charger (rectifier) converts from AC to DC * Allows 3-phase supply, fast charging, max 400A/1000V (more commonly 32A/480V) * Requires a control pin from the IEC 61851-1 standard on the vehicle AND supply side - full 'handsake' * Supply is dead if no vehicle is present, as safety issues are taken care of by the 'handshake' * Likely to become future standard
						3	250A (63A typical)	480V	52.3kW	24Kw	
<b>MODE 4</b>	'Rapid' charging using dedicated DC supply and supply-side (off-board) charger unit	IEC 62196 IEC 61851 (handshake)	Full	DC	OFF-BOARD	N/A	400A (125A typical)	1000VDC (500VDC typical)	400kW	62.5Kw	* Off-board charger inverts AC mains network to DC current for battery charge * Allows for high currents up to 400A, according to IEC 61851-1 Mode 4 * Mode 4 connectors follow IEC 61851-1 therefore must have control and signal pins * Plug type ensures that only a compatible EVs can be connected * Highest cost charging units * Case C cable option - cable is permanently attached to the charging station



### 3 Socket, plug and connector types

The key socket, plug and connector types used for EV charging are defined in most regards by international standards (eg IEC 62196). For on-road EVs, the most significant types include Type 1 (single-phase), Type 2 (single/three-phase) and Type 3 (single/three-phase with shutters). However, domestic 3-pin and industrial 'Commando' connectors (IEC 60309) are also used.

#### 3.1 3-pin plug / BS 1363

While limited to single-phase charging with a maximum current of 16A (13A in UK) and voltage of 250V, a domestic 3-pin socket and plug can be used for Modes 1 and 2 charging. Following standards BS 1363 and BS EN 60309-2, the three socket pins include two power pins and a protective earth. For reasons already described, Mode 2 is preferred to Mode 1 due to the inclusion of a RCD within the charging cable.

#### 3.2 CEEform (Commando) / IEC 60309

Already widely used for industrial applications, the CEEform or 'Commando' type connectors are also used for EV charging. The relevant IEC 60309-2 standard permits a large range of allowed current and voltages for single or three-phase, each being denoted by a unique colour, socket diameter and using either three or five pins.

The most common CEEform connectors used for EV charging applications are the 'blue commando' (200-250V) and the 'red' (380-480V) which can be used for Modes 1 and 2 charging. Depending on supply, typical current ratings include 16A, 32A, 63A and 125A. As described by standard IEC 60309-2, single-phase units have three socket pins (two power pins and a protective earth), while three-phase connectors use five socket pins (three power pins, neutral, and a protective earth).

Figure 6 BS 1363 (3-pin socket and plug)<sup>3</sup>



Figure 7 'Blue commando' socket and plug<sup>4</sup>



#### 3.3 Type 1: Yazaki / SAE J1772

Originally developed for the North American EV market by Yazaki, the SAE J1772 connector and plug can only be used for single-phase charging applications. While the original standard permitted two voltage and current options (the 120V option still being used only in North America) the international standard IEC 62196 Type 1 specification (BS EN 62196-1) only specifies 250V at 32A or 80A.

The connector has five pins for the two AC wires, a neutral and two signal pins for proximity detection and control pilot function. The connector also includes a mechanical latch to locate and

<sup>3</sup> BS 1363 13amp domestic socket-outlet, *Honeywell*

<sup>4</sup> [http://en.wikipedia.org/wiki/File:CEE\\_3P%2BN%2BPE\\_230V.jpg](http://en.wikipedia.org/wiki/File:CEE_3P%2BN%2BPE_230V.jpg)

lock the connector when in position. Although widely used by European EVs, the fact that the J1772 connector only permits single-phase charging will limit future applications, with Type 2 couplers likely to become the future standard for AC charging.

### 3.4 Type 2: Mennekes / VDE-AR-E 2623-2-2

Developed by Mennekes in partnership with a number of European EV manufactures, the Type 2 connector is based on the industrial CEEform (Commando) couplers with added functionality and resizing. Unlike Type1, Type 2 allows both single and three-phase charging, and includes two data pins for a full 'handshake'.

Unlike the IEC 60309 plugs, the Mennekes standard plug has a single size and layout for voltages up to 500V and currents from 16A single-phase up to 63A three-phase (3.7 kW to 43.5 kW). Seven socket pins include three power pins, neutral, a protective earth and two control (data) pins.

**Figure 8 Type 1 connector and plug  
(IEC 62196-2/SAE J1772)<sup>5</sup>**



**Figure 9 Type 2 connector and plug  
(IEC 62196-2/ VDE-AR-E 2623-2-2)<sup>6</sup>**



The Mennekes couplers, which comply with international standard IEC 62196-2 as well as the German standard VDE-AR-E 2623-2-2, are now recommended by the European Automobile Association (ACEA) for use with Mode 3 charging systems. As such, it is likely to become one of the main future connector types within Europe. The VDE standardization process is also being extended to include a high current DC option (proposed for inclusion by 2013).

### 3.5 Type 3C: Scame / IEC 62196

Within the IEC 62196 framework, Type 3 couplers have been developed by members of the 'EV Plug Alliance', which includes French and Italian companies (Schneider Electric, Legrand, Scame). Designed primarily for the charger side, Type 3 sockets incorporate a shutter over the socket pins for weather and user protection, a requirement in 12 European countries for public access charging units. Type 3 units permit single or three-phase AC charging at currents up to 32A with a maximum voltage of 480V. Depending on the number of phases used, five or seven socket pins include power pins, a neutral, a protective earth and two control (data) pins.

### 3.6 JARI DC: CHAdeMO / JEVS G105

A number of coupler options are available for DC charging. While the Japanese CHAdeMO standard is most widely used in Europe for DC applications, some regions (including China) have adopted the Type 2 connector adding a mode that puts DC power on existing AC pins. While Type 2 international standard IEC 62196-2 does not currently include a DC/Mode 4 option, the next part of the series (IEC

<sup>5</sup> Yazaki / IEC 62196-2 Type 1 plug and socket-outlet (SAE International).

<sup>6</sup> Mennekes / IEC 62196-2 Type 2 plug and socket-outlet (Mennekes).

62196-3) due in 2012/13 is planned to do so (with a maximum 1000VDC/ 400A). The CHAdeMO standard allows a high-voltage (up to 500VDC) high-current (125A) 'rapid' or 'quick' charging via a JARI DC connector, the standard connector used in Japan.

**Figure 10 Type 3 connectors and plugs (IEC 62196-2)<sup>7</sup>**



**Figure 11 JARI DC connector (CHAdeMO/JEVS G105-1993)<sup>8</sup>**



### 3.7 Summary

- **3-pin plug:** While limited to single-phase charging with a maximum current of 16A (13A in UK) and voltage of 250V, a domestic 3-pin socket and plug can be used for Modes 1 and 2 charging.
- **CEEform (Commando):** The most common CEEform connectors used for EV charging applications are the 'blue commando' (200-250V) and the 'red' (380-480V) which can be used for Modes 1 and 2 charging. Depending on supply, typical current ratings include 16A, 32A, 63A and 125A.
- **Type 1 (Yazaki):** SAE J1772 connector and plug can only be used for single-phase charging applications. International standard IEC 62196 Type 1 specification permits 250V at 32A or 80A.
- **Type 2 (Mennekes):** Allows both single and three-phase charging, and includes two data pins for a full 'handshake'. The Mennekes plug has a single size and layout for voltages up to 500V and currents from 16A single-phase up to 63A three-phase. Likely to become European standard.
- **Type 3C (Scame):** Incorporates a shutter over the socket pins for weather and user protection, a requirement in 12 European countries for public access charging units. Type 3 units permit single or three-phase AC charging at currents up to 32A with a maximum voltage of 480V.
- **JARI DC (CHAdeMO):** The CHAdeMO standard allows a high-voltage (up to 500VDC) high-current (125A) 'rapid' or 'quick' charging via a JARI DC connector, the standard connector used in Japan. And the most common DC connector used in UK.

<sup>7</sup> Image: [http://www.scame.com/en/prodotto/ser/libera\\_connettori.asp](http://www.scame.com/en/prodotto/ser/libera_connettori.asp)

<sup>8</sup> Image: <http://iae-connectors.com/en/news-201109KW1-en.html>

Table 2 Summary of EVSE connector and plug types

TYPE	DESCRIPTION	STANDARD	HAND-SHAKE	SUPPLY	PINS	PHASE	MAX CURRENT	MAX VOLTAGE	MAX POWER	TYPICAL POWER	NOTES
3-PIN	The 3-pin plug is the UK's most common single-phase AC plug and socket	BS 1363	No	AC	P+N+E	1	16A (UK 13A)	250V	4kW	3kW (UK 13A)	<ul style="list-style-type: none"> <li>* Socket/plug pins include live, earth and a neutral pin</li> <li>* In the UK it allows up to 13A and is used in the domestic environment</li> <li>* Example Case B cable: Supply-side 13A 3-pin (BS 1363) to vehicle-side J 1772 (with/without RCD)</li> </ul>
CEEform (Commando)	Colour-coded UK industrial 3-and 5-pin connectors - Blue (200-250V), Red (380-480V)	IEC 60309	No	AC	P+N+E	1	16A	250V	4kW	3kW (UK 13A)	<ul style="list-style-type: none"> <li>* Single phase 16A: three pins (positive, neutral, earth)</li> <li>* Three phase: five pins (3P+N+E) allows faster charging</li> <li>* No handshake capability (no data pins)</li> </ul>
					3P+N+E	3	63A (typical)	400V	44kW	22kW (32A)	<ul style="list-style-type: none"> <li>* Example Case B cable: Supply-side blue commando to vehicle-side J 1772 (with/without RCD)</li> </ul>
TYPE 1	Yazaki US/Japanese connector designed for the vehicle side which includes a manual locking mechanism	IEC 92196-2 SAE J1772	Full	AC	P+N+E 2 Data	1 (no 3P option)	32A	250V	8kW	6kW	<ul style="list-style-type: none"> <li>* Used by all Japanese or American EVs</li> <li>* Data pins include proximity detection (prevents car movement whilst connected) and control (to select charging level)</li> <li>* Conforms with IEC 62196-2, and so IEC 61851 (has 'handshake')</li> <li>* Eg Case B cable: Supply-side Type 2 to vehicle-side J1772</li> </ul>
TYPE 2	Mennekes European connector originally based on Commando but with additional data ('handshake') pins	IEC 92196-2 VDE-AR-E 2623-2-2	Full	AC (future DC option)	P+N+E 2 Data	1	16A	250V (typical)	4kW	3kW (UK 13A)	<ul style="list-style-type: none"> <li>* Mennekes connector favoured to become the common standard as it allows 3-phase (up to 63A/43kW) charging</li> <li>* Single phase charging also possible (up to 70A)</li> <li>* Conforms with IEC 62196-2, and so IEC 61851 (has 'handshake')</li> <li>* Eg Case B cable: Supply-side Mennekes to vehicle-side Mennekes</li> </ul>
					3P+N+E 2 Data	3	63A	500V	54kW	43kW (63A)	
TYPE 3C	EV Plug Alliance designed connector offering protective shutters as required in some EU Member State for public access charging points	IEC 92196-2	Full	AC	P+N+E 2 Data	1	32A	250V	8kW	N/A	<ul style="list-style-type: none"> <li>* More common in continental Europe</li> <li>* Allows both single and 3-phase current, up to 32A</li> <li>* Single phase up to 250VAC and 3-phase from 380VAC to 480VAC</li> <li>* Seven pins, including control pin and proximity pin, similar to Mennekes (compatible with Mode 3 charging)</li> </ul>
					3P+N+E 2 Data	3	32A	480V	26kW	N/A	
JARI DC	Most common socket and connector system for high-current 'rapid' DC charging based on CHAdeMO standard	CHAdeMO JEVS G105-1993	Full	DC	P+N+E 4 Control 2 Can Bus	N/A	125A	500VDC	62.5kW	50kW	<ul style="list-style-type: none"> <li>* JARI DC connector complies with CHAdeMO standard</li> <li>* DC current typically supplied at 50kW (125A and 500VDC)</li> <li>* Not all EVs can accept DC charging - charge limited to 90% SOC</li> <li>* Only Case C cable option: Eg. DC CHAdeMO charger to JARI DC connector</li> </ul>

## 4 EVSE and electric vehicle compatibility

### 4.1 Mode and type compatibility

Given the specifications of each connector/plug type, a matrix can be constructed showing which connector types can be used with each mode.

As shown in Table 3, Type 2 connectors are the most widely compatible standard, being able to be used for single and three-phase supplies and allowing the data 'handshake' as required in Mode 3. For single-phase charging, Type 1 can be used across all Modes; and if control pins are not required, CEEform (Commando) plugs are suitable for most industrial type electricity supplies.

While Types 1 and 2 are not yet universally able to be used for Mode 4 DC charging, international standards are currently being agreed to allow this option; and is the reason for Type 2 becoming the preferred European connector standard.<sup>9</sup>

**Table 3 Mode and connector/plug type compatibility**

MODE	PHASE	3-PIN BS 1363	CEEform (Commando)	TYPE 1	TYPE 2	JARI DC
MODE 1	1	✓	✓	✓	✓	
	3		✓		✓	
MODE 2	1	✓	✓	✓	✓	
	3		✓		✓	
MODE 3	1			✓	✓	
	3				✓	
MODE 4	N/A			✓	✓ (Future)	✓

### 4.2 Vehicle and EVSE compatibility

In practice, each EV model is only able to accept a limited number of charging modes, and/or connect with a limited number of socket types. This is in part due to the specifications of the vehicles on-board charger (if an AC is used), and also due to the cable connectors and plugs usually supplied with the vehicle.

For example, while a Nissan LEAF can be charged using single-phase AC Modes 1-3, most vehicles will be supplied with a Mode 2 cable with a 3-pin plug and an integrated RCD safety device. Depending on the supply used, the LEAF will draw between 10A and 16A, with an associated charging power of 2.3-4.0kW. The LEAF is also able to use a Mode 4 DC charger using a Case C type cable with a JARI DC vehicle-side connector.

Table 4 summarises the main mode and connector type options for a selection of electric cars and vans currently available in the UK.

<sup>9</sup> [http://www.acea.be/images/uploads/files/ACEA\\_position\\_on\\_EV\\_standardisation\\_May\\_2012.pdf](http://www.acea.be/images/uploads/files/ACEA_position_on_EV_standardisation_May_2012.pdf).

**Table 4 Vehicle and charger compatibility**

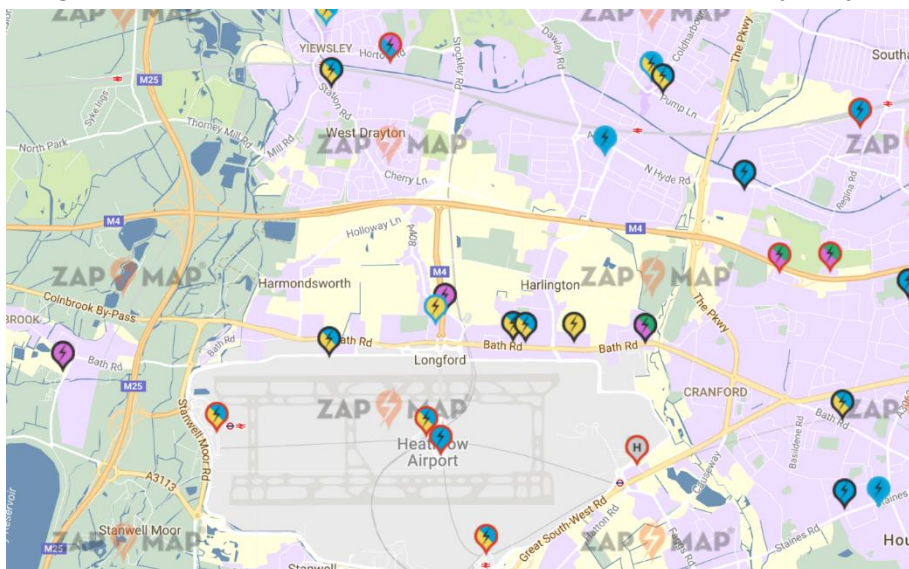
MODEL	Mode	AC Phase	Plug (Charger-side)	Connector (Vehicle-side)	Cable Type*
Nissan LEAF Peugeot iOn Citroen C-ZERO Mitsubishi i-MiEV	1	1	3-Pin	Type 1	B
	1	1	CEEform	Type 1	B
	2	1	3-Pin	Type 1	B
	3	1	Type 2	Type 1	B
	4	N/A	N/A	JARI DC	C
Renault Twizy (Quadricycle)	1	1	3-Pin	N/A	A
	2	1	3-Pin	N/A	A
Renault Fluence Renault Kangoo	1	1	3-Pin	Type 1	B
	2	1	3-Pin	Type 1	B
	3	1	Type 2	Type 1	B
Renault ZOE	1	1	3-Pin	Type 2	B
	2	1	3-Pin	Type 2	B
	3	3	Type 2	Type 2	B
Toyota Plug-in Prius Hybrid	1	1	3-Pin	Type 1	B
	2	1	3-Pin	Type 1	B
	3	1	Type 2	Type 1	B
Vauxhall Ampera Chevrolet Volt	1	1	3-Pin	Type 1	B
	2	1	3-Pin	Type 1	B
	3	1	Type 2	Type 1	B
Smiths Edison Van	2	3	CEEform	CEEform	B
	3	3	Type 2	Type 2	B
Mercedes eVito Van	3	3	Type 2	Type 2	B

Notes: \*Cable Type C (tethered to charger) option may be used by some chargers in place of Type B.

## 5 EV charging locations in the UK

A number of UK websites and databases now provide the locations and details of publicly accessible EVSE. These include the government funded National Charge Point Registry which can be freely downloaded from <http://data.gov.uk/dataset/national-charge-point-registry>.

While the database is likely to become more comprehensive in the future, at present it only includes around half of the charge points included on Zap-Map, the most UK comprehensive map which can be accessed at: <http://www.nextgreencar.com/electric-cars/charging-points.php>. Zap-Map uses the latest version of Google Maps, showing colour-coded charger types and allowing search by postcode.

**Figure 12 Public access EVSE locations around Heathrow (Zap-Map)<sup>10</sup>**

<sup>10</sup> Data supplied by [www.zap-map.com](http://www.zap-map.com).