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Analysis of charging stations for electric vehicles in Spain

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Abstract. This paper reports an analysis of the availability of charging stations for electric vehicles (EVs) in Spain. Concretely, this analysis focuses on the charging mode of each station according to the Spanish legislation, and on the type of connectors that may be used in each station, with the aim of evaluating the current accessibility of electric vehicles to the charging system and the development of a new strategy for implementing the points of charging.

Key words

Electric Vehicle, Charging Station, EV Connector, Charging mode.

1. Introduction.

The transportation sector is characterized by a high intake of fossil fuels and a strong environmental impact. The promotion of electric vehicles is presented as a way to reduce the environmental impact by limiting the dependence on fossil fuels [1], increasing the sustainability of the automotive sector.

The charging system is affected by an interaction among the different types and charging modes as well as the type of electric vehicles and the availability of charging stations. Each of these agents may be analysed under specific approaches.

Charging modes are conditioned by the employed infrastructure [2], and attend to the level of communication between the vehicle and the charging station [3], [4]. The predominant charging modes are specified in the IEC 61851, and its main specifications are summarized in Figure I.

Regarding the type of connectors, there is a wide spectrum due to the absence of any standardization. Each manufacturer uses the type that considers more convenient, developing in some cases its own models. Connectors for electric vehicles are regulated by the IEC 62196 and IEC 62196-2 modified and 62196-3.

The electric vehicle powering station (EVPS) is the main assembly of the needed elements for connecting the EV to the electric installation required for being charged [5].

The main requirement of a project for electric mobility to be developed efficiently is the implementation of accurate infrastructures to enable the electric vehicle's recharges without affecting negatively to the power grid system [6], [7].

The aim of the charging management is:

- Encouraging the establishment of vehicle charging on the electrical system by developing systems capable of regulating the battery charging depending on the availability of electricity and the its cost.
- Discriminate several charging stations into a determined parking in order to prevent overloading the network.
- Automatically select the appropriate type of recharge depending on time requirements.
- Identify the users for further payments or control the available credit.

2. Material and Methods.

A. *The recharge process.*

T he following six stages can be identified in the recharge process of an EV:

1. User sign-in: The users are registered and informed about the policies of operation service.
2. User authentication: Implies the identification and authentication of each customer of the charging station.
3. Electric Recharge: It comprises the charging operation itself and a series of instructions for subsequent charging operations.
4. Network monitoring: Involves state control of the recharge points during each use in order to ensure a

proper service as well as obtain statistical information of interest.

5. Incident management: This involves detecting, tracking and resolution of any incident that may occur.
6. Customer services: Includes bidirectional communication between the charging system and the users. This stage is aimed to answer questions, provide information, and troubleshoot problems or concerns related to the process by means of the available media.

A.1. Types of recharge.

The type of recharge may be classified depending on their duration. The main three types are:

- Slow recharge: This type of charging is performed through a single-phase AC 230 V outlet and up to 16 A. By using this method, one would need to perform a recharge with a duration between six to eight hours for a conventional electric car whereas electric motorcycles would need between two and three hours.
- Accelerated recharge: In this case the recharge is performed with a single or three phase AC socket with an intensity of up to 63 A. To load a conventional car, it will take between one and two hours charging with this method. It is worth to pointing out that motorcycles are unable to perform this kind of recharge.
- Fast recharge: This type of charging is performed by means of DC current with up to 500 V and currents between 50 and 550 A. This method allows to completely charging a conventional vehicle between 5 and 30 minutes.

A.2. Charging modes

The charging modes are conditioned by the infrastructure employed and regard to the level of communication established between the vehicle and the charging station. These modes are specified in the Electric vehicle conductive charging system, according to the Spanish Normative IEC 61851 and are detailed below

- Mode 1: The EV is connected to an AC power grid by using normalized current sockets comprising up to 16 A per phase. This kind of recharge is not allowed in stations without a residual current device. The vehicle is connected to a conventional domestic grid through an ordinary cable, which is not protected by any special control system.
- Mode 2: The EV is connected to an AC power grid by using normalized current sockets comprising up to 32 A per phase. A control pilot providing additional control functions is employed. Some of these control functions concern to verify if the EV connected in the correct way, check the protection of the ground conductor, choose the ratio of recharge and activate or deactivate the system. In this kind of recharge the EV may be connected through either domestic or industrial socket by means of a special cable incorporating all the necessary security and control elements.
- Mode 3: The connection of the EV to the power grid is performed using dedicated equipment supply Electric Vehicle Charging System. The standard Electric vehicle conductive charging system - Part 1: General requirements (IEC 61851-1) impose this mode to incorporate a protection system by means of a control pilot between the dedicated equipment and the EV. In this kind of recharge, the vehicle is connected to a specific SAVE, and the station is in charge of managing the security and control of the process. This mode along with the mode 2 are the more extended.
- Mode 4: This mode consists in an indirect connection of the power grid to the EV by means of an external charger, which perform the recharge. The control pilot is permanently extended in the charger. This mode belongs to the group of DC current recharges, which focus on fast recharges. Since the charger is external, it is needed a communication channel to keep the charger informed about the vehicle's batteries state of charge.

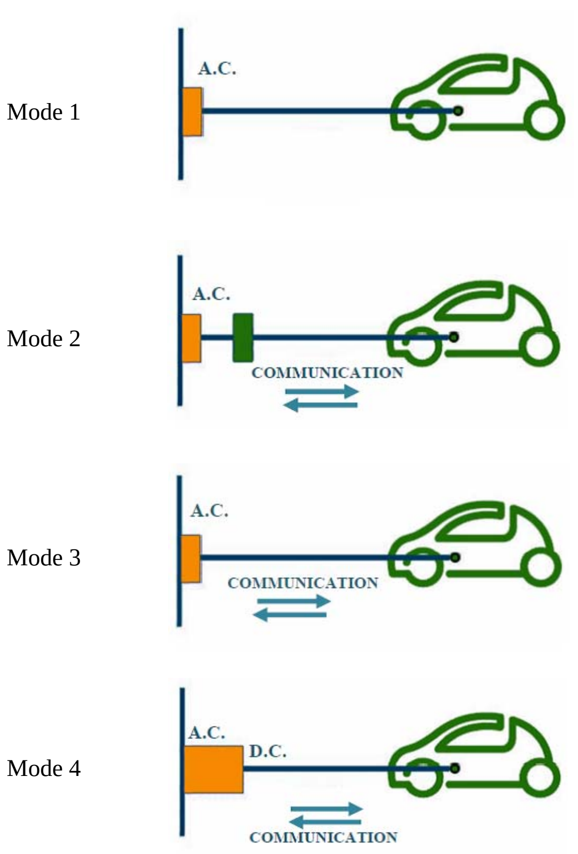

Figure 1. Charging modes.

B. Charging infrastructure.

According to ITC-BT-52 [5], the Electric Vehicle Charging System (EVCS) or electric vehicle charging infrastructure is defined as a “Set of physical and logical devices intended for recharging electric vehicles that address safety and availability expected for each case, with capacity to perform a fully and integral process of recharge. An Electric Vehicle Charging System includes charging stations, control system, electrical control panels and protection and measurement equipment which are exclusive for recharging electric vehicles”.

B.1. Charging stations.

The new ITC-BT-52 defines an electric vehicle charging station as a set of main required elements to support the connection of the EV to the fixed power grid involved in its recharge. The charging stations may be classified as:

- Charging point. Composed by the required protections and one or more sockets or cable-connector assemblies needed to perform a recharge in either mode 1 or 2.
- Specific alimentation system or EVCS. Composed of the assembled equipment to provide energy for charging an EV, including charging station protections elements, the cables needed for the connection and the current socket or connector. These systems enable the communication between the EV and the fixed station, prepared for mode 3 recharges.

B.2. Intelligent management system.

According to ITC-BT-52, the intelligent recharge management system regulates the intensity of the recharge in order to flatten the power demand curve, with the target of avoid overloads and maximize the availability of the EV recharging services. Moreover, this system may include optional functions namely scheduling and recharge rotations.

B.3. Connectors.

According to the types of connectors for electric vehicles, a wide variety can be found. Connectors for electric vehicles are regulated by the IEC 62196 and IEC 62196-2 modified and 62196-3.

- **EEC 7/4 type F (Schuko):** The Schuko connector is the connector standard used in Europe, present in all our appliances. It is especially common in scooters and electric bikes, and its intensity limit is 16 A.
- **Type 1 (SAE J1772):** It has been developed in the US by the Society of Automotive Engineers (SAE). As well as the Schuko, the SAE J1772 connector incorporates phase, neutral and ground outlets, so it does not allow the recharge with three-phase AC current. Furthermore, this connector has two additional connectors which are used to communicate with the vehicle and detect connectivity. This connector addresses a more safe design in order to avoid being used by non-authorized users.
- **Type 2 (Mennekes):** The Mennekes connector receives its name from the German company that developed its design, although it is named VDE-AR-E 2623-2-2. According to the IEC 62196, this connector is designed to perform mode 3 recharges. Its pin distribution and shape is similar to the SAE J1772, although it allows 16 A monophasic as well as 64 three-phase recharges, or, equivalently, charging power of 3.7-43.5 kW.
- **Type 3 (Scame):** The Scame connector allows a maximum charging power of 22 kW and also counts with a cover that protects the terminals when is unplugged as well as a protection of the connection terminals themselves.
- **JEVS G105 (CHAdeMO):** The CHAdeMO connector was designed by TEPCO "Tokyo Electric Power Company". It is a connector suitable for the mode 4 charging which currently provides up to 62.5 kW using DC. Communications with the vehicle is addressed through CAN bus.
- **Connectors CCS (COMBO):**
  - Combo Type 1 (SAE J1772): The SAE J1772 combo connector incorporates an extra pair of terminals for DC recharges and hence allows its use for mode 4 recharges. Its supported voltage is up to 500 V, with currents from 80 to 200 A (40-100 kW).
  - Combo Type 2 CCS (Combined Charging System): The Combo type 2 connector is a variant of the previously described Mennekes, and incorporates a new connector with a pair of terminals for DC recharges so that it use in charging mode 4 up to 500 V and 200 A is allowed.

Connector CEE 7/4 Type F (Schuko)

Connector Type 1 (SAE J1772)

Connector Type 2 (Mennekes)

Connector Type 3 (Scame)

Figure 2. Connectors CEE 7/4 type F (Schuko) and types 1 ,2 and 3.

Connector JEVS G105, CHAdeMO

Connector Combo Type 1

Connector Combo Type 2 (CCS)

Figure 3. Connectors JEVS G105, CHAdeMO, Combo Type 1 and Combo Type 2 (CCS).

Table I. Charging type.

Type of recharge	Voltage[1]	Current (A)	Power (kW)	Charging time (h)[2]	Location
Slow	I phase	10	2.3	8-9	Housing Work places Airports
		16	3.7	5.5	
		32	7.3	3	
Accelerared	I phase	63	14.5	1.5	Urban center Supermarkets Malls Leisure centers
	III phase	16	11	2	
		32	22	1	
		63	43	0.5	
Fast	c.c	50	20	1	Service stations
		100	30	0.75	
		120	50	0.41	
		200	60	0.33	
		275	125	0.16	
		550	250	0.08	

[1]I phase: 230V; III phase: 400V ; c.c: 400-500V
[2]to charge 20 kWh

Table II. – Manufacturers and number of charging stations analyzed.

Mark	Number	Models
ABB	4	Terra 51,Terra 52, Terra 53 Terra 54
AL2S	3	TPC,1Tm2, 1Tm3
AVINC	3	EVSE-FS, EVSE-PS, EVSE-RE
BlueMobility	7	Parkin Dual, Flash, Home Basic, Home Economy, Home SIMPLEX RFID, Home SIMPLEX M3, City Stand-Alone
Bosch	2	Power Max, Power Xpress
Change-Amps	1	UM-EVSE
ChargePoint	3	CT500, CT2000, CT5000
CIRCONTROL	5	CCL Modo1, CCL Modo 1/3, Quick CCL, Compact QC, Combo QC
CIRCUTOR	1	WALL-BOX
DBT	6	Quick Charge, GNS, BBR, EV STREAM, EV PURE, Wallbox Plus
Efacec	4	HomeCharger, QC45, QC50, PublicCharger
Merlyn	2	EVO 4 Poste, EVO 4 Pared
EVBOX	2	Mural, Columna
EVTEC	2	Coffe&charge 3in1, Move &charge
General Electric	3	DuraStation, WattStation, WallMount
GH Ever Drive	1	EverFlash
Indra	2	GRAI Wallbox, GRAI Poste
Ingeteam	3	Garaje, City, Road
Japan Charge N	1	QUICK CHARGER 1
KEBA	1	KeContact P20
Legrand	3	Green'up Access, Green'up Premium, Green'up Premium T
Magnum Cap	4	MCR16, MCC16, MCQC, MCCWB
Pod Point	2	Solo II, Twin
Protoscar	2	Shop&Charge, Sleep &Charge
RWE	3	eBOX, eSTATION; eSTATION COMBI
Schneider Electric	3	EVLink Residential, EVLink Parking, EVLink FastCharge
SGTE	1	Quick Charger
SIMON	3	Exterior, Interior Modo 1, Interior Modo 3
Temper	2	Home, Urban
Walther electric	6	ECOLECTRA, VOLTANEA, AMPEREA, Industry-Line, Design-Line, Robust-Line
Total	**30**	**89**

C. Charging stations.

This section addresses the evaluation of the main alternatives when purchasing or using the charging stations offered by the major manufacturers, attending to the charging times and the characteristics of the charging stations themselves.

C.1. Load time.

Charging time is considered as one of the most important characteristic of an EV according to their users or potential customers. The charging time depends on the battery capacity and power at which the recharge is performed. A summary of the charging times for an average battery according to the major powers provided by the charging points is depicted in Table I.

C.2. Charging stations.

The data for this analysis were obtained from 89 charging stations with a total of 30 manufacturers. A summary of these data is shown in Table II.

3 Analysis and discussion.

The data obtained will be structured for analysis into two blocks. The first block refers to the charging modes supported by each charging station, whereas the second one is referred to the type of connector available in each charging station.

A. Charging mode.

A summarized analysis of the 89 charging stations according to their charging mode is shown in Table III. As observed in Figure 4, the more extended mode among the charging station is mode 1, with presence of the 52%.

Table III. – Number of charging stations as charging mode.

Charging mode	Type of current	Power máx. (kW)	Number of stations
Mode 1	A.C. Monophasic	3.7	24
Mode 2	A.C. Monophasic	3.7	35
		7.3	0
Mode 3	A.C. Monophasic	3.7	18
		7.3	30
	A.C. Triphasic	11	6
		22	31
		43	10
Mode 4	D.C. Direct Current	20	2
		45	2
		50	13
		60	3
		250	2

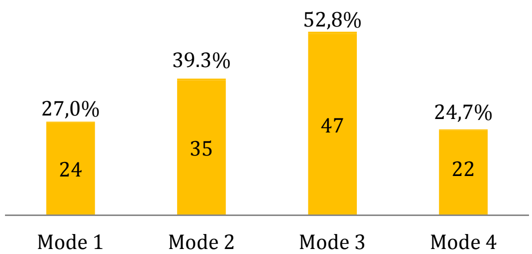

Figure 4. Accessibility charging modes in charging stations.

B. Connectors available charging stations.

Regarding the type of connector more frequently used, the Type 2 (Mennekes), with a 55.1% of availability, arises as the most standard in Europe, followed by the Schuco connector, with a 40.4%.

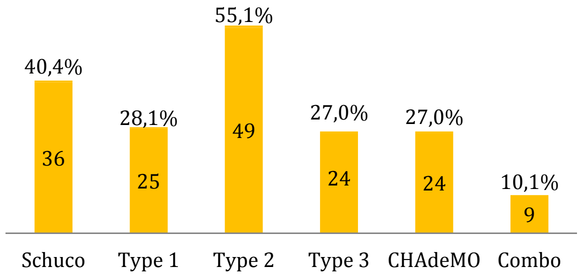

Figure 5. Number of connectors type available charging stations.

4. Conclusions

The guarantees offered by the current charging points are aimed to overcome one of the main drawbacks of electric vehicles, which is their low autonomy. We have observed that the number of types of connectors present a wide dispersion. This aspect needs to be regulated by the involved legislation. The main conclusion from this study is the evidence of the requirements of standardization by the companies in the sector so that the whole society can benefit of a future massive implementation of electric vehicles.

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