Whitepaper
of Charging Interface Initiative e.V.

DC CCS Power Classes for bidirectional charging

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1. Introduction

The present document is created using the "Position Paper of Charging Interface Initiative e.V. DC CCS Power Classes" as a base. Only Reverse Power Transfer is specified. Forward power transfer/unidirectional is specified in CharIN Position Paper DC CCS Power Classes V7.2.

The energy world of tomorrow is intelligent and sustainable. Bidirectionality of EV vehicles will not only be able to stabilize the power grid, but also optimizes the use of renewable energies in homes and the industrial sector. In this way contribute to additional CO2 optimization in the energy system and realize completely CO2-free mobility.

The bidirectional power flow is more complex and will be influenced by additional parameters, in addition to the unidirectional power transfer. The difference between the stable power over time and short power events will be important for the user requirements in the bidirectional operation. Not only the charging equipment, but also the characteristics of the built-in battery (capacity, C-rate, lifetime) can play a role in how the power and energy transfer will differ from case to case.

The possible use cases are included and considered in this document.

The focus of this document is to lay out the DC-EVSE requirements for the power classes, efficiency and reactive power related to bidirectional power transfer. The power classes are applicable to passenger's cars and other vehicles e.g., buses.

The requirements and definitions can be used as a base for a future label of DC-EVSE with the capability of bidirectional charging.

2. Terms and definitions

The definitions of the use cases of table 1 were established in the working group “UG2 DKE/AK 353.0.401 ad-hoc AK Bidirektionales Laden” and adapted from Faller et. al.[1]

The V2X grid integration levels are according to the CharIN positioning paper[2].

Table 1: V2X Use Cases[1]

Use case group	Use case description	Target customer	Control
V2H	Optimization of self consumption	Home	local/central
V2H	Tariff-optimized charging and discharging	Home	Local/central
V2H	Island mode operation	Home	Local
V2G	Intraday-trading	Home/Business/RLM customer	Central
V2G	Frequency regulation	Home/Business/RLM customer	Local
V2G	Redispatch	Home/Business/RLM customer	Central
V2B	Energy shaving	Business/RLM customer	Local/central
V2B	Fleet management	Business/RLM customer	Local/central
V2L/V2V	Vehicle to load and to vehicle	Mainly personal use	Local in the car

The use cases are differentiated in target scenarios and their control scheme. Power transfer control can be handled local within the charging equipment or central e.g. energy regulation side (for example DSO). The control scheme, efficiency, and power levels are the key factors for the EVSE operation.

[1] Sebastian Faller, Mathias Müller, Adrian Ostermann und Timo Kern, Bidirektionales Laden: Von der Last zur Lösung! In German, 1/2 2020 FFE, https://www.ffe.de/wp-content/uploads/2020/03/20200401_Bidirektionales-Laden_Von_der_Last_zur_Loesung.pdf accessed 27.07.2022

[2] https://www.charin.global/media/pages/technology/knowledge-base/60d37b89e2-1615552583/charin_levels__grid_integration_v5.2.pdf

Vehicle-to-Home (V2H_connected): This concept is intended to optimize self-consumption of available energy source, mainly self-generated such as photovoltaic. In this context it is assumed that generally no power from the EV will be fed into the grid.

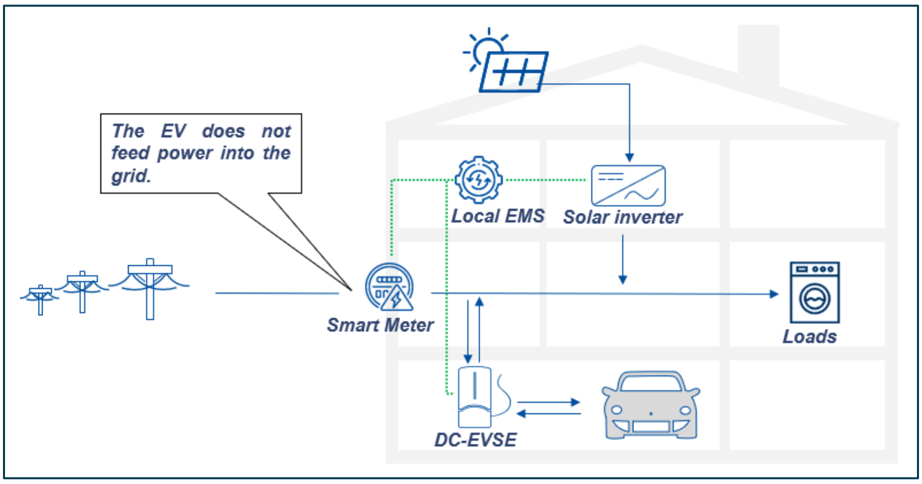

Figure 1: V2H – schematic illustration

Vehicle-to-Home (V2H_island): This concept covers the supply of the household with energy by using vehicle battery in case of a failure of the public grid or a household that is not connected to the grid. During this mode less requirements of the EVSE/EV related to the grid codes are requested.

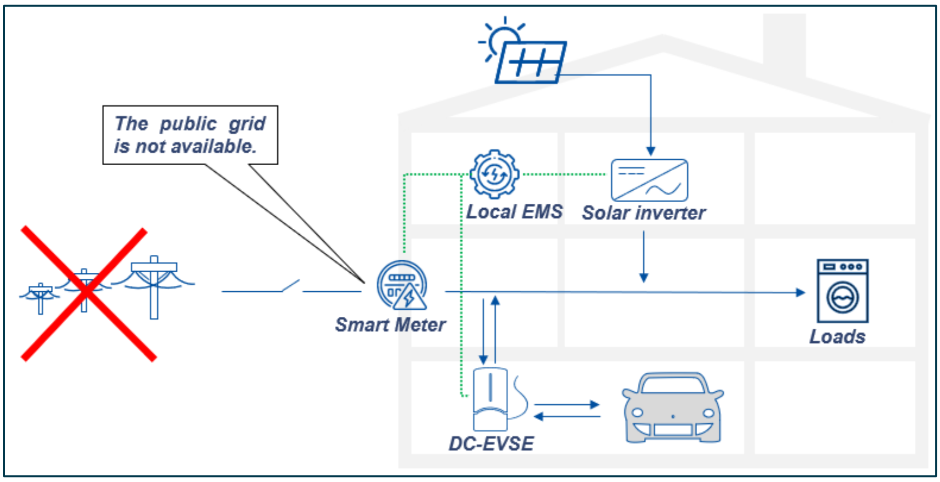

Figure 2: V2H_island - schematic illustration

Vehicle-to-Grid (V2G): This concept plans for the feed of power from the vehicle battery into the grid and thus corresponds to the function of a storage power plant, whereby, an adequate amount of (connected) electrical vehicles is required for efficient utilization. This allows for load control tasks to be fulfilled.

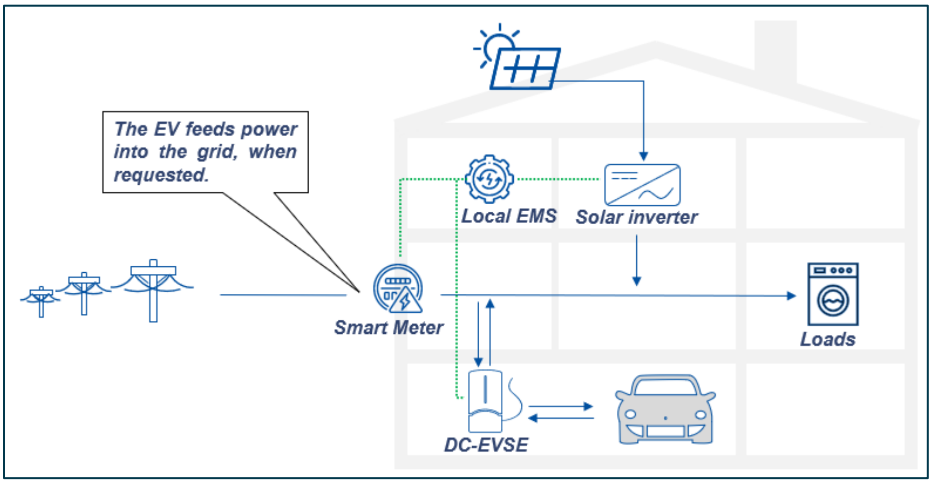

Figure 3: V2G - schematic illustration

Vehicle-to-Building (V2B): This concept enables operators of commercial building to utilize energy stored in fleet or employees EV´s to optimize energy consumption, cost and stability. This can also include the transfer of energy between vehicles in a fleet.

Vehicle-to- Load or Vehicle to Device (V2L or V2D): This concept allows for the vehicle battery (even while traveling) to be used as a power source, or emergency power generator, for electrical devices (for instance smart phones, laptops, tools on construction sites or kitchen appliances). This concept is not covered in the present document.

DSO: Distribution System Operator

Grid Code: This term is used to describe the standards related to feeding power into a public grid (e.g. EN 50549-1). These standards usually origin from the photovoltaic sector.

C-Rate: A C-rate is a measure of the rate at which a battery is discharged or charged relative to its maximum capacity. A 1C rate means that the discharge current will discharge the entire battery in 1 hour. The C-Rate may vary for charging or discharging.

DKE: German Commission for Electrotechnical, Electronic & Information Technologies of DIN and VDE (Deutsche Kommission Elektrotechnik Elektronik Informationstechnik im DIN und VDE)

DC-EVSE: DC-Electric Vehicle Supply Equipment

DC: Direct Current

AC: Alternating Current

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Definitions for calculations:

- P_{ref} is a calculated fixed value of a power class provided by the manufacturer to represent the capability of a charging station.
- I_{peak} of a charging station is the maximum output current that the charging station is able to deliver for a specific time (refer to table 2, "Duration I_{peak}") at specific environmental conditions. Value shall be provided by the manufacturer.
- I_{derted} of a charging station is the output current that the charging station is able to deliver continuously at specific environmental conditions. $I_{derated}$ of a charging station shall be at least 75% of I_{peak} of the charging station.
- I_{min} of a charging station is the minimum output current that the charging station is able to deliver continuously at specific environmental conditions.
- U_{max} of a charging station is the maximum output voltage that the charging station is able to deliver continuously at specific environmental conditions.
- U_{min} of a charging station is the minimum output voltage that the charging station is able to deliver continuously at specific environmental conditions.
- U_{ref} is the reference voltage at which P_{ref} of the power class is provided prior to derating.
- P_{min_req} describes the minimum DC-power of the DC-EVSE which is requested.
- Pmin_man describes the minimum power of the DC EV supply equipment which is specified by the manufacturer.
- Efficiency describes here the quotient of power on the supply equipment AC port to the power on the supply equipment DC port for discharging.

3. Bidirectional Power classes

See also definitions and requirements from “Position Paper of Charging Interface Initiative e.V. DC CCS Power Classes”[3]. Only Reverse Power Transfer is specified. Forward power transfer/unidirectional is specified in CharIN Position Paper DC CCS Power Classes V7.2.

In the following table 2 absolute values are used.

Table 2: Discharging - Minimum requirements for power classes.

Power Class	Power	U_{min} in [V]	U_{max} in [V]	I_{min} in [A]***	I_{peak} in [A]	I_{rated} in [A]	$P_{reference}$ in [kW]	P_{min_req} in [kW]***	Duration I_{peak}	Name (EN)
LPC_RPT	xx*/ yy** (kW)	≤200	≥920		<20	<20	<8	≤0.5	inf	Low-Power Charging
DC_RPT	xx*/ yy** (kW)	≤200	≥920	≤1	≥20	≥20	≥8	≤0.5 (<20kW) ≤2.5 (>20kW)	inf	DC Charging
FC_RPT	xx*/ yy** (kW)	≤200	≥920	≤1	≥125	≥94	≥50	≤5	≥30 min	Fast Charging
UFC_RPT	xx*/ yy** (kW)	≤200	≥920	≤5	≥250	≥188	≥100	≤7.5	≥20 min	Ultra-Fast Charging
HPC_RPT	xx*/ yy** (kW)	≤200	≥920	≤5	≥500	≥375	≥150	≤10	≥10 min	High-Power Charging
MCS			*TBD*							

RPT indicates the capability of Reverse Power Transfer

** P_{ref} values (provided by the manufacturer) shall be used (e.g.: HPC_RPT 300, FC_RPT 50). Validation will be done within CCS quality assurance program.*

***Describes the minimum power P_{min_man} (provided by the manufacturer) of the DC-EVSE (e.g.: DC_RPT 10/0.4).*

****0A current and 0W power shall be possible.*

The specification for a complete label is defined in in chapter 6.

A lowest power level for the DC-EVSE per class is required, therefore P_{min_req} is defined.

A minimum discharge power can make sense for most of the use cases. These use cases are for example “V2H – Optimization of self-consumption” or “V2H - Tariff-optimized”. Charging and discharging below a certain point of power does not make sense due to efficiency and controllability.

[3] Position Paper of Charging Interface Initiative e.V., DC CCS Power Classes V7.2, 2021, https://www.charin.global/technology/knowledge-base/ accessed 10.10.2022

For the DC-EVSE that cover the use case “V2H_island” mode operation the availability power should be, depending on the field of application and the expected loads, close to 0 W.

There can also be products that are for charging mode in one power class and for the discharging mode in another class.

Figure 4 and figure 5 depict the minimum operating ranges of the different Power Classes prior to derating (if derating applicable). The area within the respective colored operating ranges shall be supported by the EVSE to achieve the dedicated Power Class except for the LPC power class. In the LPC power class the operating range start from the given referenced power. As the referenced power is a value below 8kW, the operating range can be not drawn for all cases. A referenced power of 4kW was taken to show the difference to the DC power class in figure 5 and figure 6.

A DC charging station can provide a wider range of values for voltage, current and power but it shall provide at least the values given in table 2 to achieve a certain power class rating.

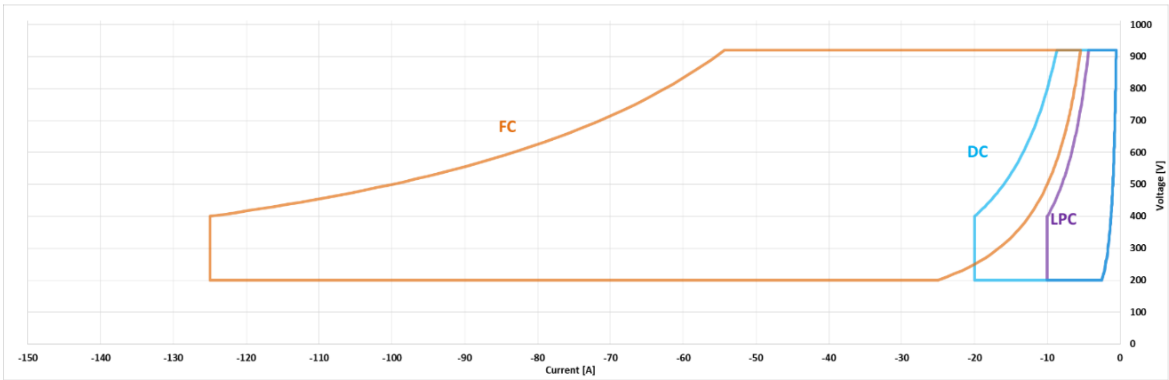


Figure 4: Discharging - Power class range diagram for low power class

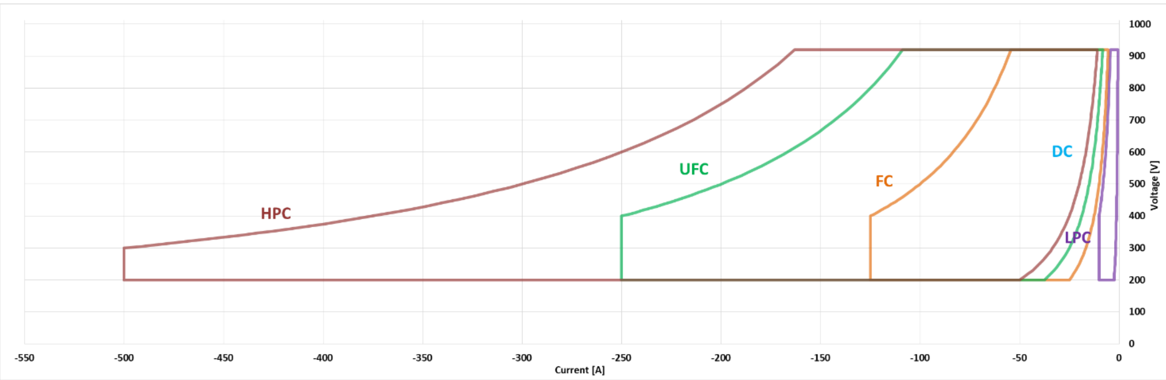


Figure 5: Discharging - Power class range diagram

4. Efficiency specifications

4.1. General definitions on efficiency

The efficiency is derived at a SOC of around 50% for the two different battery configurations (“400V technology” and “800V technology”). Efficiency is specified only for Reverse Power Transfer. No requirements for charging/forward power transfer.

The measurement points and conditions will be defined in a test specification of the FG CT&IOP.

The document *Efficiency guideline for PV storage systems*[4] should be used for guidance, where applicable.

Larger DC-EVSE for example in the power classes FC, UFC and HPC usually use several inverter modules in parallel to achieve the needed high power. This inverter modules (e.g., 10-20kW) are often switchable to react on the load demand. For the efficiency consideration this results in higher values over the entire power range since in the low power range one power module is activated and for higher power ranges several modules. This is reflected in the efficiency values in the following sections.

4.2. Concept Grade A, B and C

Based on the efficiency values the DC-EVSE will be graded. In this context the “Grade A” would be a DC-EVSE with higher efficiency, when compared to a “Grade B” DC-EVSE. Accordingly, a “Grade B” DC-EVSE will have a higher efficiency then a “Grade C” DC-EVSE.

If a DC-EVSE is not able to reach the “Grade A” or “Grade B” it will be a “Grade C”.

In order to reach a certain efficiency-grade, for example Grade A, all efficiencies of the power range, for example “16% to 20%”, shall lay in the Grade A requirements.

The specification for a complete label is defined in in chapter 6.

4.3. Discharging - Efficiency

The discharging-efficiency of the DC-EVSE shall not be less than 80% (at any point of the power range 10% to 100% and between 200-500V for the 400V battery technology and between 200 -920V for the 800V battery technology.

The discharging-efficiency of the DC-EVSE shall not be less than 60% at any point between minimum power P_{min_man} (defined by the manufacturer) to 10% and between 200-500V for the 400V battery technology and between 200 -920V for the 800V battery technology.

The guidance to obtain the values for efficiencies are defined in sub-chapter 4.1.

Table 3: LPC - Discharging Efficiency

Power Range	Power Range	Efficiency [%] (Batt. Voltage: 330V (±30V))	Efficiency [%] (Batt. Voltage: 680V (±30V)
Very low power range	P_{min_man} to 9% P_{ref}	Grade A: ≥73 Grade B: ≥70 Grade C: <70	Grade A: ≥73 Grade B: ≥70 Grade C: <70
Low power range	10% to 15% P_{ref}	Grade A: ≥93 Grade B: ≥90	Grade A: ≥93 Grade B: ≥90

[4] Efficiency guideline for PV storage systems, Version 2, 04/2019, https://www.bves.de/wp-content/uploads/2019/07/EfficiencyGuideline_PV-Storage_2.0_EN.pdf downloaded 02.06.2022

		Grade C: <90	Grade C: <90
Low power range	16% to 20% of P_{ref}	Grade A: ≥95 Grade B: ≥92 Grade C: <92	Grade A: ≥95 Grade B: ≥92 Grade C: <92
Low power range	21% to 25% of P_{ref}	Grade A: ≥96 Grade B: ≥92 Grade C: <92	Grade A: ≥96 Grade B: ≥92 Grade C: <92
Medium power range	26% to 50% of P_{ref}	Grade A: ≥96 Grade B: ≥92 Grade C: <92	Grade A: ≥96 Grade B: ≥92 Grade C: <92
Medium power range	51% to 75% of P_{ref}	Grade A: ≥96 Grade B: ≥92 Grade C: <92	Grade A: ≥96 Grade B: ≥92 Grade C: <92
High power range	76% to 100% of P_{ref}	Grade A: ≥96 Grade B: ≥92 Grade C: <92	Grade A: ≥96 Grade B: ≥92 Grade C: <92

Table 4: DC - Discharging Efficiency

Power Range	Power Range	Efficiency [%] (Batt. Voltage: 330V (±30V))	Efficiency [%] (Batt. Voltage: 680V (±30V)
Very low power range	P_{min_man} to 9% P_{ref}	Grade A: ≥72 Grade B: ≥69 Grade C: <69	Grade A: ≥72 Grade B: ≥69 Grade C: <69
Low power range	10% to 15% P_{ref}	Grade A: ≥92 Grade B: ≥88 Grade C: <88	Grade A: ≥92 Grade B: ≥88 Grade C: <88
Low power range	16% to 20% of P_{ref}	Grade A: ≥94 Grade B: ≥91 Grade C: <91	Grade A: ≥94 Grade B: ≥91 Grade C: <91
Low power range	21% to 25% of P_{ref}	Grade A: ≥95 Grade B: ≥91 Grade C: <91	Grade A: ≥95 Grade B: ≥91 Grade C: <91
Medium power range	26% to 50% of P_{ref}	Grade A: ≥95 Grade B: ≥91 Grade C: <91	Grade A: ≥95 Grade B: ≥91 Grade C: <91
Medium power range	51% to 75% of P_{ref}	Grade A: ≥95 Grade B: ≥91 Grade C: <91	Grade A: ≥95 Grade B: ≥91 Grade C: <91
High power range	76% to 100% of P_{ref}	Grade A: ≥95 Grade B: ≥91 Grade C: <91	Grade A: ≥95 Grade B: ≥91 Grade C: <91

Table 5: FC - Discharging Efficiency

Power Range	Power Range	Efficiency [%] (Batt. Voltage: 330V (±30V))	Efficiency [%] (Batt. Voltage: 680V (±30V)
Very low power range	P_{min_man} to 9% P_{ref}	Grade A: ≥72 Grade B: ≥69 Grade C: <69	Grade A: ≥72 Grade B: ≥69 Grade C: <69
Low power range	10% to 15% P_{ref}	Grade A: ≥92 Grade B: ≥88 Grade C: <88	Grade A: ≥92 Grade B: ≥88 Grade C: <88
Low power range	16% to 20% of P_{ref}	Grade A: ≥94 Grade B: ≥91 Grade C: <91	Grade A: ≥94 Grade B: ≥91 Grade C: <91
Low power range	21% to 25% of P_{ref}	Grade A: ≥95 Grade B: ≥91 Grade C: <91	Grade A: ≥95 Grade B: ≥91 Grade C: <91
Medium power range	26% to 50% of P_{ref}	Grade A: ≥95 Grade B: ≥91	Grade A: ≥95 Grade B: ≥91

		Grade C: <91	Grade C: <91
Medium power range	51% to 75% of P_{ref}	Grade A: ≥95 Grade B: ≥91 Grade C: <91	Grade A: ≥95 Grade B: ≥91 Grade C: <91
High power range	76% to 100% of P_{ref}	Grade A: ≥95 Grade B: ≥91 Grade C: <91	Grade A: ≥95 Grade B: ≥91 Grade C: <91

Table 6: UFC - Discharging Efficiency

Power Range	Power Range	Efficiency [%] (Batt. Voltage: 330V (±30V))	Efficiency [%] (Batt. Voltage: 680V (±30V))
Very low power range	P_{min_man} to 9% P_{ref}	Grade A: ≥72 Grade B: ≥69 Grade C: <69	Grade A: ≥72 Grade B: ≥69 Grade C: <69
Low power range	10% to 15% P_{ref}	Grade A: ≥92 Grade B: ≥88 Grade C: <88	Grade A: ≥92 Grade B: ≥88 Grade C: <88
Low power range	16% to 20% of P_{ref}	Grade A: ≥94 Grade B: ≥91 Grade C: <91	Grade A: ≥94 Grade B: ≥91 Grade C: <91
Low power range	21% to 25% of P_{ref}	Grade A: ≥95 Grade B: ≥91 Grade C: <91	Grade A: ≥95 Grade B: ≥91 Grade C: <91
Medium power range	26% to 50% of P_{ref}	Grade A: ≥95 Grade B: ≥91 Grade C: <91	Grade A: ≥95 Grade B: ≥91 Grade C: <91
Medium power range	51% to 75% of P_{ref}	Grade A: ≥95 Grade B: ≥91 Grade C: <91	Grade A: ≥95 Grade B: ≥91 Grade C: <91
High power range	76% to 100% of P_{ref}	Grade A: ≥95 Grade B: ≥91 Grade C: <91	Grade A: ≥95 Grade B: ≥91 Grade C: <91

Table 7: HPC - Discharging Efficiency

Power Range	Power Range	Efficiency [%] (Batt. Voltage: 330V (±30V))	Efficiency [%] (Batt. Voltage: 680V (±30V))
Very low power range	P_{min_man} to 9% P_{ref}	Grade A: ≥72 Grade B: ≥69 Grade C: <69	Grade A: ≥72 Grade B: ≥69 Grade C: <69
Low power range	10% to 15% P_{ref}	Grade A: ≥92 Grade B: ≥88 Grade C: <88	Grade A: ≥92 Grade B: ≥88 Grade C: <88
Low power range	16% to 20% of P_{ref}	Grade A: ≥94 Grade B: ≥91 Grade C: <91	Grade A: ≥94 Grade B: ≥91 Grade C: <91
Low power range	21% to 25% of P_{ref}	Grade A: ≥95 Grade B: ≥91 Grade C: <91	Grade A: ≥95 Grade B: ≥91 Grade C: <91
Medium power range	26% to 50% of P_{ref}	Grade A: ≥95 Grade B: ≥91 Grade C: <91	Grade A: ≥95 Grade B: ≥91 Grade C: <91
Medium power range	51% to 75% of P_{ref}	Grade A: ≥95 Grade B: ≥91 Grade C: <91	Grade A: ≥95 Grade B: ≥91 Grade C: <91
High power range	76% to 100% of P_{ref}	Grade A: ≥95 Grade B: ≥91 Grade C: <91	Grade A: ≥95 Grade B: ≥91 Grade C: <91

5. Reactive power control with bidirectional charging

Reactive power control for bidirectional power transfer is crucial for the V2X application. In this context the requirements of established industry standards for storage systems and PV-inverters e.g., AR-N 4105[5], AS/NZS 4777.2[6] and the EN 50549[7] depending on the market/country must be fulfilled.

Reactive power control is used to assist in the stabilization of the steady-state grid voltage. The standards require various reactive power control strategies, for example fixed power factor, fixed VAr, Volt-VAr characteristic, PF-Watt characteristic, and others.

Power factor is nominally unity (cosφ = 1.0) but should be adjustable in the range cosφ = 0.8 over-excited to cosφ = 0.8 under-excited to satisfy the current standards (values from AS/NZS 4777.2). This means that the EVSE must be able to supply or absorb reactive power.

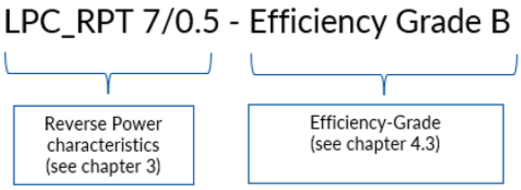
These characteristics are configured based on country and region and sometimes the particular site of the EVSE installation.

[5] VDE-AR-N 4105 Anwendungsregel:2018-11 Generators connected to the low-voltage distribution network
Technical requirements for the connection to and parallel operation with low-voltage distribution networks
[6] AS/NZS 4777.2:2020 Grid connection of energy systems via inverters, Part 2: Inverter requirements:
[7] DIN EN 50549-1 VDE 0124-549-1:2020-10
Requirements for generating plants to be connected in parallel with distribution networks
Part 1: Connection to a LV distribution network – Generating plants up to and including Type B

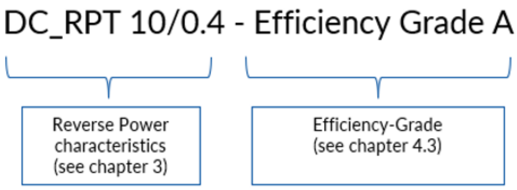
6. Examples for Labeling

There can also be products that are for charging mode in one power class and for the discharging mode in another power class.

Example 1:



Example 2:



7. Reference

This document was created within the Focus Group Grid Integration of the CharIN association.

The Focus Group Grid Integration is aiming for aligning technical definitions in the EV and EVSE industry together with grid operators and regulation. Due to the variety of the different stakeholders, CharIN is taking the responsibility to bring them together and propose technical details for bidirectional charging.

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Annex A - Identified relevant power point

Discharging - Identified relevant power point

A relevant power point is a power value that was defined as important in certain use case and power class. Importance can be due to e.g., high occurrence when considering statistical aspects. The relevant power points are expressed as an AC value.

The following table shall give relevant power points of each power class related to use cases (where applicable). These power points are defined and/or limited by the following aspects:

[1] In which power point works the DC-EVSE most probably for V2H use cases. This can be based on available load demand data from Germany. From a measurement campaign an average annual consumption of 4700kWh per year and household can be estimated[8]. When dividing this energy by the hours of the year (8760) it results to an average power value of around 0,5kW.

[2] The V2G application can be considered as use cases where a pooling of several EV is useful. The effect on the grid is created by the sum of several EVSE/EV, feedback from a DSO suggest therefore a lower power range per single EVSE for this case. Also, the remaining SOC of the battery for driving plays obviously an important role. A value of 10kW for the lower power classes and 30kW for the higher power classes is selected. For the V2B use cases equal power range are chosen.

[3] In certain cases, the maximum power of the DC-EVSE defines the power, also considering point 4 see below.

[4] From the results of a DKE working group "UG2 DKE/AK 353.0.401" a requirement of 125% design reserve is requested, which defines another limit. A DC-EVSE with a rated power of 8kW will become a 6kW power source.

The relation to the definitions above ([1] to [4]) are marked with the number in brackets.

[8] Tjaden, T.; Bergner, J.; Weniger, J.; Quaschning, V.: „Repräsentative elektrische Lastprofile für Einfamilienhäuser in Deutschland auf 1-sekündiger Datenbasis", Datensatz, Hochschule für Technik und Wirtschaft (HTW) Berlin, Lizenz: CC-BY-NC-4.0, downloaded on 02.06.2022

Table 8: Relevant AC - power points discharging.

		LPC	DC	FC	UFC
		Power [kW]	Power [kW]	Power [kW]	Power [kW]
V2H	Optimization of self-consumption	0,5 [1]	0,5 [1]	-	-
V2H	Tariff-optimized charging/discharging	0,5 [1]	0,5 [1]	-	-
V2H	Island Mode Operation	0,5 [1]	0,5 [1]	-	-
V2G	Intraday-Trading	6 [3,4]	10 [2]	30 [2]	30 [2]
V2G	Frequency regulation	6 [3,4]	10 [2]	30 [2]	30 [2]
V2G	Redispatch	6 [3,4]	10 [2]	30 [2]	30 [2]
V2B	Peak Shaving	6 [3,4]	10 [2]	30 [2]	30 [2]
V2B	Fleet management	6 [3,4]	10 [2]	30 [2]	30 [2]

In accordance with the use case definition, – “V2B Peak shaving” means to supply power in a range of several minutes (usually slots of 15 Minutes are covered). “V2B Peak shaving” does not supply power to cover inrush currents for e.g., starting machines.

In this table the HPC class is not considered.

The values of table 8 are representing the AC-values of the DC-EVSE. In order to derive the DC-power values, as shown for example in table 2, the conversion loss values should be applied.

Annex B - Indication on available power and energy from the EV

Table 9: EV Battery capacity

Model	Nominal Battery-Capacity [kWh][9, 10] (manufacturer information)	Max. charging power [kW]	C-Rate [1/h]
Smart Forfour EQ passion	17,6		
Mini Cooper SE	32		
Seat Mii electric plus	32,3	40	1,24
VW e-up! Style	32,3	40	1,24
Mazda MX-30 e-SKYACTIV	35,5		
Nissan e-NV 200 Evalia	40	50	1,25
Nissan Leaf Acenta	40	50	1,25
Renault Zoe intens	41	50	1,22
BMW i3	42,2	50	1,18
MG ZS EV	45		
DS 3 Crossback E-Tense So Chic	50		
Opel Combo-e (start autumn)	50		
Peugeot e-2008 GT	50	100	2,00
Peugeot e-208 GT	50	100	2,00
Renault Zoe R135 Z.E. 50 intens	52	50	0,96
Tesla Model 3 Standard Range Plus	53	117	2,21
Nissan Leaf e+ Tekna	62	50	0,81
VW ID.3 Pro Performance 1st Max	62	100	1,61
Hyundai Kona Elektro Trend	64		
Kia e-Niro Spirit	64	74	1,16
Kia e-Soul	64	100	1,56
Hundai Ioniq	72,6	150	2,07

[9] https://www.heise.de/autos/artikel/Ladeleistung-und-Batteriegroesse-4535987.html?seite=2 accessed 12.02.2022
[10] https://www.mobilityhouse.com/de_de/ratgeber/ladezeitenuebersicht-fuer-elektroautos accessed 12.02.2022

Tesla Model Longe Range AWD	75		
Polestar 2 Long Range Dual Motor	78	150	1,92
Volvo C40 Pure Electric	78		
Mercedes EQC 400 AMG Line	80	110	1,38
VW ID.4 Pro Performance Max	82		
Jaguar i-Pace EV400 S AWD	90	100	1,11
Porsche Taycan 45 Performance Plus	93,4	270	2,89
Audi e-tron 55 quattro	95	150	1,58
Audi e-tron Sportback 55 quattro	95		
Tesla Model X 100D	100		

Based on this data the average battery capacity is nowadays around 60kWh. This shows that in the HPC power class only several minutes could be used for bidirectional power transfer. The battery capacity may increase in the future. Furthermore, buses and commercial vehicles have a larger battery capacity than passenger cars. Which leads to additional options for the use cases.

Annex C – Discharging power class and Efficiency-Grades Examples

Table 10: Information on calculation of power/current/voltage values[11]

Power Class	DC_RPT 10/0.4	DC_RPT 30/0.2	LPC_RPT 3.7/0.2	FC_RPT 88/5	UFC_RPT 100/7.5	UFC_RPT 140/7.5	HPC_RPT 150/10
Power	10/0.4	30/0.2	3.7/0.2	88/0.5	100/7.5	140/7.5	150/10
Efficiency Grade*	A	B	A	A	B	C	C
U_{min} [V]	200	200	200	200	200	200	200
U_{max} [V]	920	920	920	920	920	920	920
I_{min} [A]	1	1	1	1	5	5	5
I_{peak} [A]	25	30	20	220	250	350	500
$I_{derated}$ [A]	18.75	22.5	15	165.00	187.50	262.50	375.00
$P_{ref} = U_{ref} * I_{peak}$	10	30	3.7	88	100	140	150
P_{min_req}	0.5	2.5	0.5	5	7.5	7.5	10
$P_{min\text{-}man}$	0.4	2	0.2	5	7.5	7.5	10
U_{ref} (specified) or (calculated) $= P_{ref}/I_{peak}$	400	400	400	400	400	400	300

*The efficiency values are exemplary.

[11] Position Paper of Charging Interface Initiative e.V. , DC CCS Power Classes V7.2, 2021, https://www.charin.global/technology/knowledge-base/ accessed 10.10.2022

Annex D - Examples from PV storage system efficiencies

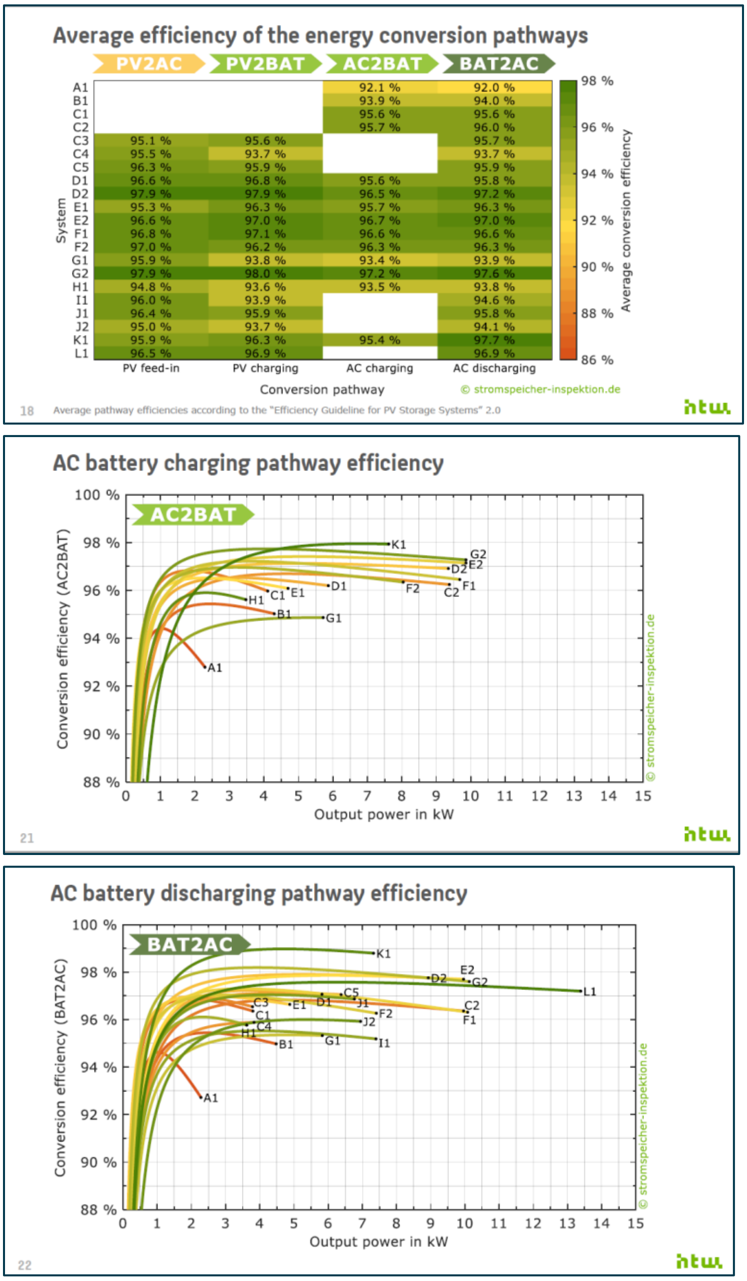

Figure 6: Examples for Efficiency curve and values

The figures are part of the HTW study Energy Storage Inspection[12].

[12] Energy Storage Inspection 2022, Nico Orth et. al., 2022, Energy Storage Inspection 2022 (htw-berlin.de) accessed 24.06.2022