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Periodic Verification of DC Electric Vehicle Charging Stations – Results of Project ProSafE²

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Executive Summary

A concept for the periodic verification of DC electric vehicle charging stations in order to guarantee a long-term safe operation is presented. Therefore, in the context of the research project ProSafE², sixteen different test cases based on (inter)national standards as well as on stakeholders' requirements have been developed. To perform realistic in-field tests and to evaluate the practicability of the test cases also a designed as well as constructed testing device demonstrator is shown. Furthermore, the results of (field) tests on different DC charging stations are discussed. Moreover, the findings were transferred into the working group responsible for the second edition of the national Austrian OVE Technical Specification R 30 (safe operation and periodic verification of electric vehicle charging stations).

Keywords: Electric Vehicles, Standardization, AC & DC Charging technology, Measuring Methods & Equipment, Health and Safety Considerations

1 Introduction

With the increasing expansion of electromobility, operators of charging infrastructure for electric vehicles are also facing new challenges. One of these challenges is the periodic verification of electric vehicle charging stations (EVCS). This is intended to ensure the long-term safe operation in terms of protection against electric shocks to persons and livestock on the one hand and legal certainty with regard to the duty of care for the operator on the other hand.

For AC charging stations (AC EVCS), this can be done with reasonable effort based on standards (e.g. according to [1] or [2]) using a simple test adapter like [3] or [4] and a conventional installation tester (e.g. [5] or [6]). However, the verification of protective measures of direct current charging stations (DC EVCS) is a greater challenge. Therefore, either an electric vehicle (EV) or an EV emulator is required to enable the charging station to be activated and to perform a corresponding test resp. verification. Testing with the use of an EV is not really useful due to the non-guaranteed reproducibility and because possible damages to the vehicle cannot be entirely ruled out. EV emulators for DC charging stations have so far only been available in a rudimentary form (e.g. [7]).

Furthermore, no regulations or standards regarding the scope of testing and test intervals for periodic verification of DC charging stations have been available so far, only product standards with tests in the sense of type testing exist which, however, are not applicable to for periodic verifications. (e.g. [8]).

This is precisely where the research project ProSafE² (Protection, Safety and Efficiency of Electric Vehicle Charging Stations) came in. One of the main objectives was to develop practicable test procedures for the periodic verification of DC EVCSs as well as a corresponding testing device demonstrator for evaluation in the field. In addition, investigations were also carried out with regard to the required earthing and equipotential bonding systems, the energy efficiency of DC EVCS as well as grid perturbations, see e.g. [9] and [10].

In the context of this contribution, the main project results and findings regarding the field tests at five different charging stations with the developed testing device demonstrator are summarized.

2 Developed Test Cases and Testing Device Demonstrator

In the course of ProSafE², a total of 16 different test cases (TC) were developed: 12 of them were proposed as the scope of a periodic verification (pv) and 4 as additional investigations (add) in the course of the research project, see also [11]. In Table 1 an overview of the test cases and a brief description is provided. It is also indicated whether the TC is carried out with a conventional installation tester according IEC 61557 series [12] (e.g. [5] or [6]), the ProSafE² testing device demonstrator, a multi-channel measuring system or a combination of these. In principle, the test cases are based on various (inter)national standards like IEC 61851-1 [13], IEC 61851-23 ED1 [14] resp. IEC 61851-23 ED2 [15], IEC 60364 series [16] resp. OVE E 8101 [2] or OVE Technical Specification (TS) R 30:2020 [17] resp. OVE TS R 30:2025 [18] and to the knowledge of the project team as well as ProSafE² stakeholders (which were involved via four stakeholder workshops in total).

Table 1: Overview of the 16 test cases developed for the periodic verification of DC EVCS [19]

TC-ID	Name	pv/ add	Description	Testing device
1	**Visual inspection**	pv	Detailed inspection of the charging station to be checked for visible defects in accordance with the checklist	n/a
2	**PE continuity**	pv	Low-resistance measurement between different PE contacts (e.g. PE connection terminal, CCS plug PE contact, metal housing)	Installation tester
3	**Charging cable insulation test**	pv	Insulation test of the conductors DC+/DC-, DC+/PE and DC-/PE	Installation tester
4	**Fault impedance AC**	pv	Measurement of the fault impedance at the AC side of the DC charging station (L1/2/3-PE)	Installation tester
5	**Test charging procedure**	pv	Test charging procedure without fault emulation	Demonstrator
6	**Insulation monitoring device test (IMD test)**	pv	Simulation of symmetrical and unsymmetrical, resistive insulation faults before and during a charging procedure	Demonstrator
7	**Interruption PE "virtual"**	pv	Interruption of the PE conductor (connected to the charge controller) during a charging procedure	Demonstrator
8	**Resistance PP**	pv	Reading the resistance value from the charge controller or measuring with a multimeter	Demonstrator
9	**Interruption CP**	pv	Interruption of the CP conductor during a charging procedure	Demonstrator
10	**Short circuit CP/PE**	pv	Short circuit of the CP and PE conductor during a charging procedure	Demonstrator
11	**Short circuit DC+/DC- before charging**	add	Short circuit between DC+ and DC- before a charging procedure	Demonstrator

12	**Voltage drop DC+/DC- during charging**	add	Simulation of a short circuit between DC+ and DC- during a charging procedure	Demonstrator
13	**Charge interruption by communication**	pv	Termination of a charging procedure by means of charging communication	Demonstrator
14	**Emergency stop**	pv	Pressing the emergency stop button (if applicable) during a charging procedure	Demonstrator
15	**Charging energy DC**	add	Measurement of the DC charging energy during a charging procedure over a specific duration	Demonstrator and multi-channel measurement device
16	**Charging energy AC and PQ**	add	Measurement of the input-side AC energy during a charging procedure over a specific period of time, including analysis of grid perturbations (e.g. $THD_{I/U}$); analysis of energy efficiency carried out together with TC 15 (‘Charging energy DC’)	Demonstrator and multi-channel measurement device

Keys to Table 1:

AC .... alternating current
add .... additional test case
CCS .... combined charging system
CP .... control pilot
DC+/-..... direct current conductor positive/negative
IMD .... insulation monitoring device
PE.......... protective earth (conductor)
PP .... proximity pilot
PQ .... power quality
pv........... periodic verification
$THD_{I/U}$ ... total harmonic distortion current/voltage
TC .... test case

In addition, Figure 1 shows a schematic diagram of the test cases based on principle illustrations of a DC charging station (left) and the ProSafE² testing device demonstrator (right). The test cases can be characterized in the form of measuring points, allocations or switches (with and without series resistors) as well as the related numbering (TC-ID number in red circle, see also Table 1). The additionally required installation tester and the multi-channel measurement device are also shown.

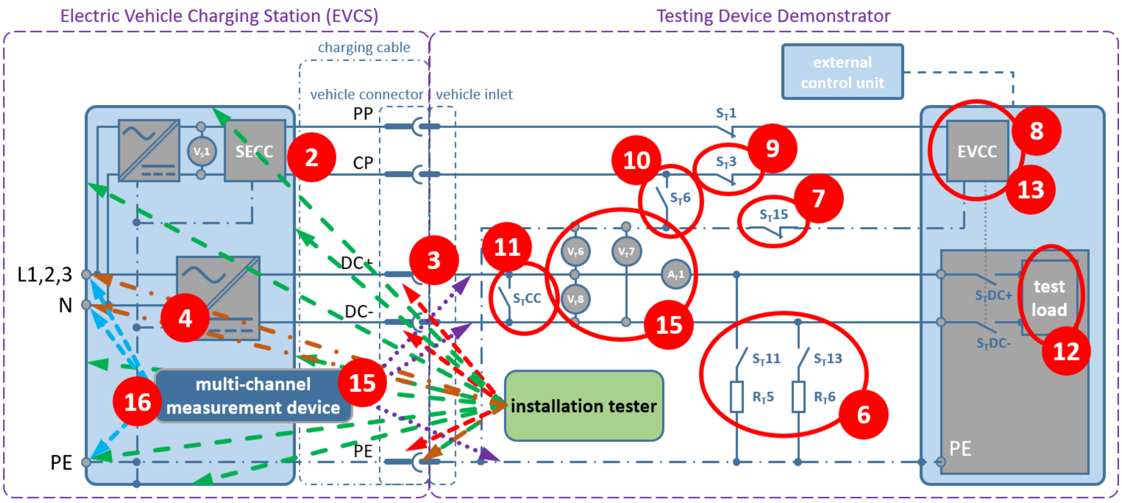

Figure 1: Schematic diagram of a DC EVCS (left) and the ProSafE² testing device demonstrator (right) including the ID numbers of the test cases ([19] – modified)

Keys to Figure 1:

A .... current measurement
EVCC .... EV communication controller
L1,2,3 .... phase conductors
N .... neutral conductor
R .... Resistor
S .... switch
SECC..... supply equipment comm. controller
V........... voltage measurement

Annotation: Also note the keys for Table 1

The already mentioned developed testing device demonstrator basically consists of a battery for the control voltage, various power electronics, a transformer to adjust the voltage level, a programmable logic controller, various contactors and relays, high-power resistors resp. a resistor decade, a high-precision power measurement device (temperature compensated) as well as an external control unit. It is able to perform CCS charging procedures with up to 1000 V_{DC} resp. 200 A_{DC} with a limited charging power of 120 kW independent from an external power supply resp. sink. The external control unit is connected via a fiber optic cable to ensure a galvanic separation with regard to the protection of the test personnel. Figure 2 shows a photograph of the finalized testing device demonstrator with its external control unit.

Figure 2: ProSafE² testing device demonstrator with fiber-connected external control unit

3 Laboratory and Field Tests

Following the development of the test procedures as well as the testing device demonstrator, laboratory and field tests were carried out on 5 different DC charging stations from various manufacturers. Table 2 summarizes the DC EVCSs investigated in terms of installation location, operator, manufacturer as well as current, voltage and charging power maxima.

Table 2: Five tested DC charging stations during six laboratory and field tests

No.	Description, location	Operator	Manufacturer / type	max. charging power	max. V/I
1	**Laboratory test** Graz (2023-12)	KS / TUG	Circontrol / CCL QPC CH CCS AC63	DC 50 kW, AC 44 kW	500 V_{DC}, 3x400 V_{AC} / 125 A_{DC}, 63 A_{AC}
2	**Field test "light" – testing hall** Graz (2024-01)	Energienetze Steiermark	ABB / TERRA 54 CJG	DC 50 kW, AC 22/43 kW	950 V_{DC}, 400 V_{AC} / 125 A_{DC}, 63 A_{AC}
3	**Motorway rest stop** Völkermarkt (2024-02)	KELAG	Efacec / EV QC45 CE GCCB	DC 50 kW, AC 22/43 kW	500 V_{DC}, 400 V_{AC} / 120 A_{DC}, 63 A_{AC}
4	**Retail center car park** Leobersdorf (2024-03)	Wien Energie	Kostad – Schrack / Triberium Fast Charger	DC 50 kW, AC 43 kW	1000 V_{DC} / 250 A_{DC}
5	**Supermarket car park** St.Veit/Glan (2024-07)	KELAG	EnerCharge / ECC 320	2 x DC 160 kW	920 V_{DC}, 400 V_{AC} / 125 A_{DC}, 63 A_{AC}
6	**Laboratory test** Graz (2024-10)	KS / TUG	Circontrol / CCL QPC CH CCS AC63	DC 50 kW, AC 44 kW	500 V_{DC}, 3x400 V_{AC} / 125 A_{DC}, 63 A_{AC}

Keys to Table 2:

KS........... KS Engineers

TUG......... Graz University of Technology

KELAG... Energy supplier in southern Austria

In the case of the tests no. 1 and 6 a 50 kW DC EVCS was temporary installed in the laboratory of our project partner KS Engineers. It was used during the development of the testing device demonstrator, for the first executed test procedure with the developed test cases and for the last test procedure considering the learnings from the field tests no. 2 to 5. Test no. 2 was done in the testing hall of another project partner whereby more realistic conditions had to be considered in terms of e.g. time management, equipment transport, test personnel, accessibility. The real field tests no. 3 to 5 were carried out at different locations within a radius of 200 km from Graz University of Technology, which resulted in a relevant logistical effort with regard to the transportation of the testing device demonstrator and the additional measuring equipment. Within except of test no. 1 (two days) every other test was able to be performed roughly in one day incl. arrival and return trip.

An exemplary field test setup from July 2024 is illustrated in Figure 3. One can see the testing device demonstrator (left, in the van), measurement adapter (left, in front of the van), the DC charging station under test (center) and the external control unit as well as the separate additional multi-channel measurement device (under the tent, both on the table). The black-yellow barriers (with the black-yellow chain) limit the hazard zone (no entry during a test) and the red-white traffic cones limit the testing area (only test personnel are allowed to enter).

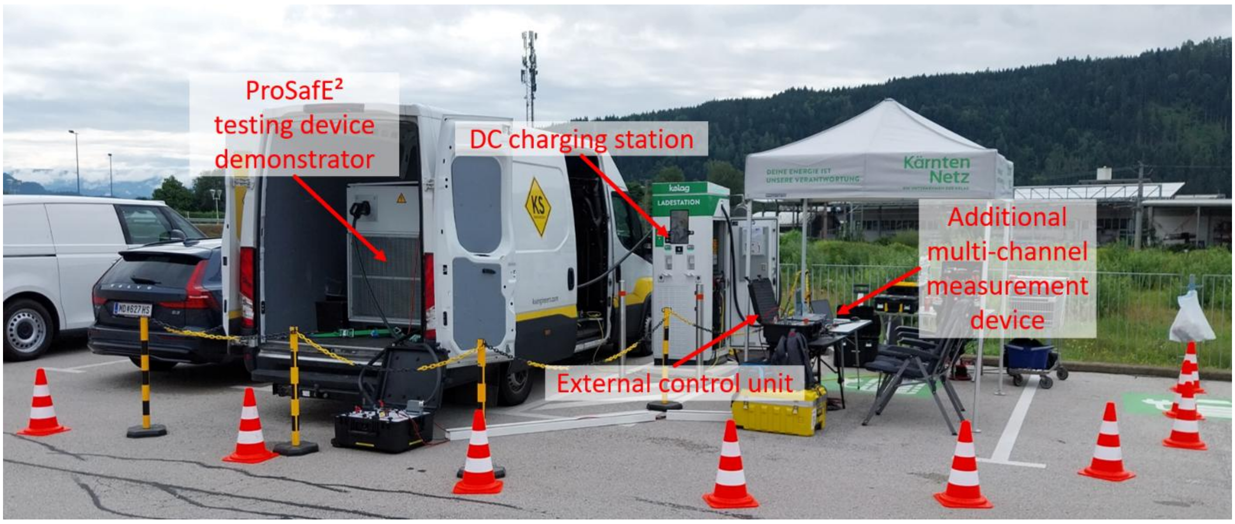

Figure 3: Exemplary test setup with testing device demonstrator,
DC charging station (160 kW) and auxiliary equipment, July 2024

4 Test Results

First of all, it can be stated that the majority of the DC charging stations tested did not show any significant defects resp. shortcomings. A detailed evaluation of the test results is summarized in Table 3. The DC EVCS tested generally complied with the manufacturer's specifications for IEC 61851-23 ED1 [14] valid at the time of production. In the spirit of the research character of the project, the charging stations were also tested in accordance with the IEC 61851-23 ED2 [15] standard, which is valid since 2023-12-13 (corresponding results are marked in grey in Table 3).

Furthermore, the following aspects resp. findings were identified during the laboratory as well as in the field tests:

- The DC charging stations tested showed significantly different behavior during individual test cases / faults, for example when testing the insulation monitoring device (IMD, TC 6) with the corresponding six sub-variants (DC+/DC-/PE symmetrical/unsymmetrical before or during the charging process. E.g., one of the DC charging stations tested showed deficits with regard to the detection of all unsymmetrical faults (DC+/PE and DC-PE before and during a charging process).
- Depending on the design of a charging station, an IMD can be installed at different positions, which has two aspects to consider:
  - If the IMD is installed upstream of the DC output contactor it is not able to detect an insulation fault in the charging cable before the output-side contactor is switched on. (TCs 6a, 6b and 6c)
  - If the IMD is installed after the contactor on the charging station side, however, an unaffected insulation test of the charging cable is not possible. (TC 3)
- It has been determined that some DC EVCS already fulfil the new product standard IEC 61851-23 ED2 [15] with regard to various test cases, although only IEC 61851-23 ED1 [14] applied at the time of placing on the market.
- It is noticeable that the majority of the charging stations did not fully pass the TCs 9 (interruption CP) and 10 (short circuit CP/PE) with regard to the specified switch-off times. This means that the respective charging process is cancelled after the fault occurs, but not within the time specified in the standard.
- Those TCs that require an active charging process and/or should initiate a termination of the charging process (TCs 5, 6d-f, 7, 9, 10, 12, 13, 14) were carried out at different operating points (resp. charging powers) including the minimum and maximum DC charging current. Thereby, no difference in the behavior of the individual DC charging stations was observed.
- None of the DC EVCS' tested was able to react on the additional test case TC 12 (emulated short circuit due to voltage reduction during a charging process, project definition, not standardized) developed in the research context of the project.

Additionally, it is worth mentioning that – depending on the test case – some charging stations may require access (inside the enclosure) in order to perform a hard reset or reboot. Due to the fact that interoperability is not always guaranteed, various challenges and problems occurred during the communication between the testing device demonstrator and the charging station. A laboratory or field test lasted around one day, including travelling, assembly and disassembly as well as processing the test cases (excluding evaluation and documentation of the test resp. measurement results). The time required for a periodic verification of a DC charging station (excluding preparation of the test report, travelling to and from the station) is currently estimated at around 1.5 to 2.0 hours.

Beside the evaluation of the protection against electric shock (verification of protective measures) one additional aspect was the energy efficiency of DC charging stations as well as the power quality resp. grid perturbations (impact of the charging station under test on the supplying grid). Figure 4 shows the exemplary result of the efficiency measurement of four different charging stations. In doing so, the phenomenon known from inverters could be determined that the efficiency also decreases with decreasing charging power (in relation to the rated charging power). Further evaluations and details on energy efficiency as well as power quality can be found in [10].

Table 3: Summarized results of the laboratory and field tests sorted by the test cases

<table>
<tr><th rowspan="2">TC-ID</th><th rowspan="2">TC name</th><th rowspan="2">pv/ add</th><th colspan="5">Tested charging stations</th><th rowspan="2">(normative) Reference</th></tr>
<tr><th>20 %</th><th>40 %</th><th>60 %</th><th>80 %</th><th>100 %</th></tr>
<tr><td>1</td><td>Visual inspection</td><td>pv</td><td colspan="5">OK</td><td>OVE TS R 30:2025 [18]</td></tr>
<tr><td>2</td><td>PE continuity</td><td>pv</td><td colspan="5">OK</td><td>IEC 61851-23 ED1 [14]</td></tr>
<tr><td>3</td><td>Charging cable insulation test</td><td>pv</td><td colspan="3">OK</td><td colspan="2">n/a</td><td>OVE E 8101 [2]</td></tr>
<tr><td>4</td><td>Fault impedance AC</td><td>pv</td><td colspan="5">OK</td><td>OVE E 8101 [2]</td></tr>
<tr><td>5</td><td>Test charging procedure</td><td>pv</td><td colspan="5">OK</td><td>IEC 61851-1 [13]</td></tr>
<tr><td rowspan="2">6a</td><td rowspan="2">IMD test DC+/PE/DC- (symm.) before charging</td><td rowspan="2">pv</td><td colspan="4">OK</td><td>NOK</td><td>IEC 61851-23 ED2 [15]</td></tr>
<tr><td colspan="4">OK</td><td>n/a</td><td>IEC 61851-23 ED1 [14]</td></tr>
<tr><td rowspan="2">6b</td><td rowspan="2">IMD test DC+/PE before charging</td><td rowspan="2">pv</td><td colspan="2">OK</td><td>NOK*</td><td colspan="2">NOK</td><td>IEC 61851-23 ED2 [15]</td></tr>
<tr><td colspan="4">OK</td><td>NOK</td><td>IEC 61851-23 ED1 [14]</td></tr>
<tr><td rowspan="2">6c</td><td rowspan="2">IMD test DC-/PE before charging</td><td rowspan="2">pv</td><td colspan="2">OK</td><td>NOK*</td><td colspan="2">NOK</td><td>IEC 61851-23 ED2 [15]</td></tr>
<tr><td colspan="4">OK</td><td>NOK</td><td>IEC 61851-23 ED1 [14]</td></tr>
<tr><td rowspan="2">6d</td><td rowspan="2">IMD test DC+/PE/DC- (symm.) during charging</td><td rowspan="2">pv</td><td colspan="4">OK</td><td>NOK</td><td>IEC 61851-23 ED2 [15]</td></tr>
<tr><td colspan="4">OK</td><td>n/a</td><td>IEC 61851-23 ED1 [14]</td></tr>
<tr><td rowspan="2">6e</td><td rowspan="2">IMD test DC+/PE during charging</td><td rowspan="2">pv</td><td colspan="3">OK</td><td>NOK*</td><td>NOK</td><td>IEC 61851-23 ED2 [15]</td></tr>
<tr><td colspan="4">OK</td><td>NOK</td><td>IEC 61851-23 ED1 [14]</td></tr>
<tr><td rowspan="2">6f</td><td rowspan="2">IMD test DC-/PE during charging</td><td rowspan="2">pv</td><td colspan="3">OK</td><td>NOK*</td><td>NOK</td><td>IEC 61851-23 ED2 [15]</td></tr>
<tr><td colspan="4">OK</td><td>NOK</td><td>IEC 61851-23 ED1 [14]</td></tr>
<tr><td rowspan="2">7</td><td rowspan="2">Interruption PE “virtual”</td><td rowspan="2">pv</td><td>OK</td><td colspan="3">NOK*</td><td>NOK</td><td>IEC 61851-23 ED2 [15]</td></tr>
<tr><td colspan="4">OK</td><td>n/a</td><td>IEC 61851-23 ED1 [14]</td></tr>
<tr><td>8</td><td>Resistance PP</td><td>pv</td><td colspan="5">OK</td><td>IEC 61851-23 ED2 [15]</td></tr>
<tr><td rowspan="2">9</td><td rowspan="2">Interruption CP</td><td rowspan="2">pv</td><td colspan="2">OK</td><td colspan="3">NOK*</td><td>IEC 61851-23 ED2 [15]</td></tr>
<tr><td colspan="2">OK</td><td colspan="3">NOK*</td><td>IEC 61851-23 ED1 [14]</td></tr>
<tr><td rowspan="2">10</td><td rowspan="2">Short circuit CP/PE</td><td rowspan="2">pv</td><td>OK</td><td colspan="4">NOK*</td><td>IEC 61851-23 ED2 [15]</td></tr>
<tr><td>OK</td><td colspan="4">NOK*</td><td>comp. IEC 61851-23 ED1 [14]</td></tr>
<tr><td rowspan="2">11</td><td rowspan="2">Short circuit DC+/DC- before charging</td><td rowspan="2">add</td><td colspan="4">OK</td><td>n/a</td><td>IEC 61851-23 ED2 [15]</td></tr>
<tr><td colspan="5">n/a</td><td>IEC 61851-23 ED1 [14]</td></tr>
<tr><td>12</td><td>Voltage drop DC+/DC- during charging</td><td>add</td><td colspan="5">n/a</td><td>ProSafE² definition (not normative)</td></tr>
<tr><td rowspan="2">13</td><td rowspan="2">Charge interruption by communication</td><td rowspan="2">pv</td><td colspan="2">OK</td><td colspan="2">NOK*</td><td>n/a</td><td>IEC 61851-23 ED2 [15]</td></tr>
<tr><td colspan="4">OK</td><td>n/a</td><td>IEC 61851-23 ED1 [14]</td></tr>
<tr><td rowspan="2">14</td><td rowspan="2">Emergency stop</td><td rowspan="2">pv</td><td colspan="3">OK</td><td colspan="2">n/a</td><td>IEC 61851-23 ED2 [15]</td></tr>
<tr><td colspan="3">OK</td><td colspan="2">n/a</td><td>IEC 61851-23 ED1 [14]</td></tr>
<tr><td>15</td><td>Charging energy DC</td><td>add</td><td colspan="4">OK</td><td>n/a</td><td>ProSafE² definition (not normative)</td></tr>
<tr><td rowspan="2">16</td><td rowspan="2">Charging energy AC and PQ</td><td rowspan="2">add</td><td colspan="4">OK</td><td>n/a</td><td>AC charging energy measurement (together with TC 15)</td></tr>
<tr><td colspan="3">OK</td><td colspan="2">n/a</td><td>IEC 61000-3-12:2011 [20], IEC 61000-2-4:2024 [21] and OVE EN 50160:2020 [22]; analogous: TOR D1 V2.0 [23] and TOR D2 V2.4 [24]</td></tr>
</table>

Keys to Table 3:

add .... additional test case

n/a............ test case could not be performed or evaluated for various reasons

NOK .... DC charging station did not pass the test case according to (normative) criteria/limits

pv .... periodic verification

OK.......... DC charging station has passed the test case according to (normative) criteria/limits

NOK*..... DC charging station did not pass the test case according to (normative) criteria/limits, but was at least switched off

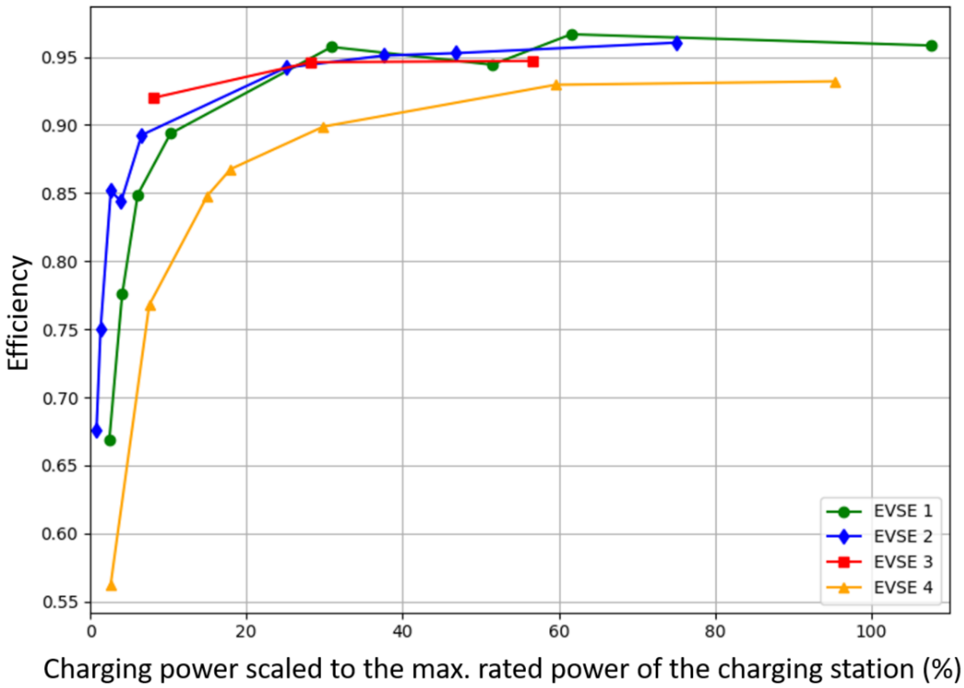

Figure 4: Efficiency ($P_{\text{charge,DC}}/P_{\text{charge,AC}}$) of the DC EVCS investigated in relation to the charging power [10]

5 Knowledge Transfer to OVE Technical Specification R 30

With the help of the findings from the laboratory and field tests mentioned in the previous chapter, a test procedure and scope for a periodic verification of DC charging stations has been recommended. This consists of the twelve test cases 1-10 and 13-14, see also the entries ‘pv’ in Table 1. These TCs were included in the discussions of the ‘OVE AG Ladestationen’ (en. OVE working group on charging stations), which in parallel to the ProSafE² project revised the national Austrian OVE Technical Specification (TS) R 30 (Safe operation and periodic testing of electrical, conductive charging systems for electric vehicles) [18]. Among other things, this TS includes the recommended scope of testing as well as testing intervals, as long as nothing else is specified by the charging station manufacturer. It applies to publicly accessible and commercially operated AC and DC charging stations; application is recommended for exclusively privately-operated charging stations.

Table 4 compares which of the ProSafE² test cases were included in the scope of testing in the new edition of the OVE Technical Specification R 30 [18] and which were not accepted by the experts in accordance with the consensual principle of standardization. Unless otherwise specified in Table 4, a test interval of 5 years is generally recommended, and 3 years for charging stations subject to abnormal stress (e.g. depending on installation location, frequency of use, weather conditions, environmental influences, pollution). Furthermore, more frequent visual inspections are recommended during each visit to the charging station by the operator (e.g. in the course of maintenance or servicing measures). It also has to be mentioned that some tests (already established in the course of the periodic verification of AC EVCS) are not within the scope of ProSafE²'s research and therefore cannot be mapped in test cases. This applies in particular to those tests in Table 4 with the IDs C, D and E.

Table 4: Allocation of OVE Technical Specification (TS) R 30 scope of testing to ProSafE² Test Cases (TCs)

ID	**Test according to OVE TS R 30**	**R 30 minimum verification interval**	**ProSafE² TC(s)**
A	Visual inspection	In the event of any other inspection/test	TC 1
B	Periodic verification of the final circuit of the electrical installation until the input terminals of the DC EVCS	5 resp. 3 years	TC 1, TC 4
C	RCD(s) inside/outside the DC EVCS:		
C1	- Pressing the test button	According to manufacturer, min. every 6 months or after fault	n/a
C2a	- RCD outside of the DC EVCS: Verification according to OVE E 8101 [2] resp. IEC 60364 [16] part 6; (if applicable) verification of the DC fault current detection (e.g. RDC-DD)	According to the verification intervals valid for the supplying electrical installation	n/a
C2b	- RCD inside the DC EVCS: Verification based on OVE E 8101 [2] resp. IEC 60364 [16] part 6; (if applicable) verification of the DC fault current detection (e.g. RDC-DD)	5 resp. 3 years	n/a
D	SPD indicator check (if no LPS installed)	Not required for automatic monitoring, otherwise together with any other inspection and after lightning strikes	n/a
E	Periodic verification of the LPS incl. SPD indicator check	In accordance with the documentation of the electrical installation or national regulations	n/a
F	Functional test of the insulation monitoring (e.g. IMD)	5 resp. 3 years	TC 6
G	Insulation resistance test of the charging cable (if active liquid cooled check the cooling circuit)	5 resp. 3 years	TC 3
H	Test of emergency stop (press emergency stop button, if applicable)	5 resp. 3 years	TC 14
I	Continuity of the protective conductor	5 resp. 3 years	TC 2
J	Test of emergency stop via disconnection of a communication conductor (e.g. CP)	5 resp. 3 years	TC 9 (resp. 7, 10 & 13)
K	Measurement of PP resistor	5 resp. 3 years	TC 8

Keys to Table 4:

CP .... Control pilot
LPS .... Lightning protection system
n/a .... Not applicable
PP .... Proximity pilot
RCD .... Residual current device
RDC-DD . Residual direct current detection device
SPD .... Surge protection device

6 Summary and Outlook

In the course of the ProSafE² research project a method as well as test procedures for the periodic verification of DC electric vehicle charging stations (DC EVCS) in terms of protection against electric shock resp. electrical safety was developed. Furthermore, a testing device demonstrator (grid independent electric vehicle emulator with possibility of fault emulations, max. 120 kW @ 1000 V_{DC} resp. 200 A_{DC}) has been developed and built. With the help of this demonstrator six laboratory resp. field tests at five different charging stations have been carried out to evaluate practical usability of the test cases as well as to get an impression of the real behavior of commercially available DC EVCS in terms of protective measures. Additionally, the five tested charging stations were evaluated regarding their efficiency as well as power quality issues.

The majority of the DC charging stations tested did not show any significant defects resp. shortcomings. The DC EVCS tested broadly complied with IEC 61851-23 ED1 [14], the product standard valid at the time of production. Also, it's worth mentioning, that some charging stations reacted completely different to individual test cases / faults. In some cases, a couple of DC EVCS reacted on faults and terminated the actual charging process, but not within the standardized break time. (In terms of risk assessment also see [25] and [26].) Beside protection against electric shock (protective measures) an additional aspect was the energy efficiency of DC charging stations and power quality issues, see also Figure 4 and [10]. All detailed results of the laboratory as well as field tests (incl. the results for complying with the new product standard IEC 61851-23 ED2 [15]) are summarized in Table 3.

The findings of the project were actually transferred to the national standardization committee 'OVE AG Ladestationen' (en. OVE working group on charging stations) to include them in the new edition of the OVE Technical Specification (TS) R 30 [18]. This TS has been published soon after the end of ProSafE² project on March 1st, 2025. As a further step, the real-life experience with the new OVE TS R 30 [18] as well as feedback from the field are going to be collected in the next months to discuss it within the working group of ProSafE². Also, it is planned to publish a new standardized verification report to harmonize the documentation of the periodic verification of DC electric vehicle charging stations (comparable to the already existing report for AC EVCS [27]).

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References

[1] *IEC 60364-6:2016 – Low voltage electrical installations – Part 6: Verification*, IEC, Geneva, Switzerland.

[2] *OVE E 8101:2019+AC1:2020 – Low-voltage electrical installations (consolidated version, original in German)*, based on [16], OVE, Vienna, Austria.

[3] *Fluke FEV300 EV Charging Station Test Adapter*, Fluke, https://www.fluke.com/en-gb/product/electrical-testing/installation-testers/fev300, accessed 2025-03-12.

[4] *A 1532 XA EVSE adapter*, Metrel, https://www.metrel.si/en/shop/EIS/emobility/a-1532-xa-evse-adapter.html?[...]., accessed 2025-03-12.

[5] *PROFITEST MXTRA installation tester*, GMC Instruments, https://www.gossenmetrawatt.de/en/products/[...]/profitest-mxtra/, accessed 2025-03-12.

[6] *CA 6117 installation tester*, Chauvin Arnoux, https://catalog.chauvin-arnoux.at/at_en/c-a-6117.html?___from_store=at_de, accessed 2025-03-12.

[7] *Easy Chester – The Next-Gen EV Charger Tester for CCS and CHAdeMO*, comemso, https://comemso.com/ccs-evse-tester/, accessed 2025-03-12.

[8] *IEC 61851 series – Electric vehicle conductive charging system*, IEC, Geneva, Switzerland.

[9] Fuernschuss, M., Herbst, D., Reichel, P., Stahleder, D., Auer, C., Schmautzer, E. & Schuerhuber, R., *Electromagnetic interference and the effect of low voltage protective measures at electric vehicle charging stations*, Paper, e+i elektrotechnik und informationstechnik, issue 7-8/23, Springer-Verlag, OVE Austrian Electrotechnical Association, Vienna, Austria, 2023.

[10] Hinteregger, A., Stahleder, D., Ledinger, S., Herbst, D., Fuernschuss, M., Stainer, T. & Reicher, P., *Periodic Verification of DC EVCS: results of the ProSafE² (Protection, Safety and Efficiency of Electric Vehicle Charging Stations) Research Project*, CIRED 2025 Conference, Paper 134 (paper accepted), Geneva, Switzerland, 2025.

[11] Herbst, D., Fuernschuss, M., Schuerhuber, R., Reichel, P., Stahleder, D., Auer, C. & Schmautzer, E., *DC Electric Vehicle Charging Stations – A Periodic Verification Approach*, paper and presentation, EVS37 2024: 37th Electric Vehicle Symposium – Seoul, Republic of Korea, 2024.

[12] *IEC 61557 series – Electrical safety in low voltage distribution systems up to 1 000 V AC and 1 500 V DC – Equipment for testing, measuring or monitoring of protective measures*, IEC, Geneva, Switzerland.

[13] *IEC 61851-1:2017+COR1:2023 – Electric vehicle conductive charging system – Part 1: General requirements*, IEC, Geneva, Switzerland.

[14] *IEC 61851-23:2014+COR1:2016 (ED1) – Electric vehicle conductive charging system - Part 23: DC electric vehicle supply equipment*, IEC, Geneva, Switzerland.

[15] *IEC 61851-23:2023 (ED2) – Electric vehicle conductive charging system - Part 23: DC electric vehicle supply equipment*, IEC, Geneva, Switzerland.

[16] *IEC 60364 series – Low-voltage electrical installations*, IEC, Geneva, Switzerland.

[17] *OVE Technical Specification (TS) R 30:2020-08-01 – Safe operation of electrical, conductive charging systems for electric vehicles with a rated voltage of up to AC 1000 V and DC 1500 V (original title in German)*, OVE, Vienna, Austria.

[18] *OVE Technical Specification (TS) R 30:2025-03-01 – Safe operation and periodic verification of electrical, conductive charging systems for electric vehicles with a rated voltage of up to AC 1000 V and DC 1500 V (original title in German)*, OVE, Vienna, Austria.

[19] Herbst, D., Schaupp, C., Reichel, P., Fuernschuss, M., Hinteregger, A. & Stainer, T., *ProSafE² research project: Test procedure developed for direct current charging stations (original in German)*, e+i elektrotechnik und informationstechnik, issue 1/25, Springer-Verlag, OVE Austrian Electrotechnical Association, Vienna, Austria, 2025.

[20] *IEC 61000-3-12:2011 – Electromagnetic compatibility (EMC) - Part 3-12: Limits - Limits for harmonic currents produced by equipment connected to public low-voltage systems with input current > 16 A and ≤ 75 A per phase*, IEC, Geneva, Switzerland.

[21] *IEC 61000-2-4:2024 – Electromagnetic compatibility (EMC) - Part 2-4: Environment - Compatibility levels in power distribution systems in industrial locations for low-frequency conducted disturbances*, IEC, Geneva, Switzerland.

[22] *OVE EN 50160:2020-12-01 - Voltage characteristics of electricity supplied by public electricity networks*, IEC, Geneva, Switzerland.

[23] *TOR D1 V2.0 – Technical and organizational guidelines for operators and users of grids – Part D: Special technical guidelines – Main section D1: Electrical equipment relevant to system perturbations; Threshold values for the necessary assessment by the grid operator and specifications for electromagnetic compatibility (original title in German)*, e-control, Vienna, Austria, 2004.

[24] *TOR D2 V2.4 – Technical and organizational guidelines for operators and users of grids – Part D: Special technical guidelines – Main section D2: Guideline for the evaluation of system perturbations (original title in German)*, e-control, Vienna, Austria, 2017.

[25] *IEC 60479-1:2018 – Effects of current on human beings and livestock – Part 1: General aspects*, IEC, Geneva, Switzerland.

[26] *IEC 60479-2:2019 – Effects of current on human beings and livestock – Part 2: Special aspects*, IEC, Geneva, Switzerland.

[27] *Verification report on an electric vehicle charging station (mode of charging 1-3) (original title: „Prüfbefund über eine Stromtankstelle (Ladebetriebsart 1-3)“)*, Kuratorium für Elektrotechnik, shop.kfe.at/[...]/351/pruefbefund-[...]-stromtankstelle-ladebetriebsart-1-3[...], accessed 2025-03-12.

Presenter Biography

Daniel HERBST studied electrical engineering, specialization in power engineering at Graz University of Technology (TU Graz). Within the scope of his current work at the Institute of Electrical Power Systems at TU Graz, he deals with the topics of protection concepts at low voltage level (ongoing PhD subject), protection against electric shock (protective measures), standardization, safety of DC electric vehicle charging stations as well as measurement technology in electrical power systems. He is also active in various (inter)national standardization committees at OVE and IEC. Before working at the university, he was part of the team of a consulting company for electrical engineering in the areas of planning, tendering and construction supervision for more than five years.