Insights and best practice

EMC COMPLIANCE KNOW-HOW

TECHNICAL NOTE 0119

ELECTRIC VEHICLE

CONDUCTED EMISSION AND IMMUNITY TESTING

IN CONFIGURATION REESS AS PER UNECE REGULATION 10 (REVISION 6)

Overview

ECE R10 stands as a legally binding document that outlines the defined limits and test procedures for both vehicles and ESAs (electrical sub-assemblies). Its applicability extends to both non-electric and electric vehicles, encompassing crucial tests such as radiated emission and radiated immunity.

With the introduction of Revision 5, ECE R10 incorporated specific requirements for electrical vehicles, including the charging mode of REESS (rechargeable electrical energy storage system) connected to the power grid. Building upon this foundation, the latest Revision 6, published in October 2019, further expands the scope of EMC testing. Notably, it introduces conducted emission and immunity tests, such as burst, surge, harmonics, and flicker, which take center stage in this technical note.

Introduction

The UNECE Regulation 10 Revision 6 (ECE R10) was published within the agreement of the states of the united nations (UN) regarding full vehicle EMC testing. This regulation is part of the E-marking process for vehicles which is almost similar to tests for CE-marking in the industrial area.
ECE R10 is a legally binding document which defines the limits and test procedures for vehicles and ESAs (electrical sub-assemblies).

Generally the ECE R10 is applicable for non-electric vehicles also as for electric vehicles. Tests like radiated emission and radiated immunity need to be performed on both, non-electrical and electrical vehicles.

With Revision 5 of ECE R10 requirements for electrical vehicles like the REESS (rechargeable electrical energy storage system) charging mode coupled to the power grid were added.
The latest revision 6 was published in October 2019 and besides other well known EMC tests it includes conducted emission and immunity tests such as burst, surge, harmonics and flicker which will be the main focus of that technical note.

It is required to test conducted immunity or emission while the e-vehicle is in charging mode connected to the power grid.

A link between the industrial area and the automotive area has been made since electric vehicles are connected to AC mains while charging.

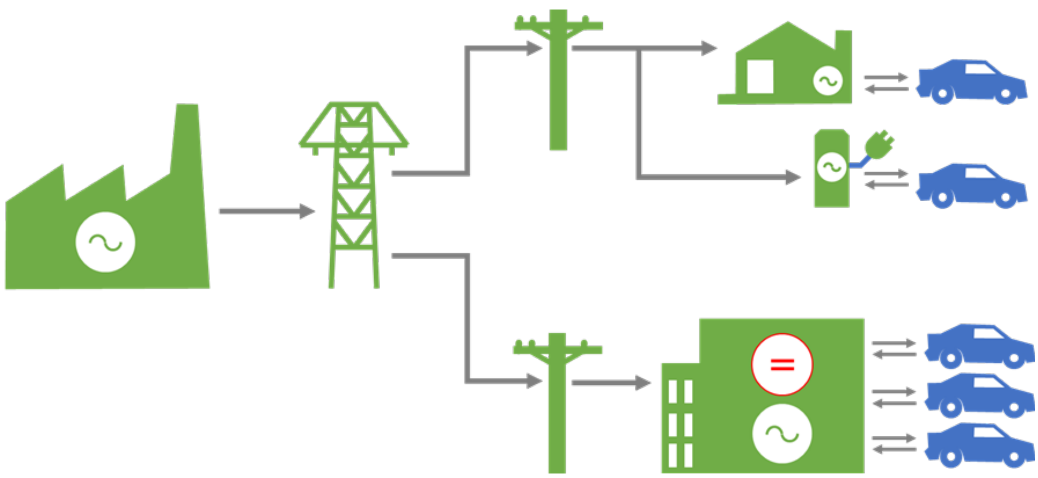


Figure 1
Connection between industrial area (AC mains) and automotive area (e-vehicles)

Figure 1: Connection between industrial area (AC mains) and automotive area (e-vehicles)
That means that EMC tests which are normally required to be performed on devices made for the industrial area are now also required to be performed on electrical vehicles that are connected to AC mains while charging.

In case of testing a vehicle according to the requirements included in ECE R10 we are speaking about full vehicle testing and not about component testing (except ESAs) which is normally the case in the low voltage area where standards like LV 124 or LV 148 are applicable.

General requirements as per ECE R10

Since the release of ECE R10 Revision 5 the REESS charging mode coupled to the power grid has been added.

This requirement applies primarily to e-vehicles, as an e-vehicle is charged using the on-board charger, which is connected to power mains to charge the batteries.
A more detailed definition of the REESS charging mode coupled to the power grid is shown as follows.

REESS charging mode coupled to the power grid
REESS is the abbreviation for rechargeable (electrical) energy storage system. The REESS provides electric energy for electric propulsion of the vehicle.

According to ECE R10 tests like conducted emissions (e.g. Harmonics) and immunity to conducted disturbances (e.g. Burst) should be tested in configuration REESS charging mode coupled to the power grid where it is required. That means that the on-board-charger of the EUT need to be connected to the power grid and the charging status of the battery should be between 20 % and 80 %.

Electrical/electronic sub-assembly (ESA)
Another abbreviation which is often mentioned in ECE R10 is ESA which means electrical/electronic sub-assemblies. ESA is an electrical and/or electronic device or set(s) of devices intended to be part of the vehicle, together with any associated electrical connections and wiring, which performs one or more specialized functions.

The requirement of a charging status between 20 % and 80 % in configuration REESS charging mode coupled to the power grid also applies for ESAs while testing according to ECE R10.

Required tests in configuration "REESS charging mode coupled to the power grid"
The following table shows the tests and references to basic standards which are included in ECE R10.

Chapter	Annex	Description	Standard
7.2 / 7.10	4/7/5	Broadband electromagnetic radiation	RF Emission Test
7.3 / 7.11	11/17	Harmonics on AC power lines	IEC 61000-3-2/-12
7.4 / 7.12	12/18	Voltage changes, voltage fluctuations and flicker	IEC 61000-3-3/-11
7.5 / 7.13	13/19	Emission of RF conduced disturbances on AC or DC power lines	CISPR 16-2-1, IEC 61000-6-3
7.6 / 7.14	14/20	Emission of RF conducted disturbances on network and telecommunication lines	CISPR 22 , IEC 61000-6-3
7.7 / 7.15	6/7/19	Immunity to electromagnetic radiation	ISO 11451-2
7.8 / 7.16	15/21	Immunity to electrical fast transients / burst on AC or DC power lines	IEC 61000-4-4
7.9 / 7.17	16/22	Immunity to surge conducted on AC or DC power lines	IEC 61000-4-5
7.18	6/7/19	Specifications concerning immunity of ESAs to electromagnetic radiation	ISO 11452 series
7.19	10	Specifications concerning the immunity of ESAs to transient disturbances along 12 /24 V supply lines	ISO 7637-2

Table 1
Test requirements in configuration REESS

The tests shown in the table are applicable for full vehicle testing including the chapters 7.2 to 7.9 and regarding electronic sub assemblies from chapter 7.10 to 7.19.

ECE R10 only refers to already existing tests that are defined in other "basic" standards from the industrial or automotive area. That means that ECE R10 does not define its own new tests.

Conducted test setup according to ECE R10 in REESS charging mode

As already written ECE R10 requires to test electrical vehicles or ESA's, which are intended to be charged through public mains, in REESS mode coupled to the grid.

That requirement demands to connect a suitable AC or DC source to the on board charger of the e-vehicle or to the ESA.

The charging status should lay between 20 and 80 % which can only be ensured by using an EVSE (electric vehicle supply equipment) simulator that communicates with the e-vehicle. Further test equipment is required to measure emissions or apply/ couple pulses onto the supply lines.

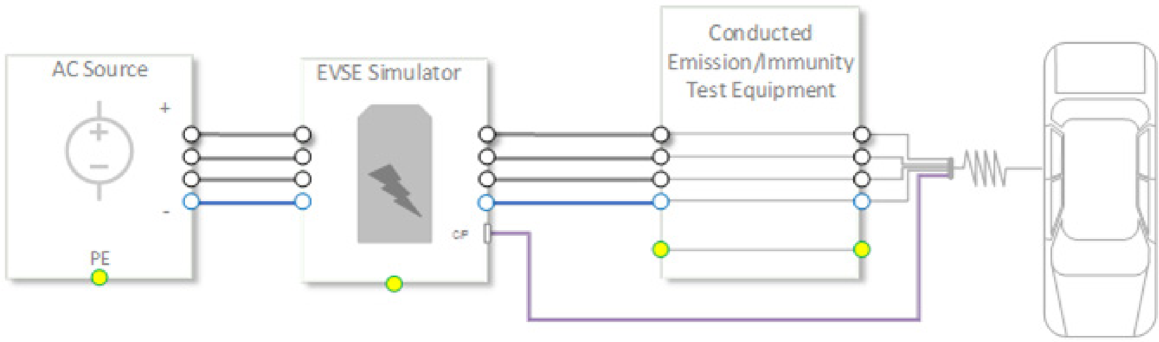


Figure 2
General AC test setup for conducted immunity an emission testing

There are different ways of charging an e-vehicle. The ways of charging are called mode 1; 2; 3; 4. Mode 1; 2; 3 is "AC charging". The test setup for AC charging is almost straightforward using a grid simulator or source. Usually it is not the grid that is used but some kind of electronic source combined with an EVSE, which is normally a charging station simulator that is also shown in Figure 2.

The source delivers the AC supply to the EVSE which in turn is connected to the conducted emission or immunity test equipment and to the EUT.

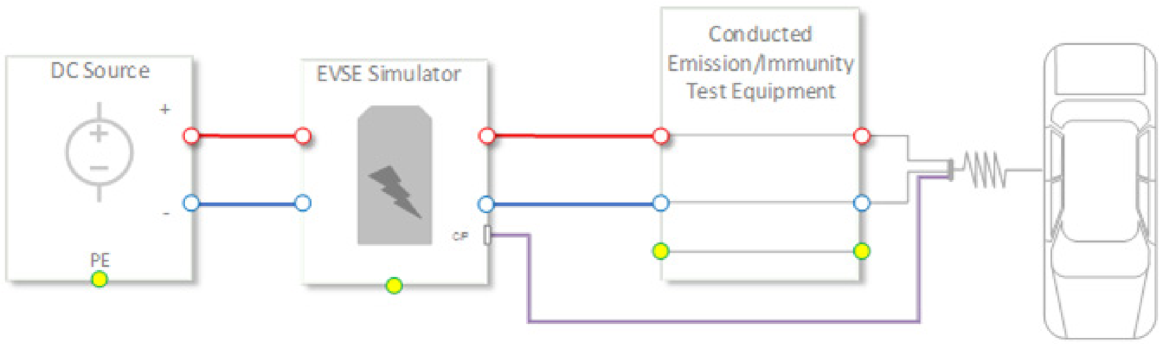


Figure 3
General DC test setup for conducted immunity an emission testing

For DC supply it is a very similar setup (shown in Figure 3) in comparison to the AC test setup. DC charging (Mode 4) is high power charging. Typically a high voltage DC charger can be found on highways for fast charging which enables the possibility to charge an e-vehicle in 30 minutes to get a state of charge of approx. 80 %.

The challenge while testing according to ECE R10 is the circumstance that the charging status in REESS mode should lay between 20 and 80 % which could be a problem while using a DC fast charger that charges the e-vehicle in probably 30 minutes up to 80 %. That short time window may be not enough to perform the whole test. Means that the test will be outside of the conditions according to ECE R10.

There are several ways to discharge the e-vehicle while or between testing to ensure the test conditions at 20 up to 80 % state of charge.

One way is driving around in the parking lot or another way is using a dynamometer which is installed on the test bench to “roll off” the energy.

The third solution seems to be the most effective method by discharging the battery through the charging station simulator or source. This method is much faster with the added advantage of recovering the electrical energy to the grid.

The following chapters describe conducted emission and immunity tests required in ECE R10 with an EUT set in REESS mode coupled to the grid.

Test requirements for Harmonics measurement in REESS charging mode

Harmonics measurement as per IEC 61000-3-2/-3-12 is required in a lot of product standards in the industrial area where a device is connected to mains, no matter if it is one or three phase supplied.

Since on-board chargers and ESAs included in e-vehicles are directly connected to AC mains while charging it is required to measure harmonics according to ECE R10 which refers to the basic standards IEC 61000-3-2 and IEC 61000-3-12. In special cases and if a supply current of more than 75 A is required, the developer of the car needs to discuss with the DSO (distribution system operator) about the test requirements.

Harmonics are sinusoidal voltages or currents having frequencies that are whole multiples of the frequency at which the supply system is designed to operate (e.g. 50 Hz or 60 Hz). Any signal component having a frequency which is not an integer multiple of the fundamental frequency is designated as an interharmonic component or referred more simply as an interharmonic. In a linear system the characteristics of the voltage and the current are manifested by a sinusoidal progress. The current contains only one frequency, the mains frequency or the so called fundamental. Beside this e.g. 50 Hz component there are no other frequencies and there are no harmonic components. But this is not the reality.

The main purpose of harmonics measurement is to limit the distortion created by equipment connected to the mains supply. The distortion of mains supply can be limited by reducing the current harmonic content delivered by the connected equipment. Therefore the generation of current at unwanted frequencies ought not to be allowed to grow without limit, because it may impact the public mains. In consequence the harmonic content of each on the public networks connected items has to be limited. Furthermore the same item has to show sufficient immunity in order to continue to operate as intended in the presence of a certain allowed harmonic distortion.

While testing harmonics according to the requirements of ECE R10 the vehicle need to be situated in REESS mode, coupled to the power grid until the AC current reaches a minimum of 80 % of the starting value.

It is required to measure the even and odd harmonics up to the 40th harmonic.
The test setup need to be configured by using an AC source, a charging station emulator/simulator, a harmonics analyser and the EUT as follows**:**

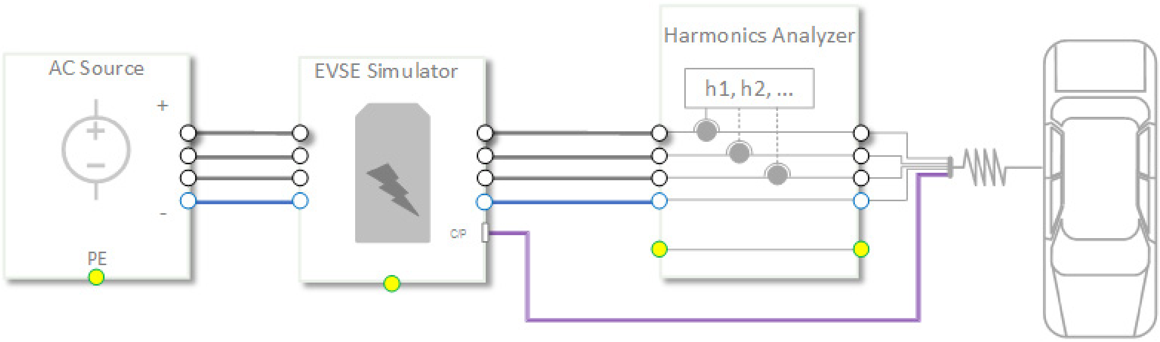


Figure 4
: *Test Setup for Harmonics testing*

As can be seen in Figure 4 the communication connection, shown in violet, won't be tested. That communication connection between EVSE and e-vehicle is required to set the e-vehicle into charging mode.

Table 2 lists the different standards for harmonic testing depending on the EUT current:

Table 2
Test Requirements for Harmonics testing

Current	Standard	Condition
≤ 16 A / phase	IEC 61000-3-2	Class A
> 16 A to ≤ 75 A / phase	IEC 61000-3-12	According flow chart (unconditional or conditional connection with RSCE)
> 75 A	None	agreement with DSO

The following technical requirements regarding the test equipment need to be kept:

Table 3
Test Equipment Requirements for Harmonics testing

Test Equipment Requirements	
Max. voltage	3 x 480V ACph-ph
THD	< 0.5 %
Analyzer	according IEC 61000-4-7
Frequency range	50 Hz – 2 kHz

Test requirements for Flicker measurement in REESS charging mode

Flicker measurement is like harmonic measurement mainly intended to be performed in the industrial area where a device is connected to mains, whether it is one or three phase supplied by AC.

Basic standards for flicker measurement are IEC 61000-3-3 and IEC 61000-3-11 which are also the standards ECE R10 refers to.

Voltage fluctuations caused by varying load currents may influence luminance or spectral distribution of lightning systems. The impression of unsteadiness of visual sensation induced by this light stimulus is called flicker. Whereby the limits on the voltage fluctuations are based on the equivalent levels of light flicker in a 60 W incandescent bulb which is perceived as disturbing.

Potential sources of voltage fluctuations are the followings:

- Start procedure of motors
- Motors with turbulent running
- Soldering machines
- Arc welding ovens
- Load control by voltage or frequency switching
- In general all other loads with changing current consumption characteristic

The main purpose of flicker measurement is to limit the variations in voltage caused by equipment connected to the power supply system.

Limits for flicker are defined in IEC 61000-3-3 which states that the limit for short term flicker (P¬ST) is PST = 1 over an observation time of TP = 10 min. The long term flicker value (PLT) results from consecutive PST values over an observation time of TP = 2 hours (12 x 10 min). The limit for PLT is 0.65.

To calculate the PLT out of PST the following formula need to be used

$$P_{LT} = \sqrt[3]{\frac{1}{n} * \sum_{i=1}^{n} P_{ST,i}^{3}}$$

If it comes to flicker measurements on electrical vehicles it is required to perform the measurement while the vehicle is in REESS mode, coupled to the power grid with a charging state between 20 % and 80 %.

Therefore an AC source, a charging station simulator, a flicker meter and the EUT is required to build the test setup, shown in Figure 5:

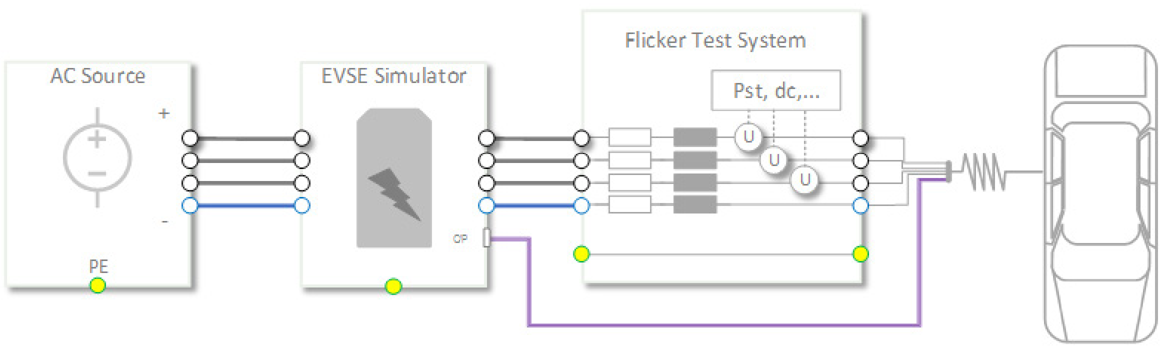


Figure 5 *Test Setup for Flicker testing*

As can be seen in Figure 4 the communication connection, shown in violet, won't be tested. That communication connection between EVSE and e-vehicle is required to set the e-vehicle into charging mode.

Table 2 lists the different standards for harmonic testing depending on the EUT current:

Current	Standard	Condition
≤ 16 A / phase	IEC 61000-3-3	PST ≤ 1, PLT ≤ 0.65, d(t) ≤ 500ms, dc ≤ 3.3%, dmax ≤ 6%
> 16 A to ≤ 75 A / phase	IEC 61000-3-11	
> 75 A	None	agreement with DSO

Table 4
Test Requirements for Flicker testing

The following technical requirements regarding the test equipment need to be kept:

Test Equipment Requirements	
Flickerimpedance	according IEC 60725
Flickermeter	according
IEC 61000-4-15	according IEC 61000-4-7
THD	< 3%

Table 5
Test Equipment Requirements for Flicker testing

Test requirements for Burst in REESS charging mode

As already written conducted tests from the industrial area are included in the test requirements of ECE R10 regarding e-vehicles or ESAs which are intended to be coupled to the power grid. Therefore, it is also required to perform burst/ EFT testing on the OBC (On-Board Charger) or ESA according to the international standard IEC 61000-4-4.

Through opening and closing of contacts in electrical circuits it comes to sparks over the electrical contacts which result in high frequency interaction with the capacitive and inductive mains net. This phenomenon is called burst or EFT (electrical fast transient).
Bursts are sporadic, pulse-shaped, low-energy, high-frequency, broadband disturbances that occur in pulse packets.

The basic standard IEC 61000-4-4 describes the pulse form of 5/50 ns with amplitudes of 500 V, 1000 V, 2000 V and 4000 V with a repetition frequency of 5 kHz or 100 kHz. In reality it is possible that amplitudes up to 10 kV occur with different repetition frequencies.

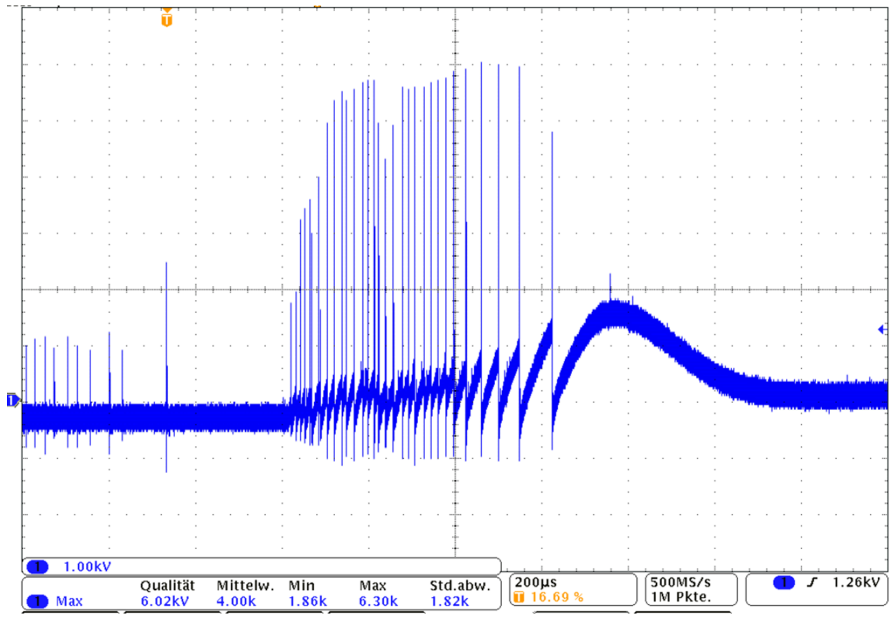


Figure 6
Measured Burst pulses

Results of a burst are for example disturbances of signals in the process data work which could cause logic errors and other consequences. Furthermore, bursts can influence analogue signals and controls.

Burst pulses should be tested according to the requirements of ECE R10 with a test voltage of ± 2 kV for EUTs connected to AC and DC supplies.

The EUT need to be set in REESS mode, coupled to the grid while testing. The motor need to be shut off and every auxiliary equipment inside the EUT need to be shut off too.
While testing the vehicle is not allowed to set in motion.

The test setup for AC supplied EUTs is shown in Figure 7 which includes an AC source, the EVSE which communicates with the EUT, a burst generator with a suitable single or three phase coupling network and the EUT (e-vehicle).

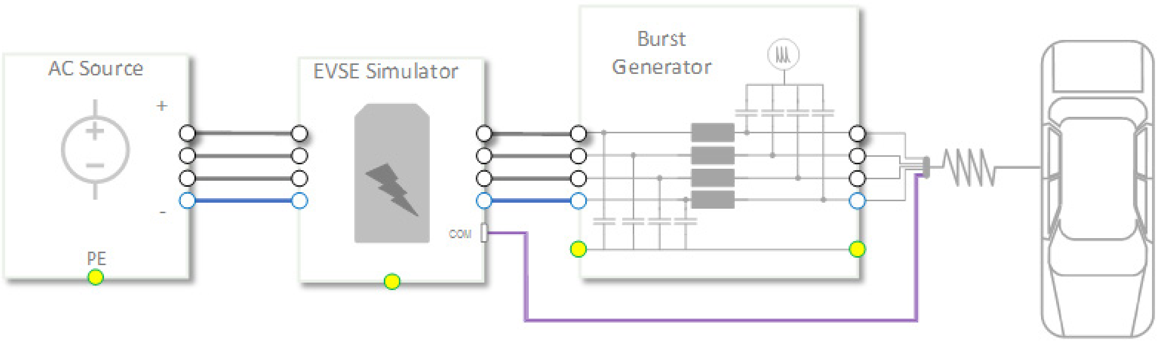


Figure 7
Test Setup for Burst testing, AC

The following table shows the test requirements included in ECE R10 for AC supplied EUTs:.

Burst AC	
Standard	IEC 61000-4-4
Pulse	± 2kV 5 ns / 50 ns, 5kHz, 1 minute
Supply	Up to 690 VAC Up to 80 A typ.

Table 6
Test Requirements for Burst testing AC

The DC test setup is shown in the following picture (Figure 8) which includes a DC source, the EVSE, a burst generator with a suitable DC coupling network and the EUT.

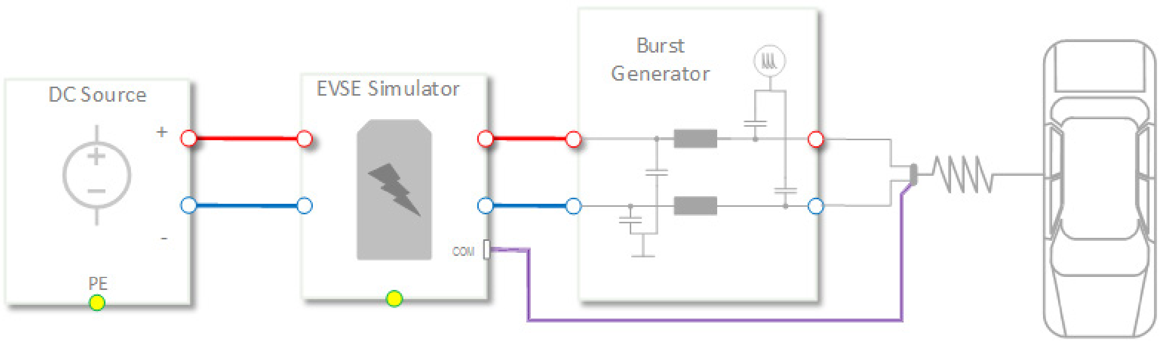


Figure 8
Test Setup for Burst testing, DC

The following table shows the test requirements included in ECE R10 for DC supplied EUTs

Burst DC	
Standard	IEC 61000-4-4
Pulse	± 2kV 5 ns / 50 ns, 5kHz, 1 minute
Supply	Up to 1000 VDC Up to 200 A

Table 7
Test Requirements for Burst testing DC

Test requirements for Surge in REESS charging mode

Surge as phenomenon is a simulation of atmospheric discharges with a maximum peak value of current. Through switching operations of electromechanical compensation processes surge impulses could also occur because of switching of capacitive loads in high voltage circuits or switching of loads in low voltage systems.

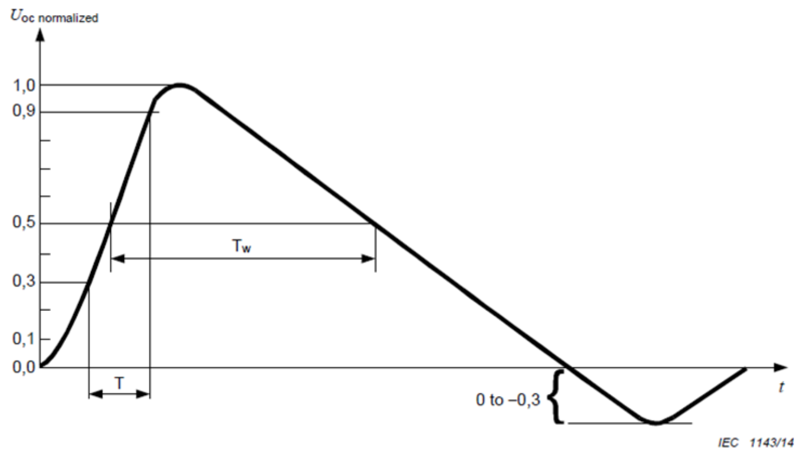
Further sources for surge impulses are for example switching of resonance circuits with thyristors, short circuits and flashovers in insulators or triggering of protective elements such as surge arrestors and fuses.

Surge tests required in ECE R10 should be performed according to IEC 61000-4-5 on AC- and DC- supply lines with a test voltage of ± 2 kV.

The EUT should be set up in REESS mode coupled to the grid with a state of charge between 20 % and 80 %.

While testing the vehicle is not allowed to set in motion.

The surge impulse definition with a pulse form of 1.2/50 µs is shown in the following picture and is basically defined in IEC 61000-4-5 Edition 3.1 (2017-08).



Front time: T_f = 1,67 × T = 1,2 µs ± 30 %
Duration: T_d = T_w = 50 µs ± 20 %

Figure 9
Surge impulse definition as per IEC 61000-4-5 (Source: IEC 61000-4-5 Ed.3.1 (2017-08))

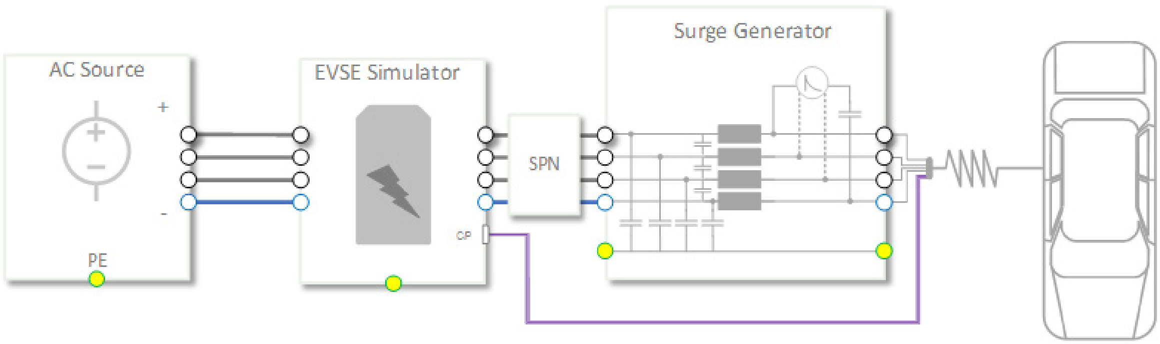


Figure 10
Test Setup for Surge testing, AC

The test setup shown in Figure 10 includes an AC source, an EVSE simulator to establish communication to the e-vehicle, a surge protection network to ensure a minimal residual voltage that comes from the surge generator in connection to a coupling network (SPN) which is connected to the EUT.

Table 8 lists the test requirements for surge testing of AC supplied EUTs according to ECE R10.

Surge AC	
Standard	IEC 61000-4-5
Pulse	± 2 kV L-PE / ± 1 kV L-L 1.2 µs / 50 µs, 5 pulses 0/90/180/270 °
Supply	Up to 690 VAC Up to 80 A typ.

Table 8
Test Requirements for Surge testing AC

The following test setup shown in Figure 11 includes a DC source, an EVSE simulator, a surge protection network, the surge generator and a suitable coupling network for DC supply which is connected to the e-vehicle.

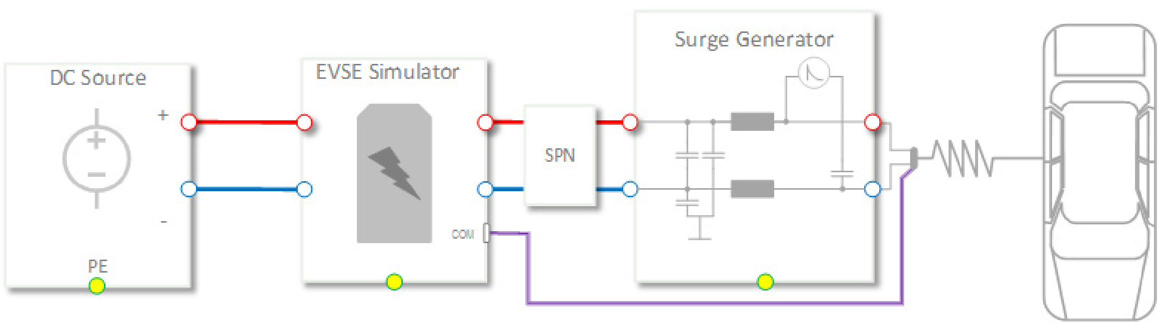


Figure 11
Test Setup for Surge testing, DC

The following table briefly lists the test requirements for surge testing of DC supplied EUTs according to ECE R10.

Surge DC	
Standard	IEC 61000-4-5
Pulse	± 0.5 kV L-PE / ± 0.5 kV L-L 1.2 µs / 50 µs, 5 pulses
Supply	Up to 1000 VDC Up to 200 A and higher

Table 9
Test Requirements for Surge testing DC

Challenge

All the conducted tests that were described in the chapters before require a source to be connected to the OBC of the e-vehicle. In order to ensure that the REESS charging mode coupled to the power grid requirement is met, an EVSE simulator has to be used in the test setups, described in the previous chapters, to put the e-vehicle into charging mode. Connected to an AC or DC source, the EVSE simulator provides the required power and establishes a communication to the e-vehicle, ensuring that a state of charge between 20 % and 80 % can be maintained.

The biggest challenge is to test within the limits of 20 % up to 80 % state of charge which could cause a problem because fast charging processes can charge an electric vehicle from 20 % up to 80 % in almost 30 minutes. The test time for most tests is longer than 30 minutes which makes it impossible to finish the test in that time frame.

To ensure that the test will be performed within the required state of charge over the test time, it is required to discharge the e-vehicle by either driving around, using a dynamometer or to discharge the battery through the charging station simulator or source.

Furthermore surge testing can cause problems in direction to the output ports of the source/ the EVSE because of the residual voltage that occurs at the EUT supply input of the coupling network. That residual voltage could destroy the outputs of either the source or the EVSE simulator. Therefore a surge protection network (SPN) can be used between source/ EVSE simulator and coupling network to limit the residual voltage to a lower value.

Furthermore it is required to use an almost ideal source with a very low THD to measure harmonics and flicker according to the requirements of ECE R10.