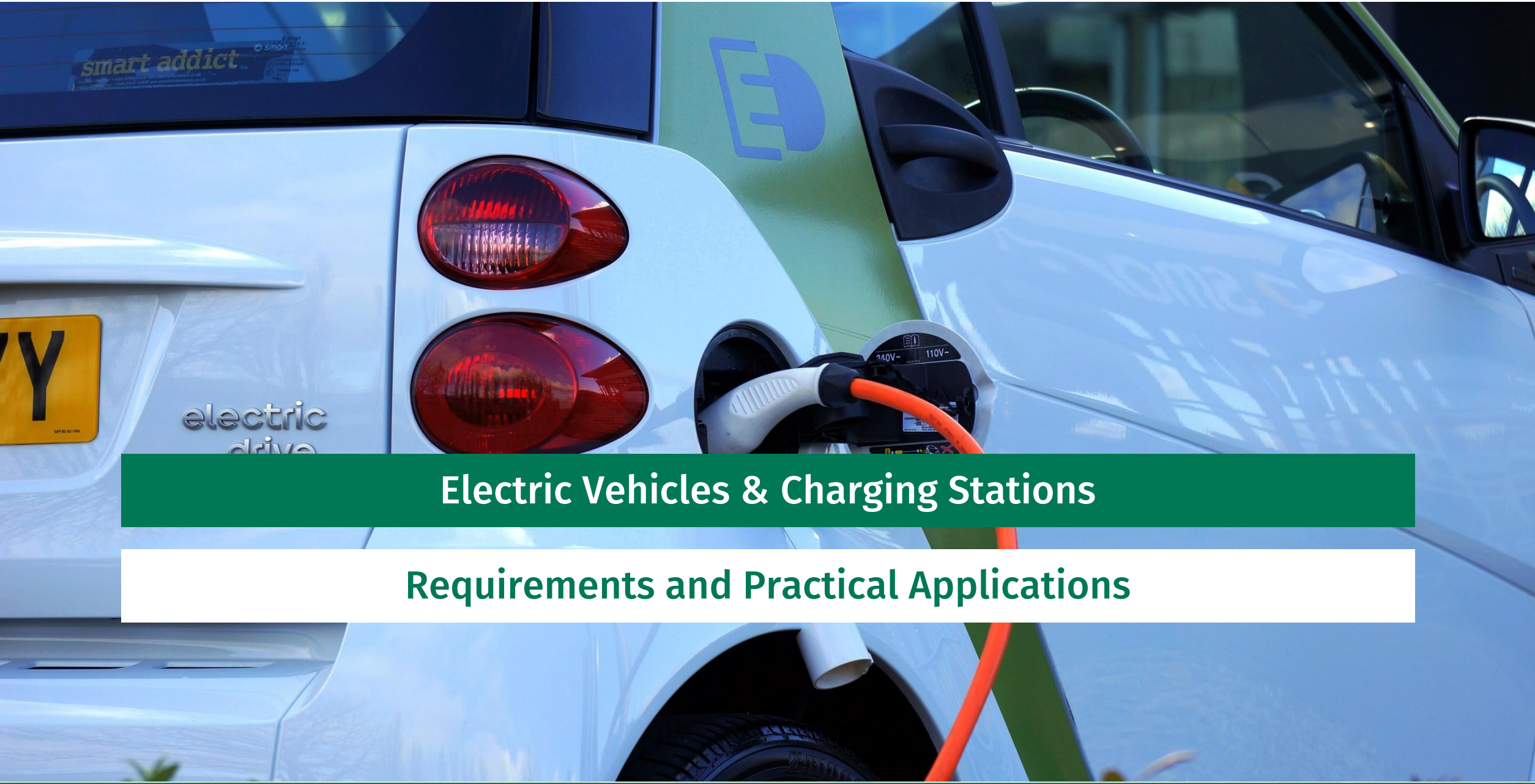




Electric Vehicles & Charging Stations

Requirements and Practical Applications

- ✓ Introduction
- ✓ Overview standardization
- ✓ Detailed discussion of specific issues
- ✓ Conclusion

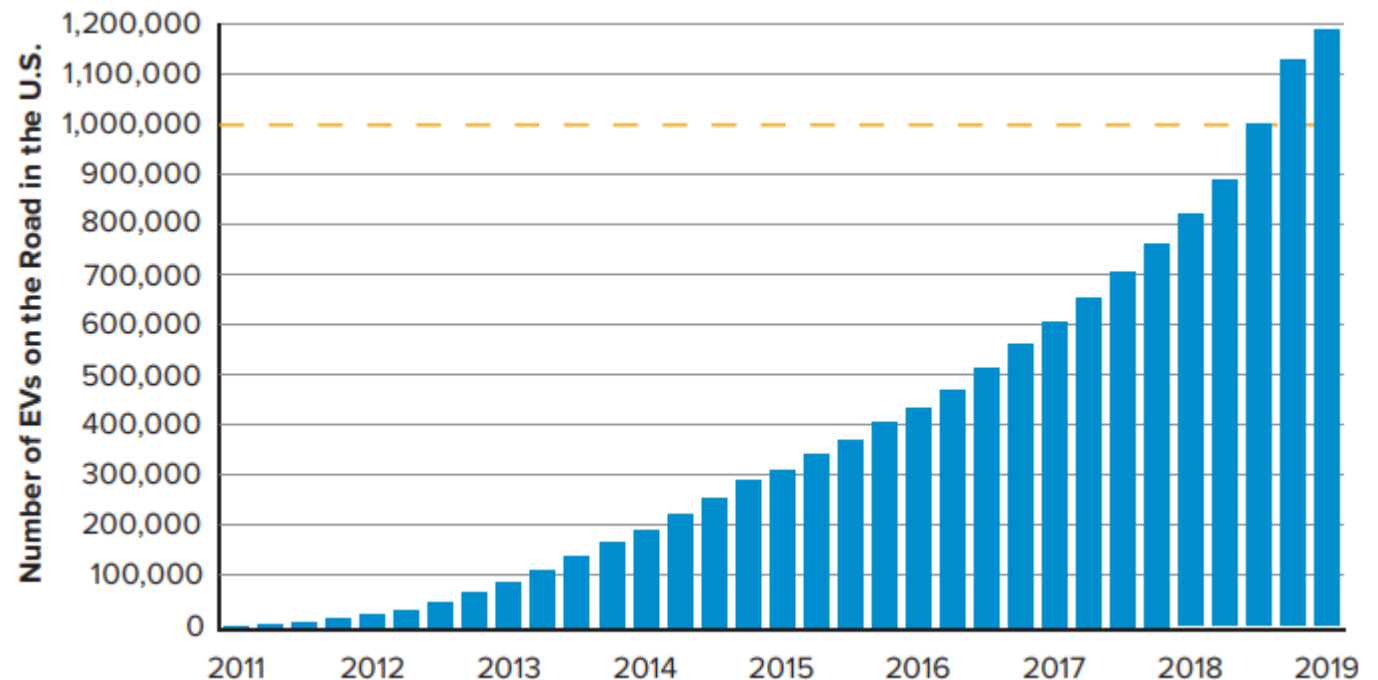
Introduction

Growth in sales of electric vehicles.

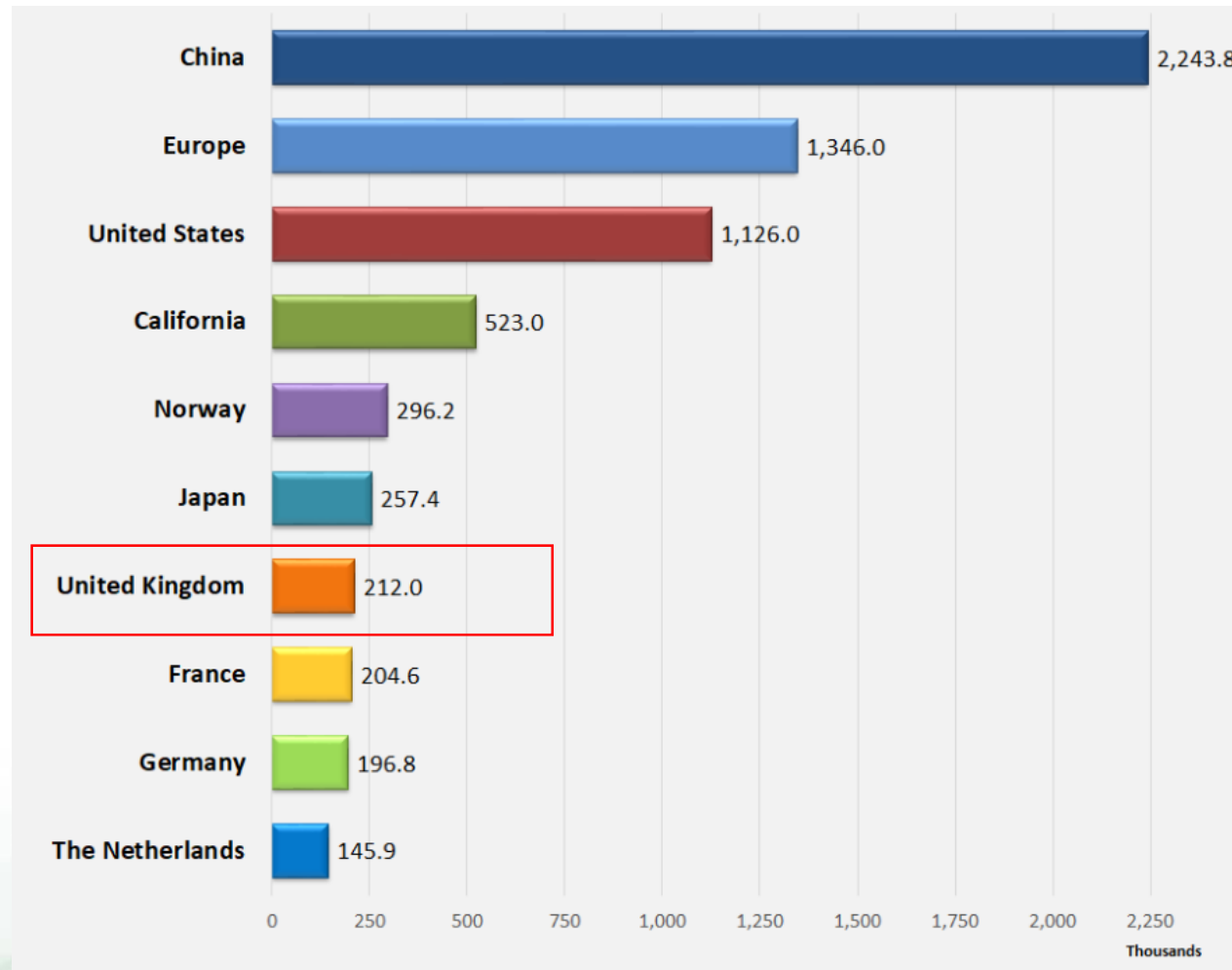
Increasing number of electric vehicle models available on the market.

Some countries want to have **ONLY** electric vehicles **on sale** by 2024

For example Sweden.

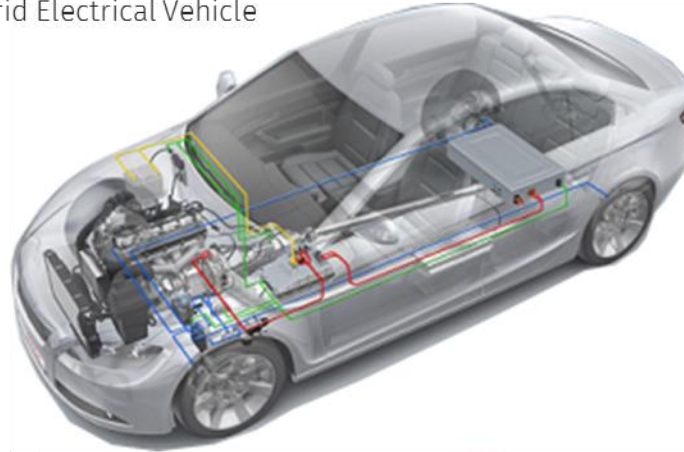


Introduction

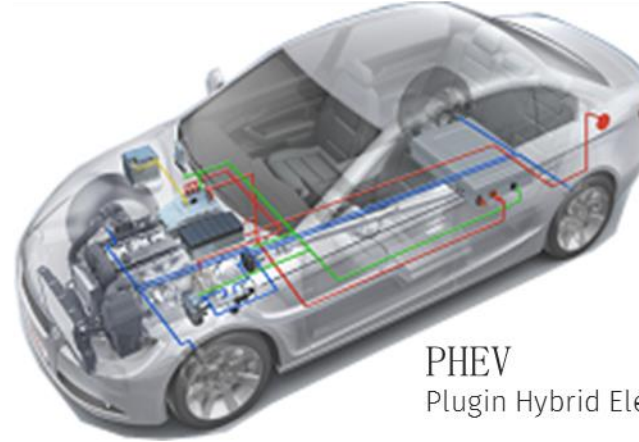


Types of Electric Vehicles

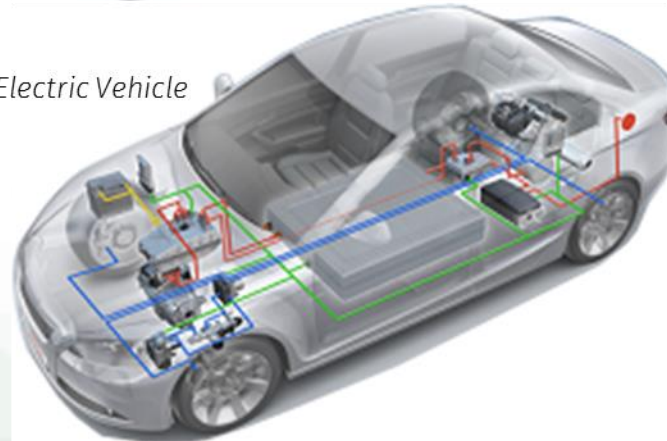
HEV
Hybrid Electrical Vehicle



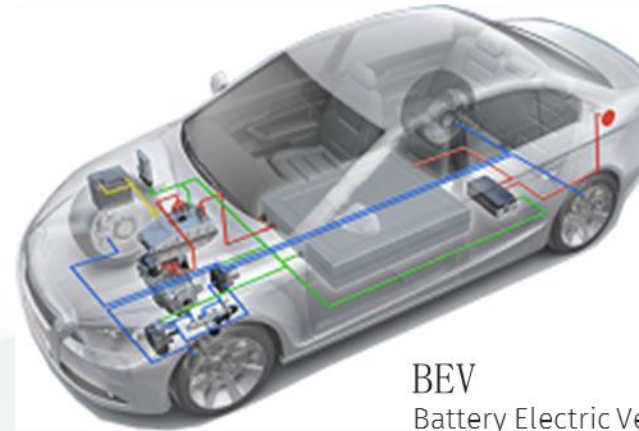
PHEV
Plugin Hybrid Electrical Vehicle



REEV
Range Extended *Electric* Vehicle



BEV
Battery Electric Vehicle



Types of Electric Vehicle Plugs

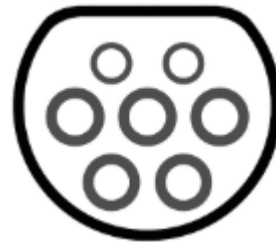
- Type 1 plug

- 7.4kW
- 230V/32Aac



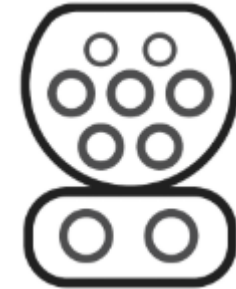
- Type 2 plug

- 22 – 43kW
- 400V/63Aac



- Combination plug

- 50 – 170kW
- 480V/300Aac



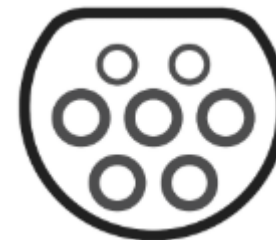
- Chademo plug

- 62.5kW
- 500V/125Adc
- 1000V/400Adc



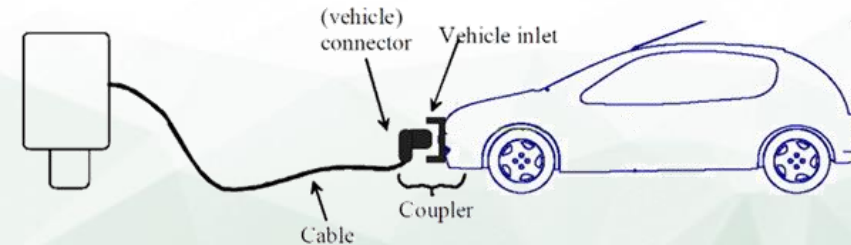
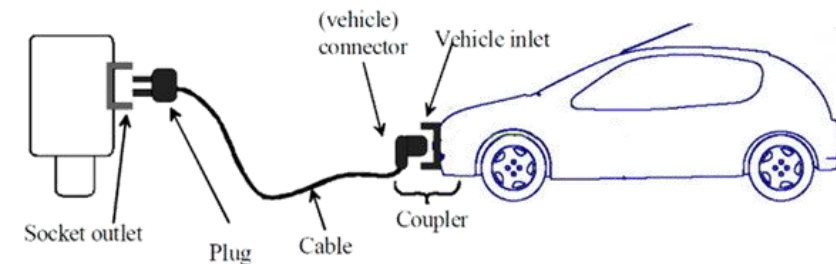
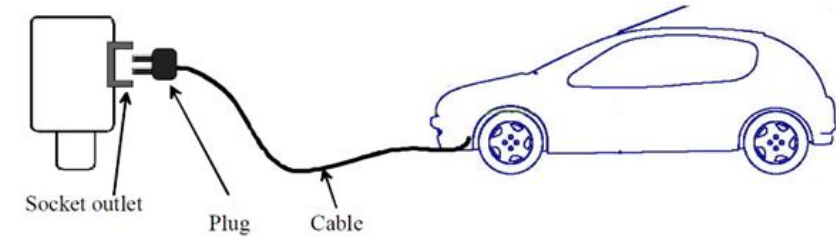
- Tesla supecharger plug

- 72 – 250kW
- 480V/400Adc



Electric Vehicle Charging Connections

- Case A connection
 - Cable not part of the charging station
 - Cable fixed on vehicle
- Case B connection
 - Cable not part of the charging station
 - Cable free at both ends
- Case C connection
 - Cable is part of the charging station



Electric Vehicle Charging Modes

- Mode 1
 - AC up to 250 V / 16 A or 3 x 480 V / 16 A
 - Not allowed in all countries
- Mode 2
 - AC up to 250 V / 32 A or 3 x 480 V / 32 A
 - In Cable Control Box (ICCB) required, e.g. pilot function
 - Normal socket
- Mode 3
 - Electrical Vehicle Supply Equipment (EVSE) always connected to AC power network
 - In Cable Control Box (ICCB) required, e.g. pilot function
 - Dedicated equipment
- Mode 4
 - DC Quick charging
 - dedicated EVSE
 - In Cable Control Box (ICCB) required, e.g. pilot function
 - Only case C connection

Overview of EMC Standards

IEC 61851 – 1	1000Vac and 1500Vdc
IEC 61851 – 21 – 1	1000Vac and 1000Vdc
IEC 61851 – 21 – 2	1000Vac and 1500Vdc
IEC 61980 – 1	1000Vac and 1500Vdc
ECE R-10 Rev. 5	

EMC relevant technical parameters

Parameter	Conventional vehicles	Electric vehicles
Onboard voltage	12 V / 24 V (48 V)	60 – 1500V dc
Charging voltage	-	up to 1500 V dc up to 1000 V ac
Supply current conductive	-	Ex: 160 A @ 480 Vac
Charging current conductive	-	Ex: 210 A @ 410 Vdc*
Charging current inductive	-	Ex: ~100A@380 Vdc **
Current peak while driving	-	range 100 A – 800 A

* Tesla supercharger 120 kW

** Given for a 50 kW quick charger, battery current

Overview

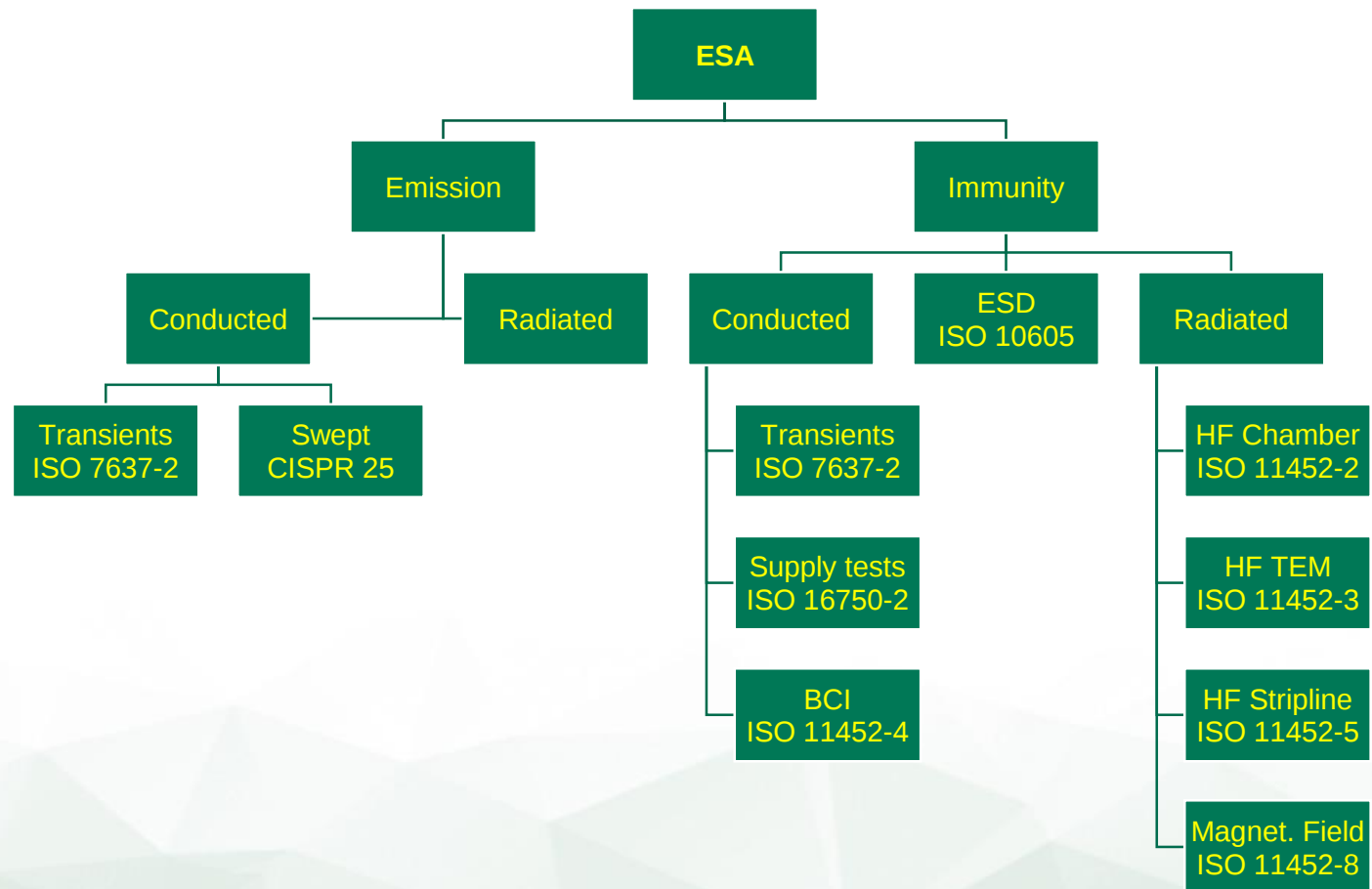
Some Standards from around the world

Application	IEC	SAE	UL
Onboard charger	IEC 61851	SAE J2894	UL 2202
Charging inlet	IEC 62196	SAE J1772	UL 2251
Charging plug	IEC 62196	SAE J1772	UL 2251
Charging station conductive	IEC 61851	SAE J2293	UL 2594
Charging station inductive	IEC 61980	SAE J2954	UL 2750

Presentation focuses on **IEC series** of standards

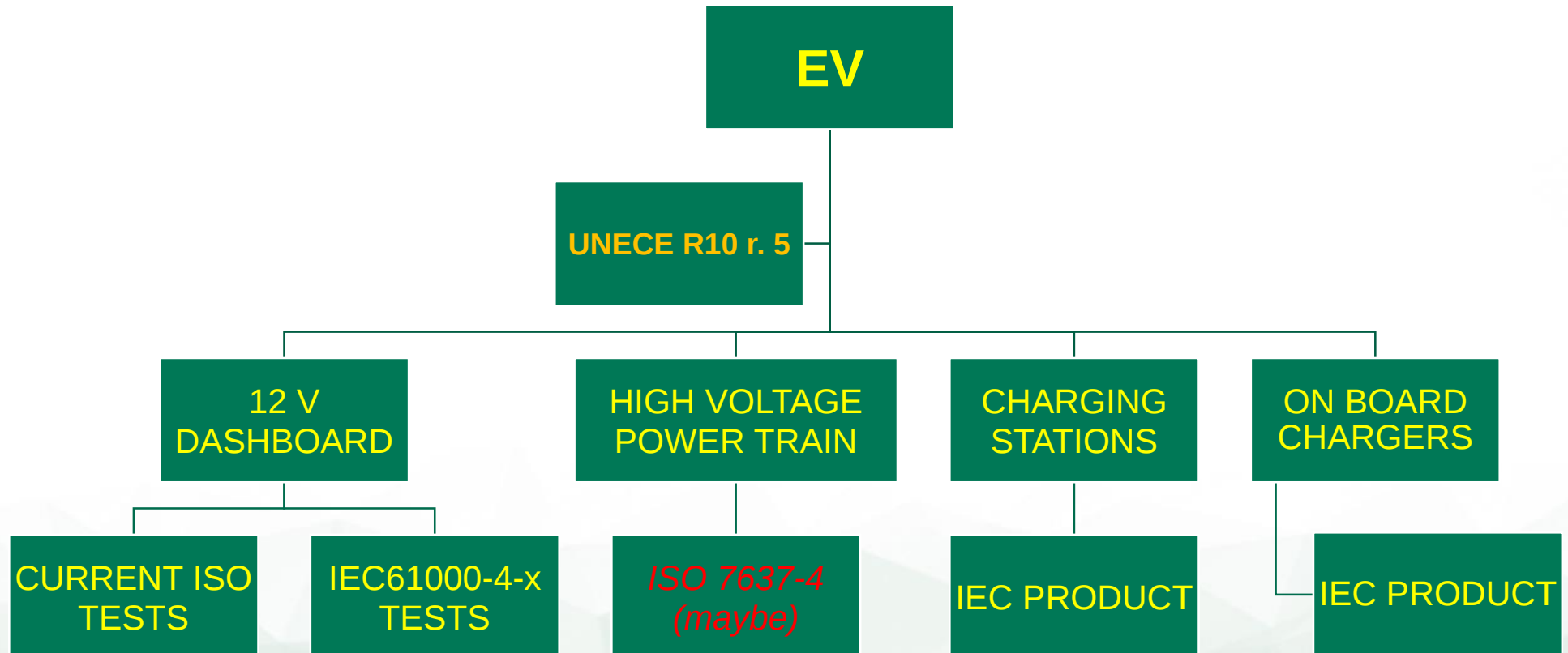
Relevant EMC Standards

Applicable international standards for conventional vehicles



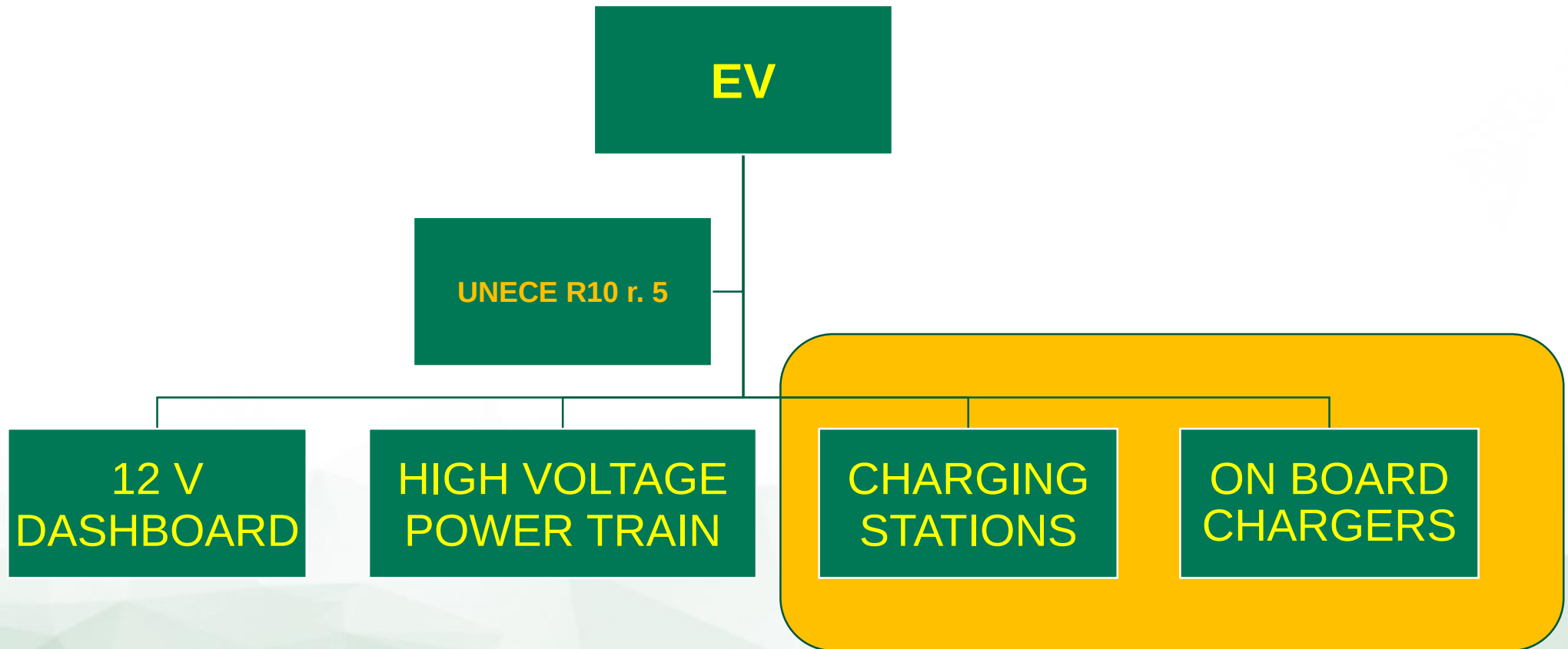
Relevant EMC Standards

International standards for electric vehicles



Relevant EMC Standards

International standards for electric vehicles



Conductive charging systems – SAFETY & EMC

IEC 61851

- Electric Vehicle Conductive Charging Systems

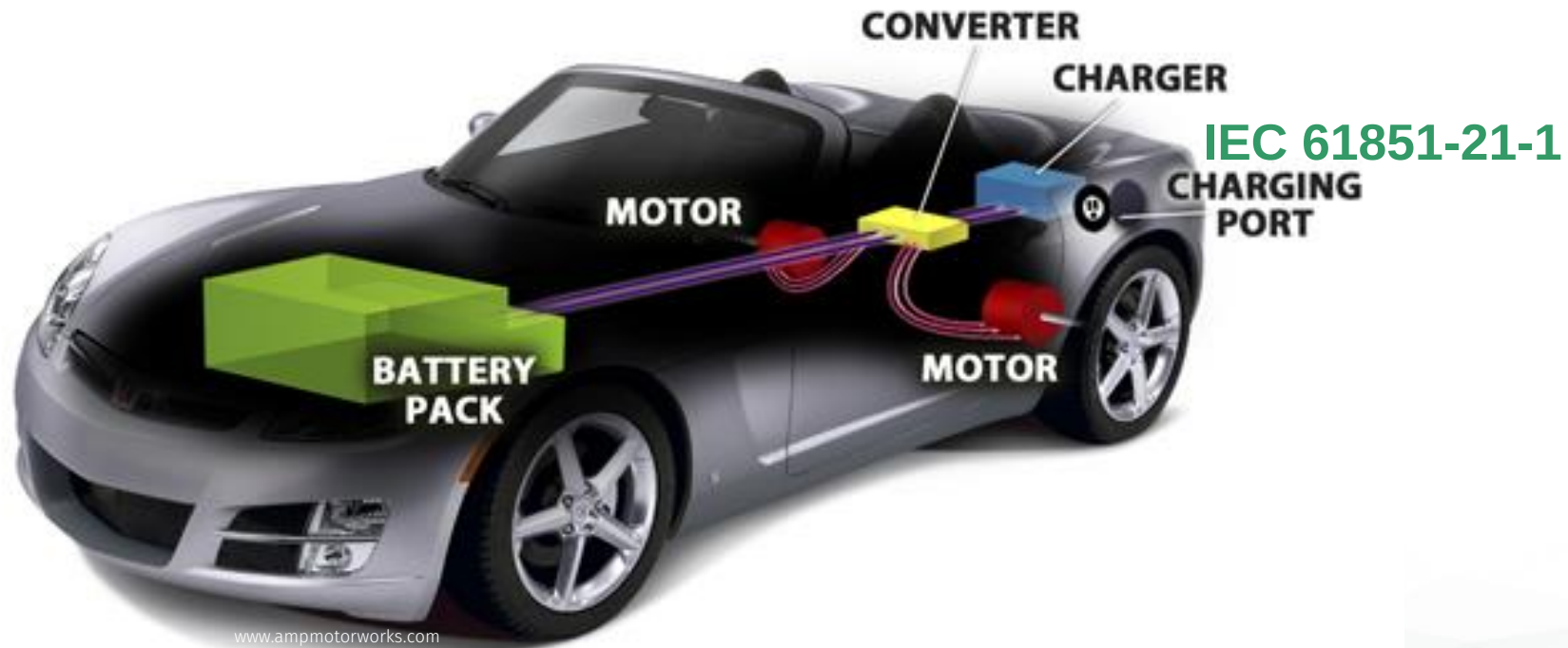
IEC 61851-21-1

- EMC requirements for ON BOARD charging systems

IEC 61851-21-2

- EMC requirements for OFF BOARD charging systems

IEC standardization conductive charging



IEC 61851-21-2



Off Board Chargers & Charging Stations

- IEC 61851-21-2



Product Standard Requirements vs Basic Standards

Basic Standard	IEC 61851-21-2	ECE R10 v 5
ISO 10605	★	
ISO 11451-2	★	★
ISO 11451-4		★
ISO 11452-2		★
ISO 11452-3	★	★
ISO 11452-4		★
ISO 11452-5		★
ISO 7637		★
IEC 61000-3-2	★	★
IEC 61000-3-3		★
IEC 61000-3-11		★
IEC 61000-3-12	★	★

Product Standard Requirements vs Basic Standards

Basic Standard	IEC 61851-21-2	ECE R10 v 5
IEC 61000-4-2	★	
IEC 61000-4-4	★	★
IEC 61000-4-5	★	★
IEC 61000-4-11	★	
IEC 61000-4-13	★	
IEC 61000-4-3	★	
CISPR 12	★	
CISPR 14	★	★
CISPR 22	★	★
CISPR 25	★	★

IEC 61851-21-2 Overview all Test Types

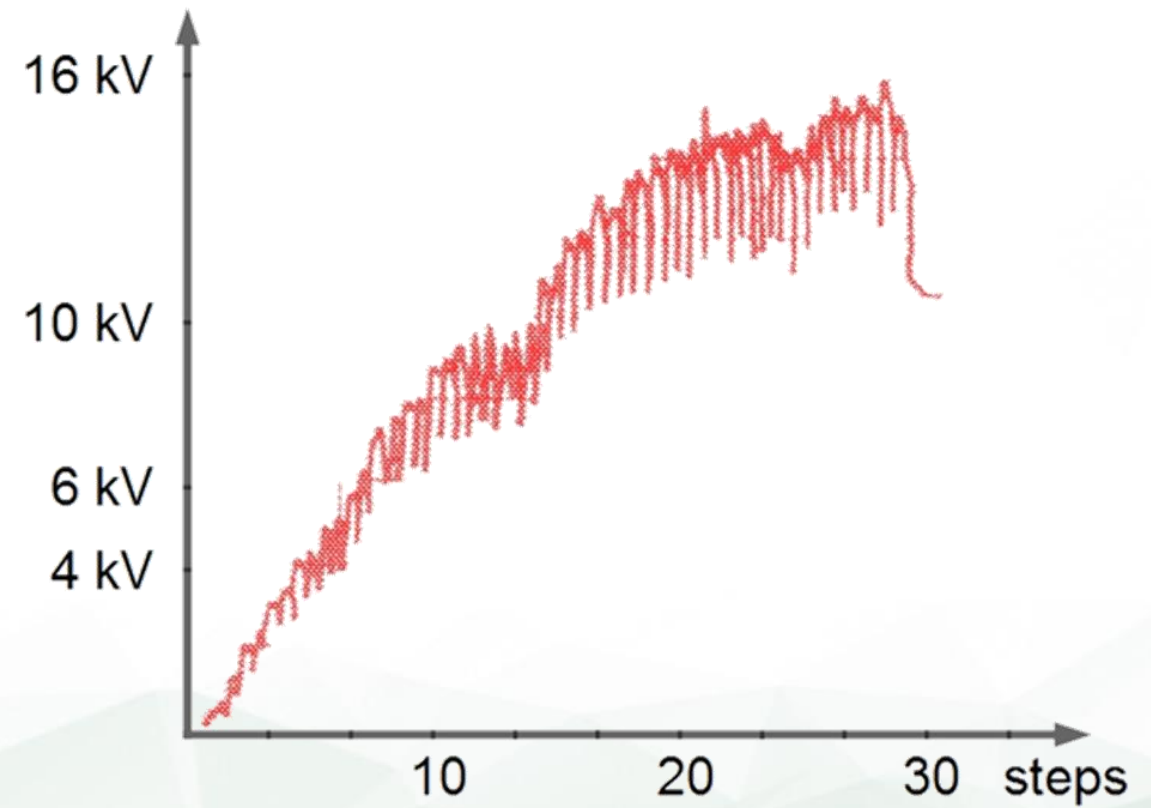
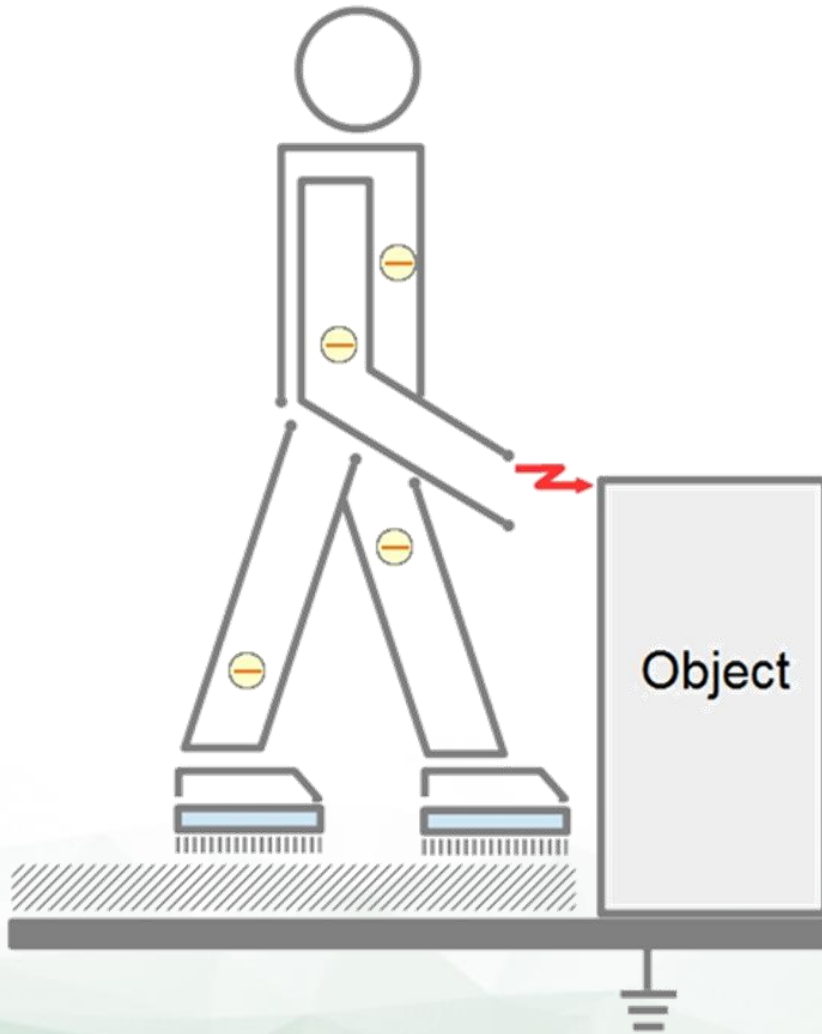
Phenomena	Test Level	Basic Standard
ESD	8kV Contact & 15kV Air	ISO 10605
RF EM Fields (AM)	20 – 80MHz, 30V/m,	ISO 11451-2
RF EM Fields (Pulse)	800 – 2000MHz, 30V/m,	ISO 11452-2
EFT	±2kV, 5kHz (5/50ns)	IEC 61000-4-4
Surge (AC power)	±2kV (L-PE), ±1kV (L-L)	IEC 61000-4-5
Surge (DC power)	±0.5kV (L-PE), ±0.5kV (L-L)	IEC 61000-4-5
DIPS up to 16A	0%, 40%, 70%	IEC 61000-4-11
DIPS up to 75A	0%, 40%, 70%	IEC 61000-4-34
INTERRUPT up to 16A	0%	IEC 61000-4-11
INTERRUPT up to 75A	0%	IEC 61000-4-34
BCI	20 – 200MHz, 60mA	ISO 11452-4
RF Field (AM)	200 – 800MHz, 30V/m	ISO 11452-2
RF Field (Pulse)	800 – 2000MHz, 30V/m	ISO 11452-2

Electrostatic Discharge (ES)

Electrostatic discharge (ESD) is the release of static electricity when two objects come into contact. Familiar examples of ESD include the shock we receive when we walk across a carpet and touch a metal doorknob.

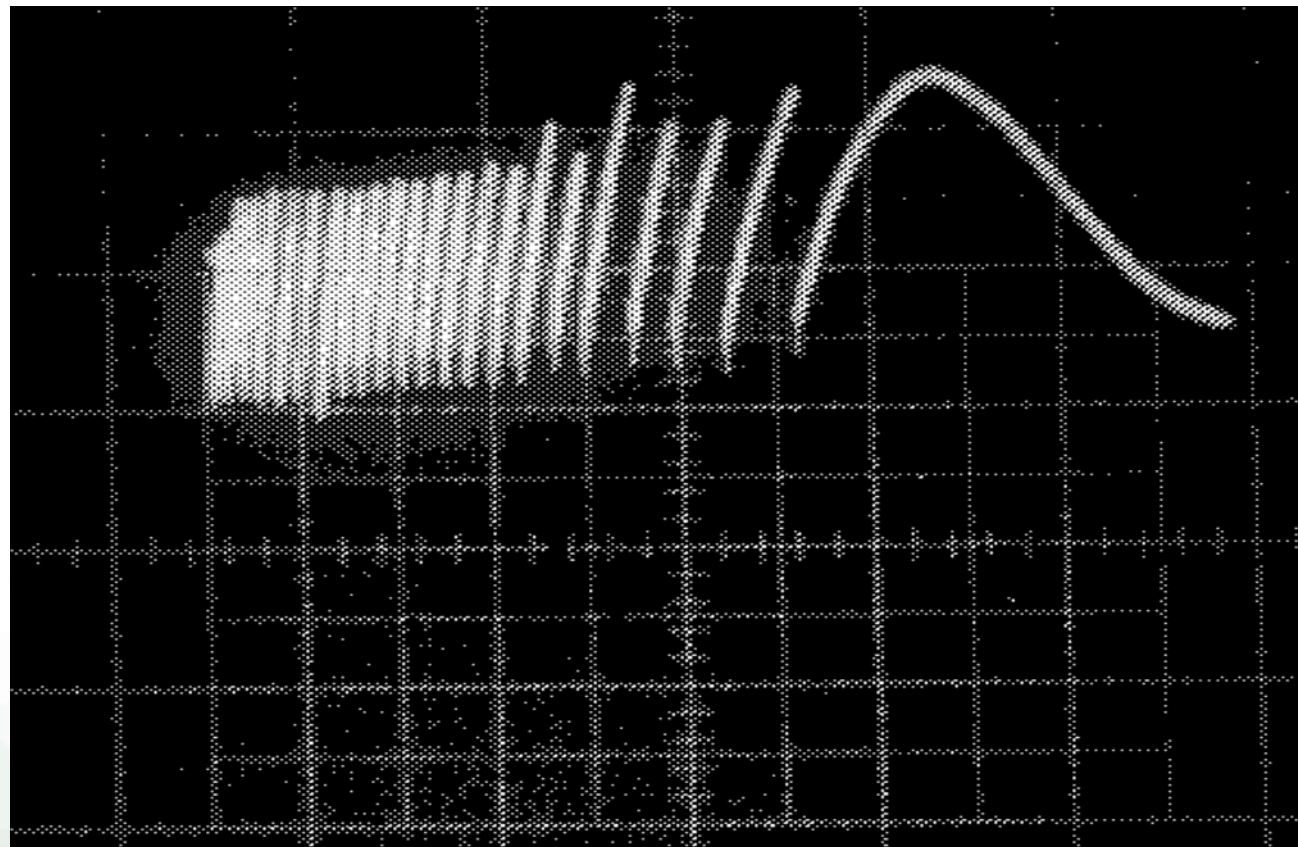


Electrostatic Discharge (ESD)



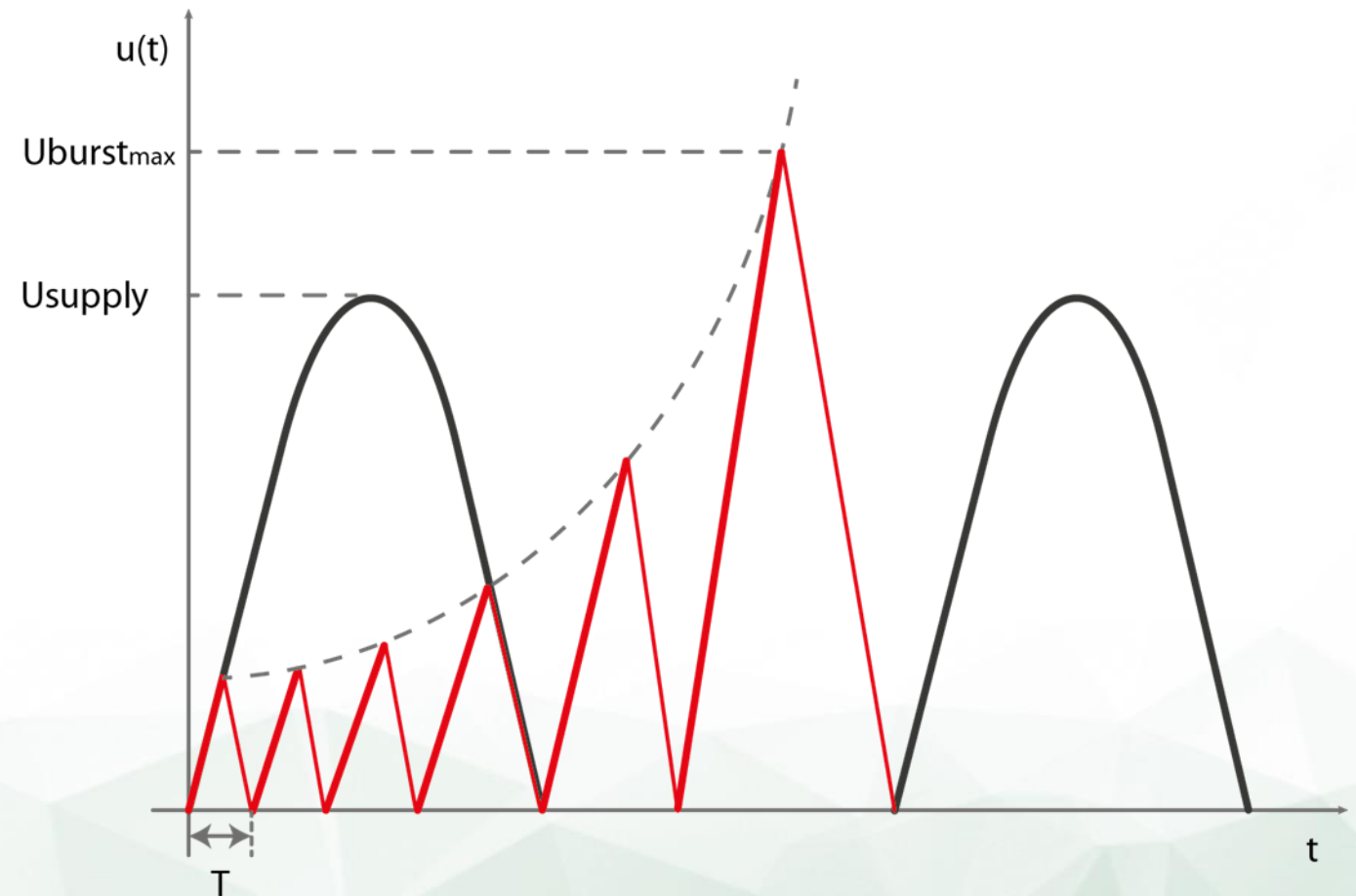
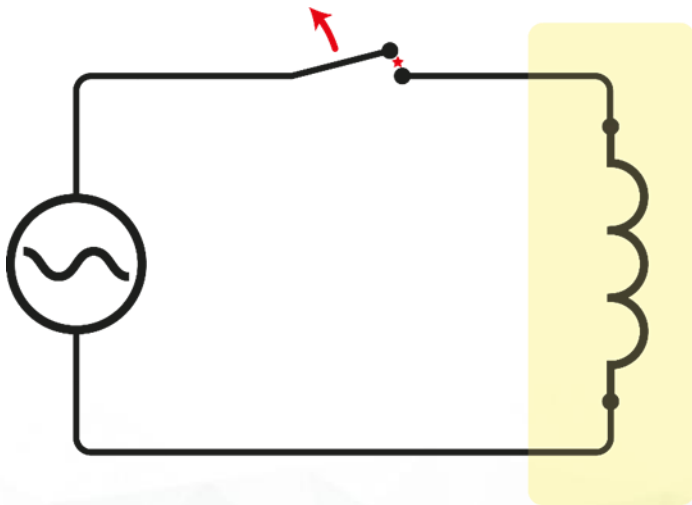
Electric Fast Transient (EFT) / Burst

- The switching of inductivity with electromechanical switch causes in the circuits of neighboring consumers a significant influence. Here is a burst opening contact.



Electric Fast Transient (EFT) / Burst

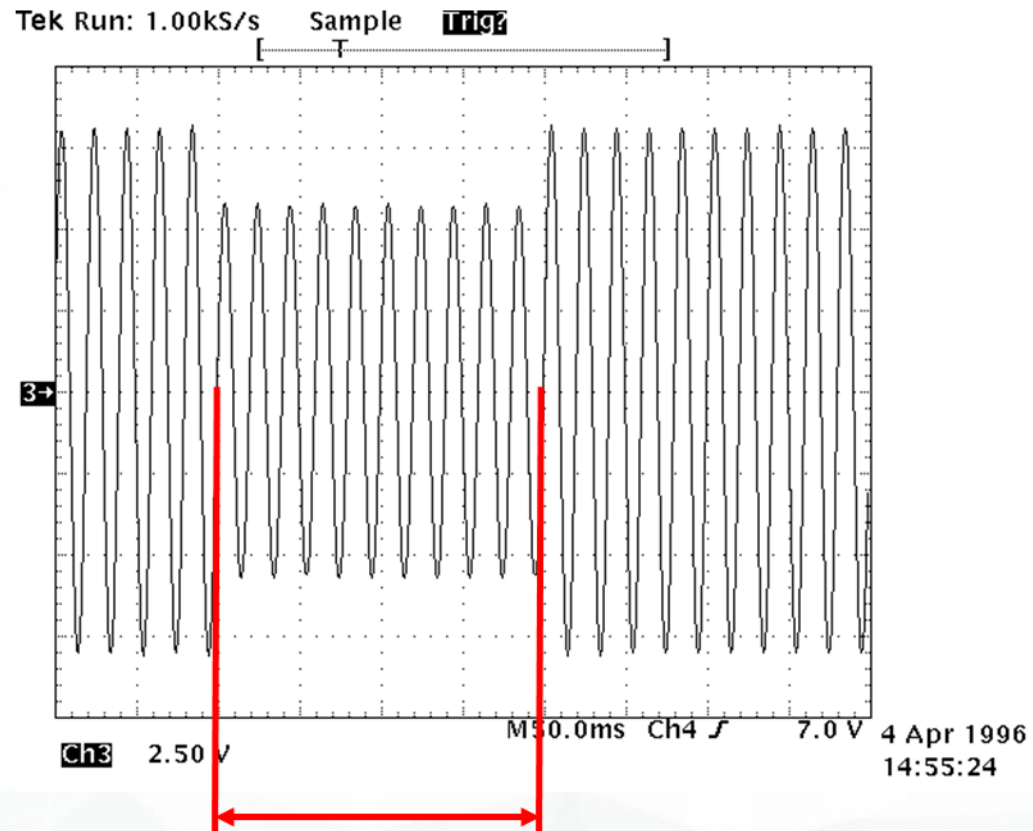
- Arcing during switching of an inductive load



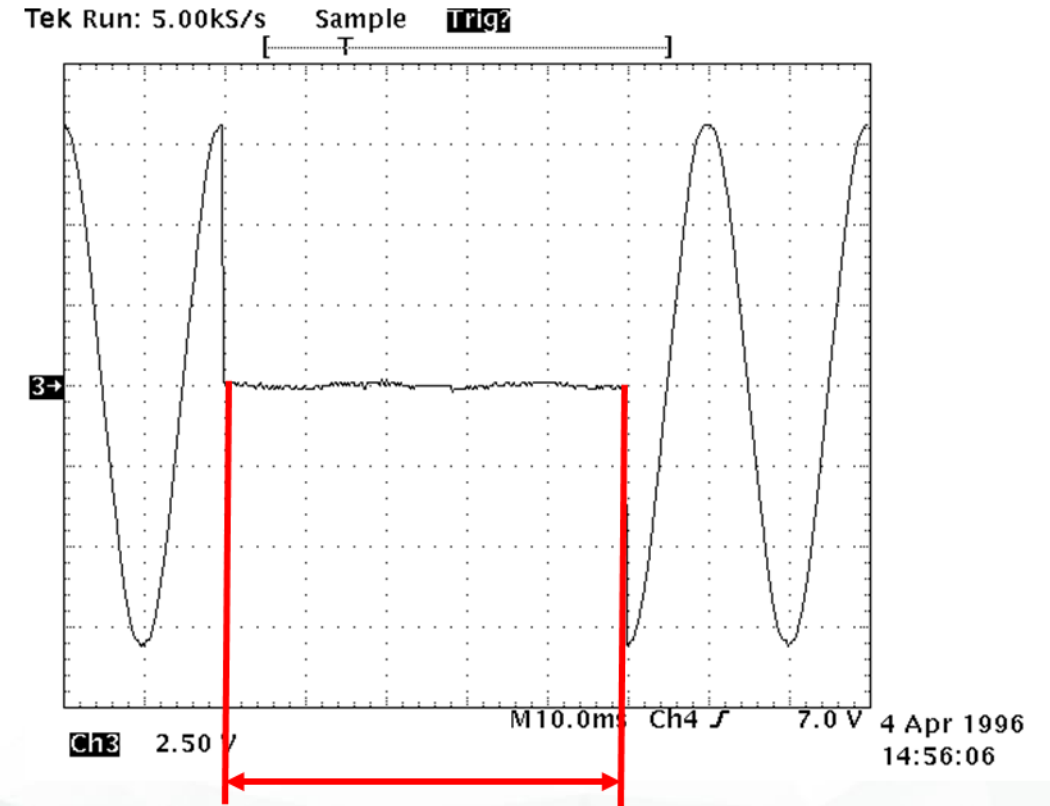
Surge



Voltage Dips and Short Interruptions

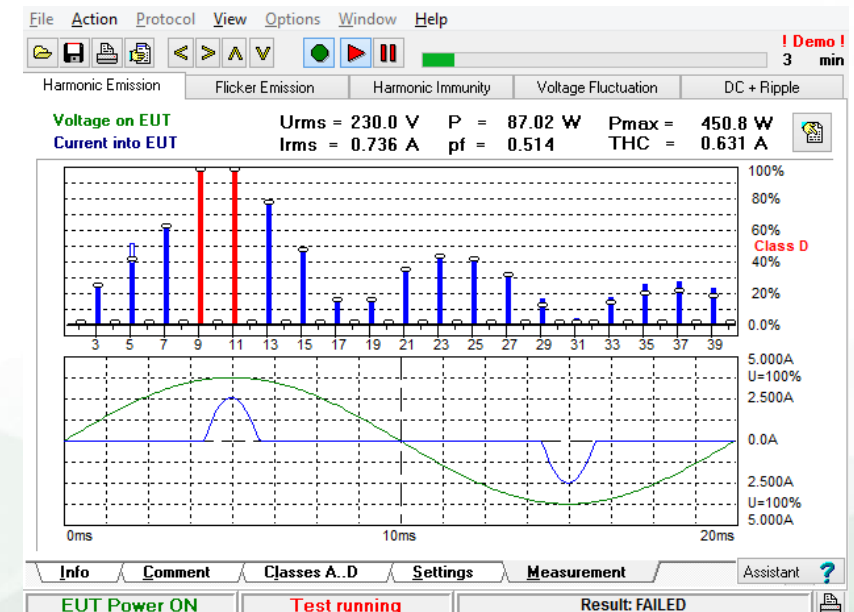
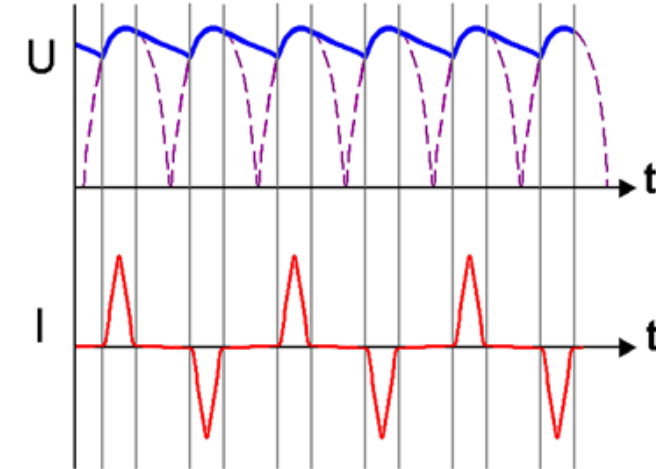
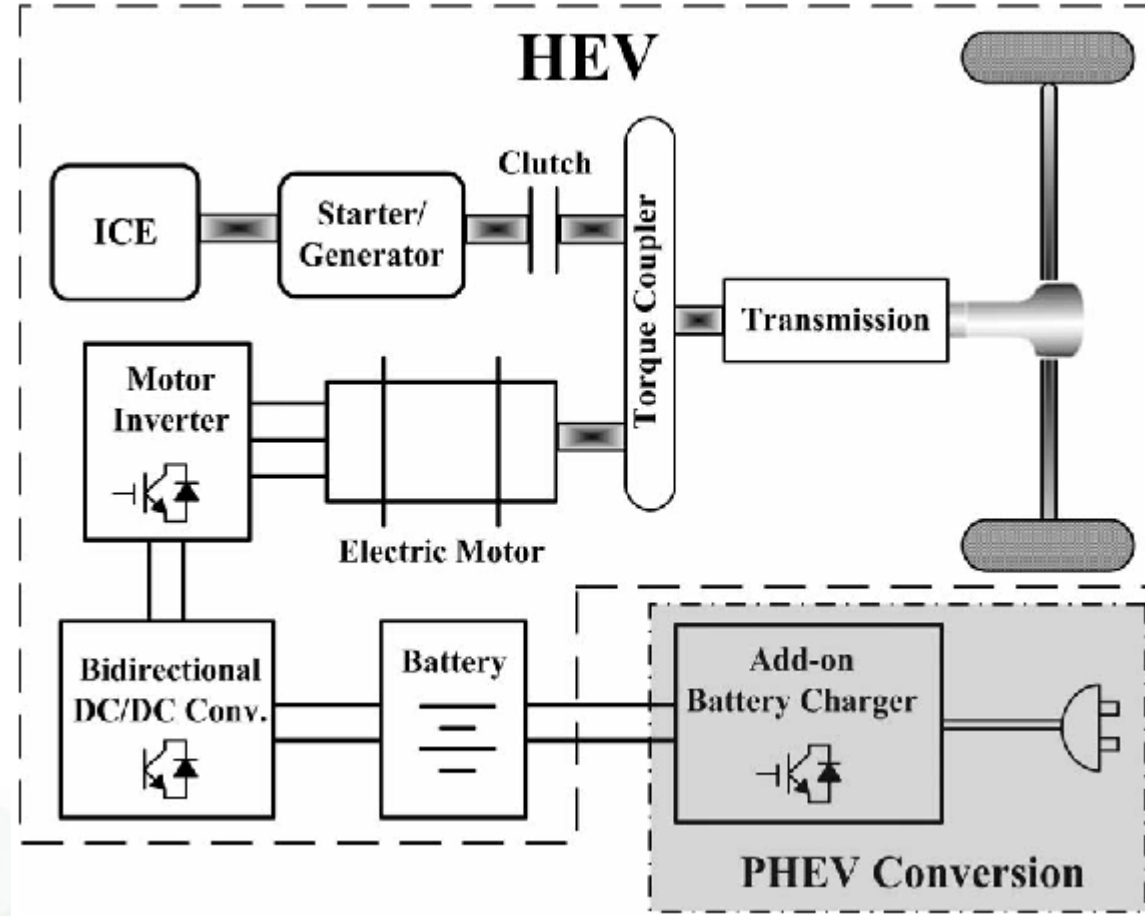


70% dips with a duration of 200 ms
begin = 0° and end = 0°



0% dips with a duration of 50 ms
begin = 90° and end = 270°

Harmonic Current Measurement



IEC 61851-21-2 Location Categories for Test Levels – Example SURGE (1.2/50us)

Port	AC Non-Residential	AC Residential	DC Non-Residential	DC Residential
Enclosure				
Input (ac)	±4kV	±2kV	±4kV	±2kV
Input (dc)	±4kV	±2kV	±2kV	±2kV
Signal / Control	±1kV	±1kV	±1kV	±1kV
CPT	±2kV	±2kV	±2kV	±2kV

IEC 61851-21-2 Enclosure Port all tests

Phenomena	Test Level	Basic Standard
ESD	4kV Contact & 8kV Air	IEC 61000-4-2
RF EM Fields (AM)	80 – 1000MHz, 10V/m,	IEC 61000-4-3
RF EM Fields (AM)	1.4 – 2GHz, 3V/m,	IEC 61000-4-3
RF EM Fields (AM)	2 – 2.7GHz, 3V/m	IEC 61000-4-3
AC Magnetic Field	30A/m and 100A/m	IEC 61000-4-8

IEC 61851-21-2 Power Input (ac) all tests

Phenomena	Test Level	Basic Standard
EFT	±4kV	IEC 61000-4-4
Surge (AC power)	±4kV (L-PE), ±2kV (L-L)	IEC 61000-4-5
Conducted RF	0.15 – 80MHz, 10V	IEC 61000-4-6
DIPS up to 16A	100%, 40%, 70%	IEC 61000-4-11
DIPS up to 75A	100%, 40%, 70%	IEC 61000-4-34

IEC 61851-21-2 Wired Network & Signal Control all tests

Phenomena	Test Level	Basic Standard
EFT	±2kV, 5kHz	IEC 61000-4-4
Surge (AC power)	±1kV	IEC 61000-4-5
Conducted RF Fields	0.15 – 80MHz, 10V	IEC 61000-4-6

IEC 61851-21-2 Conductive Power Transfer (CPT) all tests

Phenomena	Test Level	Basic Standard
EFT	±2kV, 5kHz	IEC 61000-4-4
Surge (AC power)	±2kV (L-PE), ±1kV (L-L)	IEC 61000-4-5
Conducted RF Fields	0.15 – 80MHz, 10V	IEC 61000-4-6

Conductive charging systems – SAFETY

IEC 61439

- Low-voltage switch gear and control gear assemblies

IEC 61439-7

- Changed to include electric vehicle charging stations

SAFETY
TESTS

- 1000Vac & 1500Vdc

IEC 61851-21-1 & IEC 61851-21-2 SAFETY TESTS

- ✓ Defines
 - ✓ connection types
 - ✓ charging modes
 - ✓ impulse dielectric withstand test
 - ✓ 1.2/50 μ s
 - ✓ Overvoltage category III from IEC 60664-1

Impulse safety tests in IEC 60664-1

Chapter 15.5 impulse dielectric withstand 1.2/50 μ s

Table F1, IEC 60664-1

Supply system – nominal voltage [V]		Voltage L-N derived from nominal ac and dc voltages up to and equal [V]	Rated impulse voltage [V] Overvoltage category			
Three phase	One phase		I	II	III	IV
		50 330	-	500	800	1'500
		100	500	800	1'500	2'500
	120-240	150*	800	1'500	2'500	4'000
230/400, 277/480		300	1'500	2'500	4'000	6'000
400/690		600	2'500	4'000	6'000	8'000
1'000		1'000	4'000	6'000	8'000	12'000

* Single phase networks in Japan exhibit voltages between 100 V and 200 V. Conventionally, 150 V is considered reference value for this purpose.

IEC 60664-1

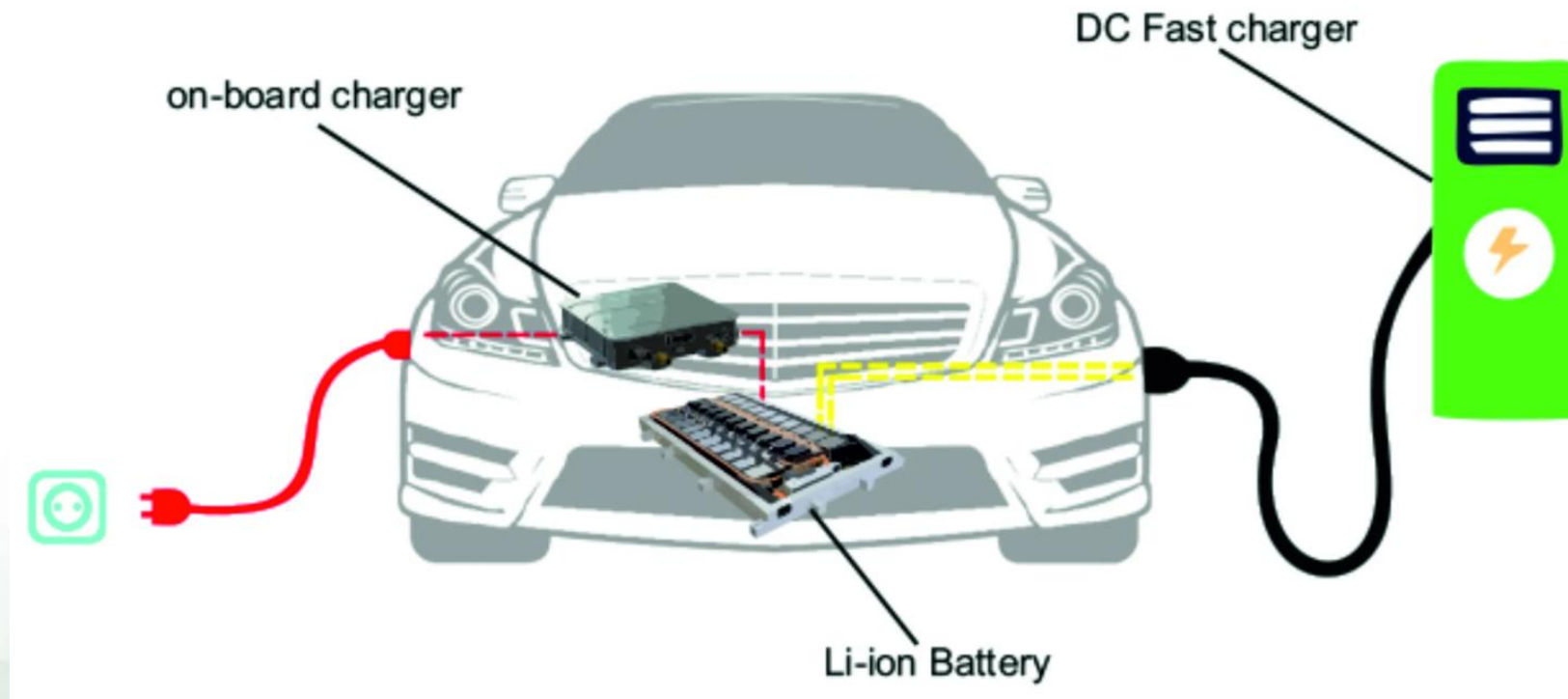
Chapter 15.5 Impulse dielectric withstand: EMCP test equipment



EMCP generator	INS3000
Output voltage 40Ω	0.2 – 15 kV

IEC 61851-21-1

- EMC requirements for **on board** equipment while charging
- Conductive connection only 50 Hz and 60 Hz and DC



Product Standard Requirements vs Basic Standards – On Board Chargers

Basic Standard	IEC 61851-21-1	ECE R10 v 5
ISO 10605	★	
ISO 11451-2	★	★
ISO 11452-2	★	★
ISO 11452-4	★	★
IEC 61000-3-2	★	★
IEC 61000-3-3	★	★
IEC 61000-3-11	★	★
IEC 61000-3-12	★	★

Product Standard Requirements vs Basic Standards – On Board Chargers

Basic Standard	IEC 61851-21-1	ECE R10 v 5
IEC 61000-4-2		
IEC 61000-4-4	★	★
IEC 61000-4-5	★	★
IEC 61000-4-11	★	
IEC 61000-4-34	★	

IEC 61851-21-1 On Board Chargers

Phenomena	Test Level	Basic Standard
ESD	8kV Contact & 15kV Air	ISO 10605
RF EM Fields (AM)	20 – 80MHz, 30V/m,	ISO 11451-2
RF EM Fields (Pulse)	800 – 2000MHz, 30V/m,	ISO 11452-2
EFT	±2kV, 5kHz (5/50ns)	IEC 61000-4-4
Surge (AC power)	±2kV (L-PE), ±1kV (L-L)	IEC 61000-4-5
Surge (DC power)	±0.5kV (L-PE), ±0.5kV (L-L)	IEC 61000-4-5
DIPS up to 16A	0%, 40%, 70%	IEC 61000-4-11
DIPS up to 75A	0%, 40%, 70%	IEC 61000-4-34
INTERRUPT up to 16A	0%	IEC 61000-4-11
INTERRUPT up to 75A	0%	IEC 61000-4-34
BCI	20 – 200MHz, 60mA	ISO 11452-4
RF Field (AM)	200 – 800MHz, 30V/m	ISO 11452-2
RF Field (Pulse)	800 – 2000MHz, 30V/m	ISO 11452-2

IEC 61851-21-1

Test equipment for Mode 1, Mode 2, Mode 3 and Mode 4 (quick charging)

EUT/ESA up to 1000 Vac and 1500 Vdc

EMC Partner
3 x 200 A @ 690 Vac
1 x 200 A @ 1500 Vdc

Norm	Parameter	Test equipment
ISO 10605:2008	CD 8 kV, AD 15 kV	ESD3000 + DNs
IEC 61000-4-4	2 kV	IMU3000 F5-S6-D + CDN-A-06-200 + OPTION 1500Vdc PFS75-690V+SRC75-690V
IEC 61000-4-5	max. 2 kV	
IEC 61000-4-11	0 %, 40 %, 70 %	

IEC 61851-21-2

- **Formulates EMC requirements for off board equipment**
- **Conductive and wireless power transfer covered: CPT, WPT**
- **1000 Vac and 1500 Vdc at both input and output**
- **In Cable Control Box (ICCB) tested as off board equipment**
- **If data communication, highest data rate is selected during test**

IEC 61980-1

Test equipment for EMC immunity requirements in chapter 15.2
EUT/ESA supply up to 1000 Vac and 1500 Vdc

EMC Partner
3 x 200 A @ 690 Vac

Norm	Parameter	Test equipment
IEC 61000-4-2	CD 4 kV, AD 8 kV	ESD3000 + DM
IEC 61000-4-4	2 kV	IMU3000 F5-S6-D-V + CDN-A-06-200 PFS75-690V+SRC75-690V MF 1000-1
IEC 61000-4-5	max. 2 kV	
IEC 61000-4-11	0 %, 30 %, 60 % 95%	
IEC 61000-4-8	100 A/m	

UNECE R10 revision 5/2014

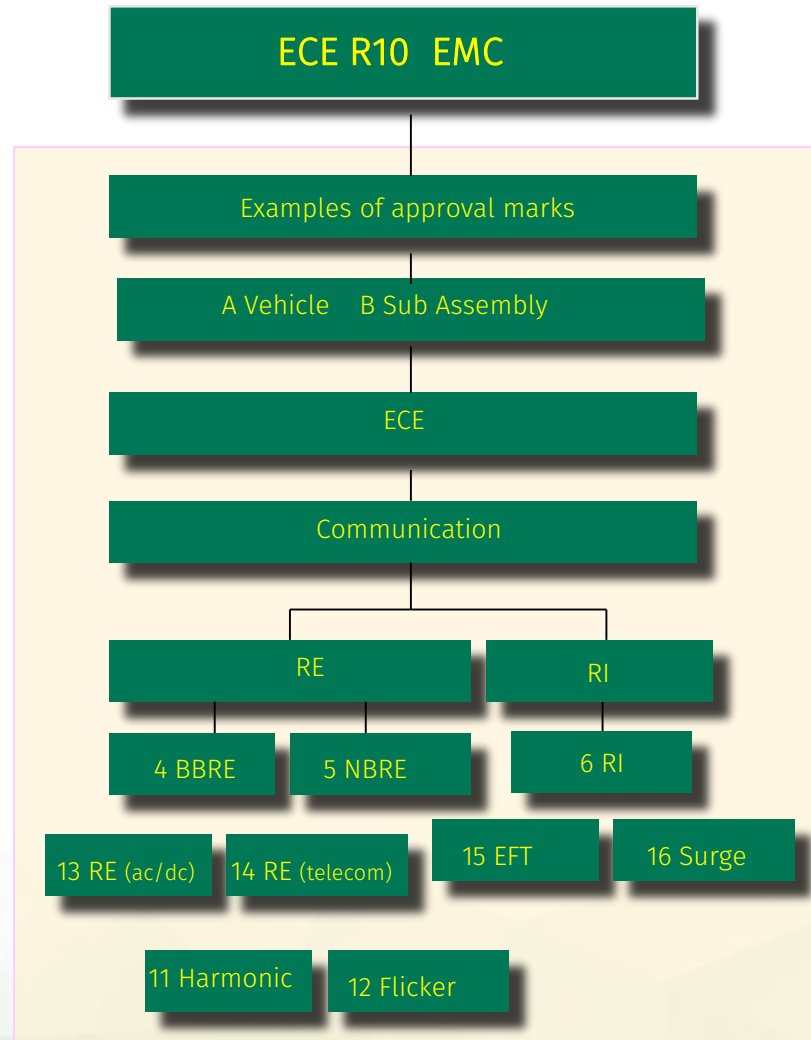
Uniform provisions concerning the approval of vehicles
with regard to electromagnetic compatibility



Date	Demands
31-12-2006	e approval of ESAs mandatory as per 2004/104/EC, e approval of vehicles as per ECE R10 rev. 02 or ECWVTA
11-07-2008	e approval as per ECE R10 rev. 03 possible
31-12-2008	e approval as per 72/245/EEC - 95/54/EC no longer valid
11-07-2009	e approval for new products as per ECE R10 rev. 03 possible
11-07-2012	e approval in accordance with ECE R10 rev. 03 mandatory
	e approval/update from ECE R10 rev. 02 to ECE R10 rev. 03 required
2014	Publication of ECE R10 rev. 05 Includes EVs



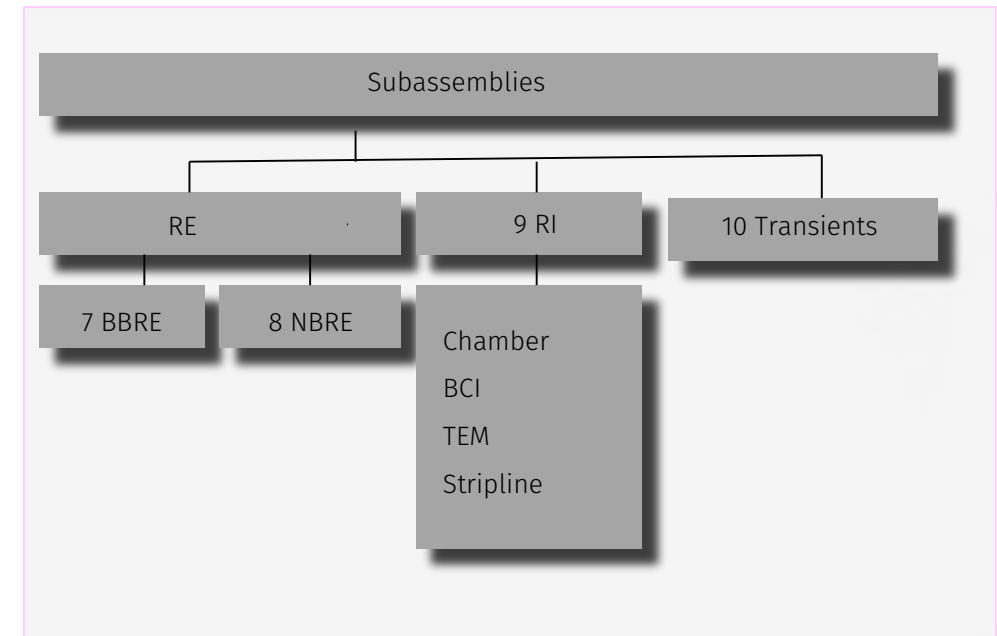
ECE 10 Annex overview



Vehicle

Annex 4, 5, 6,
11, 12, 13, 14, 15,
16

Method of
Measurement
or Testing

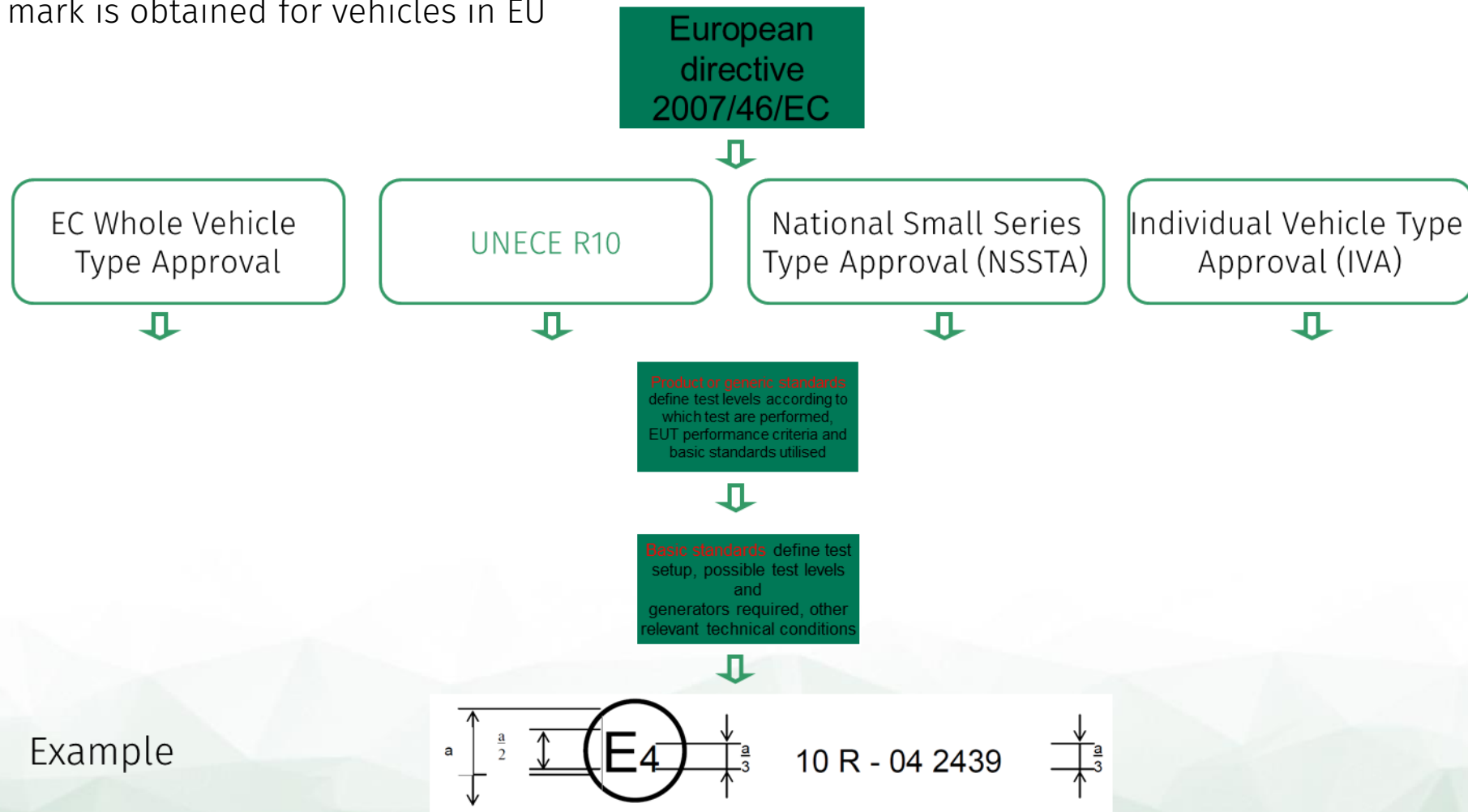


Sub Assemblies

Annex 7, 8, 9, 10, 17, 18, 19, 20, 21, 22
Methods of Measurement / Testing

UNECE R10

- Vehicle type approval
- How CE mark/e mark is obtained for vehicles in EU



UNECE R10 Harmonic Emission Requirements

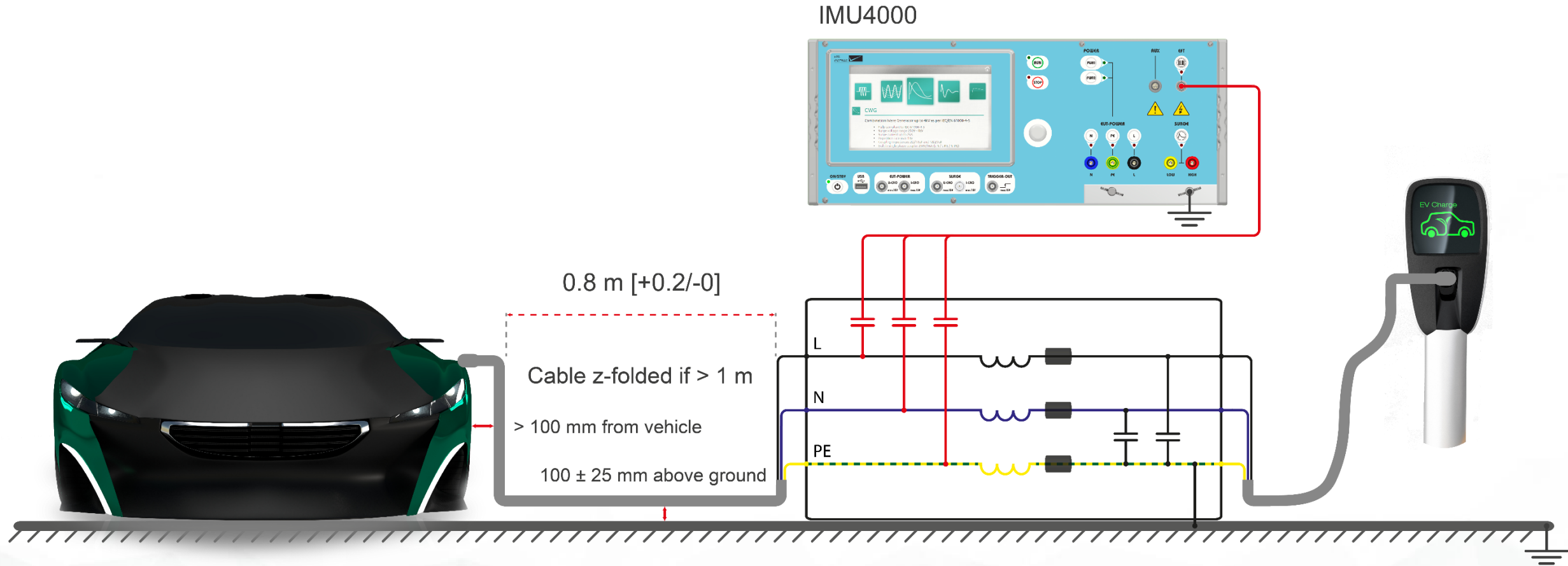
- Conducted emission requirements
- Harmonic emission (Chapter 7.3 and annex 11)
- IEC 61000-3-2 harmonic emission from equipment up to 16A/phase
- IEC 61000-3-12 harmonic emission from equipment 16A/phase - 75A/phase
- Observation time as per IEC 61000-3-2 T4 for quasi-stationary equipment
- Limits explicitly specified for:
 - ✓ Maximum harmonics $I < 16$ A
 - ✓ Maximum harmonics $16 \text{ A} < I < 75 \text{ A}$, other than balanced 3 phase equipment
 - ✓ Maximum harmonics $16 \text{ A} < I < 75 \text{ A}$, balanced 3 phase equipment
 - ✓ Maximum harmonics $16 \text{ A} < I < 75 \text{ A}$, balanced 3 phase equipment, certain conditions (at least one of the a, b, c condition - clause 5.2 / IEC 61000-3-12 is met)

UNECE R10 Flicker Requirements

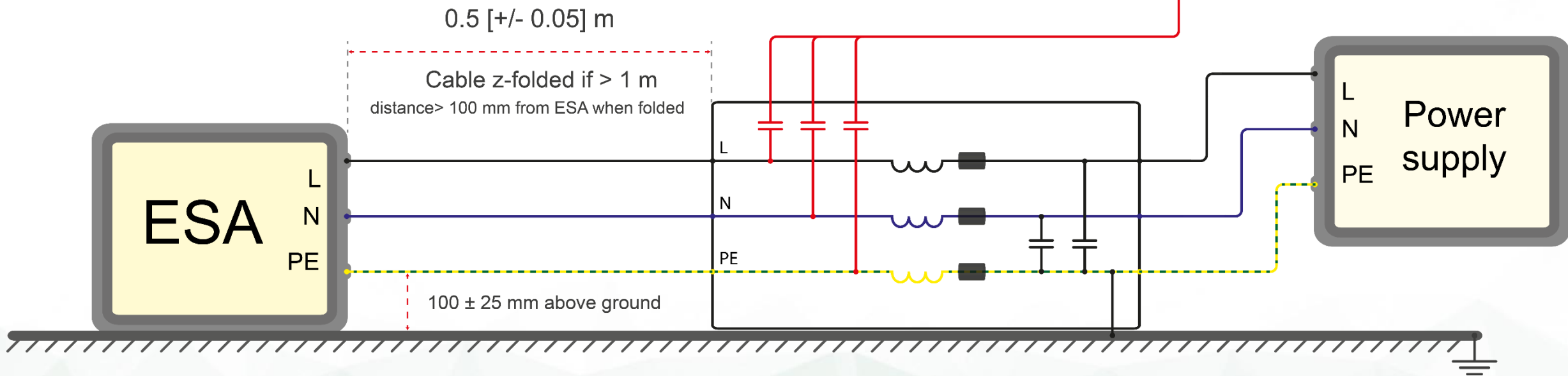
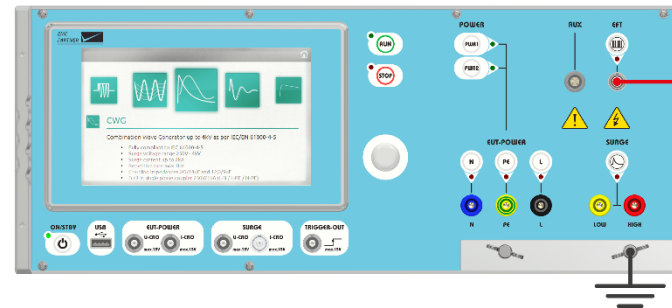
- Conducted emission requirements
- Voltage fluctuations and flicker (Chapter 7.4 and annex 12)
- IEC 61000-3-3 voltage fluctuation and flicker from equipment up to 16A/phase
- IEC 61000-3-11 voltage fluctuation and flicker from equipment 16A/phase - 75A/phase
- Limits defined by IEC apply

IEC 61000-3-3 IEC61000-3-11	p _{ST}	p _{LT}	Δu(t) [%]
	short duration flicker value	long duration flicker value	voltage relative variation

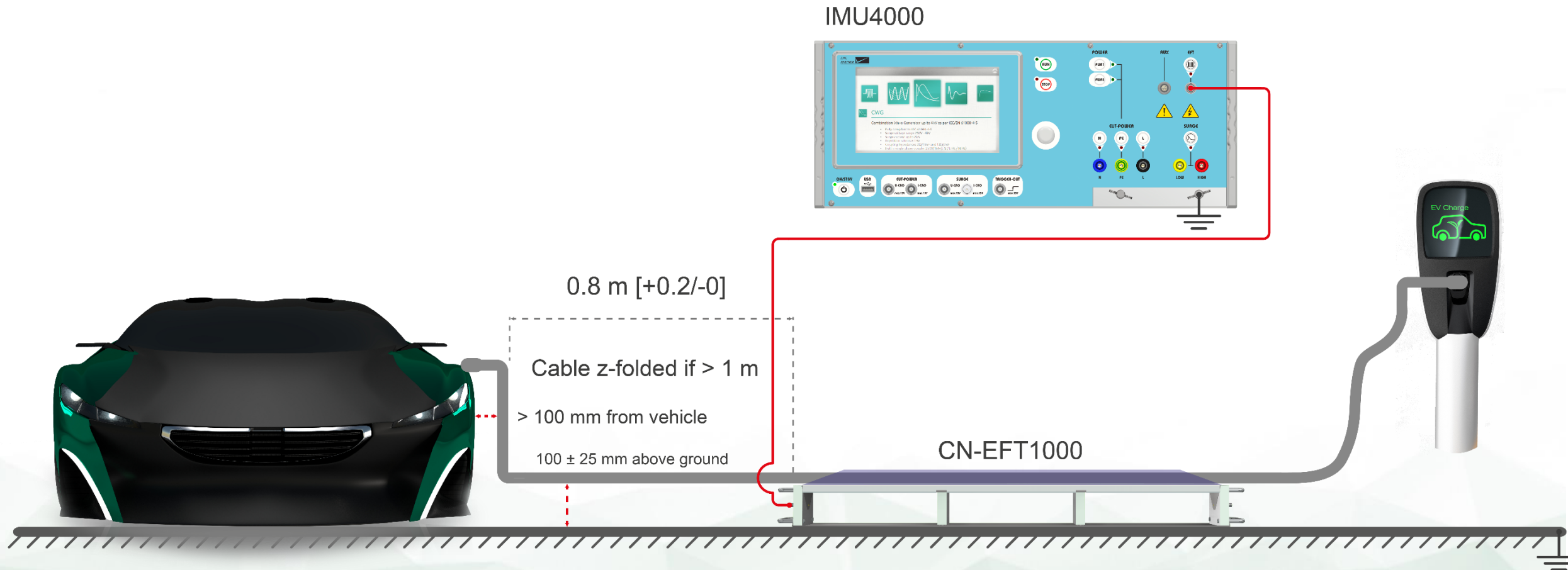
EFT/Burst-Test on Vehicle



IMU4000

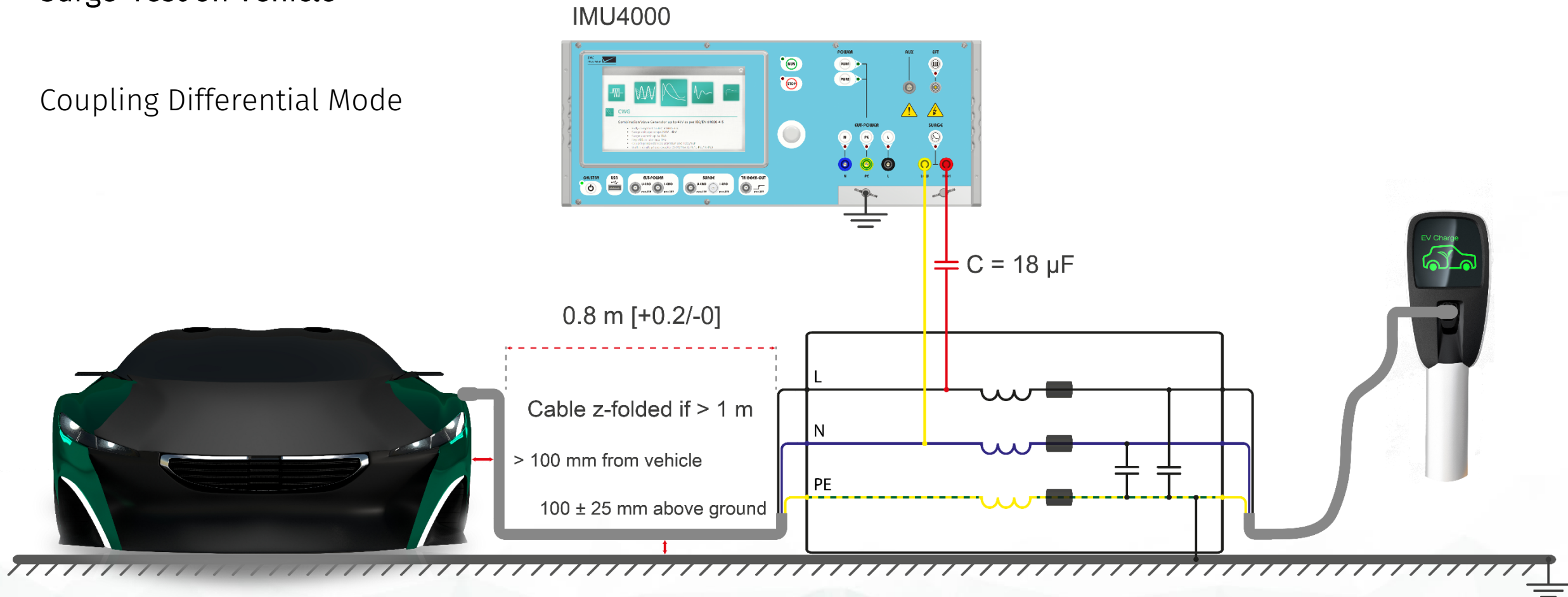


Example using Capacitive Coupling Clamp



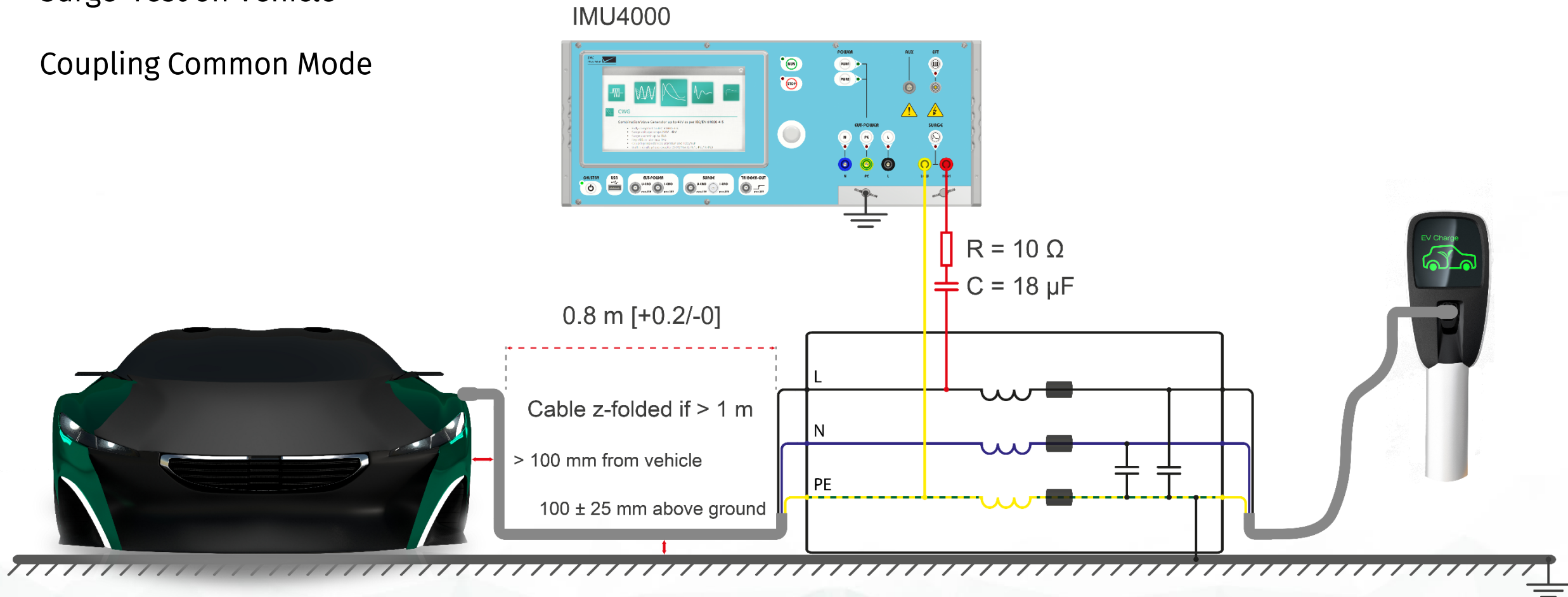
Surge-Test on Vehicle

Coupling Differential Mode



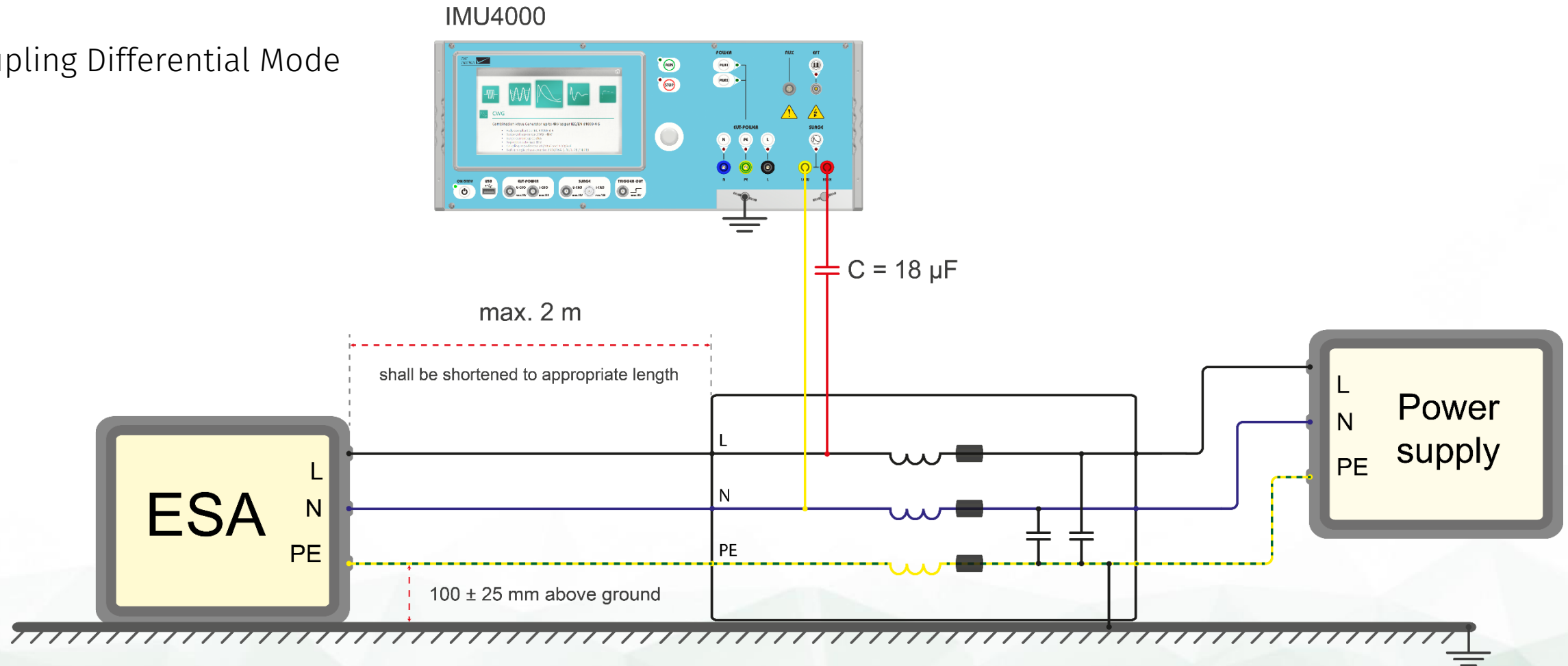
Surge-Test on Vehicle

Coupling Common Mode



Surge-Test on ESAs

Coupling Differential Mode



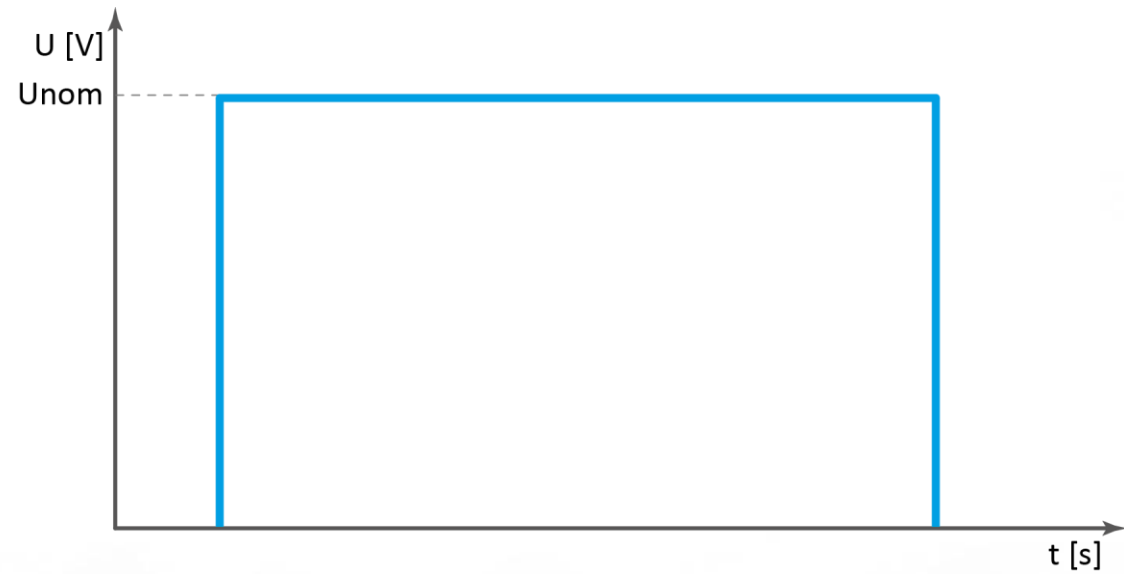
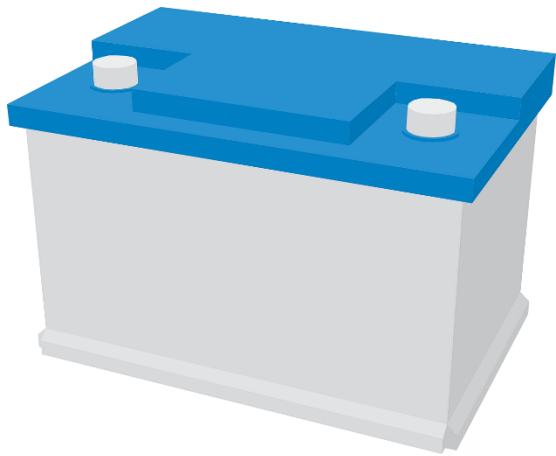
Footnote to DC Testing

DC or not DC? That is the question!

Apologies to Wiliam Shakespeare

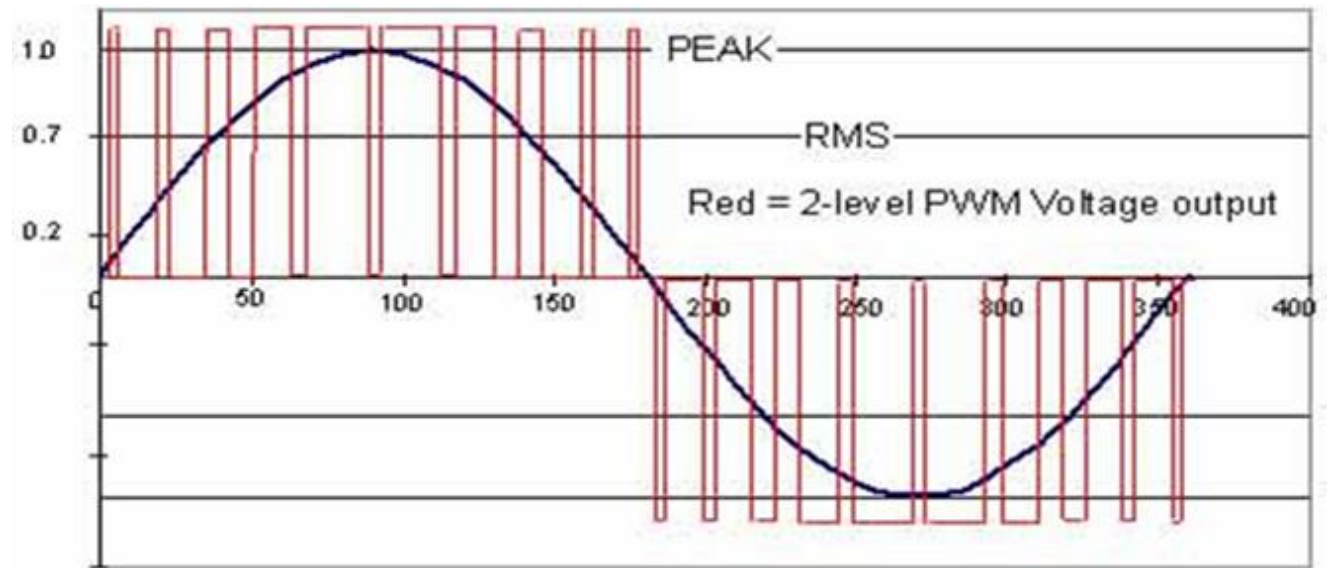
What is happening here?

DC voltage and current from a Battery

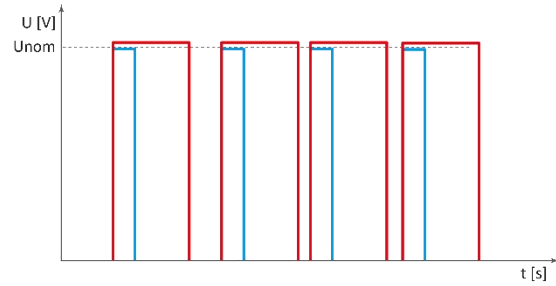


What is happening here?

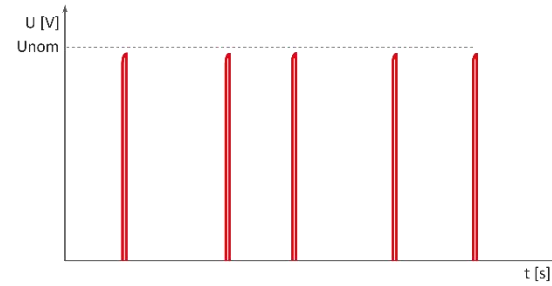
DC voltage and current from a charging station



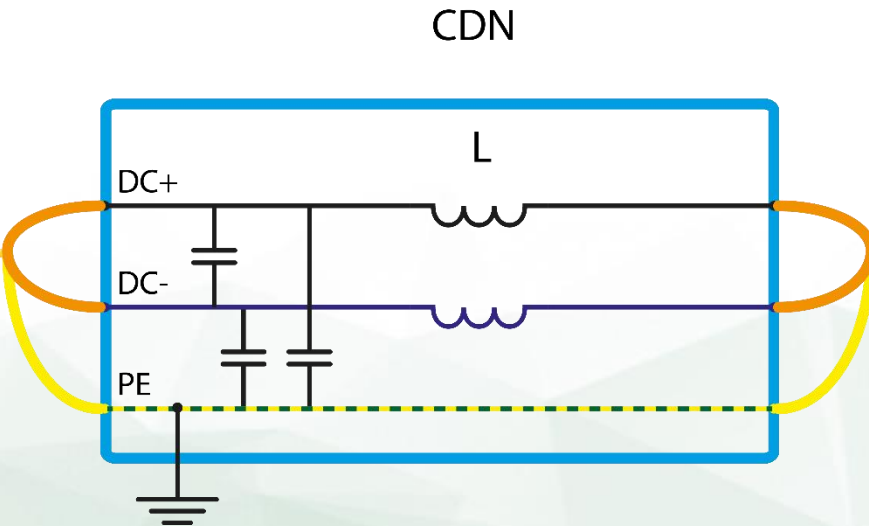
What is happening actually? How does the charging station react?



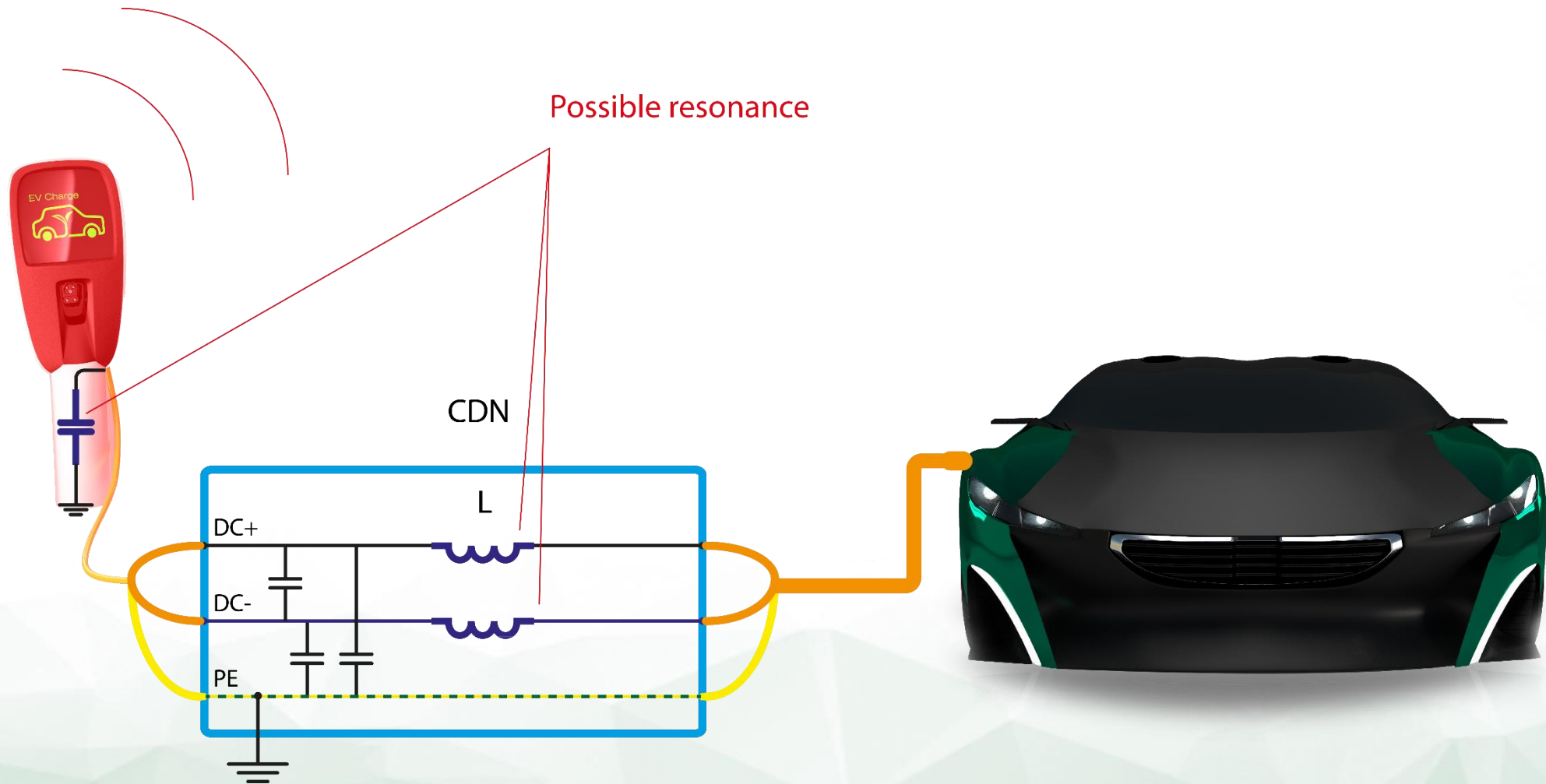
⇒ CDN ⇒



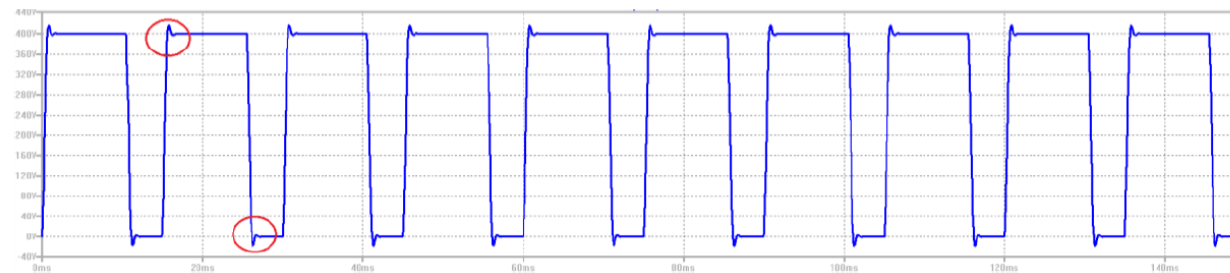
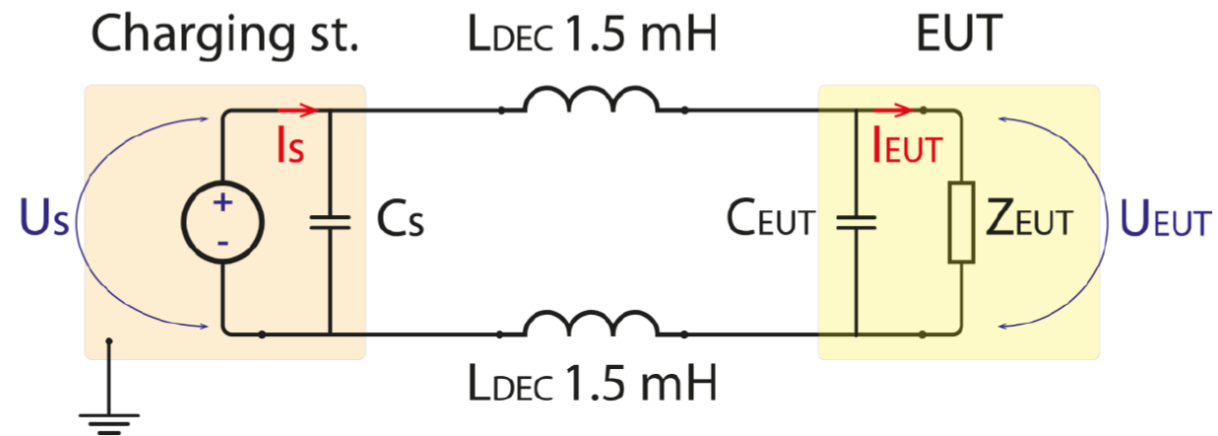
*Comprehension model



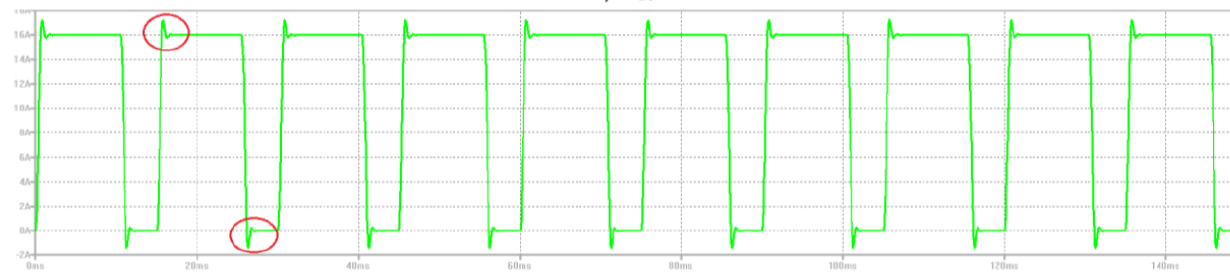
Capacitive output of a switch mode DC-Power supply can start a resonance with the CDN capacitors and inductors.



Resonance with CDN



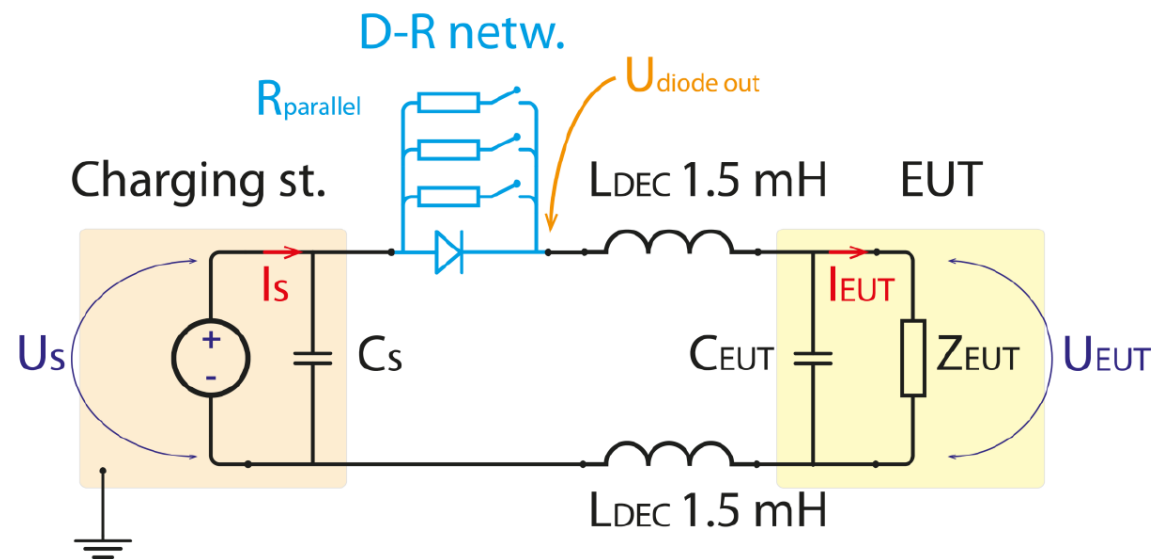
a) U_{EUT}



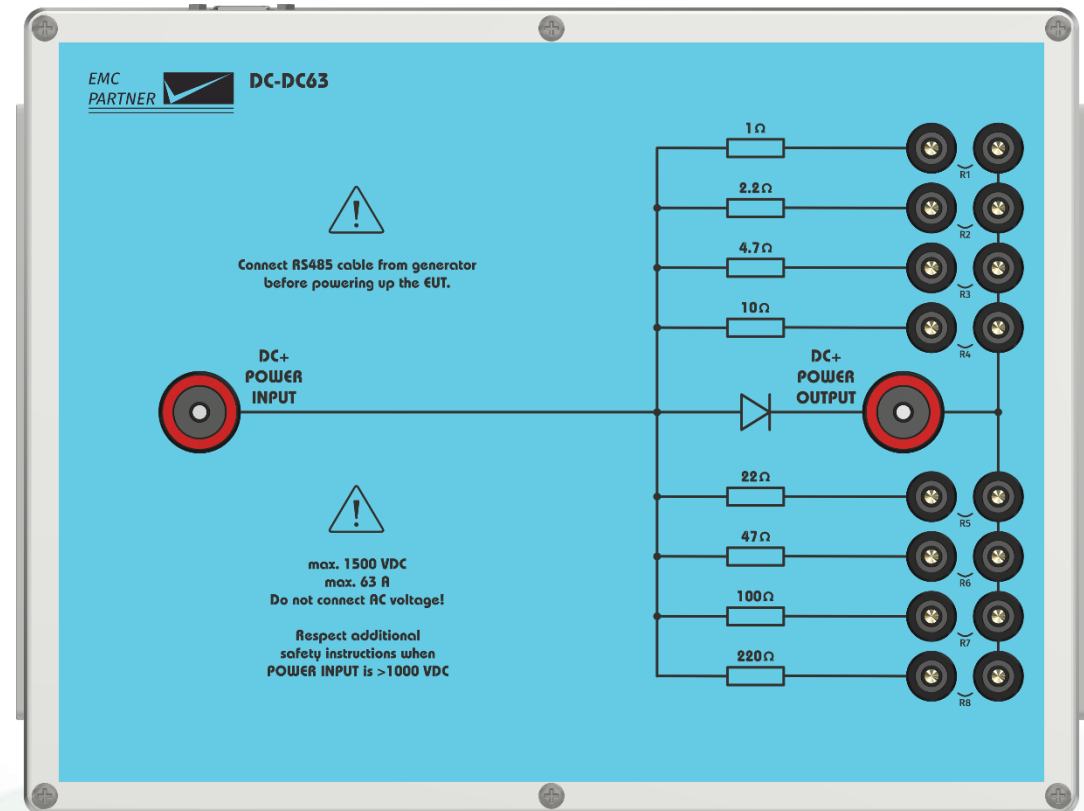
b) I_{EUT}

(in case overvoltage/oscillations appear)

Use a damping circuit

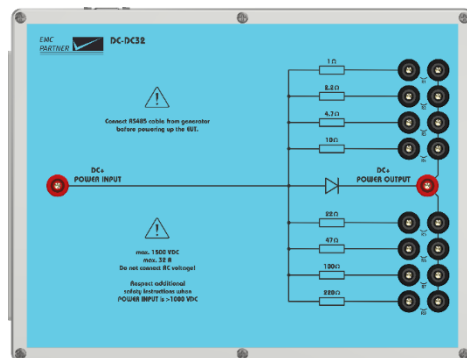


OPT-63 DC-DC

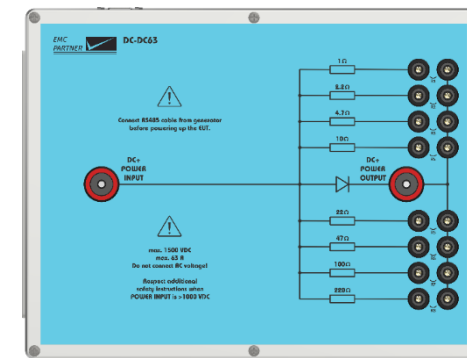


External DC-DC damping circuits for DC only, based on IEC 61000-4-5 Edition 3 Amendment 1 are available for

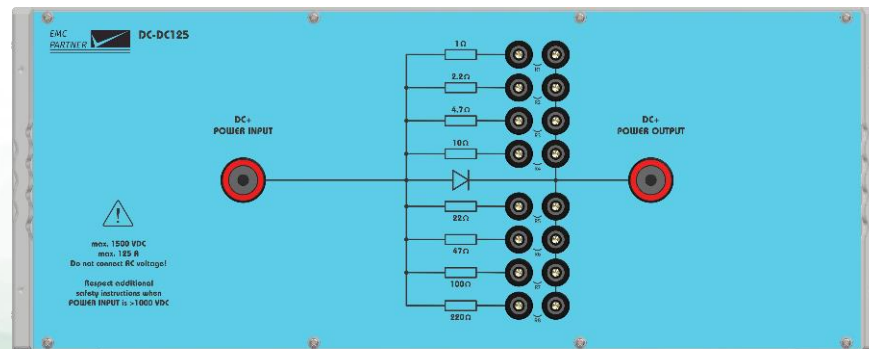
✓ EUT voltage max. 1500V / max. current 32A



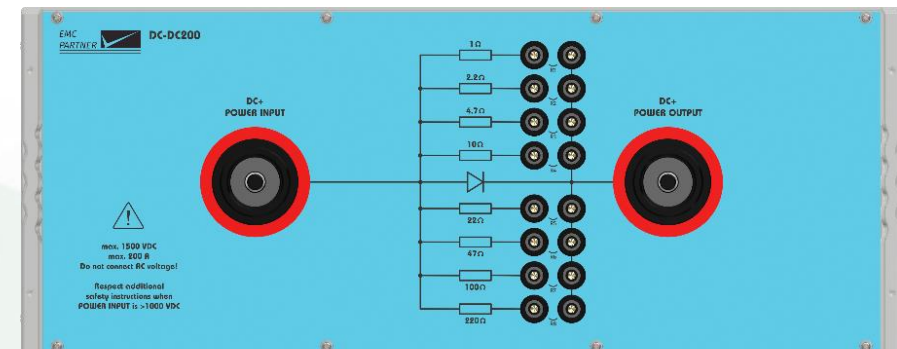
✓ EUT voltage max. 1500V / max. current 63A



✓ EUT voltage max. 1500V / max. current 125A

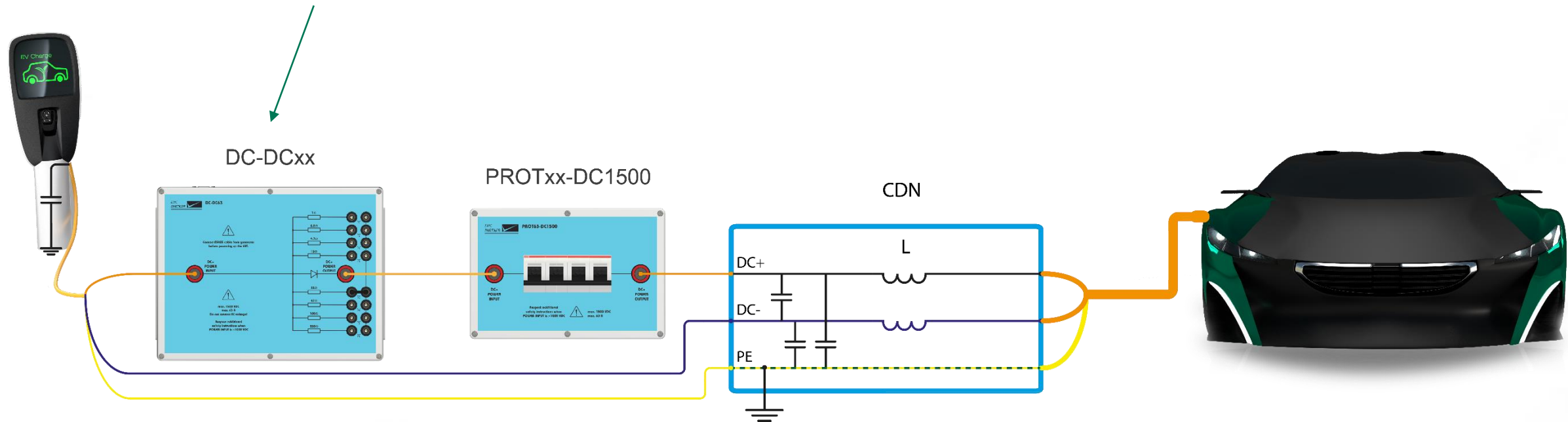


✓ Eut voltage max. 1500V / max. current 200A



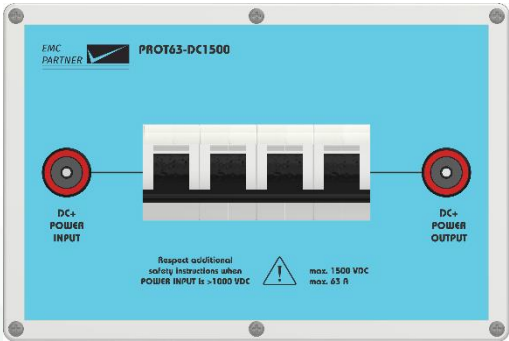
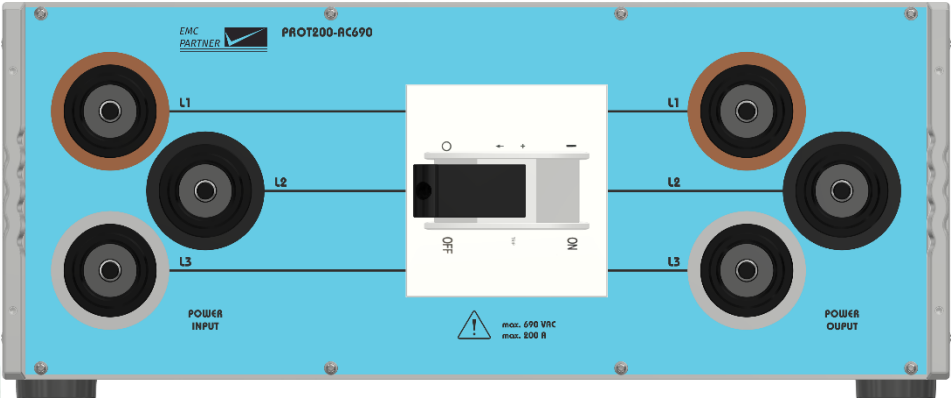
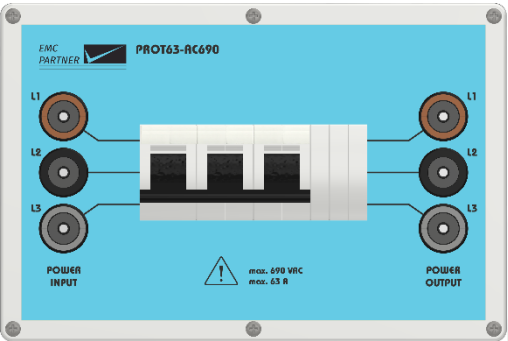
To prevent an overvoltage that could shut down the Power supply

- ✓ Use a damping resistor in series



Wide range of over current protection available

	AC Over current~	DC Over current =		
	AC 690 V	DC 500 V	DC 1000 V	DC 1500 V
32 A	✓ yes	✓ yes	✓ yes	✓ yes
63 A	✓ yes	✓ yes	✓ yes	✓ yes
125 A	✓ yes	✓ yes	✓ yes	✓ yes
200 A	✓ yes	✓ yes		



Thank you



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