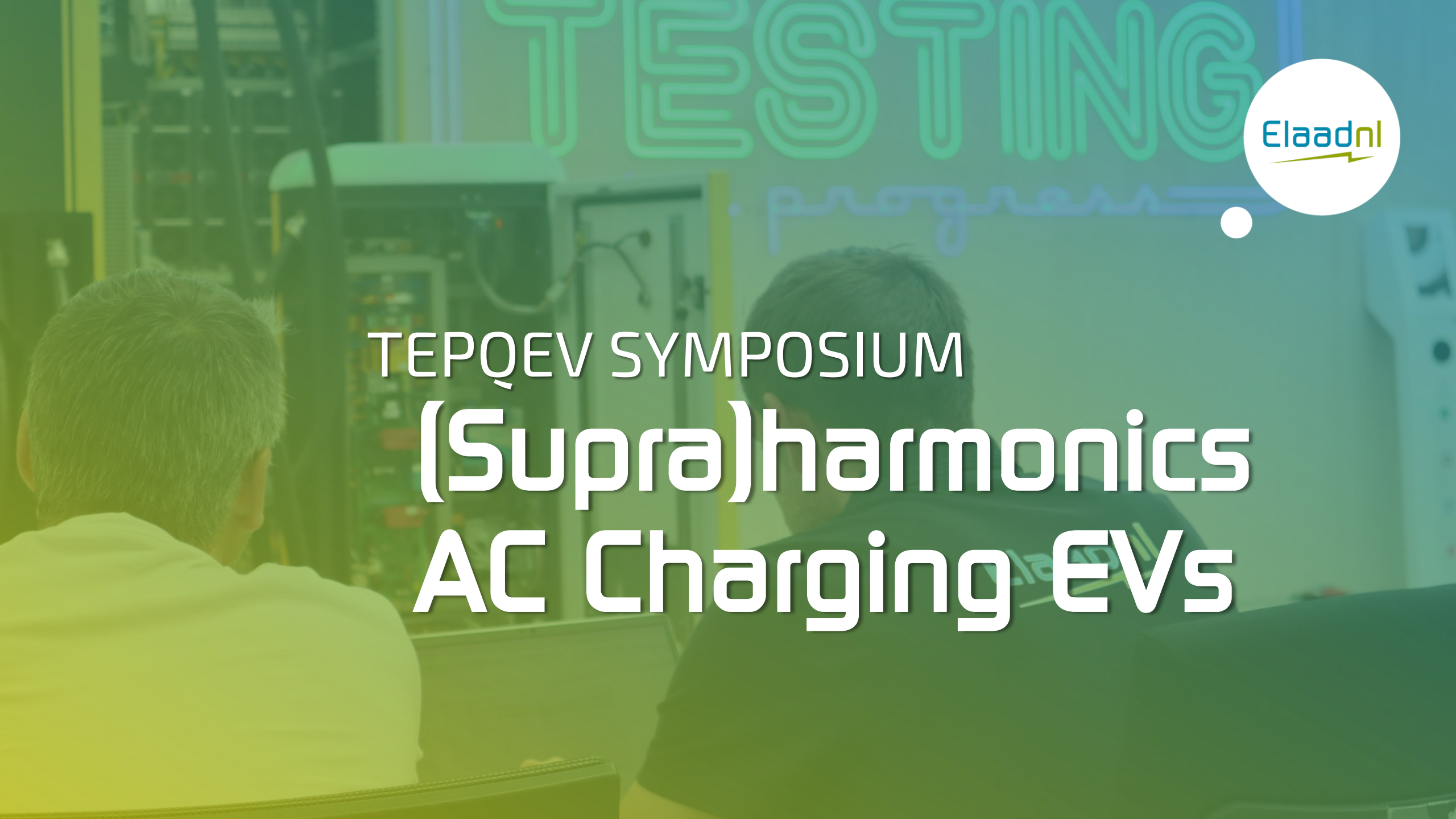


Elaadnl

TEPQEV SYMPOSIUM

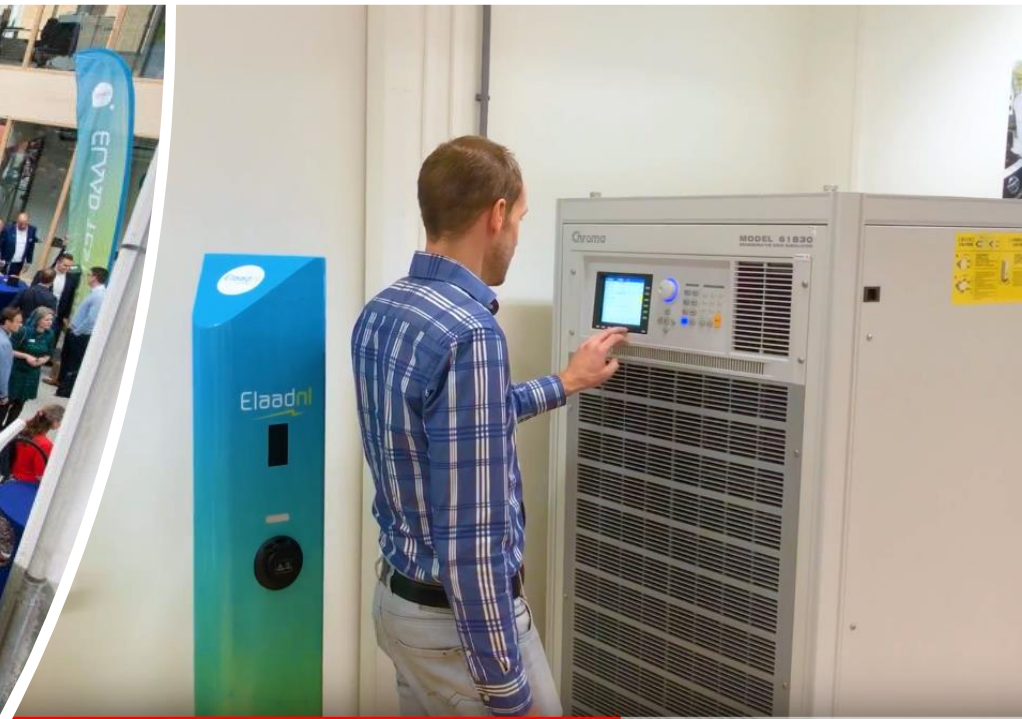
(Supra)harmonics AC Charging EVs

ElaadNL Testlab Introduction

- Open test lab for EVs and charging systems
- Free to use, paid by Dutch DSOs
- To make sure (smart) charging works and is secure
- To learn and advise about power quality emissions and immunity
- To help development of new protocols and standards, like 15118-20 V2G functionality

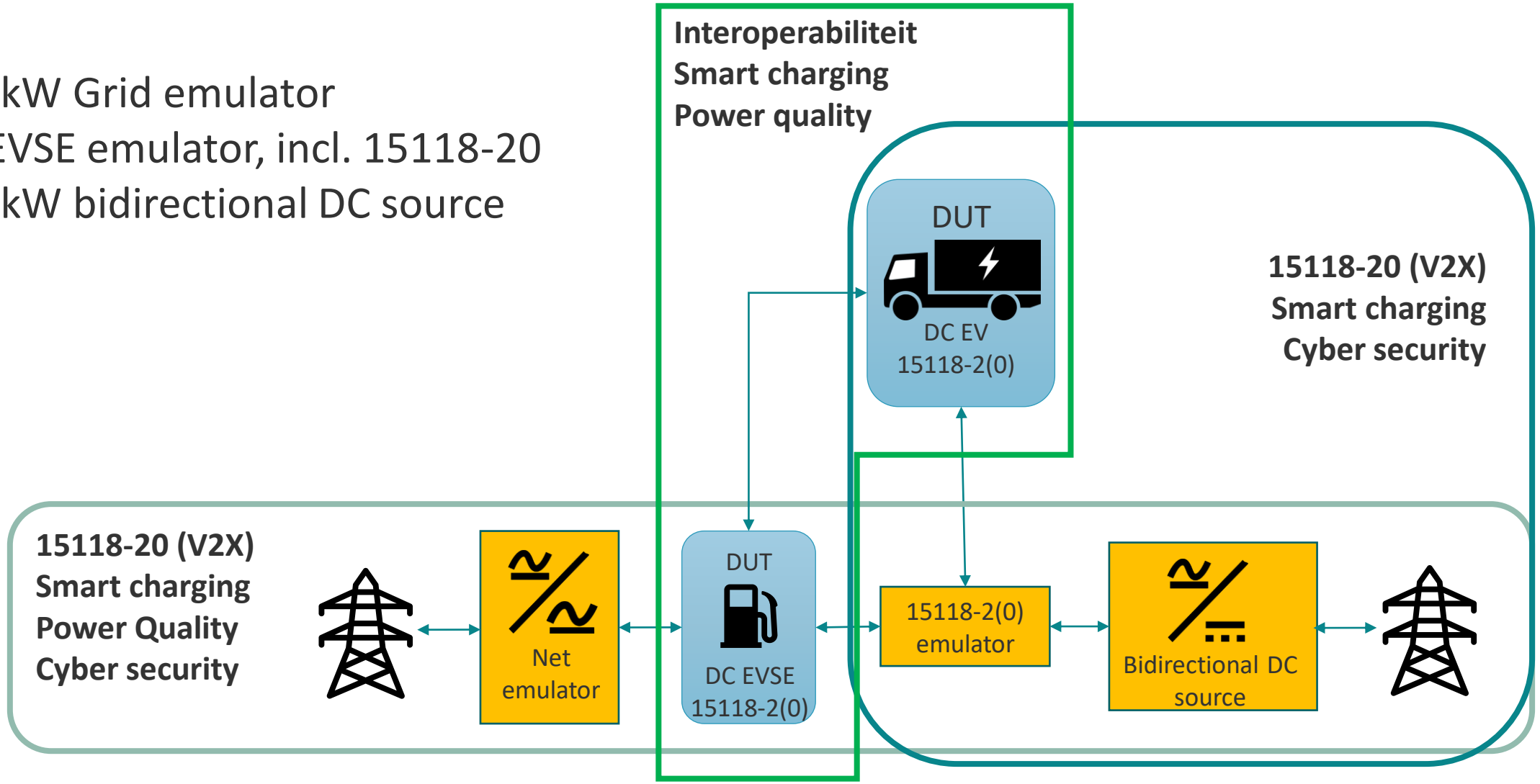
Specs

- 2x 800A mains connection
- 1x 500A High Power test connection
- 3x 125A medium power test connection
- 30 kW Grid emulator (3x43A) for clean or (controlled) distorted grid
- 1 MS/s data acquisition
- 16-bit resolution
- High-accuracy current transducers
- 600 kHz bandwidth



New HP test setup

- 360 kW Grid emulator
- EV/EVSE emulator, incl. 15118-20
- 360 kW bidirectional DC source



Role within TEPQEV

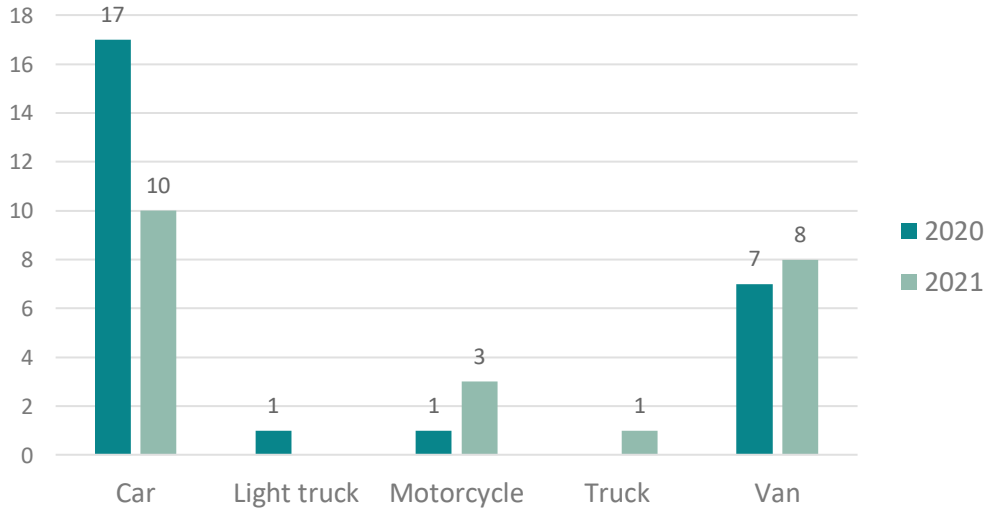
Gathering PQ impact data on AC charging EVs on a clean grid at different charging speeds, focusing on;

- Inrush currents and transients
- Reactive current/power factor
- Harmonic distortions (< 2 kHz)
- Supraharmonic distortions (2 – 150 kHz)

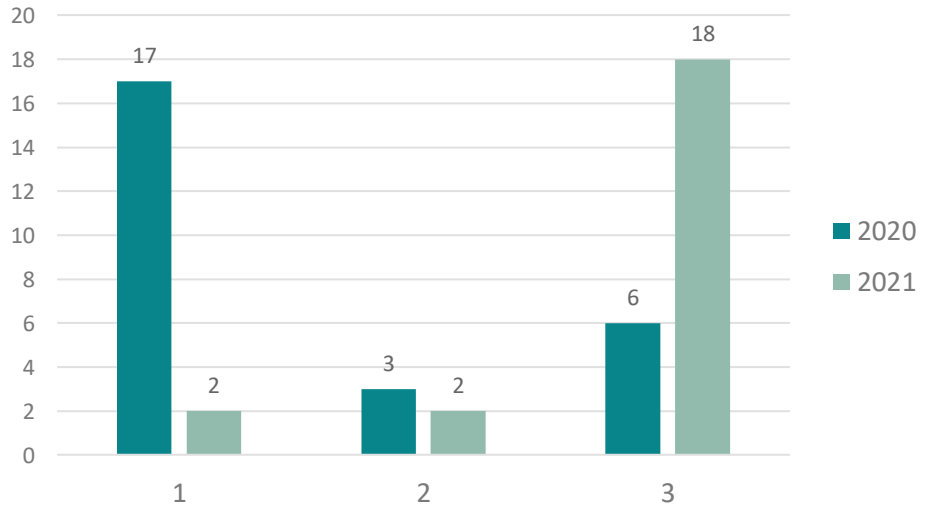
Using this data to;

- Advise manufacturers on their results and how to improve (best practices)
- Gather data about impact on grid for creation of better EV models
- Open discussions about the need for specific/adjusted standards for electric vehicles
- Use in further research on the effects and propogation of supraharmonic distortions on the grid and appliances

Overall tests 2020-2021

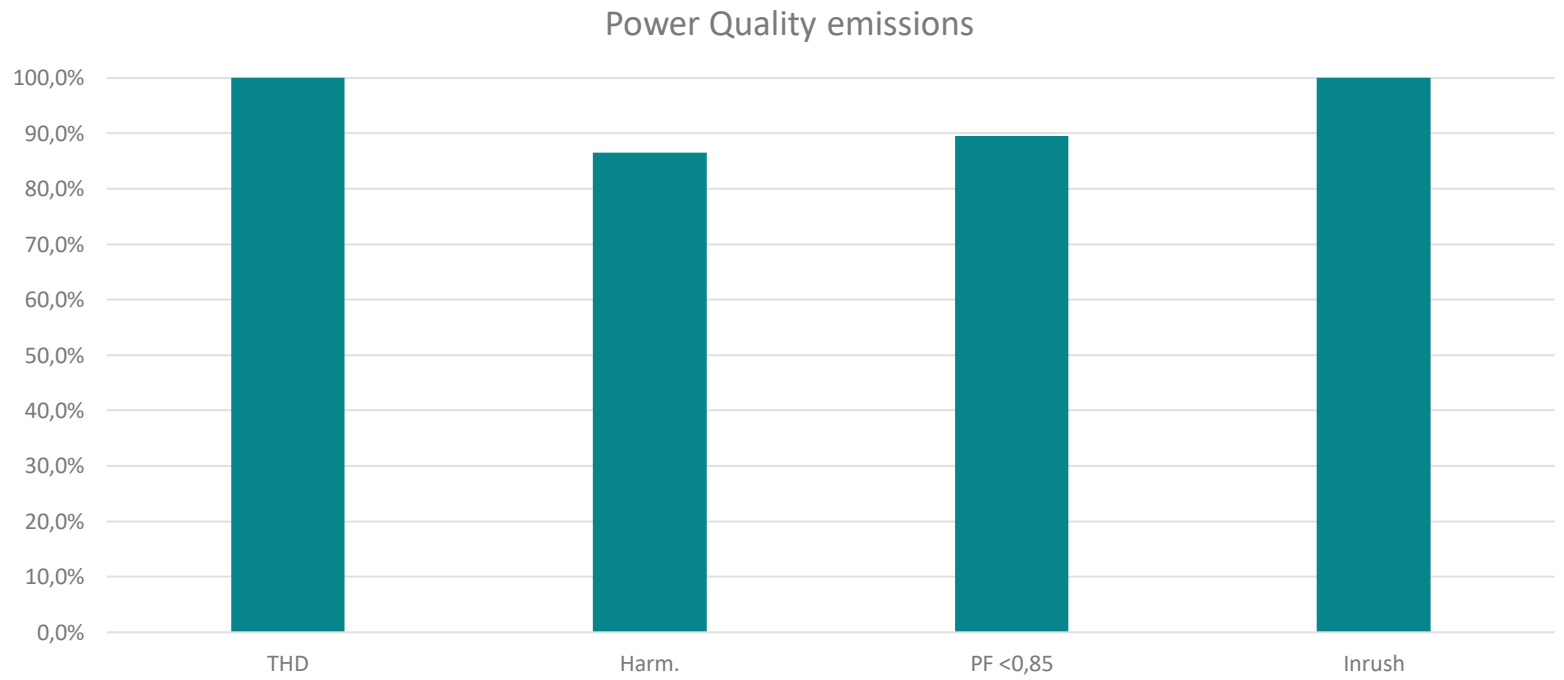


EV types



Number of phases

PQ emission trends



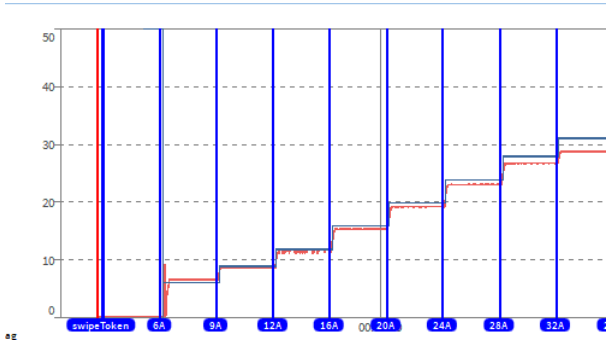
Power quality emission; positive test results

Results Harmonic limits

IEC 61000-3-2 (up to 16A) and IEC 61000-3-12 (16A till 75A) standards define the harmonic current limits for electronic equipment. In both cases, the nominal current is used for compliancy testing

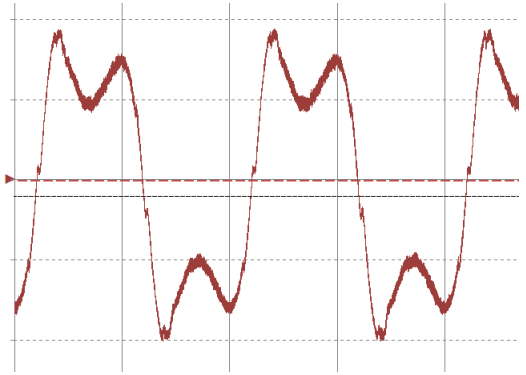
- However, EV charging speed is controllable, typically in between 6 and 16A for three phase charging, and 6 to 32A for single phase charging. Depending on the power available at that time, or the fixed maximum of the station, an EV can belong in the 61000-3-2 or in the 61000-3-12.

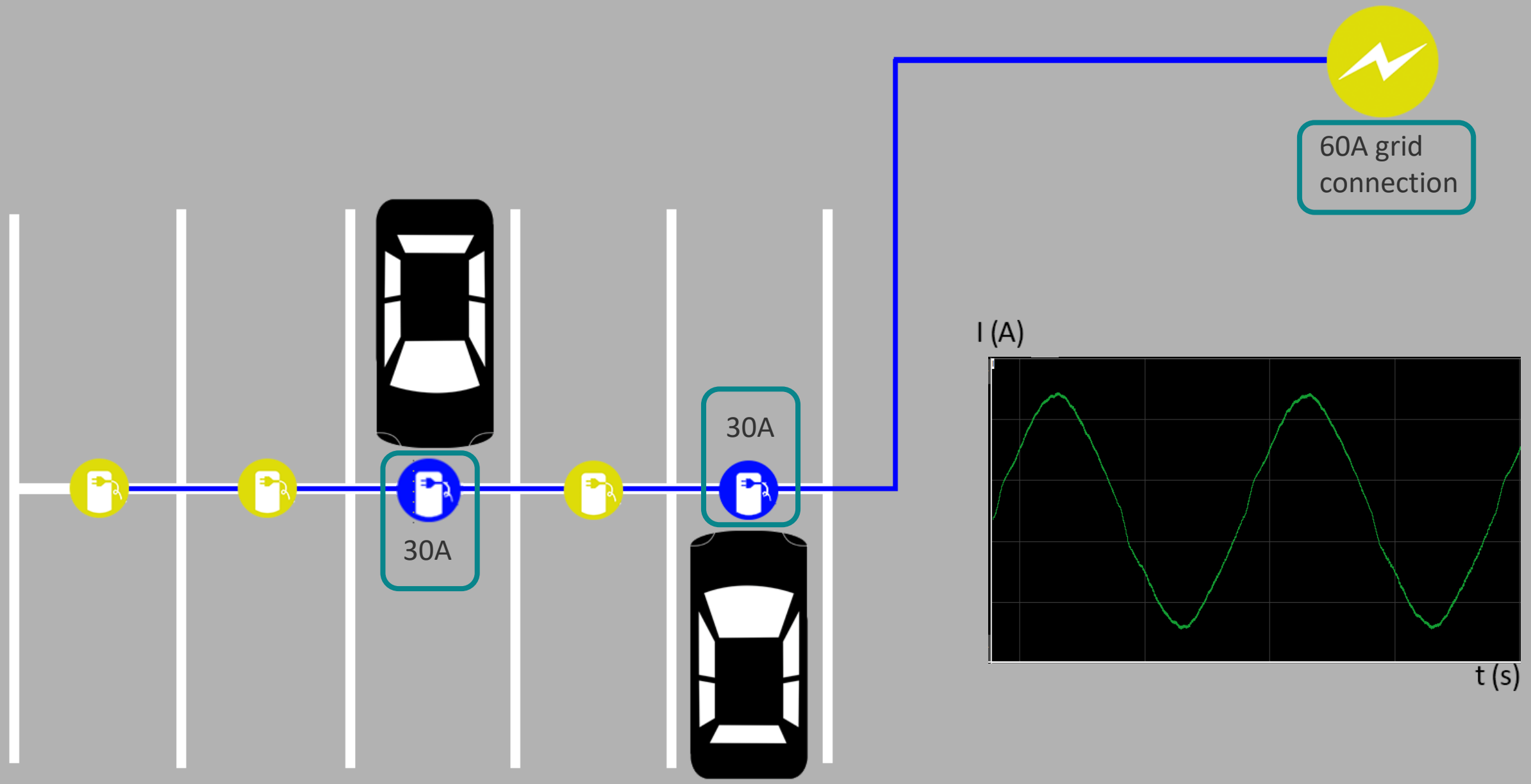
- And this can significantly alter the behaviour of the equipment emissions, especially when lowering the charging power. Consequently, low power operation points can generate much higher total harmonic distortion than the rated operation point.

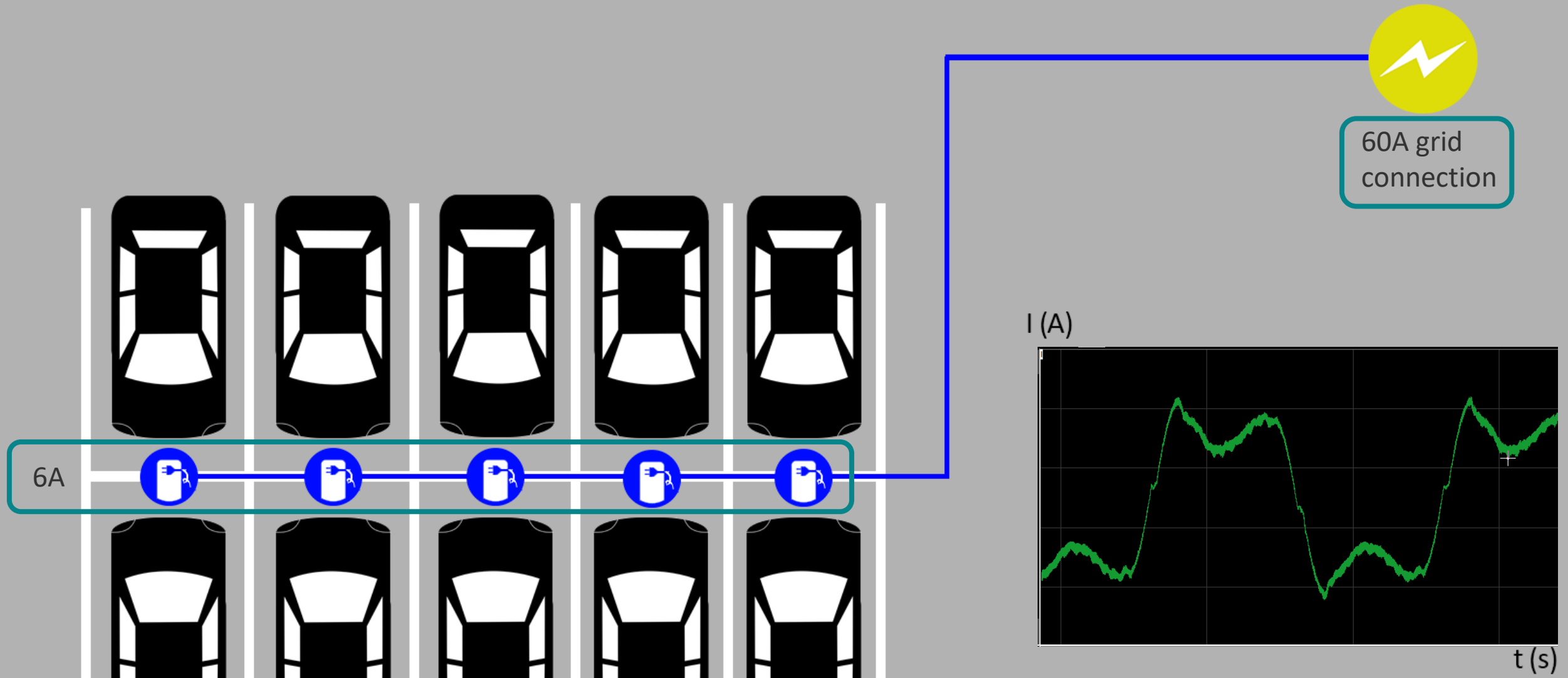


Current		Phase 1 (THD: 46.14%)
Order	RMS	%
1	5.91A	100.00%
3	2.67A	45.10%
5	470.17mA	7.95%
7	112.88mA	1.91%
9	94.09mA	1.59%
11	50.24mA	0.85%

Maximum allowed limit 2,3A




60A grid connection
30A
30A
I (A)
t (s)


60A grid connection
6A
I (A)
t (s)

Recommendation Harmonics

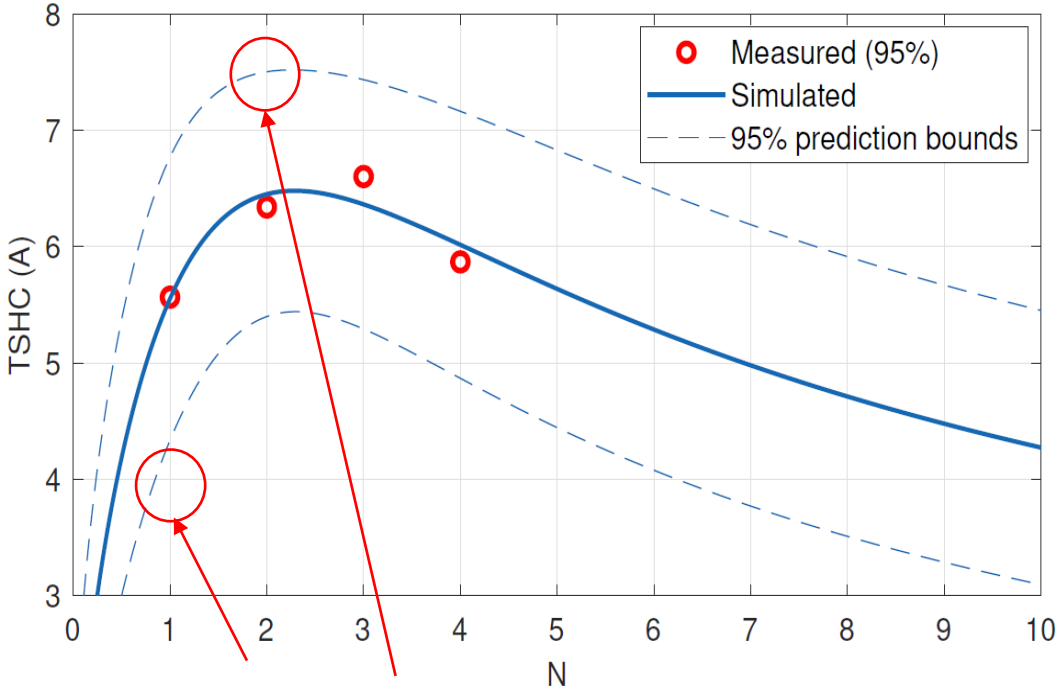
Recommendation regarding Harmonic currents limits

1. For both standards; create a new category of controllable load specifically for, or which includes, electric vehicles
2. For this category; set harmonic limits at different operating points as a percentage of the drawn current.
3. Adapt the compliancy tests to address several operating points.

Limits Supraharmonics

The supraharmonic current limit range derived in the TEPQEV project is a limit at the grid connection point.

- When multiple EVs are connected to a single grid connection, the Supraharmonic distortions tend to add up at first, and then start to decline.
- Using the TSHC graph per number of vehicles from the research, while taking the opposite 95% prediction bounds for 1 vehicle and 2 vehicles, we can see the TSHC can roughly double

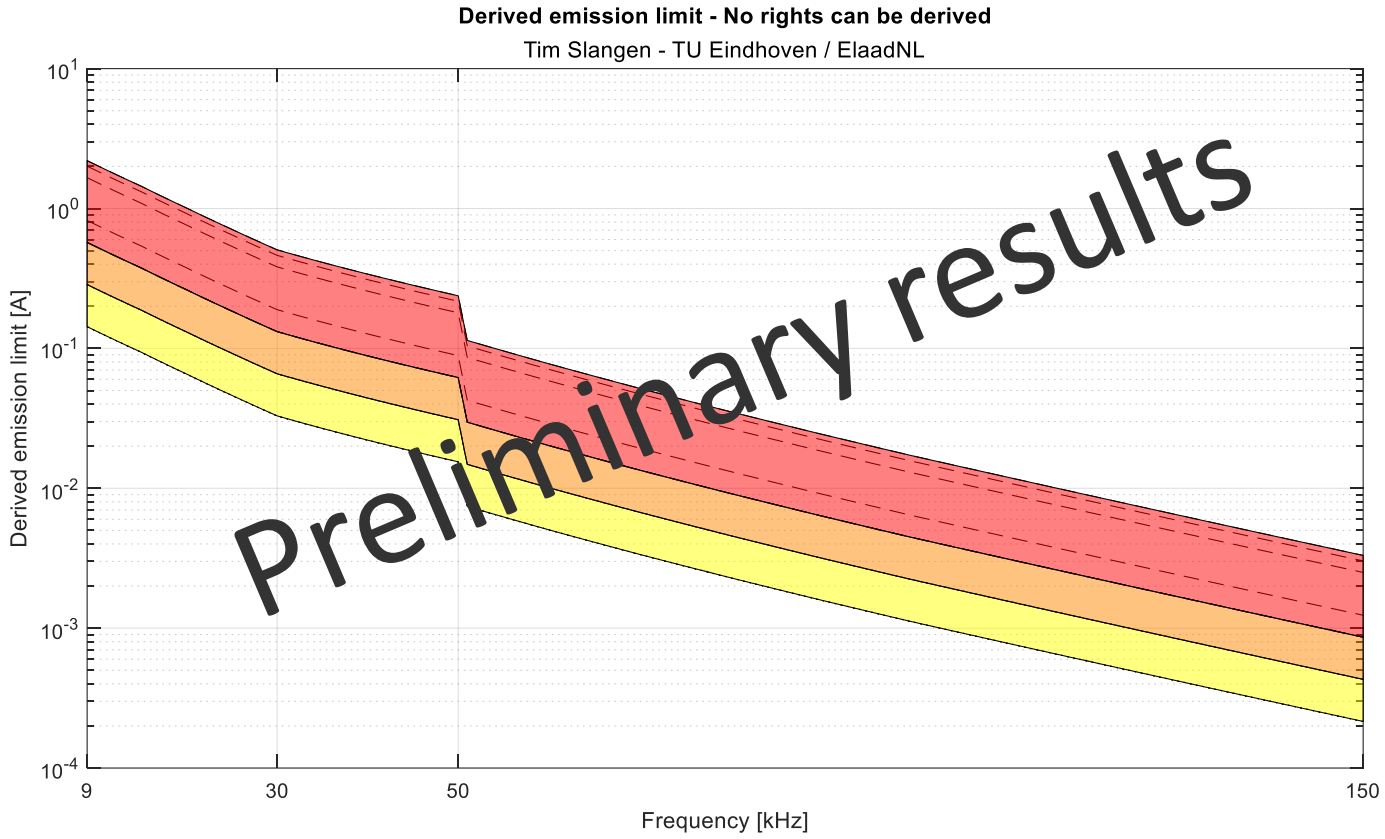


lower TSHC at 1 device is 4A,
upper TSHC at 2 devices about 8A

Figure source:
Tim Slangen – TU Eindhoven / ElaadNL

Suggested emission limits

- **Red**: the limit range as derived from the TEPQEV research. This is NOK
- **Orange**: the lower limit from the research, till 0.5 of that limit to take into account the possible doubling with multiple EVs. This is likely NOK
- **Yellow**: Orange lower limit till 0.25 of TEPQEV limit. To also cover the cases in more extreme situation or when the grid impedance is lower than usual. This is on the border of NOK/OK
- Any distortions with a value below the yellow line are considered to be OK



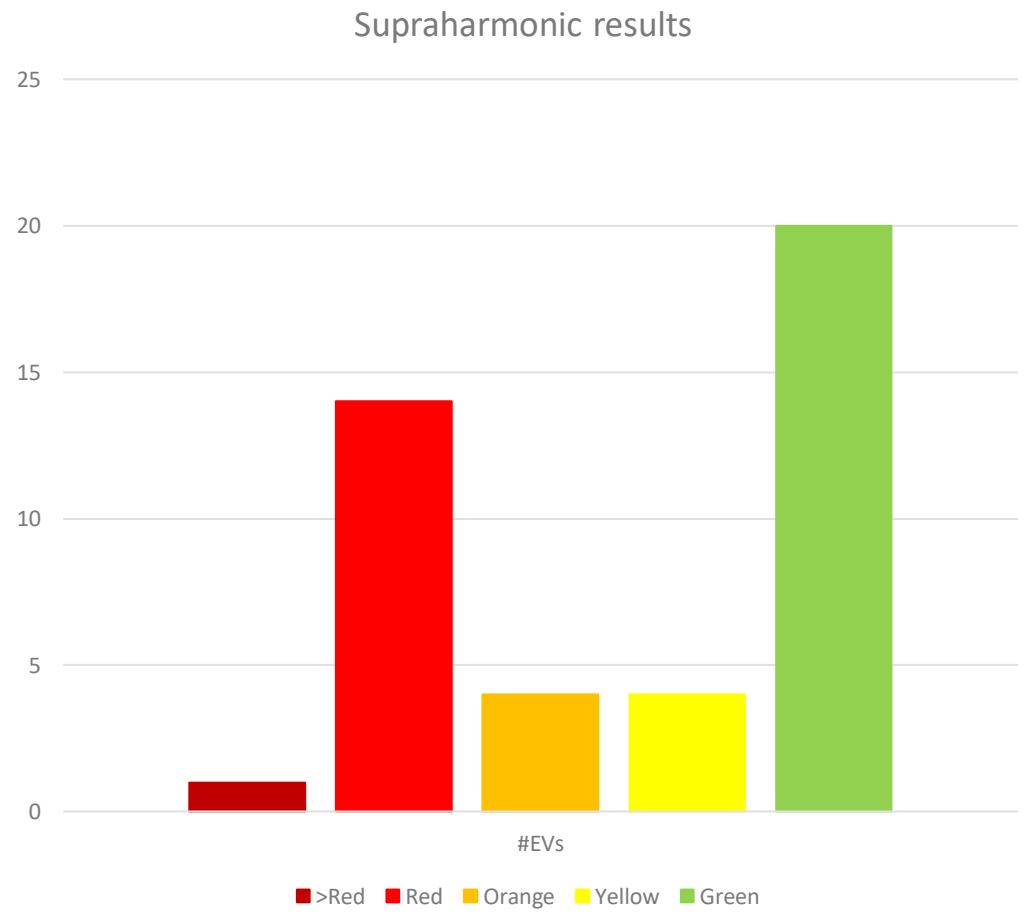
Results Supraharmonic

Method:

- Total number of EVs; 43
- Just observable peaks in the FFT have been measured
- The highest peak found at any charging speed was used
- No special treatment for broadband distortions

Results:

- 20 EVs seem OK, 23 seem to be in one of the limit ranges
- 14 EVs in the “red range”, even one above that range
- Moment of highest peak differ per EV; at max charging current, min charging current, 1 phase, 3 phase.



Conclusion Supraharmonic

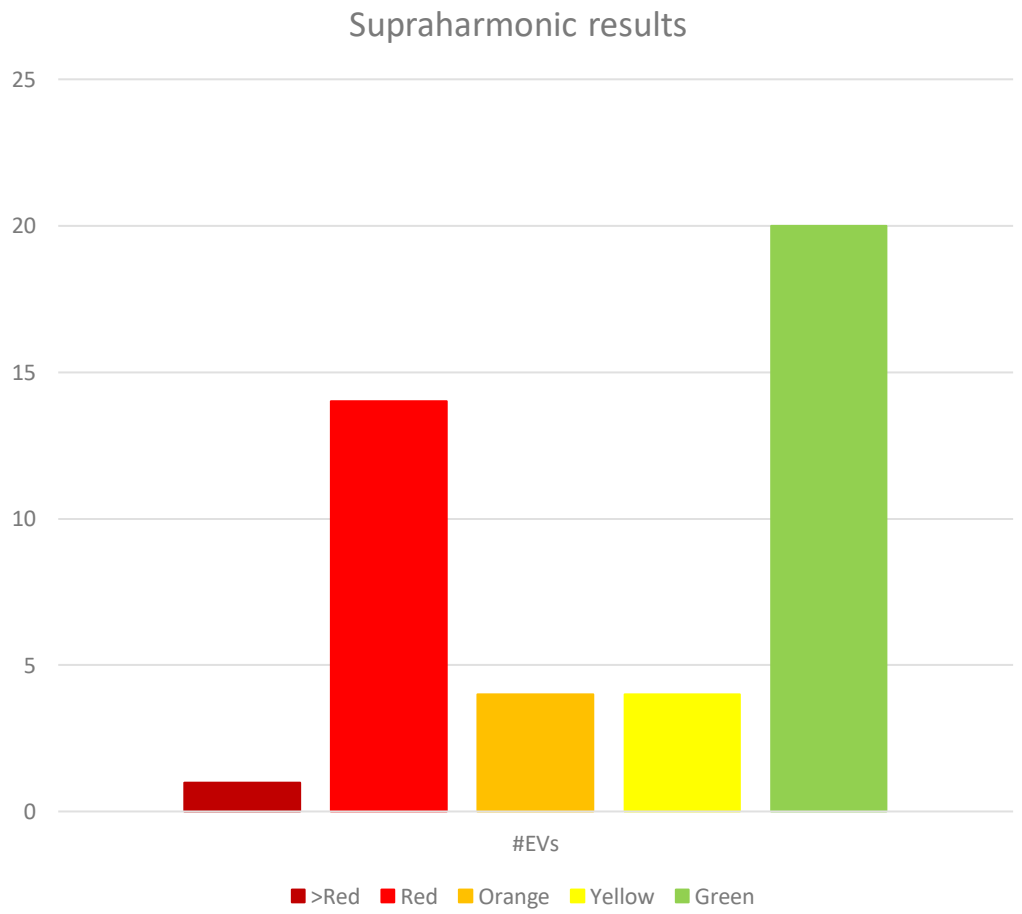
Conclusion:

The suggested limits seem to be workable.

- The limits show EVs can be a high source of Supraharmonics
- But also that it is possible to stay below the lowest limit!

Recommendations:

- A standard and certification is needed to get all into the green zone
- The suggested limits seem to be a good starting point
- The measurement method should include;
  - Testing at different charging speeds, and
  - at 1 phase charging and 3 phase charging



Questions?

RESEARCHING AND TESTING
SMART AND SUSTAINABLE
CHARGING