FICHTNER

Analysis and evaluation of power quality aspects in a low-voltage network with regard to a high penetration of decentralized generation and charging infrastructure

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Technical standards for harmonics

Technical standard	Application	Threshold of the 5th Harmonic as example	Basis
DIN EN 50160	Low voltage network	6.0 %	Fundamental component of the voltage U_1
DIN EN 61000-3-12	Photovoltaic system	10.7 %	Fundamental component of the current I_1
DIN EN 61000-3-2	Electric vehicle	1.14 A	Absolute current I_1

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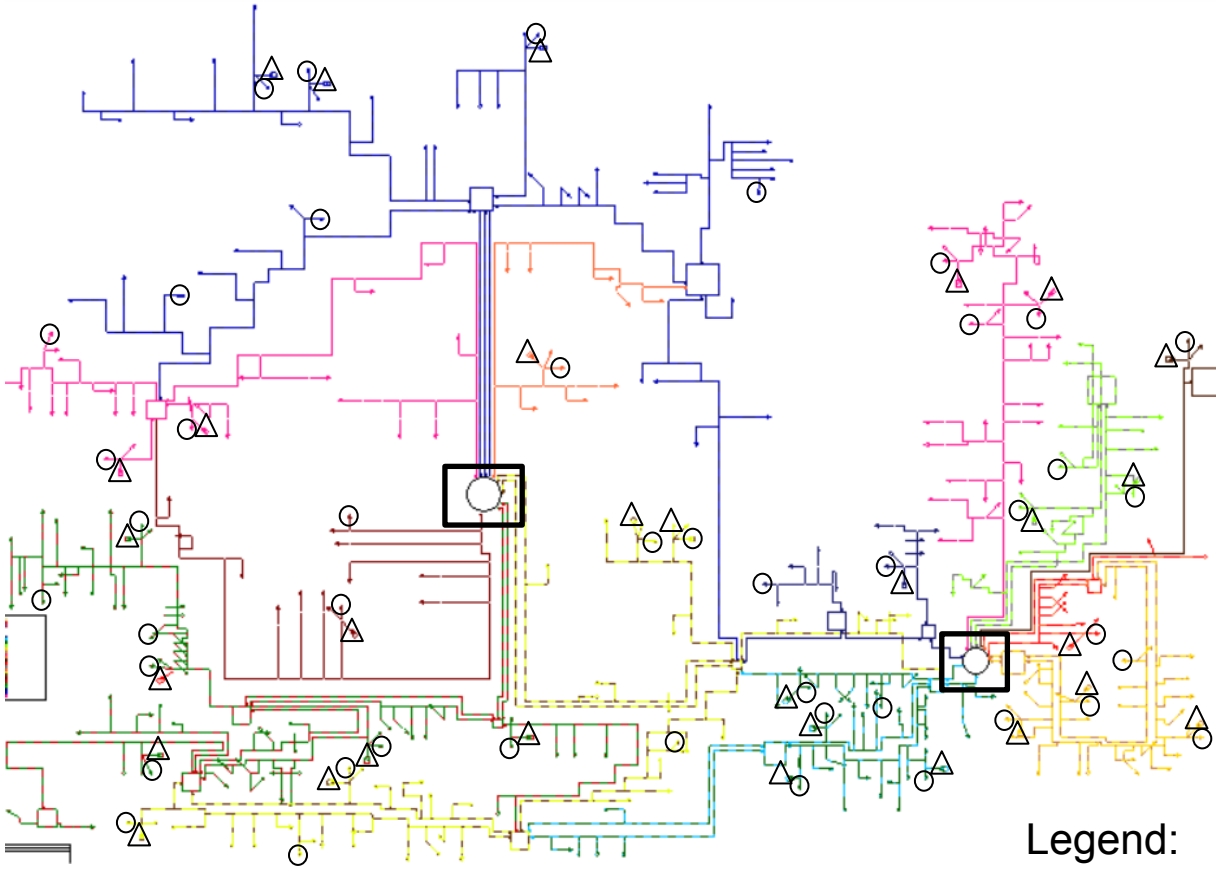
Grid details



Legend:
- △ PV-system
- ○ EV
- □ Transformer

Parameters of the grid:

- Position: Provincial town close to a large city
- 2 transformers (T1, T2) of a local distribution system: 0.63 MVA
- Household loads: 292
- Photovoltaic systems: max. 30 rooftops à 4 kWp
- Electric vehicles: max. 44 in 2030

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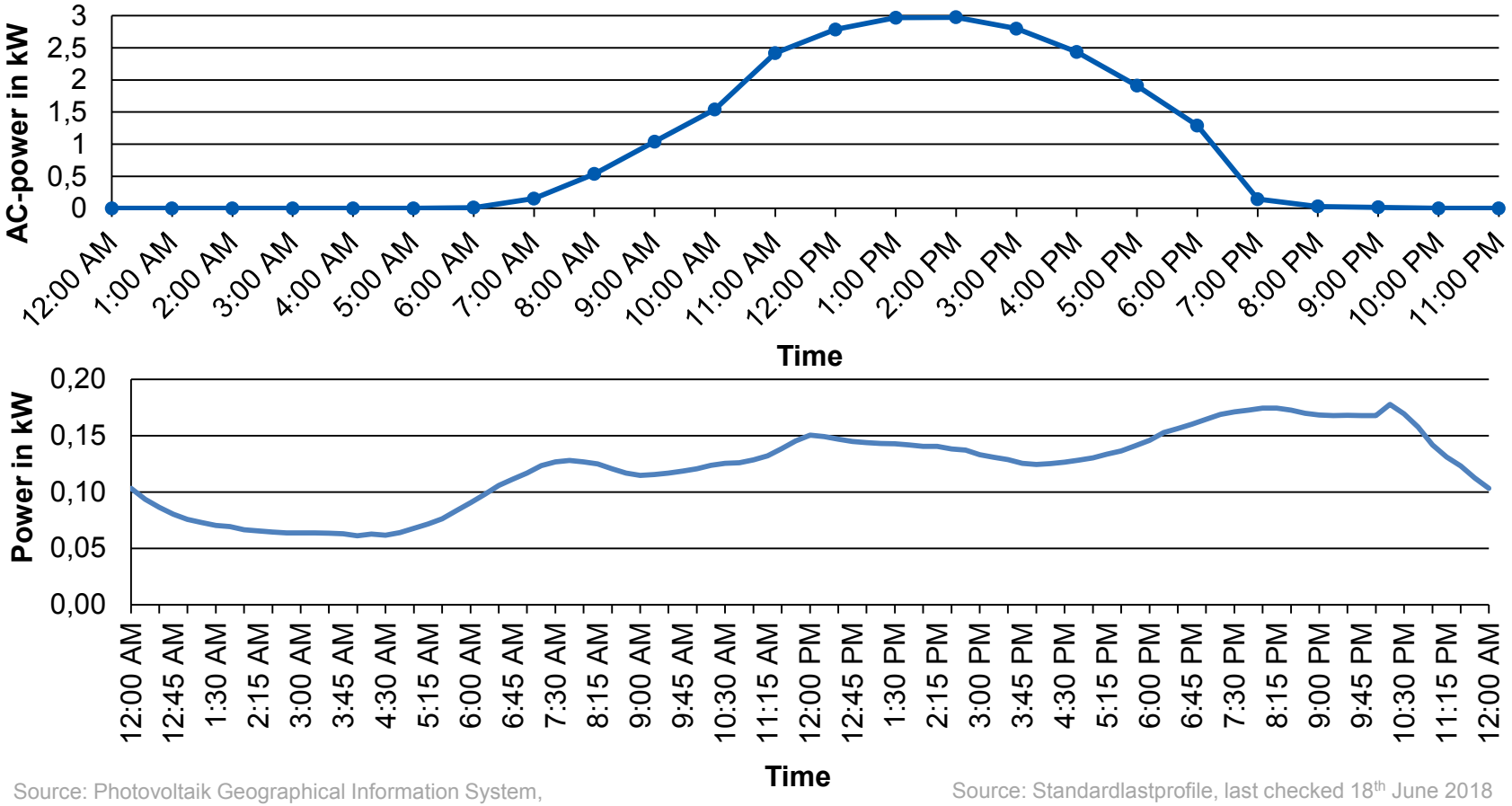
Grid modelling: Load profiles in summer

Performance of one PV-system, installed load of 4 kWp;
Standard load profile for one person per household at a weekday,
Loading increase according to network operator: 1 % per year

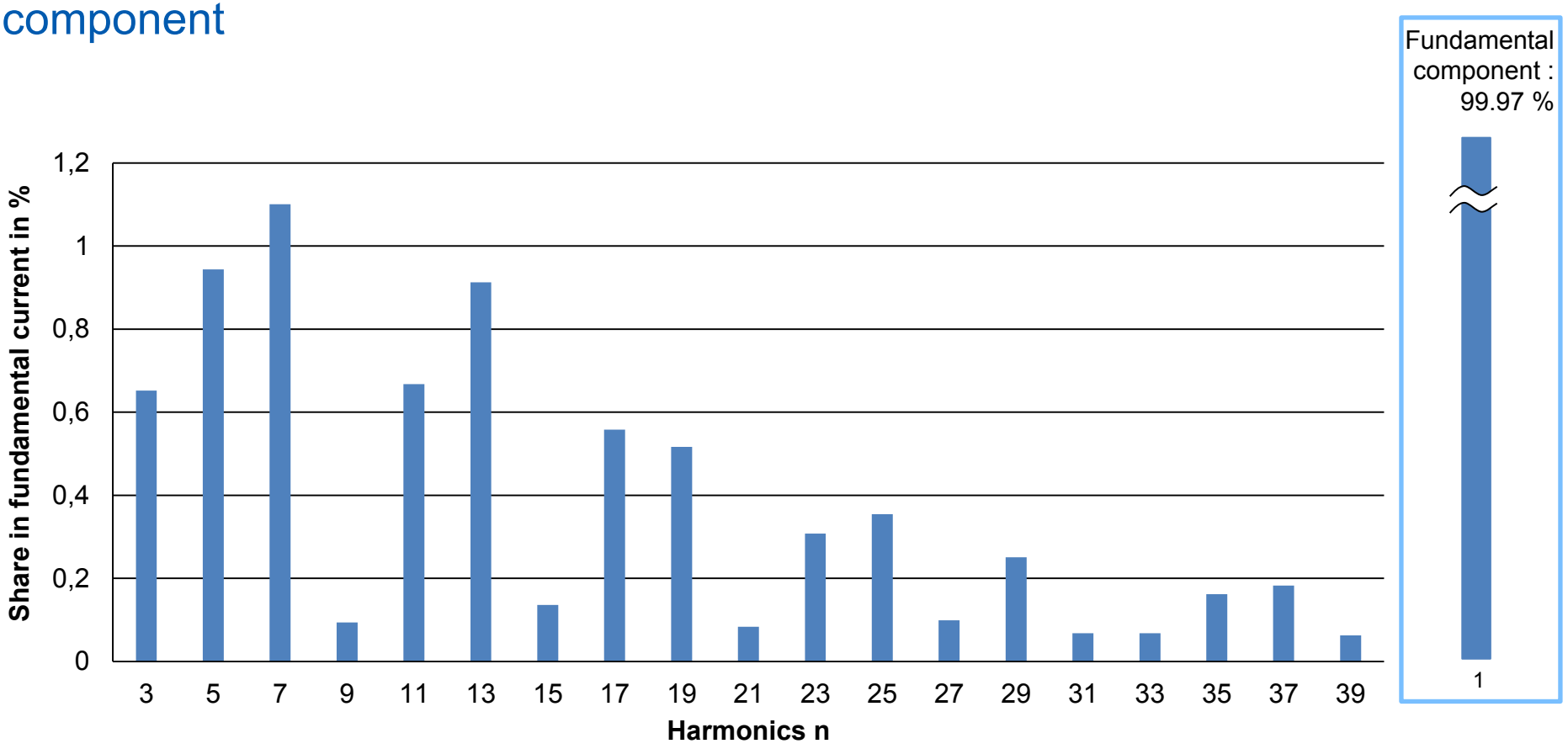


Source: Photovoltaik Geographical Information System, http://re.jrc.ec.europa.eu/pvg_tools/en/tools.html, last checked 18th of June 2018

Source: Standardlastprofile, last checked 18th June 2018 https://swe-emmendingen.de/strom-netz/lastprofile/

Grid modelling: Spectrum PV

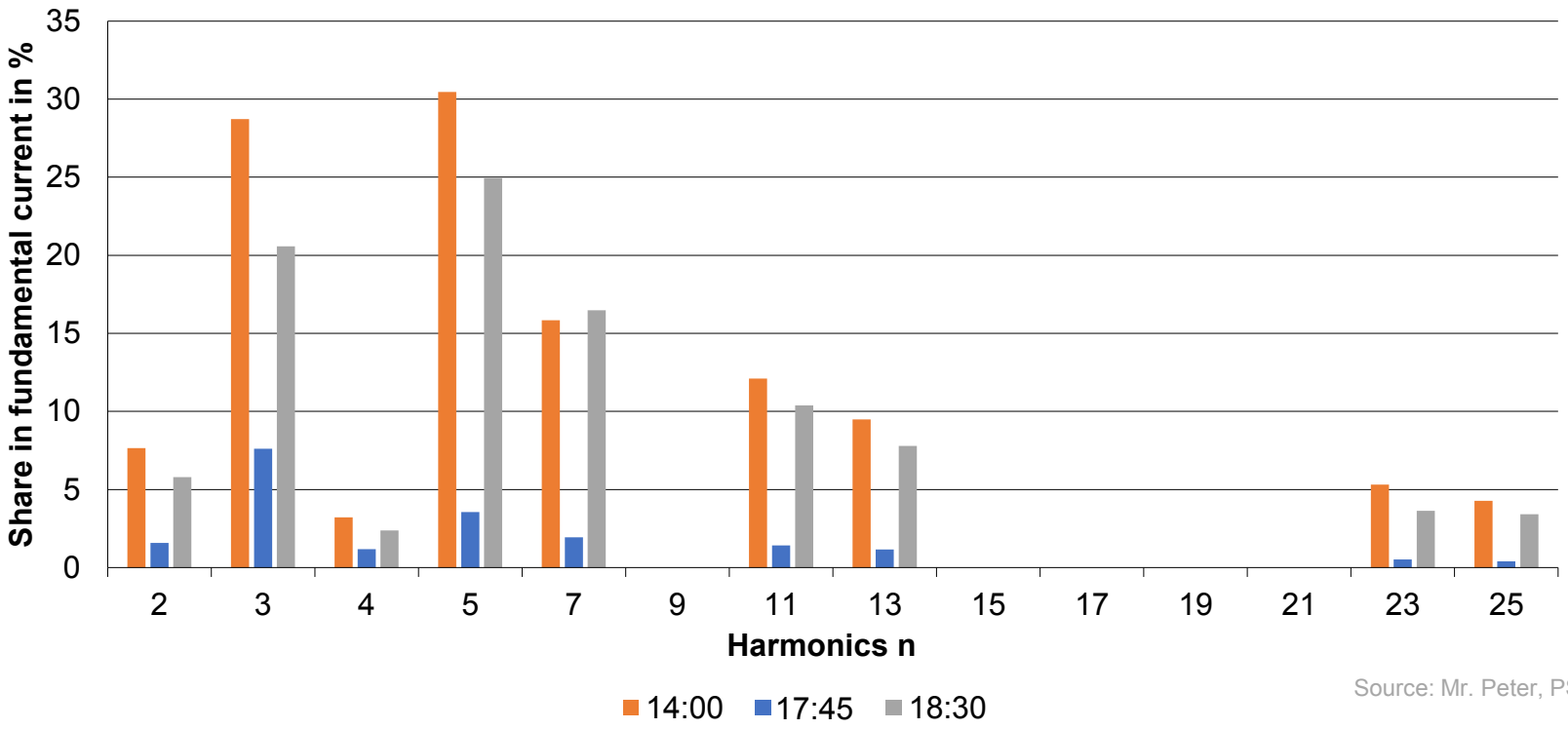
Spectrum of a photovoltaic system in percentage of the fundamental component

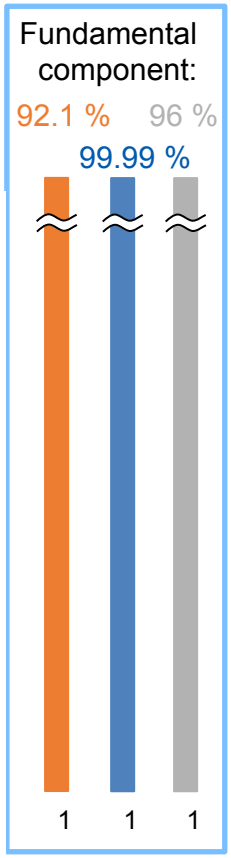


Source: Mr. Peter, PSC – Power Systems Consulting

Grid modelling: Spectrum Households

Spectrum of one household at different times





Source: Mr. Peter, PSC – Power Systems Consulting

Grid modelling: EV

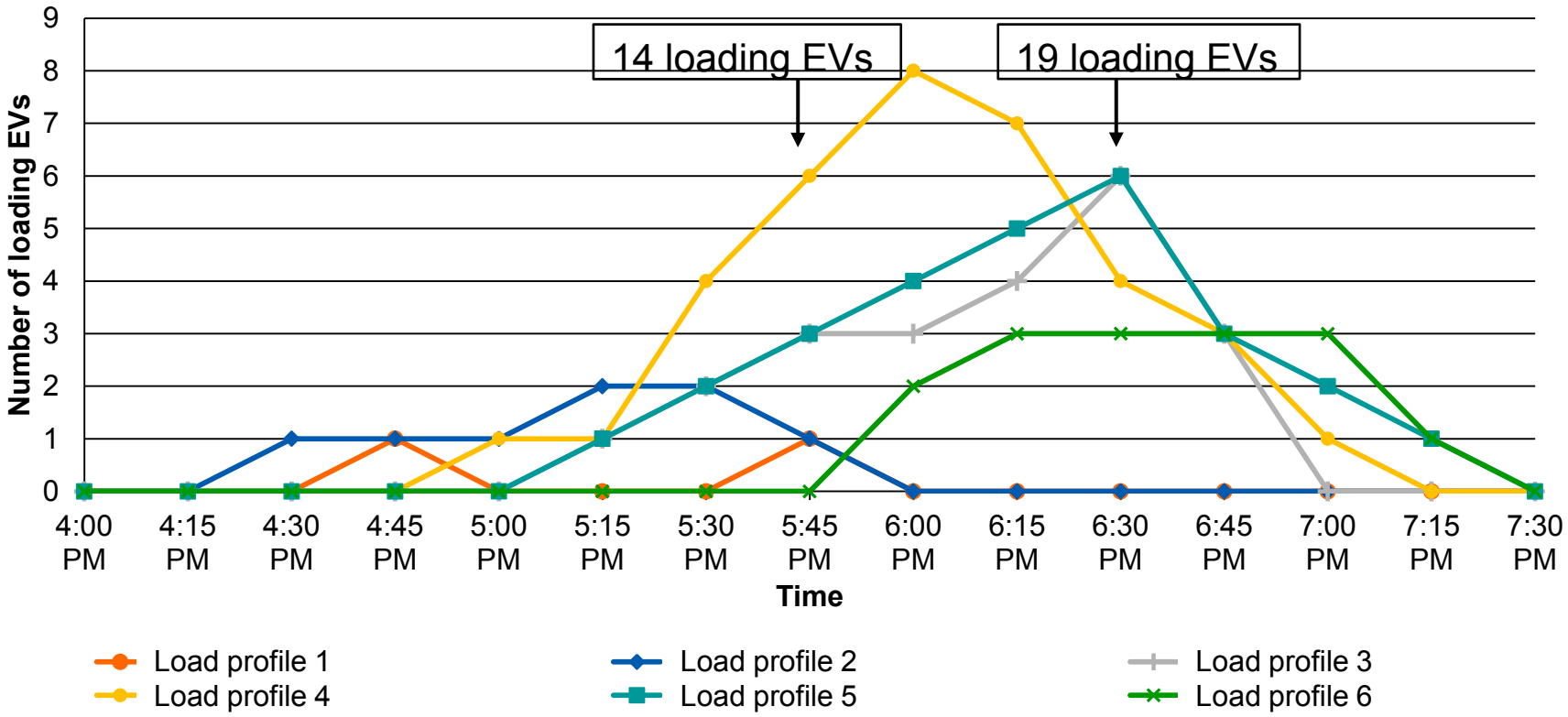
Six user profiles of the electric vehicles

Profile	Distance	Assumed covered distance per day	Numbers of persons out of 44 users
1st profile	under 10 km	5 km	2
2nd profile	11 - 20 km	15 km	8
3rd profile	21 - 40 km	30 km	11
4th profile	41 - 65 km	53 km	12
5th profile	66 - 100 km	83 km	8
6th profile	over 100 km	110 km	3

Source: study: Mobilität in Deutschland 2008, own calculation

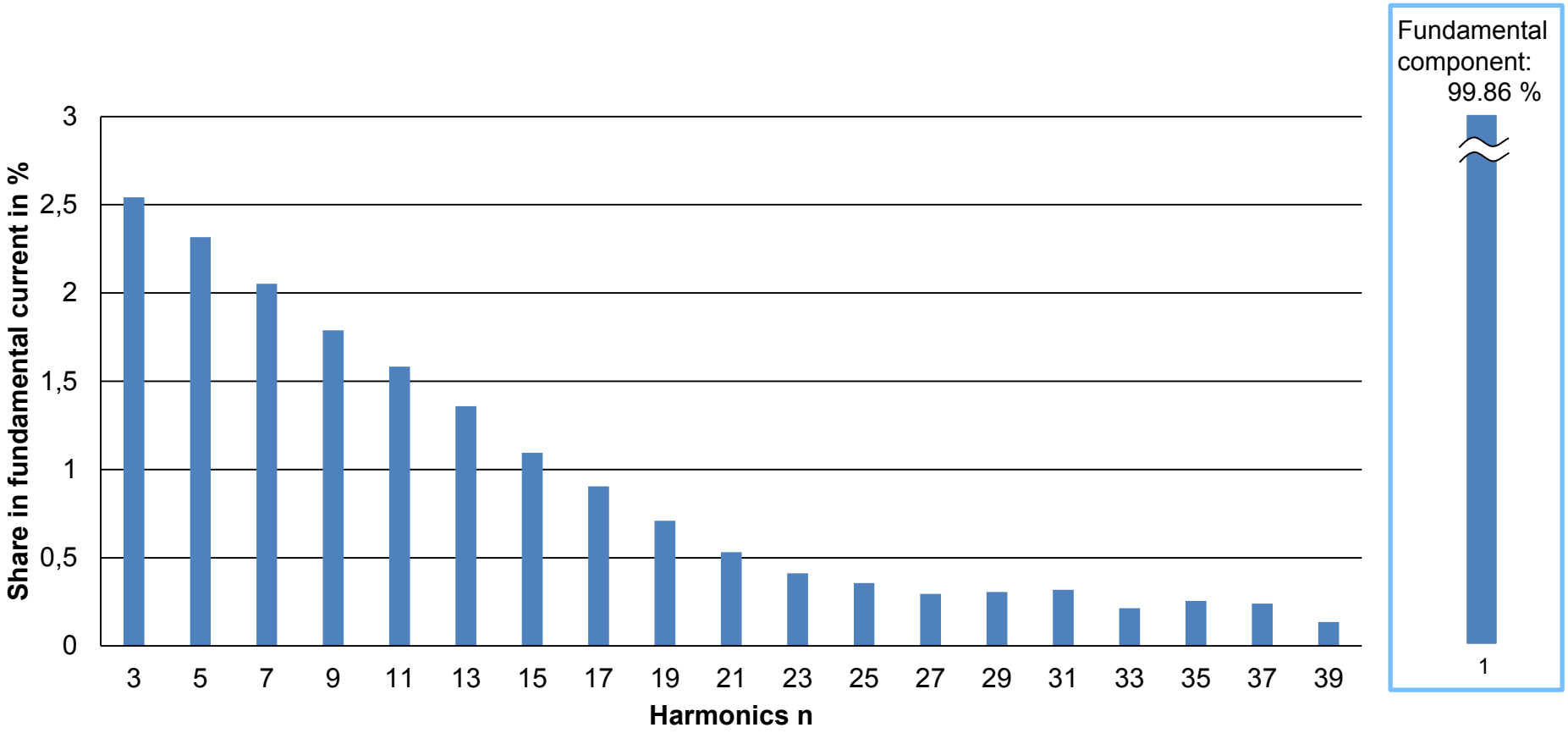
Grid modelling: EV

Simultaneous loading of electric vehicles in the year 2030



Grid modelling: EV

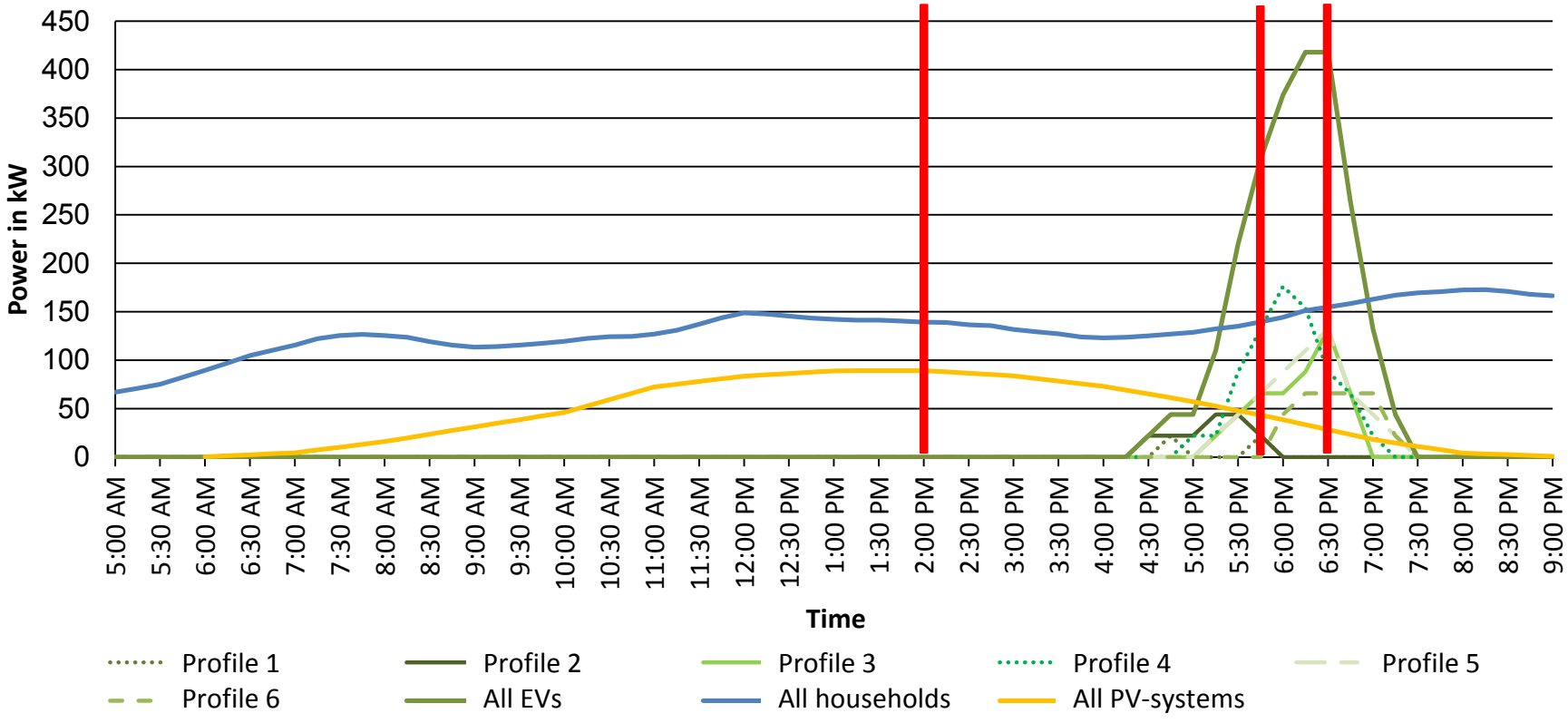
Spectrum of one electric vehicle, three-phase loading with 22 kW



Source: study ElmoNetQ, TU Dresden

Grid modelling: Instant of times

Profiles of all generator and consumer loads in 2030, at 2 pm, 5:45 pm and 6:30 pm



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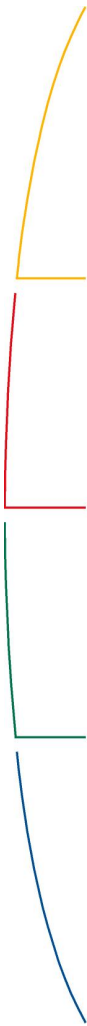


Results: Power flow

Load distribution 2030

292 households (T1: 118 households, T2: 147 households)

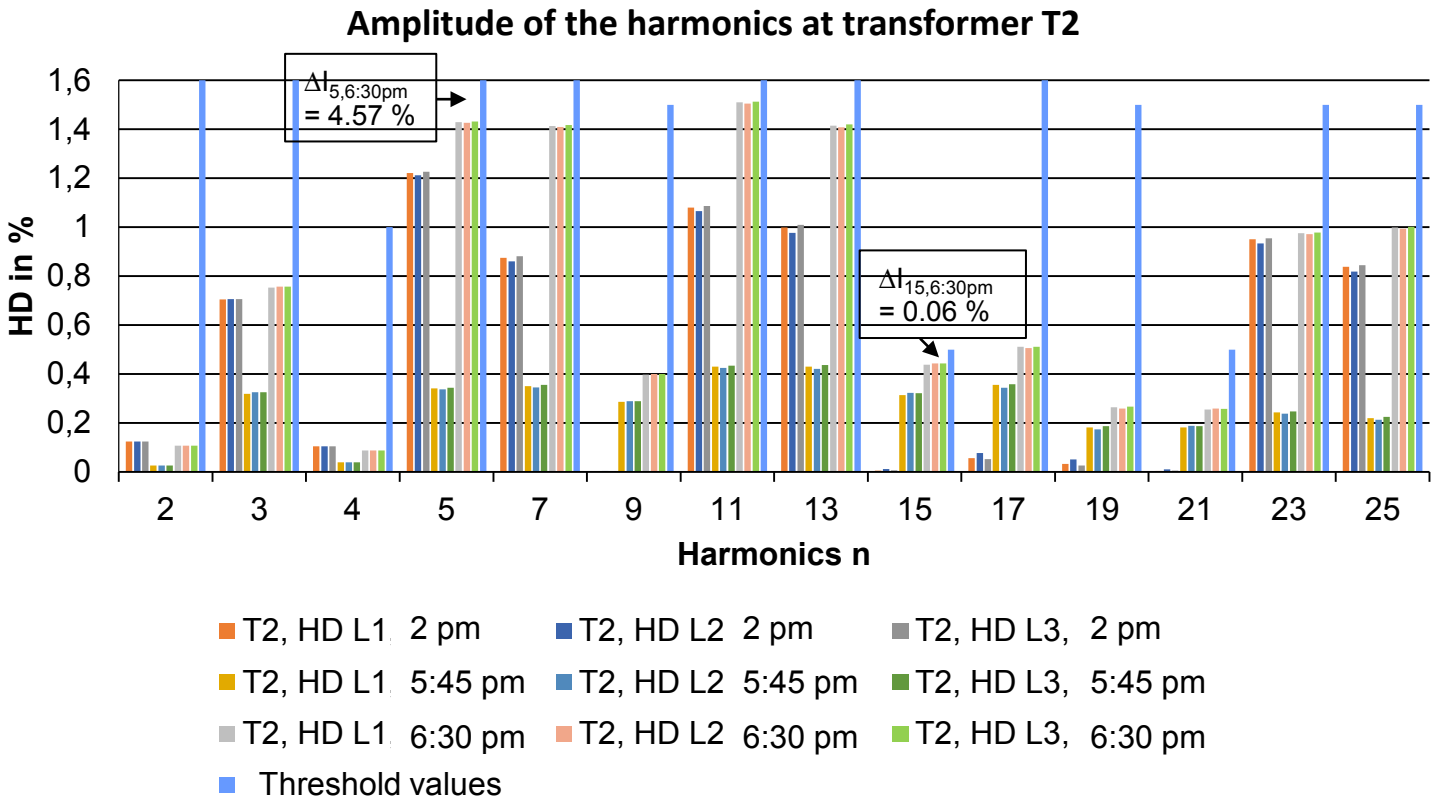
44 EVs, three-phase loading with 22 kW

30 PV-systems, each installed load: 4 kWp

Time	Number of loading EVs at T1	Number of loading EVs at T2	P_{1_PV} 2030	Load of household in %	Load households T1	Load households T2	Total load T1	Total load T2
2 pm	0	0	2.98 kW	79.1 %	56.2 kW	82.9 kW	15.2 kW	35.5 kW
5:45 pm	6	8	1.44 kW	79.3 %	56.4 kW	83.1 kW	169.3 kW	242.5 kW
6:30 pm	8	11	0.95 kW	88 %	62.5 kW	92.2 kW	234.8 kW	323.6 kW

Results 2030

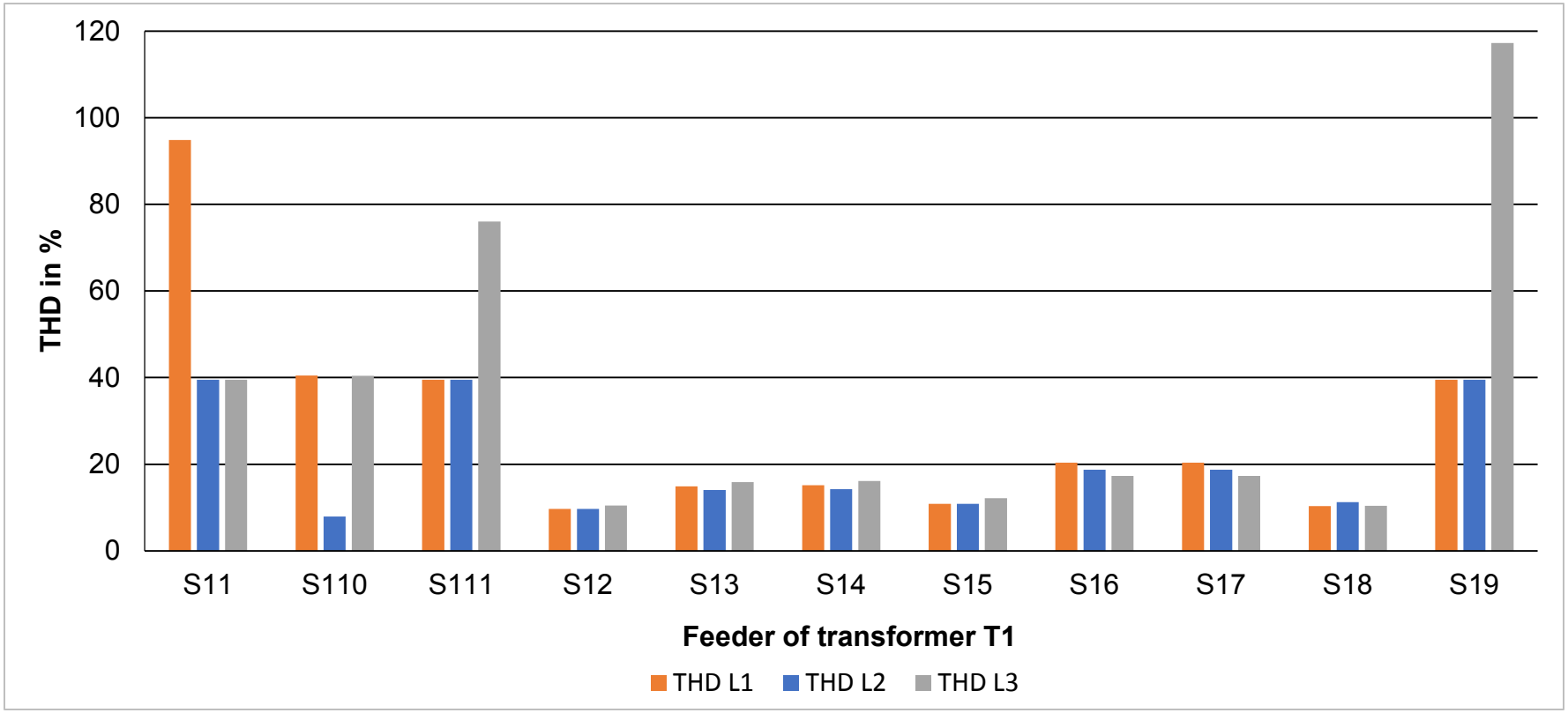
Thresholds will be observed, highest load at 6:30 pm



Order	Threshold value
2	2
3	5
4	1
5	6
7	5
9	1.5
11	3.5
13	3
15	0.5
17	2
19	1.5
21	0.5
23	1.5
25	1.5

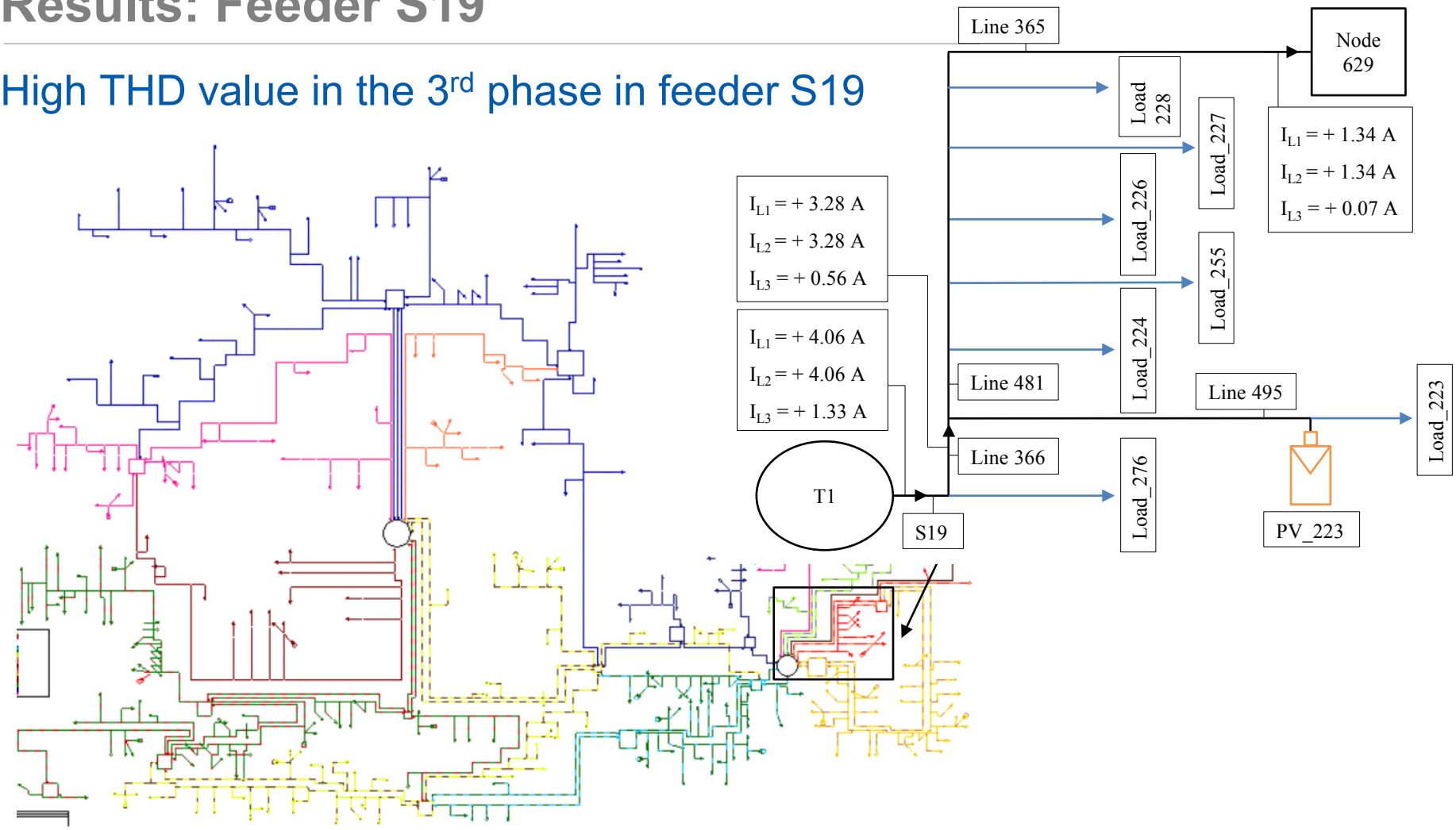
Results 2030

THD current values of transformer T1 feeder, THDi value S19: 117.3 %



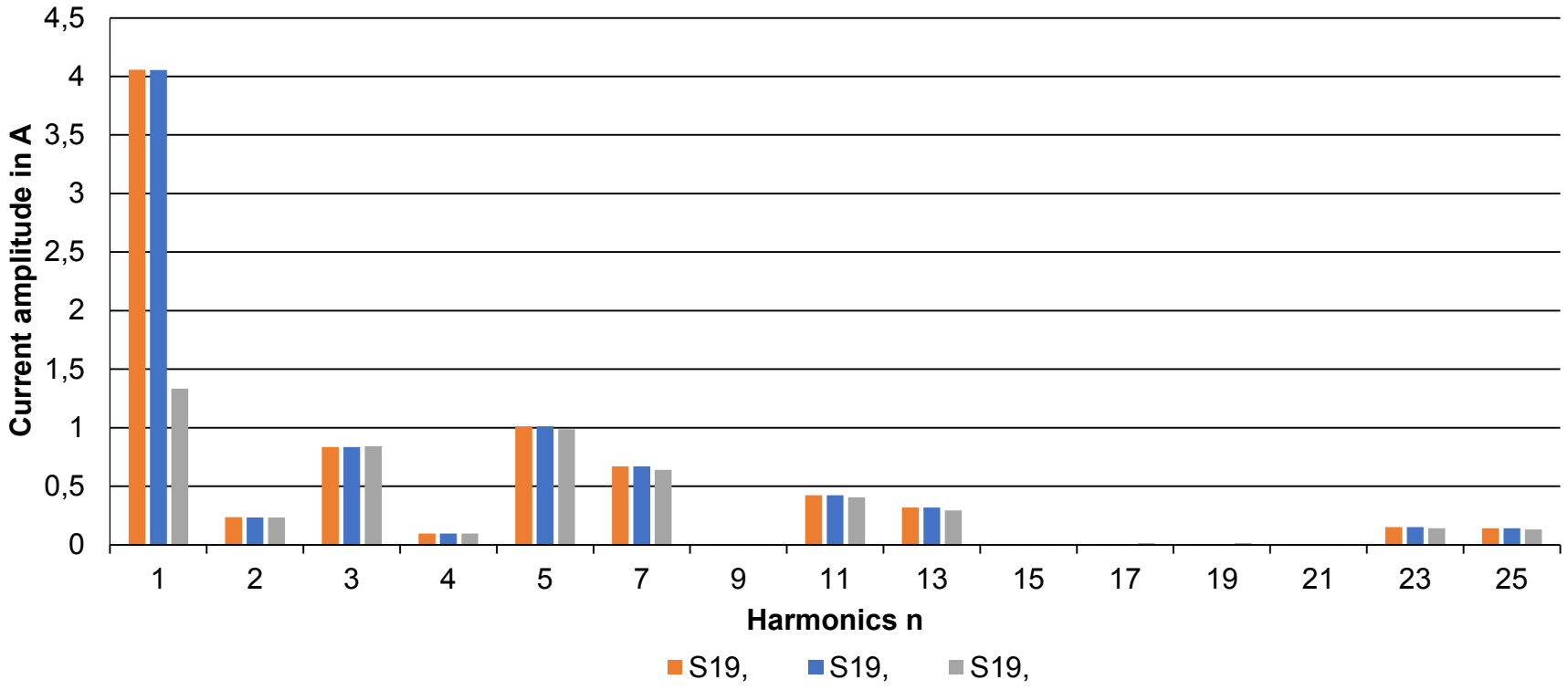
Results: Feeder S19

High THD value in the 3rd phase in feeder S19



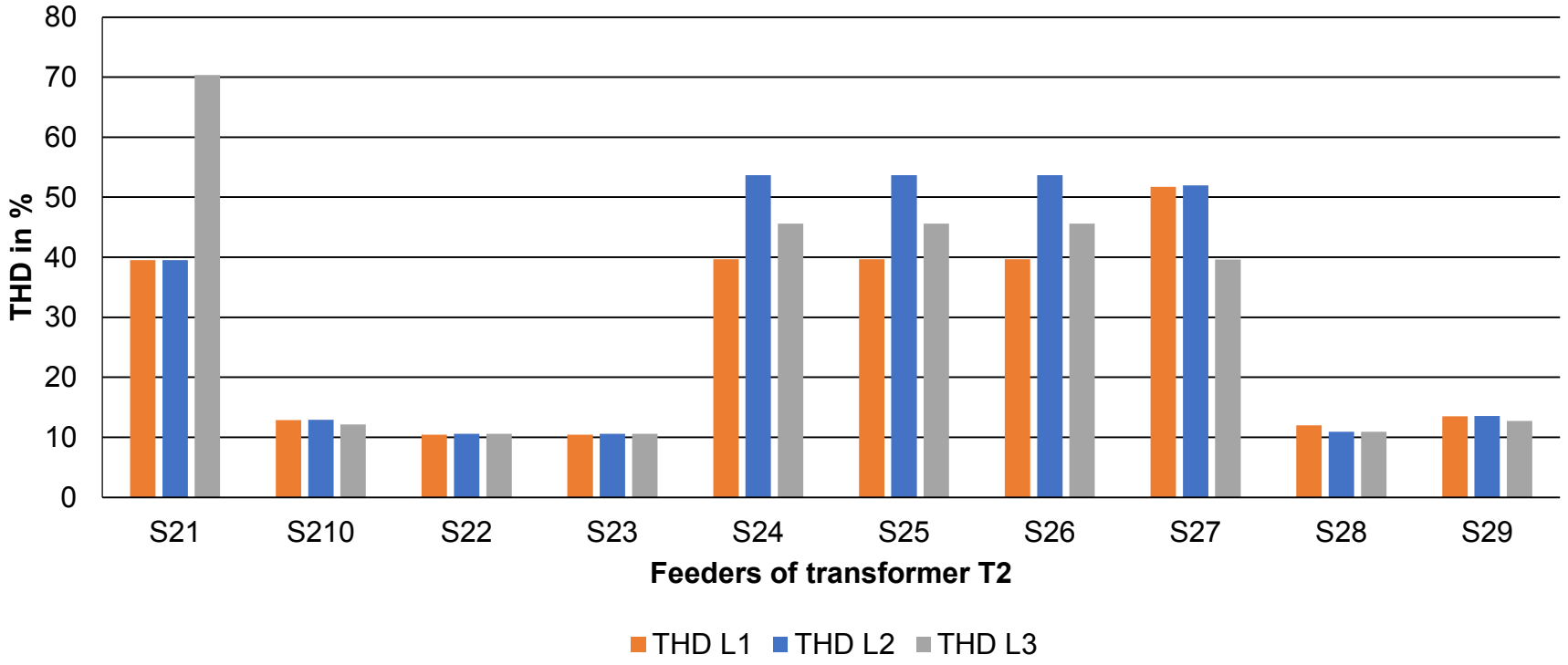
Results: Feeder S19

Spectrum of the current of S19, THD value in the 3rd phase: 117.3 %



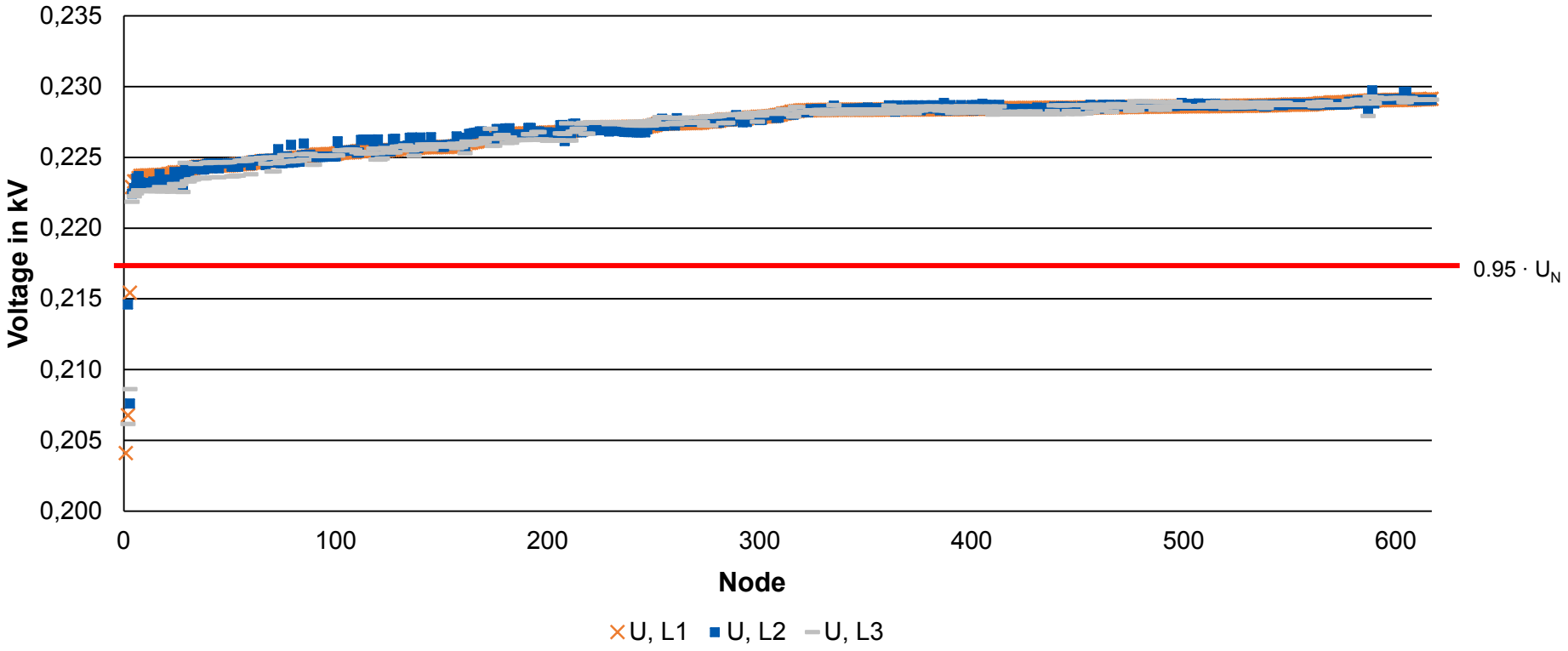
Results: Feeder of transformer T2

THD current values of the feeder of transformer T2, low THDi values at feeders with EVs



Results: voltage stress level

Voltage undercut at four nodes, off-limit condition



Conclusion

a. Compliance of all threshold values, small reserve at 15th and 21st harmonics as a reason of EVs → possible problems in future
b. Some high THD current values due to single-phase feeding of PV systems → no problem due to low currents
c. EVs reduce THD current values due to the higher supply current
d. Location of home plug in the low-voltage public network critical with reference to voltage criterion (95 %)
e. Operating grade of transformers and lines is not exceeding 60 % for the simulated scenarios, in case of outages (transformer, main cable) critical

Conclusion

(But with the addition), the results are heavily dependent on the assumptions made, such as

a. Electric vehicle: number, loading time, start time of the loading process
b. Feeding of PV systems
c. Number of PV-systems and loads at one feeder
d. Spectra (measured 2017)

Thank you!

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