Technische Universität Braunschweig

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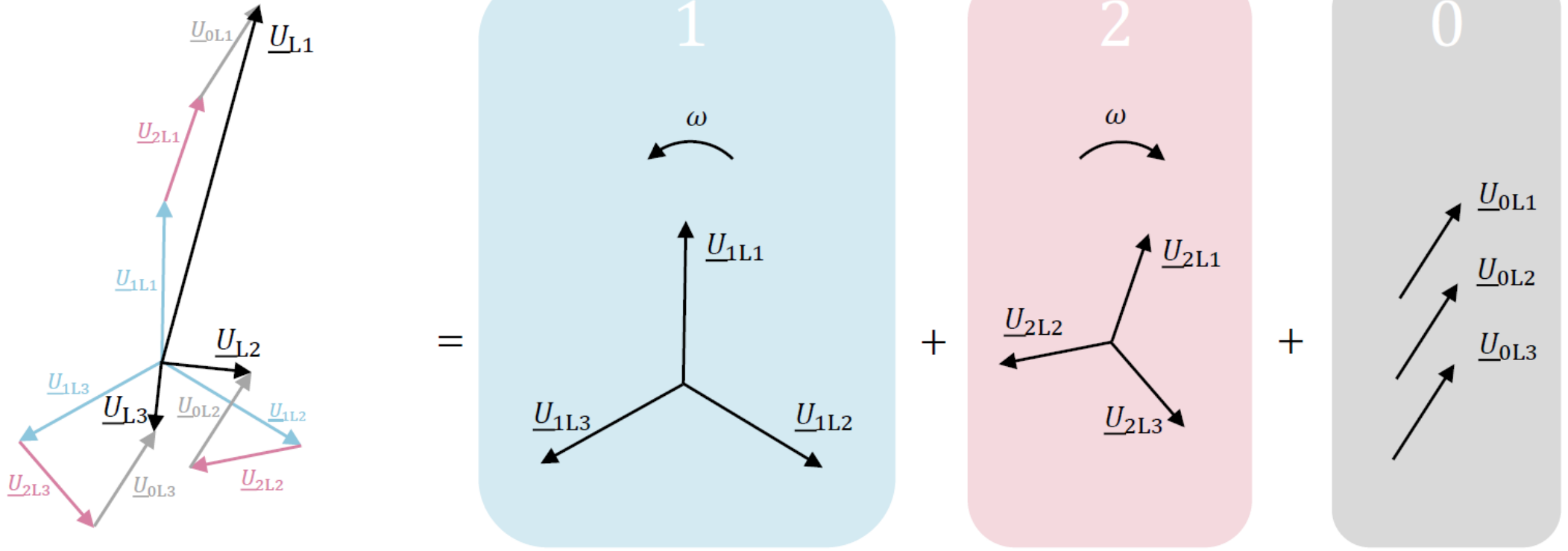
Unbalance in low voltage grids

Cornelius Biedermann 1st conference 2022 Interessensverband Netzimpedanz| 07.04.2022

Symmetrical components



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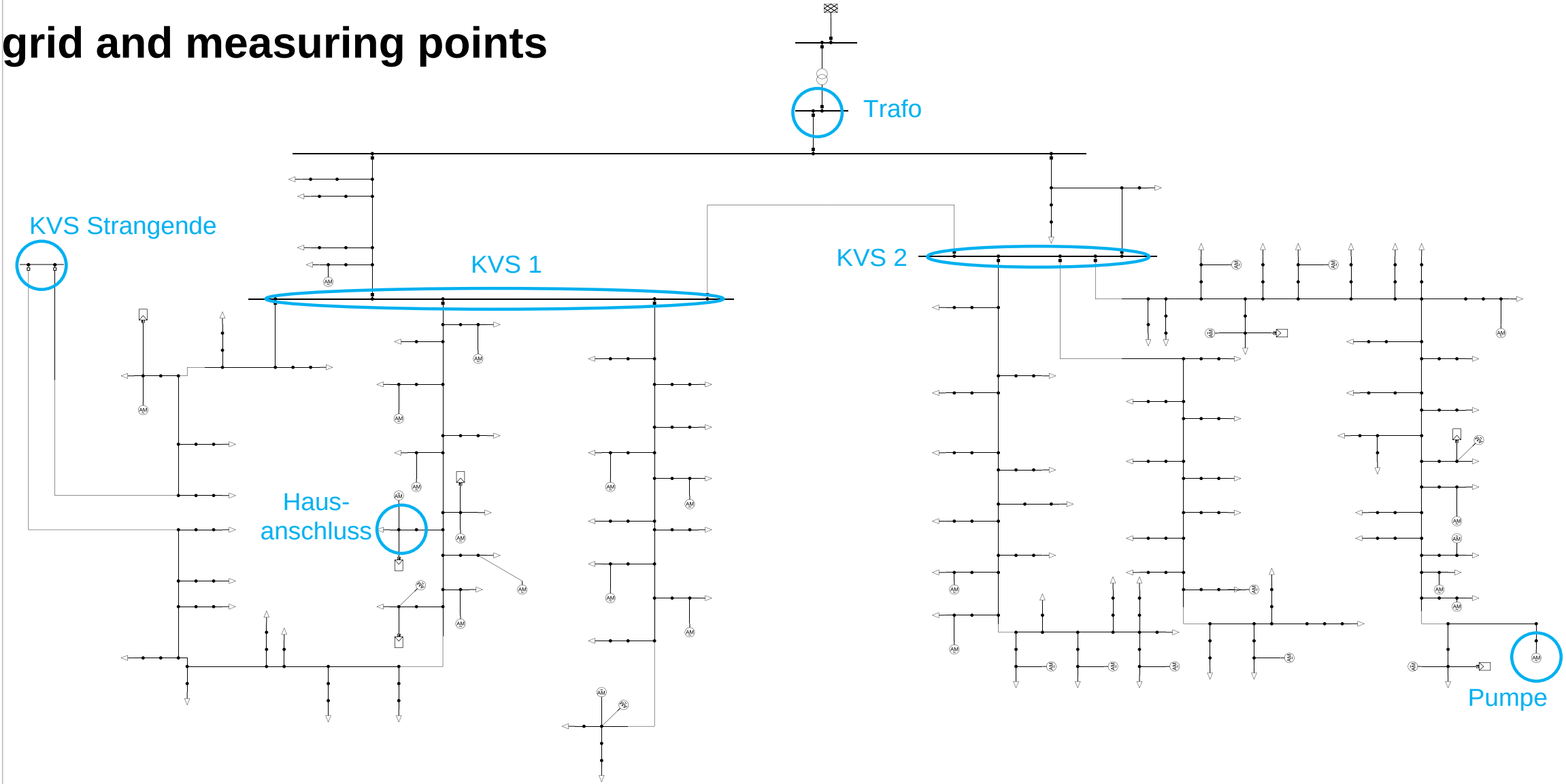
Profile of the low-voltage grid

characteristic	value	Explanation / addition
generators	7 PV systems	reported facilities
loads	96 households with 33 heat pumps (WP) and at least one battery electric vehicle and one plug-in hybrid vehicle	sewage pump at the end of the line; WP: reported systems plus systems without gas connection
net length	Total grid: 2,595.51 km	farthest point from the transformer: 217.6 m
impedance in the main	R'=0.207Ω/km, X'=0.080Ω/km	according to the grid model
impedance in outlets from the cable distribution cabinet (KVS)	R'=0.207Ω/km, X'=0.080Ω/km	according to the grid model
impedance in outlets to HH	R'=0.869Ω/km, X'=0.085Ω/km	according to the grid model
net class	suburban grid (radial grid); many single family homes	KVS 1 and KVS 2 are connected

grid and measuring points



Measured values

- Unbalance

- Negative phase sequence voltage unbalance higher at the end of the string
- No value violates the limit values according to DIN EN 50160 with 2%

measuring location	Maximum value unbalance in %	mean unbalance in %
KVS 1	0.5800	0.1562
House	0.8640	0.1831
end	0.9180	0.2017
sewage pump	1.0660	0.2158
substation	0.2290	0.1435

Extract of field measurement results (summer)

- unbalance of 0.39% occurs in a household with a PV system, EV, home storage system and heat pump
- unbalance increases towards the end of the string
- values are below the normal limit

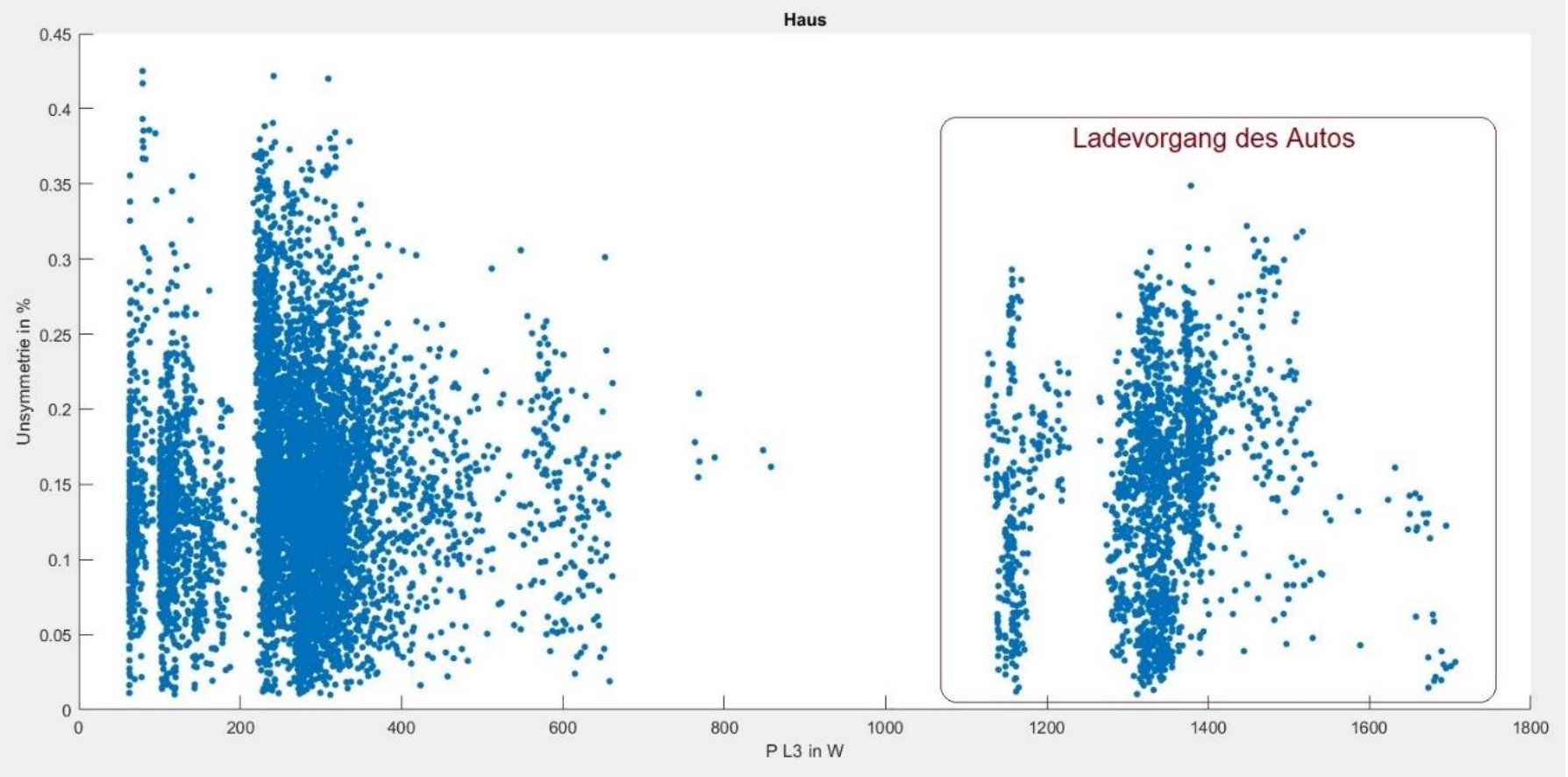
measuring point	unbalance acc. DIN EN 50160 in %
period	Aug 21, 2020 10:24 am to Sep 4 2020 9:30
local grid station to KVS1	Max: 0.3 3 Avg.: 0.10
KVS1 (cable distribution cabinet)	Max: 0.40 Average: 0.11
house connection box	Max: 0.39 Avg.: 0.12
strand end	Max: 0.41 Avg.: 0.10

measuring point	unbalance acc. DIN EN 50160 in %
period	4 Sep 2020 12:42 to Sep 23 2020 9:06
local grid station KVS2	Max: 0.28 Average: 0.11
KVS2(cable distribution cabinet)	Max: 0.40 Average: 0.11
sewage pump	Max: 0.70 Avg.: 0.15

Measured values

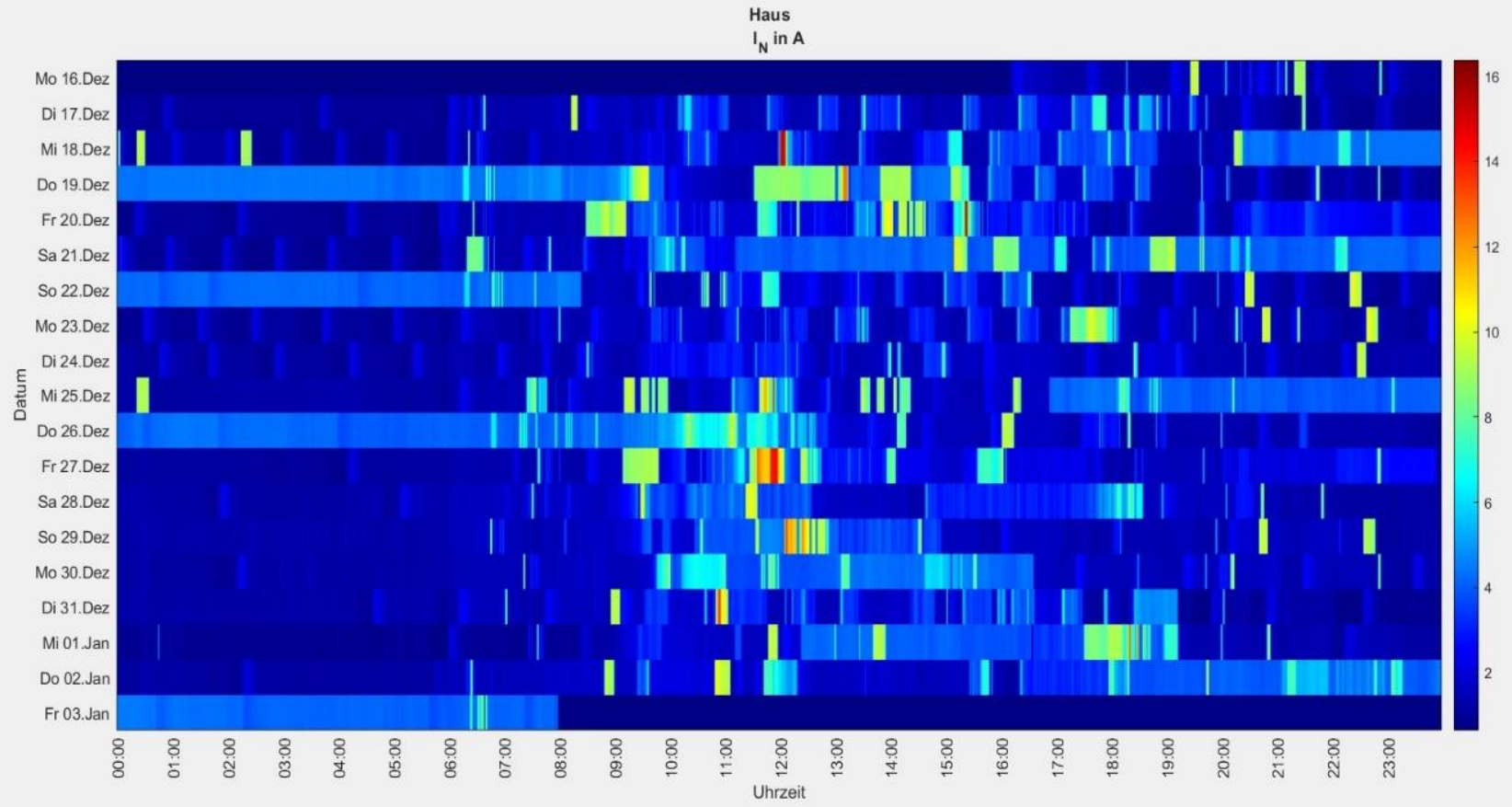
- Schukoladen EV at night

- EV charges on phase L3
- Unbalance is lower at night
- No increased effect on unbalance compared to other loads from this EV
- Nevertheless, slightly increased neutral conductor currents



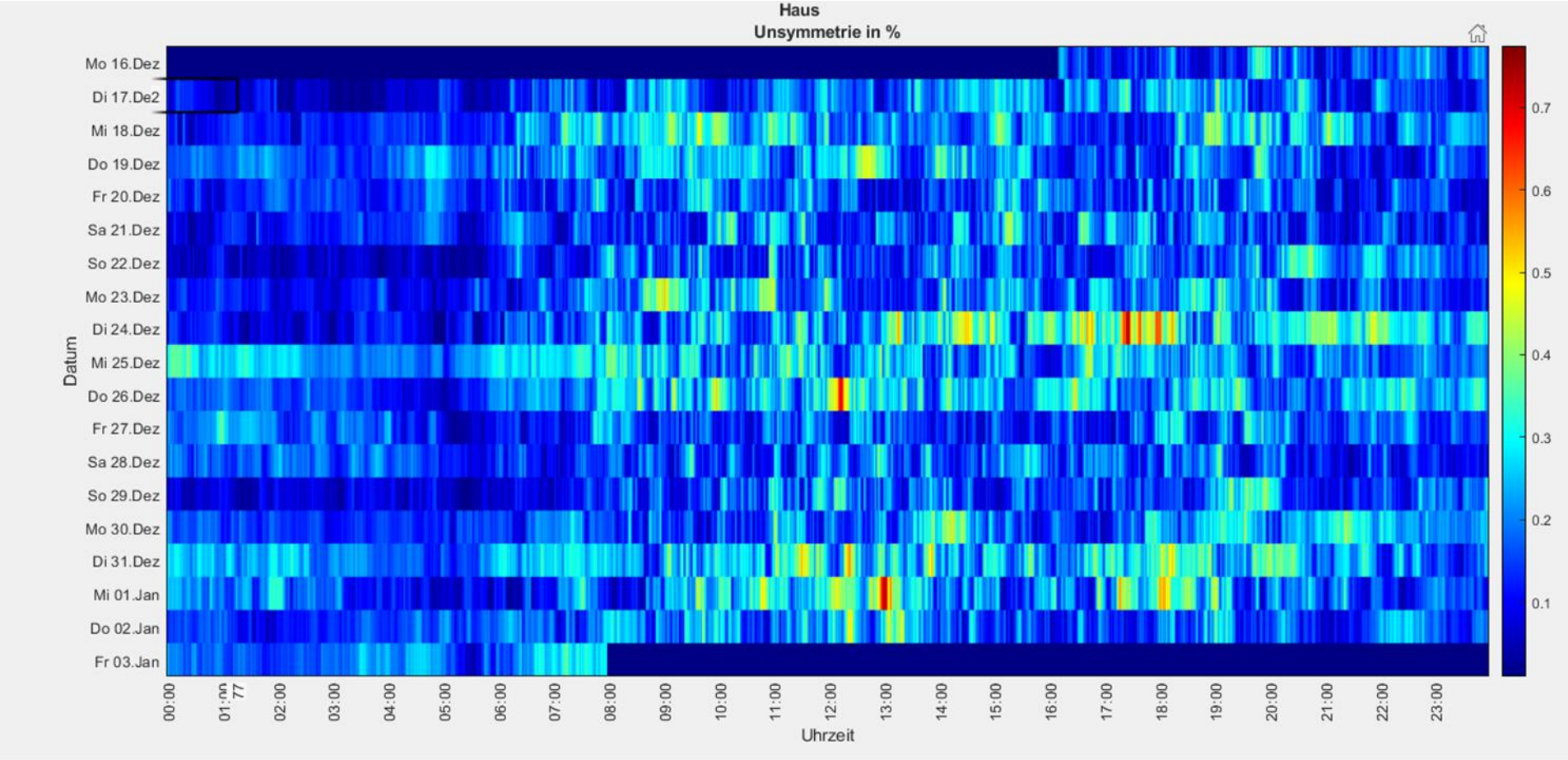
Measured values

- Schukoladen EV at night



Special feature unbalance

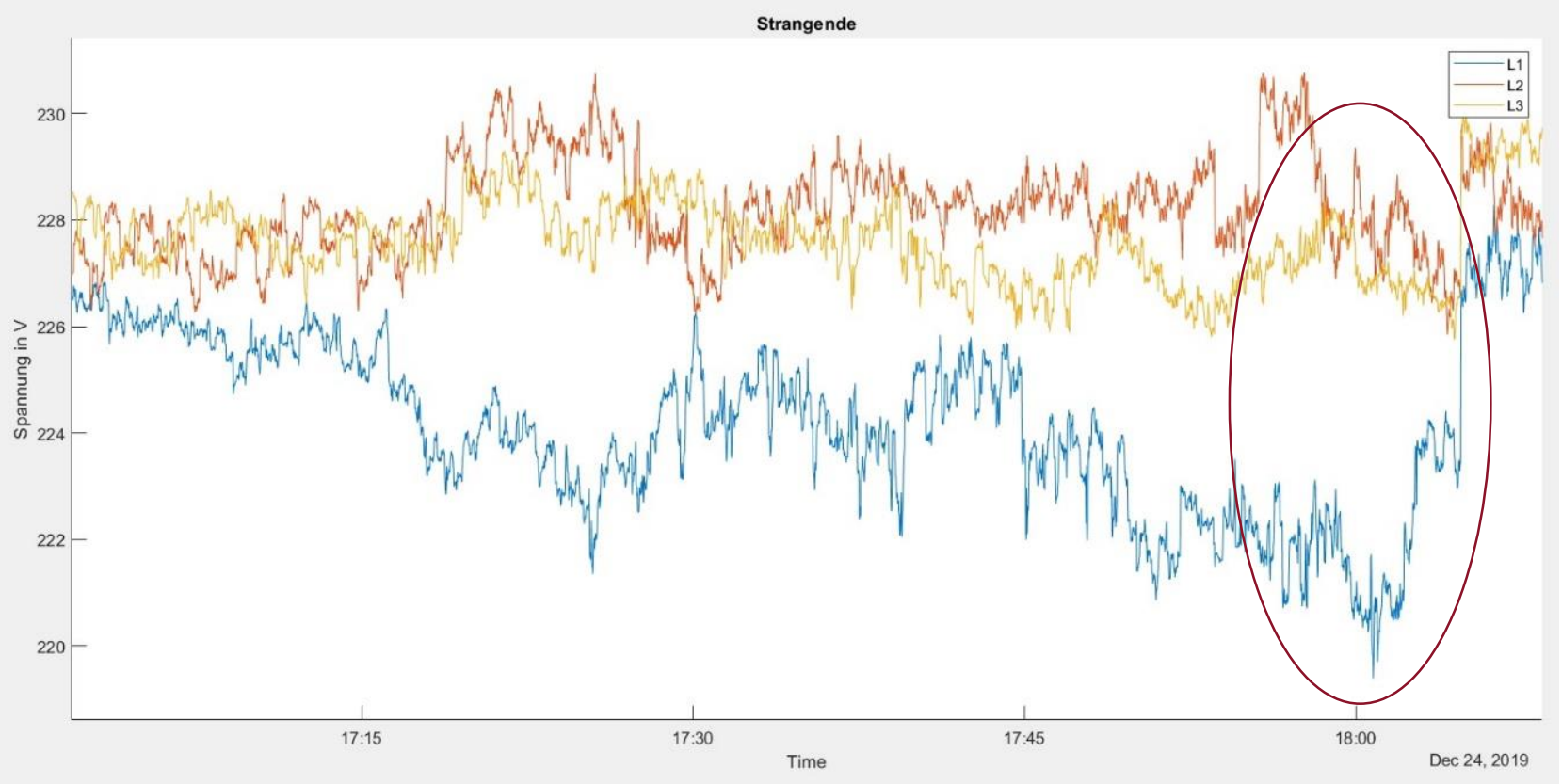
heat map

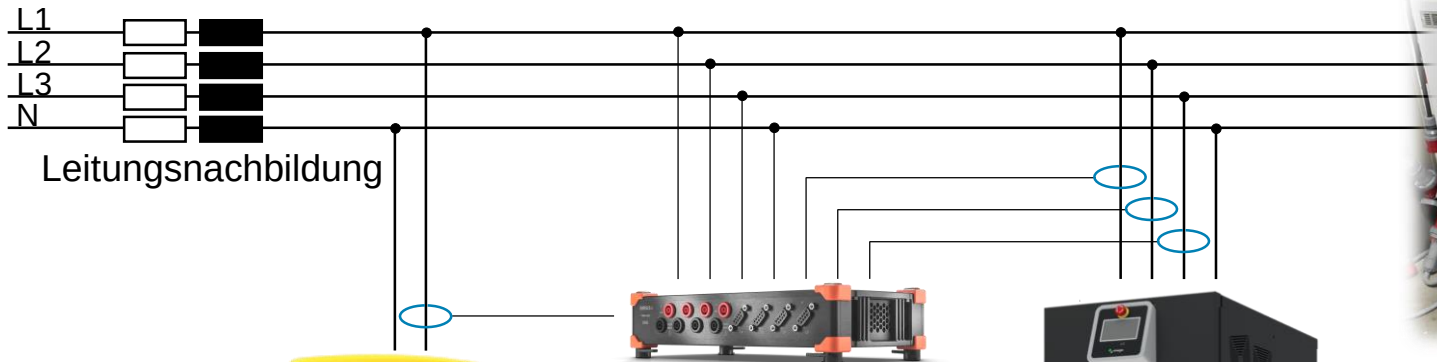


Special feature unbalance

unbalance due to high simultaneity on Christmas Eve (and other public holidays)

- Simultaneous user behavior
- Presumably increased use of stove and oven on Christmas Eve from 5 p.m. and around noon on 25.12. and 26.12.
- Control special events in the future, e.g. B. through incentive systems



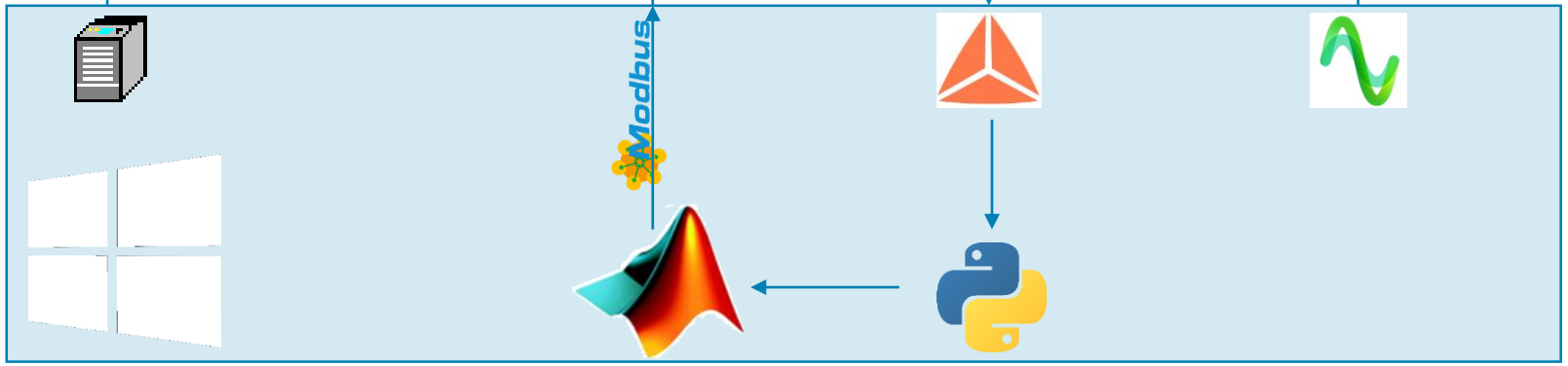


Grid simulator

Messsystem

BESS

Load



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Different Scenarios

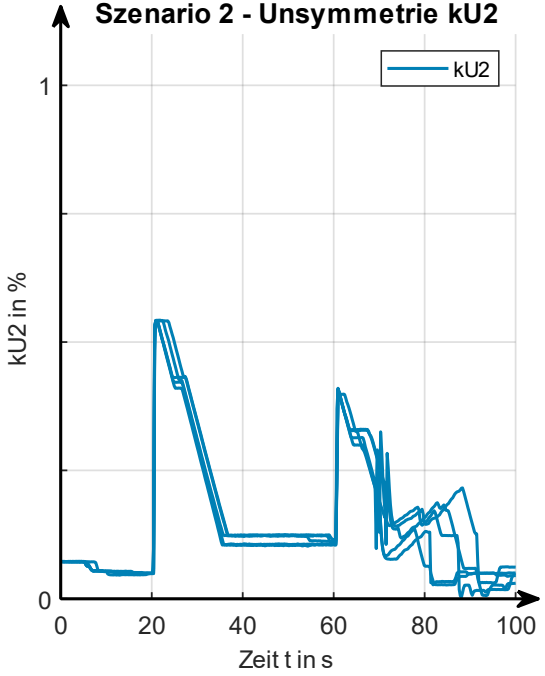
Szenario	Last			Unsymmetrie ohne Regler		Unsymmetrie und Reglerleistung			
	L1	L2	L3	kU2	kU0	kU2	kU0	P in W	Q in var
2_3	3 kW	0	0	0,51 %	1,69 %	0,11 % (+)	0,47 % (+)	2900	-200
2_5	5 kW	0	0	0,85 %	2,86 %	0,41 % (+)	1,53 % (+)	3100	-750
6_3	0	0	3 kW	0,47 %	1,70 %	0,40 % (o)	1,42 % (+)	-1800	-250
6_5	0	0	5 kW	0,82 %	2,89 %	0,71 % (+)	2,60 % (o)	-1800	-100
10_3	3 kW	3 kW	3 kW	0,05 %	0,03 %	0,04 % (o)	0,04 % (o)	0	-100
14_3	3 kvar	0	0	0,49 %	1,59 %	0,11 % (+)	0,32 % (+)	-100	-3300
14_5	5 kvar	0	0	0,80 %	2,66 %	0,42 % (+)	1,41 % (+)	-260	-3300
18_3	3 kW	0	3 kW	0,50 %	1,66 %	0,51 % (o)	1,30 % (+)	2400	-450
22_3	0	3 kW	3 kvar	0,28 %	3,24 %	0,63 % (-)	2,18 % (+)	-1800	1600
25_3	0	3 kvar	3 kW	0,95 %	0,78 %	0,55 % (+)	1,96 % (-)	-1800	2000
26	4 kW	-3 kvar	-4 kW + 2 kvar	2,17 %	1,86 %	1,69 % (+)	1,97 % (-)	3200	-700

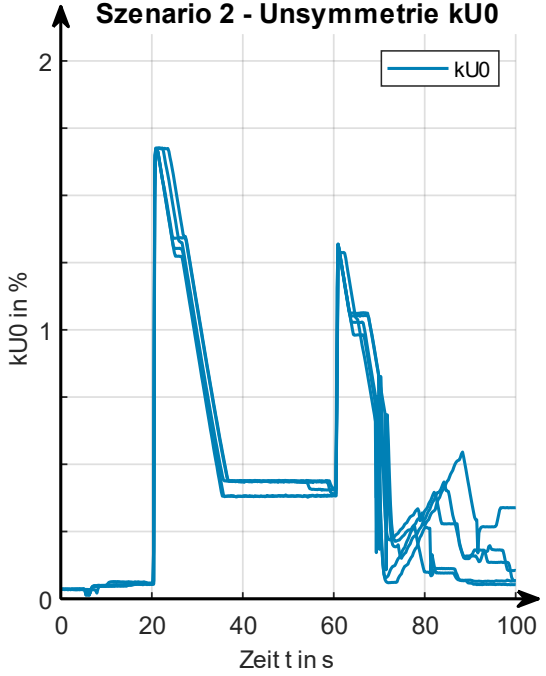
Control unbalance with controlled BESS in laboratory

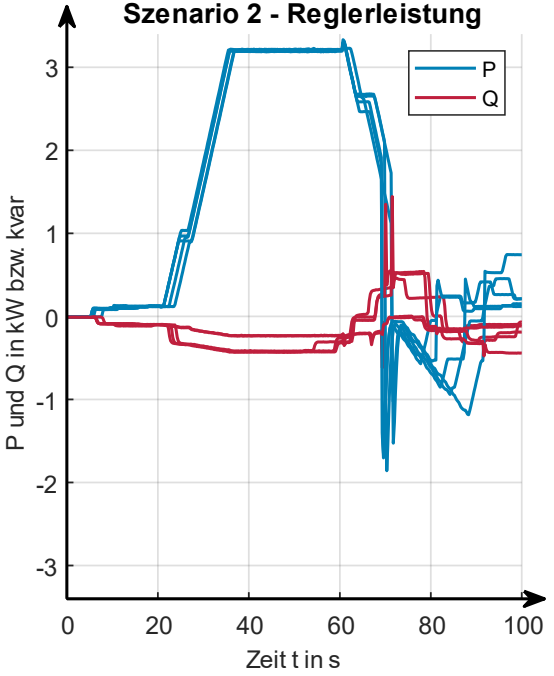
BESS with active and reactive power on a grid simulator

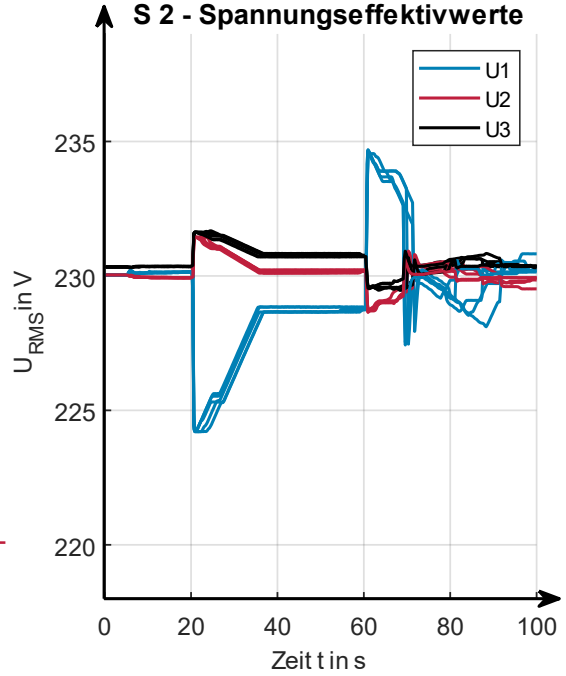
- Single-phase Battery Electric Storage System (BESS) 4.4 KVA
- Load up to 4 kVA per Phase
- Grid simulator

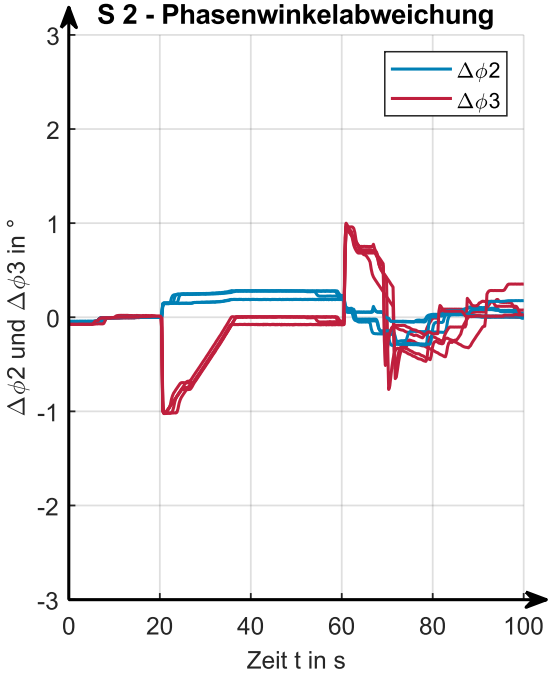
- Unbalance factor kU2 from DIN EN 50160

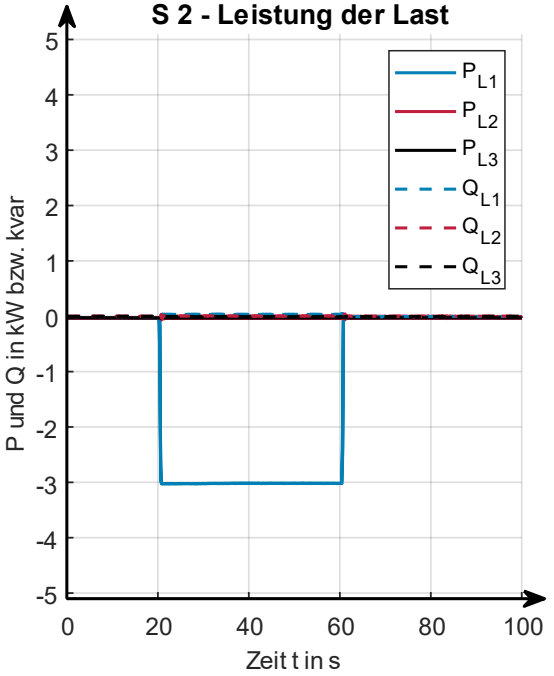


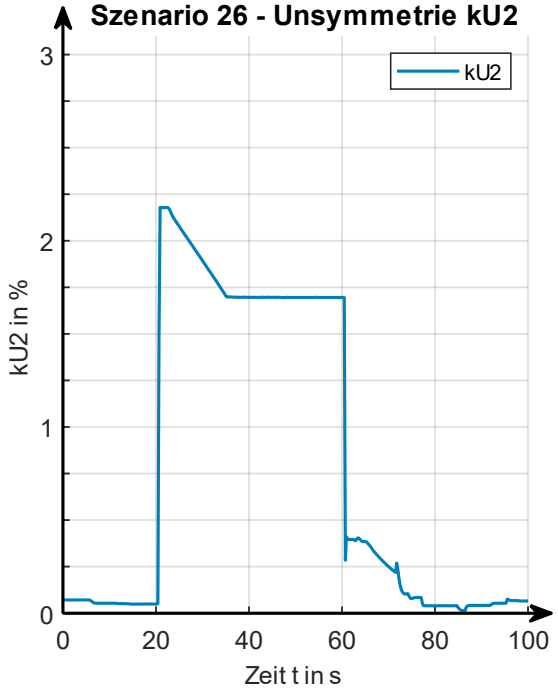


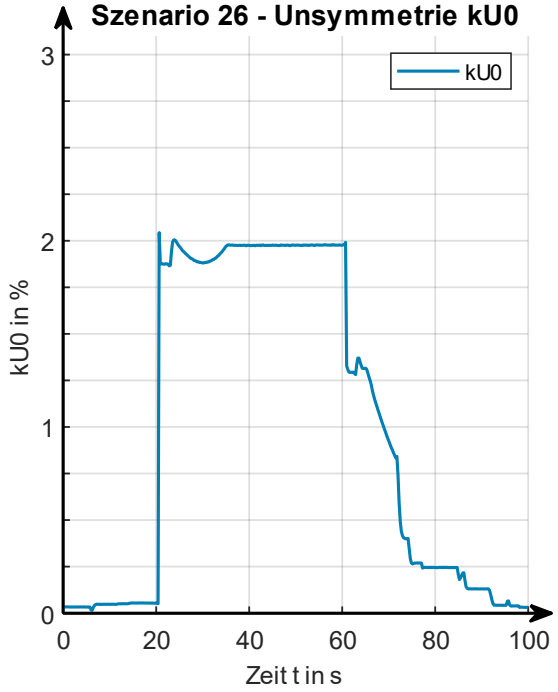


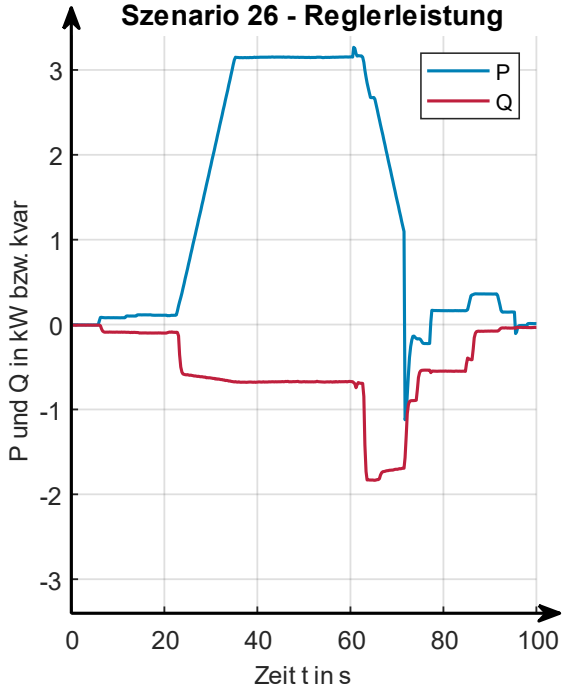


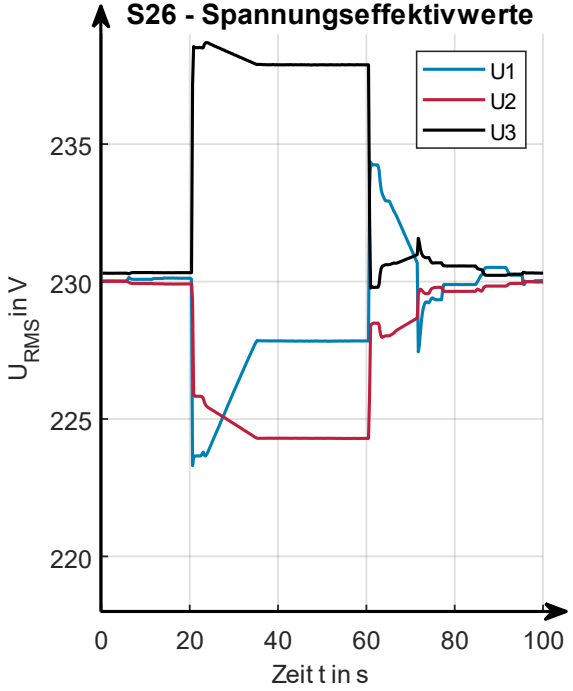


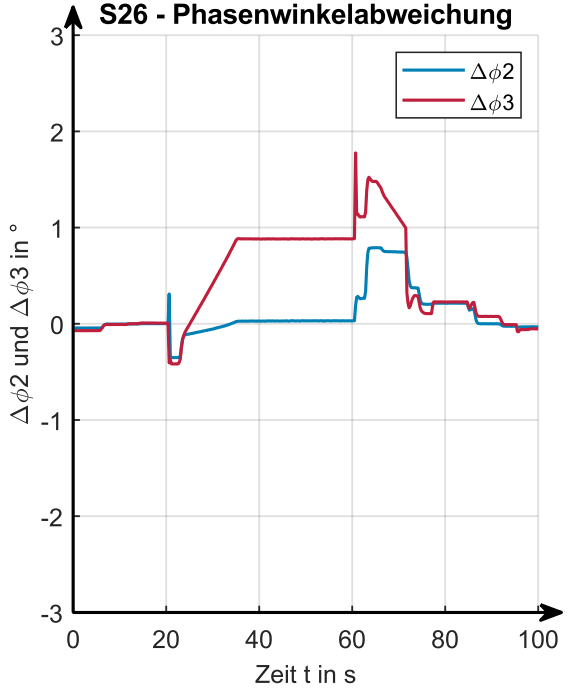


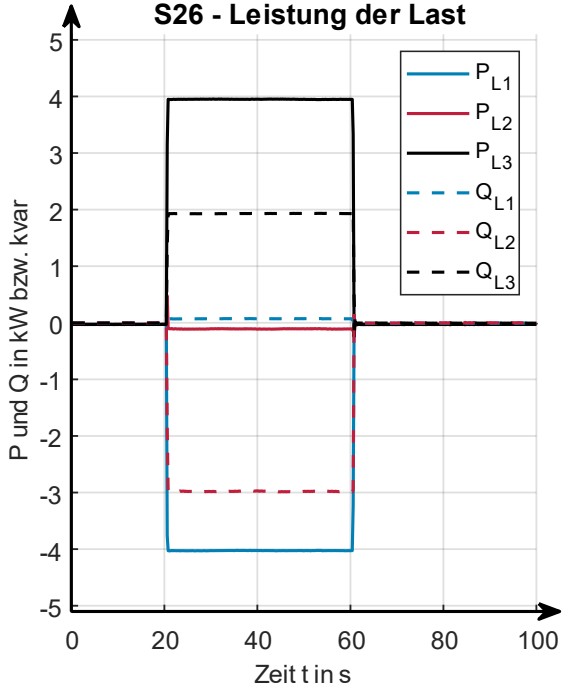

Szenario 26 - Unsymmetrie kU2
kU2
kU2 in %
Zeit t in s


Szenario 26 - Unsymmetrie kU0
kU0
kU0 in %
Zeit t in s


Szenario 26 - Reglerleistung
P
Q
P und Q in kW bzw. kvar
Zeit t in s


S26 - Spannungseffektivwerte
U1
U2
U3
U_RMS in V
Zeit t in s


S26 - Phasenwinkelabweichung
Δφ2
Δφ3
Δφ2 und Δφ3 in °
Zeit t in s


S26 - Leistung der Last
P_L1
P_L2
P_L3
Q_L1
Q_L2
Q_L3
P und Q in kW bzw. kvar
Zeit t in s

Conclusions field measurements and from laboratory

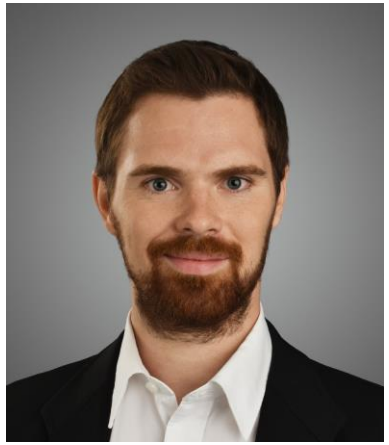
From laboratory measurement

- Unbalance can be improved by BESS with a 3 ph. measurement
- In a „worst-case“ high unbalance scenario the unbalance factor could decrease from 2,17% to 1,69%
- BESS are a good opportunity to fight unbalance

From field measurement

- charging at night does not show increased unbalance compared to household loads
- Christmas Eve and christmas holidays days can be special in suburban areas
- PV systems reduce the neutral conductor currents during low load periods

Ich danke für ihre Aufmerksamkeit!



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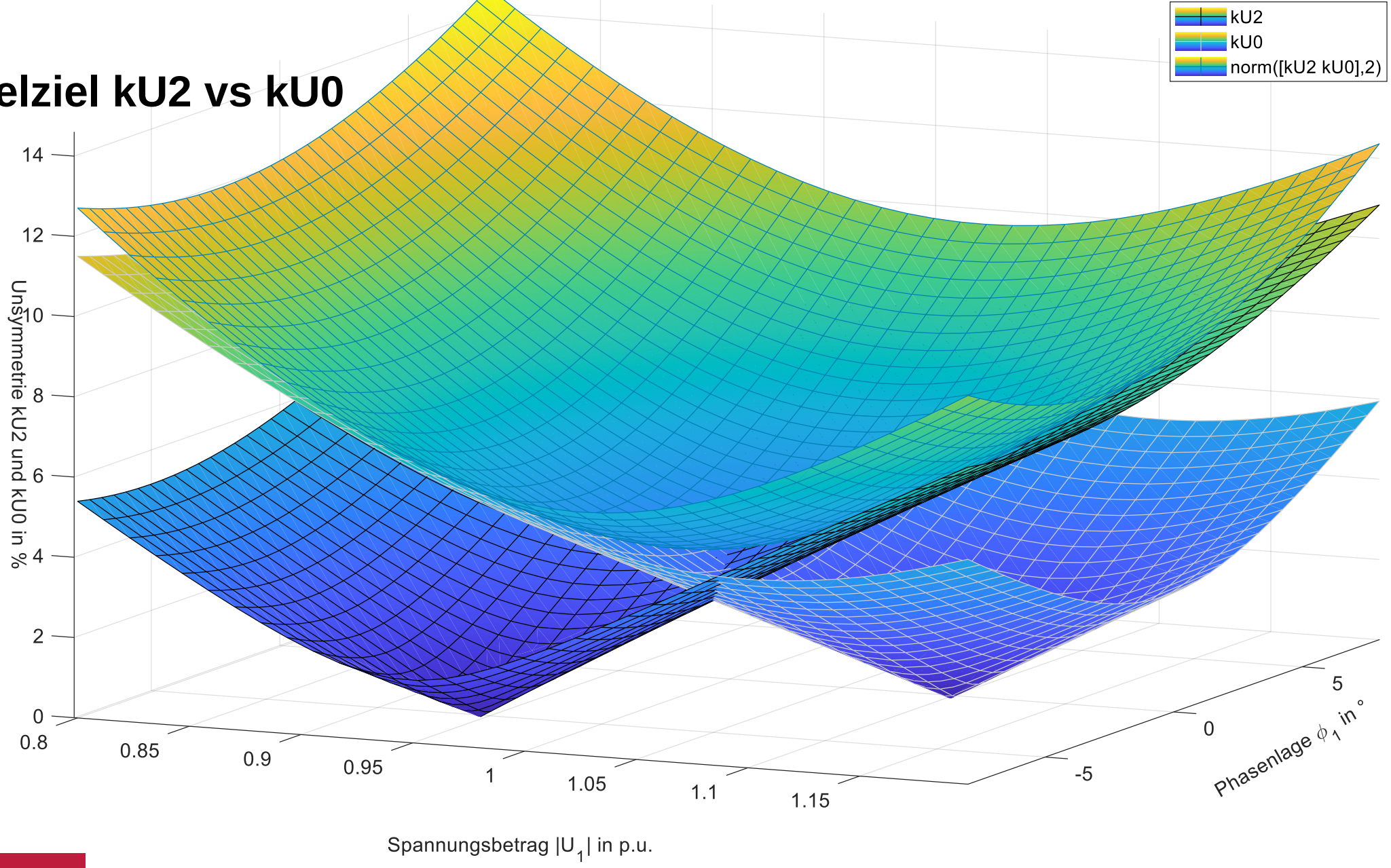
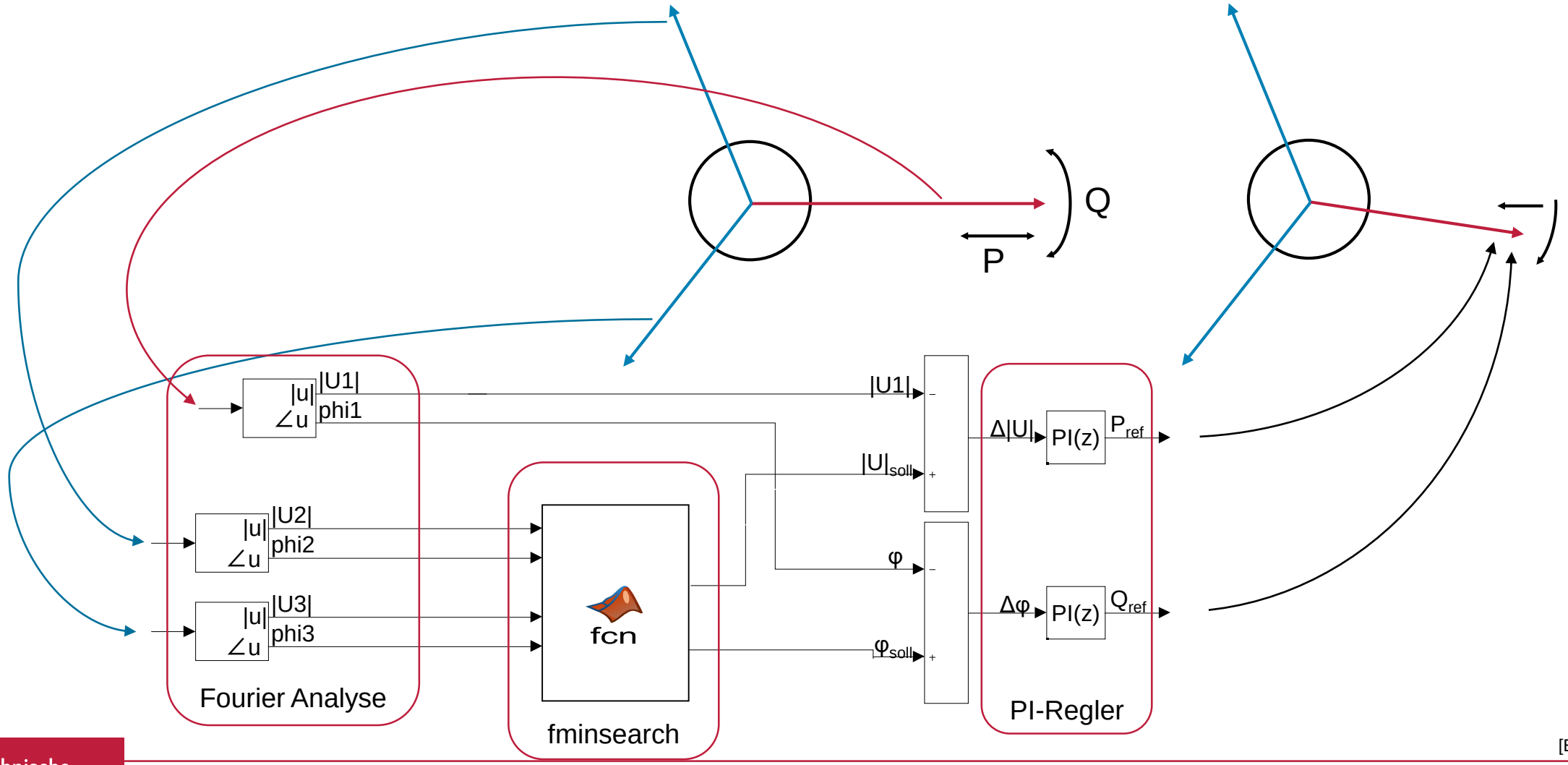
Regelziel kU2 vs kU0



Unsymmetrieregelung mit allpoliger Spannungsmessung



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