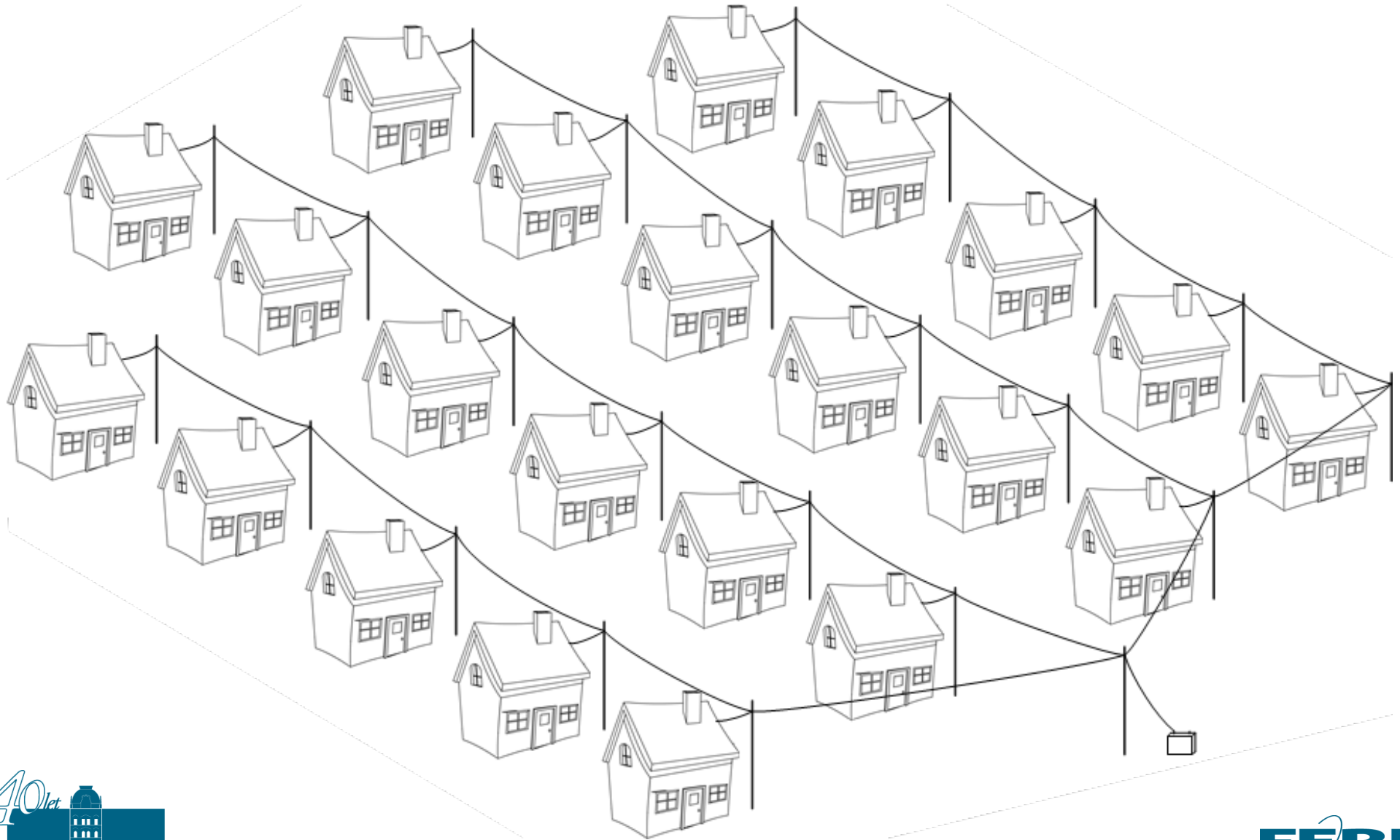


PHOTOVOLTAIC POWER PLANTS as **ACTIVE ELEMENTS** of **DISTRIBUTION NETWORKS**

Primož SUKIČ, Ernest BELIČ, Nevena SREČKOVIĆ, Mislav TRBUŠIĆ,
Katarina DEŽAN, Jurček VOH, Gorazd ŠTUMBERGER

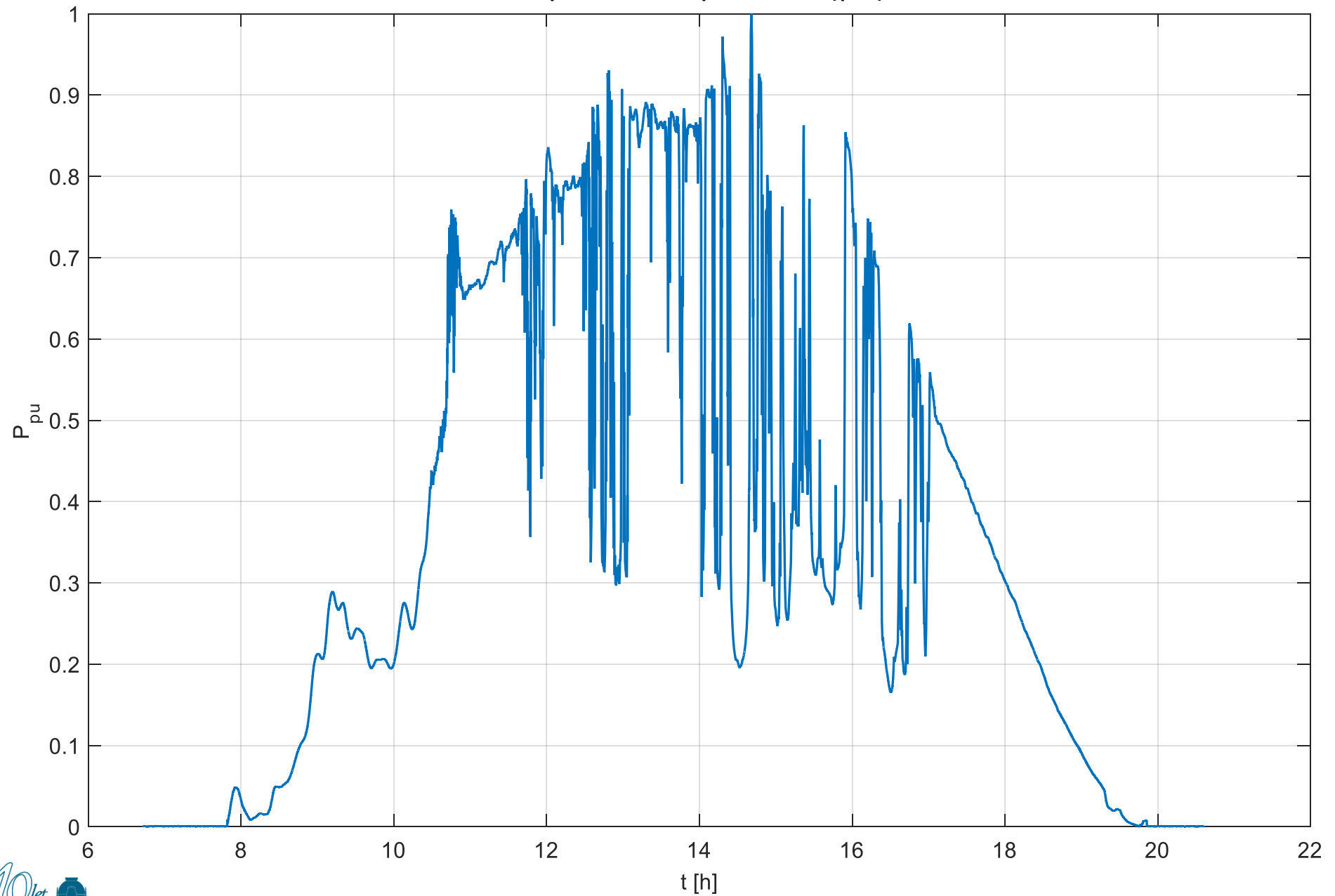
?

How many micro PV plants can be installed?

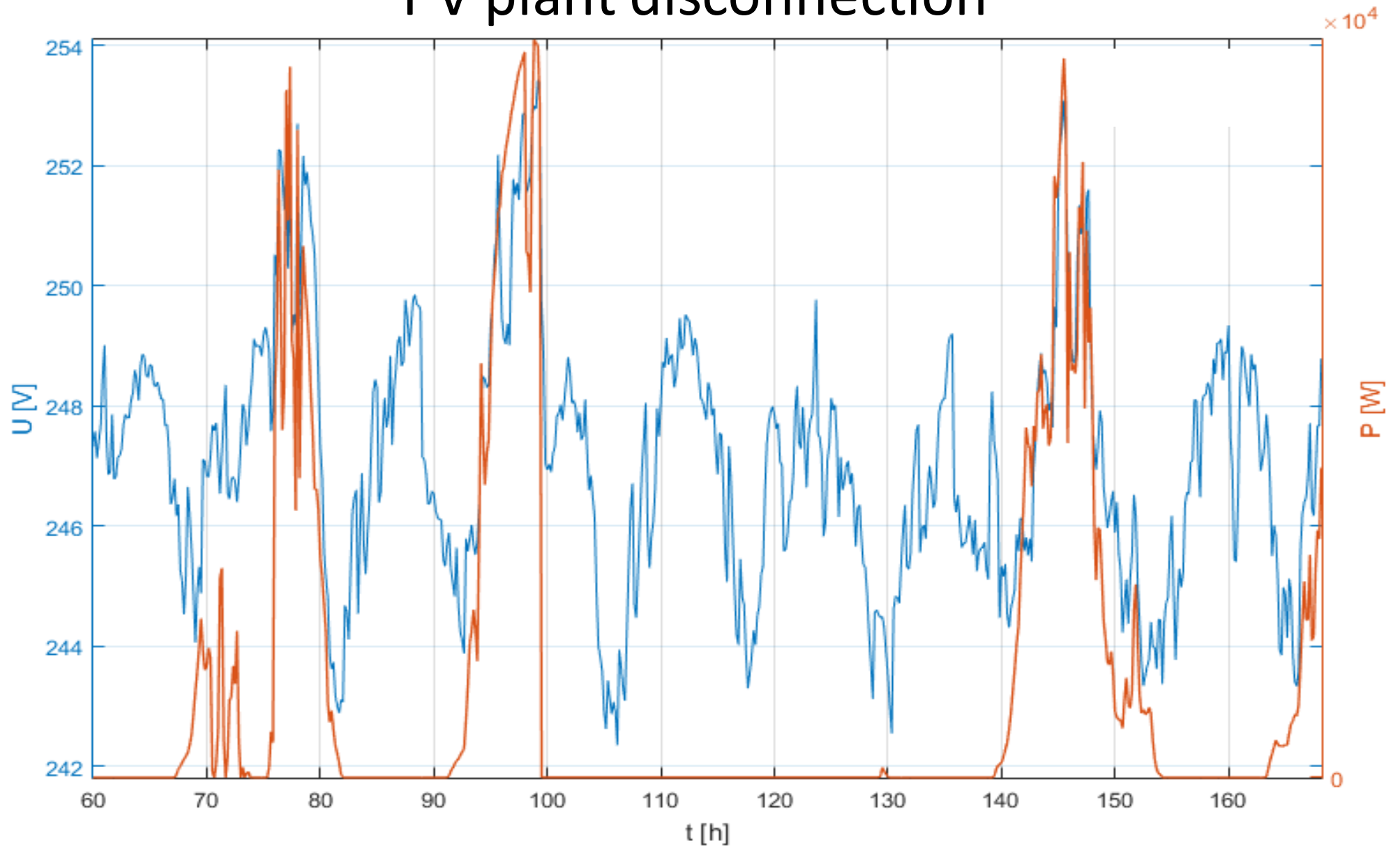


PV power plants

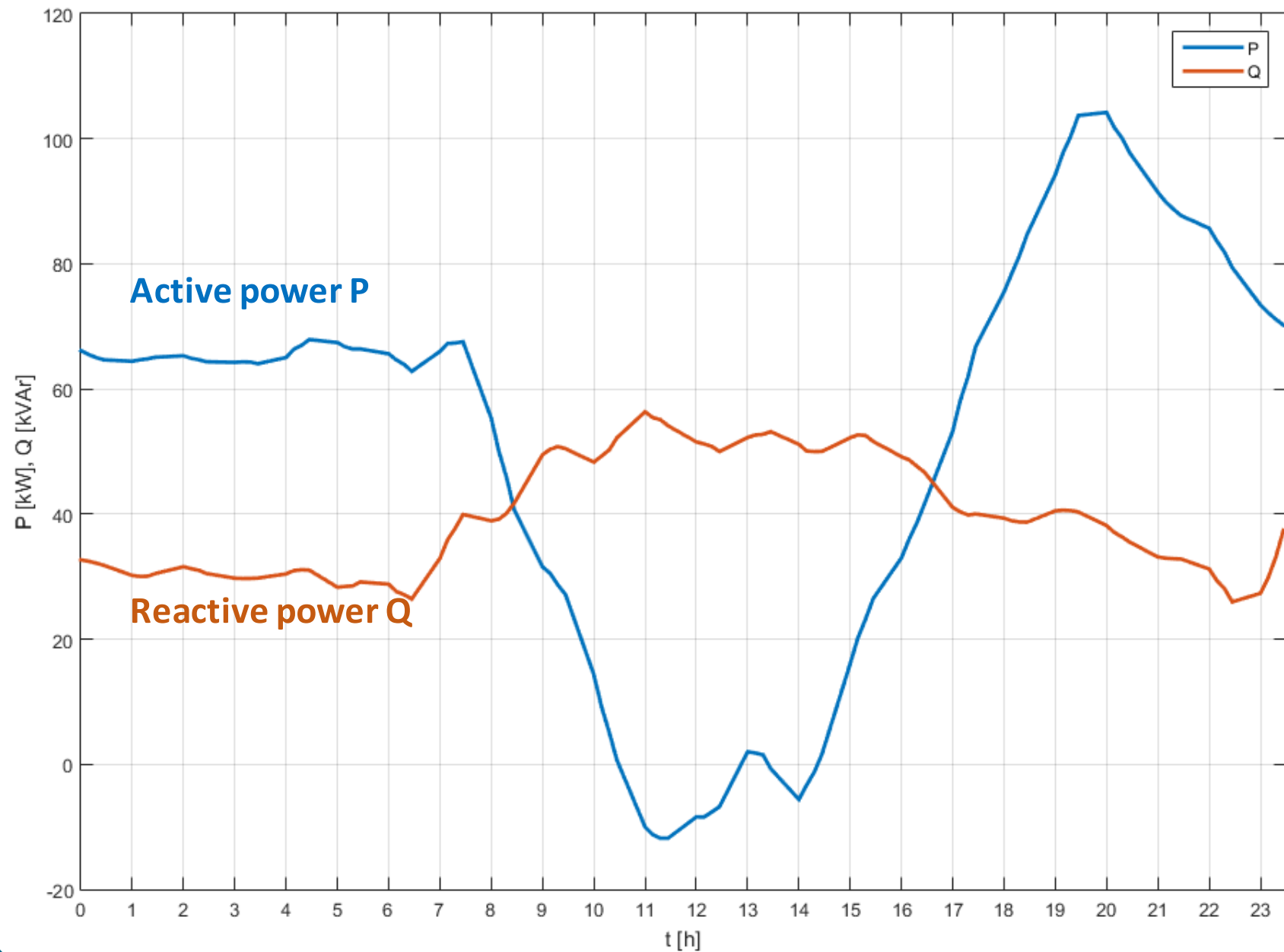
PV output active power P (pu)



PV plant disconnection



Reactive power non

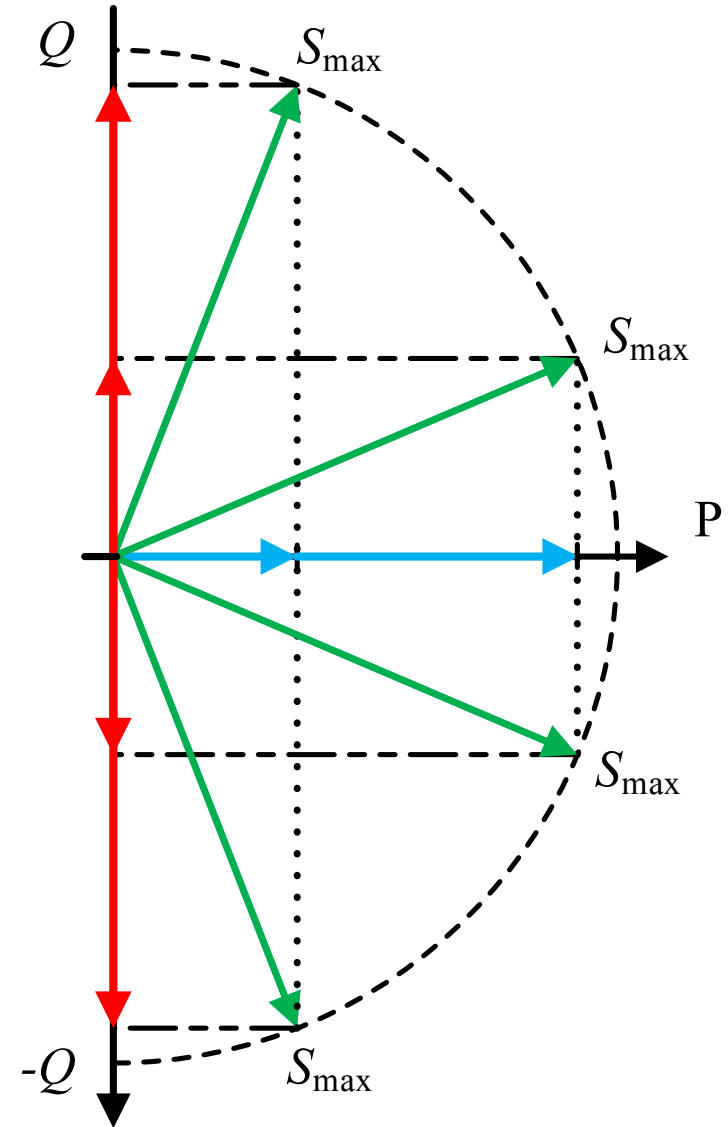


How to control PV power plant for grid benefit

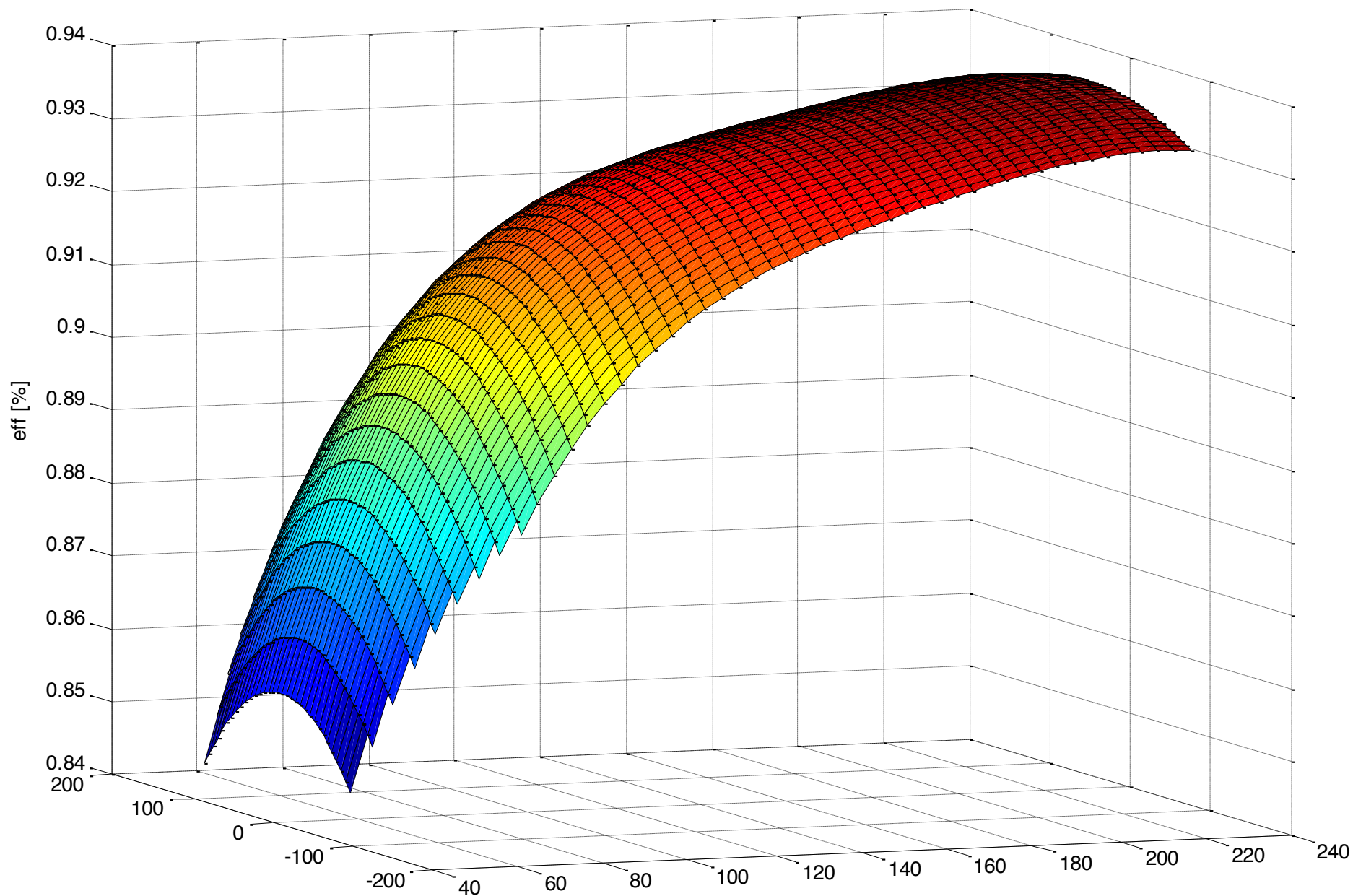
?

Inverter limits

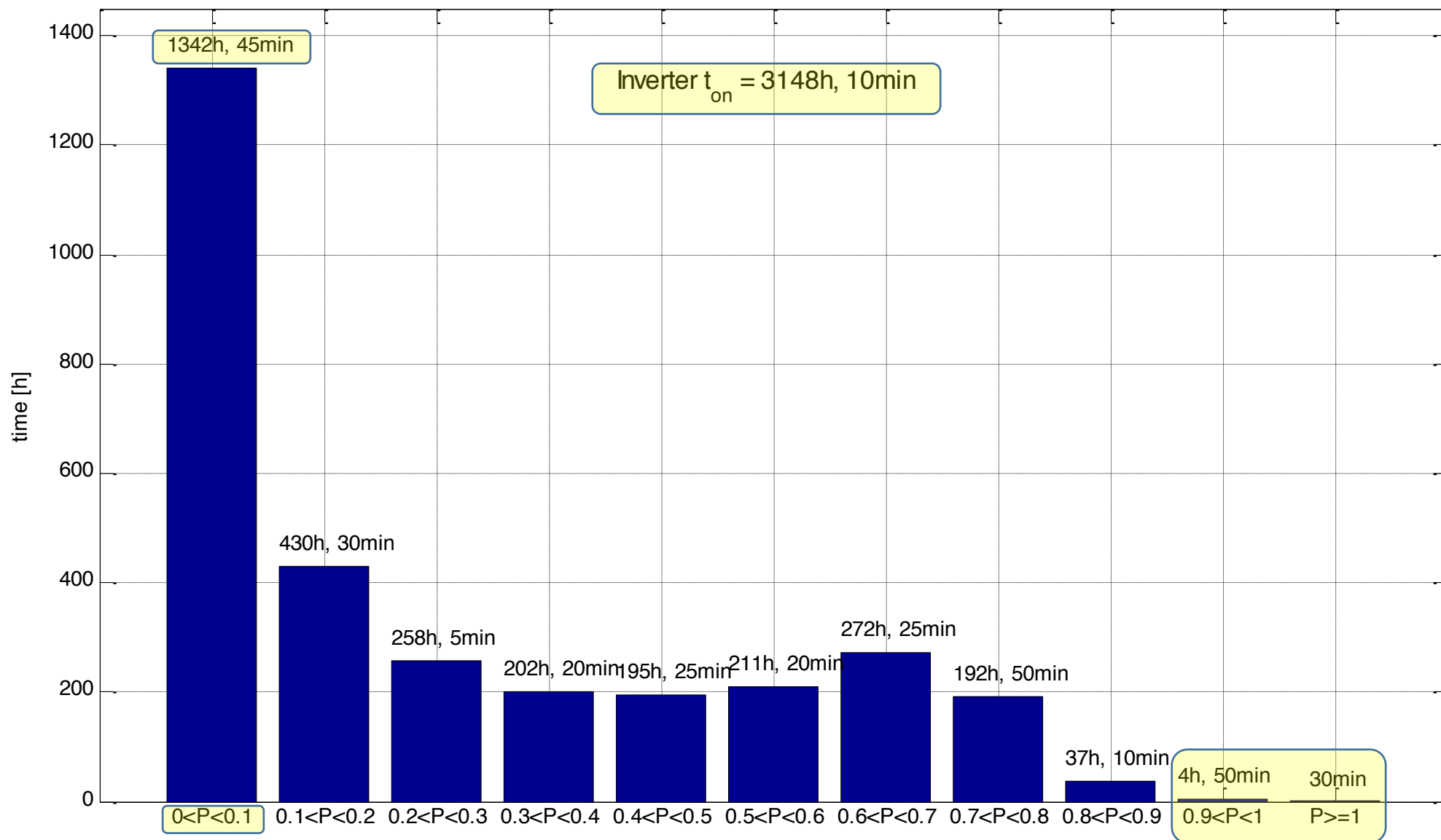
$$Q_{\max} = \sqrt{S_{\max}^2 - P^2}$$



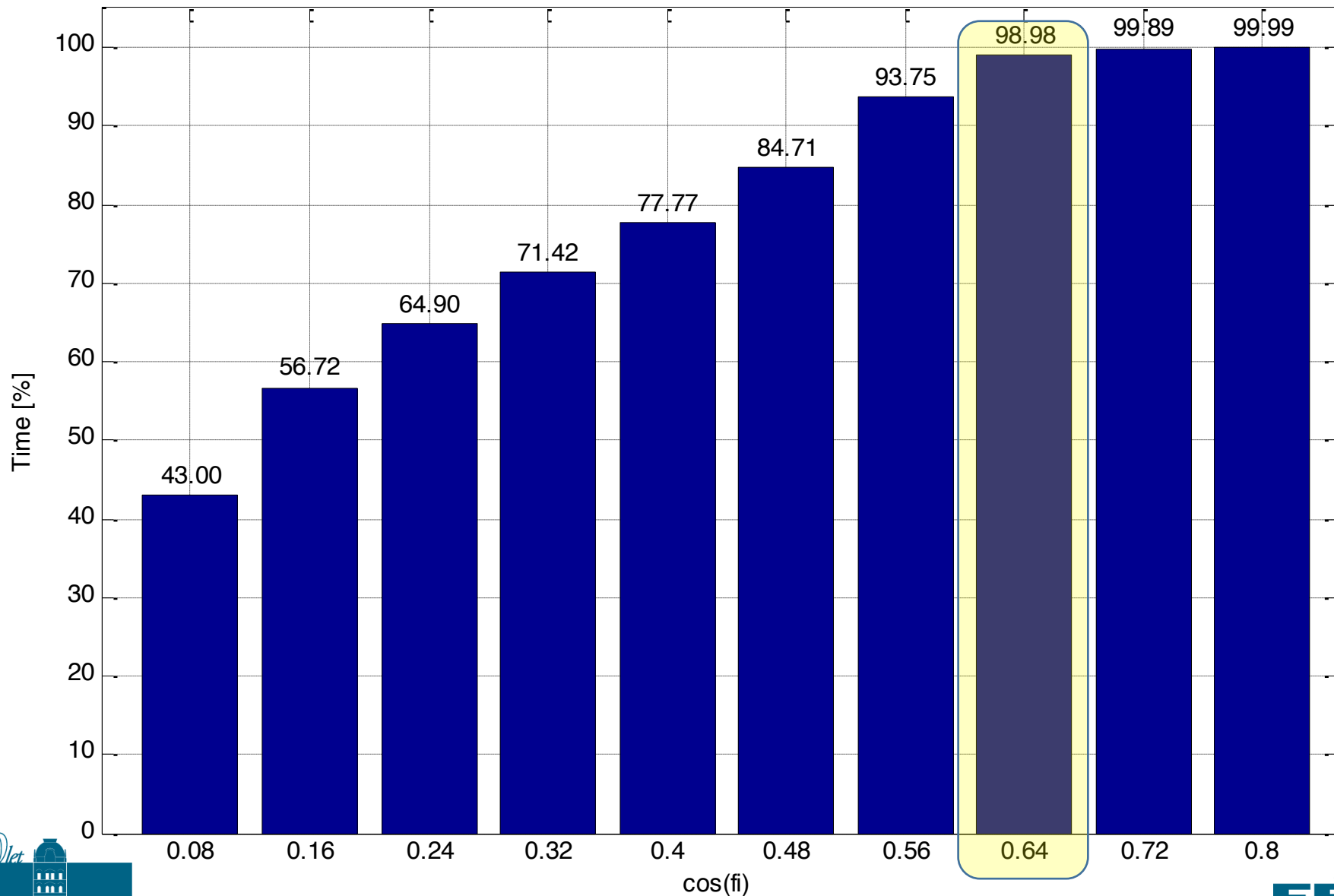
Efficiency characteristic of an inverter given as a function of active power P and reactive power Q



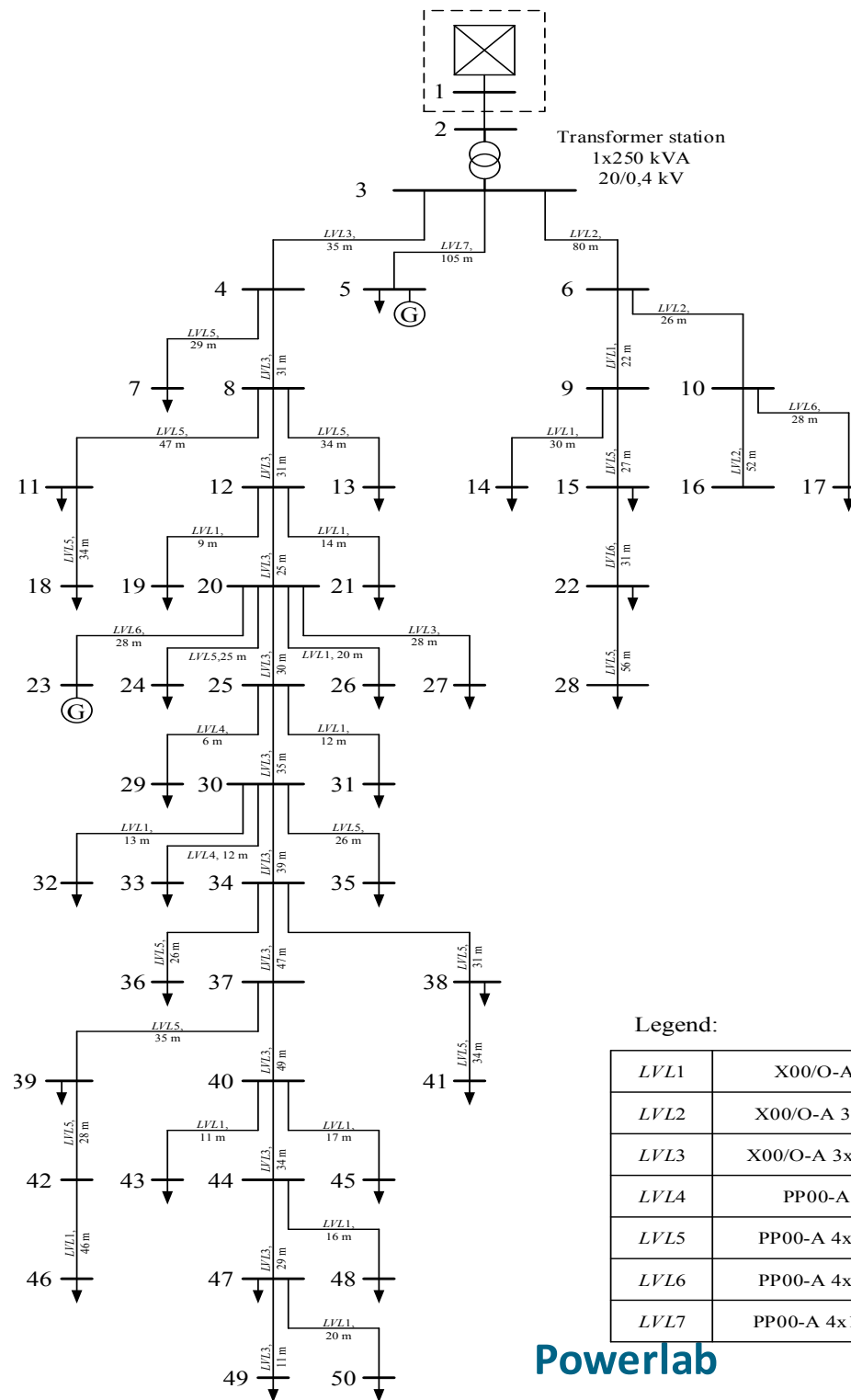
Average active power generation over a year



Percentage of operation time in a year where PV power plant is capable to operate at different values of $\cos(\varphi_i)$



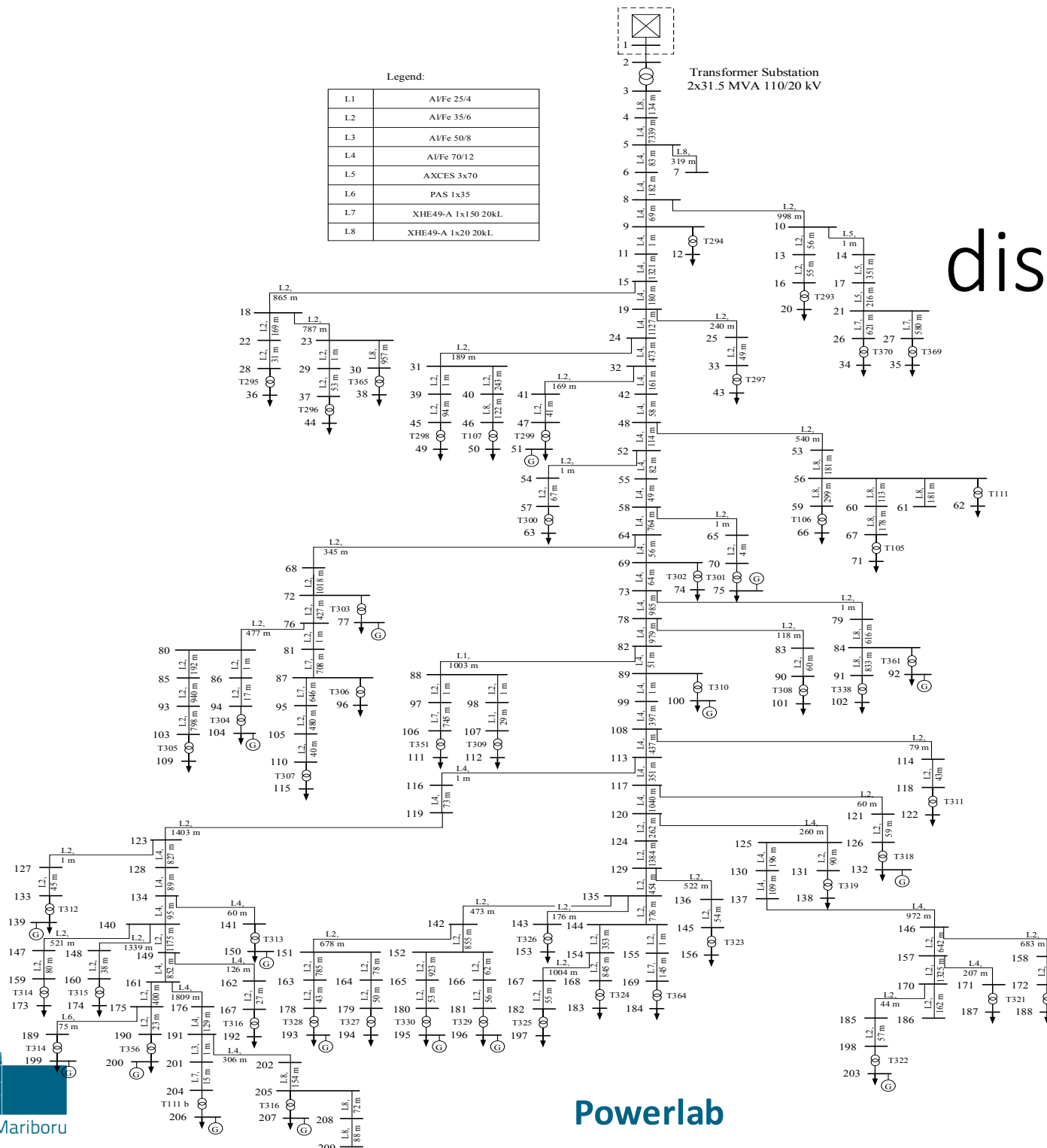
Low voltage distribution network



Medium voltage distribution network

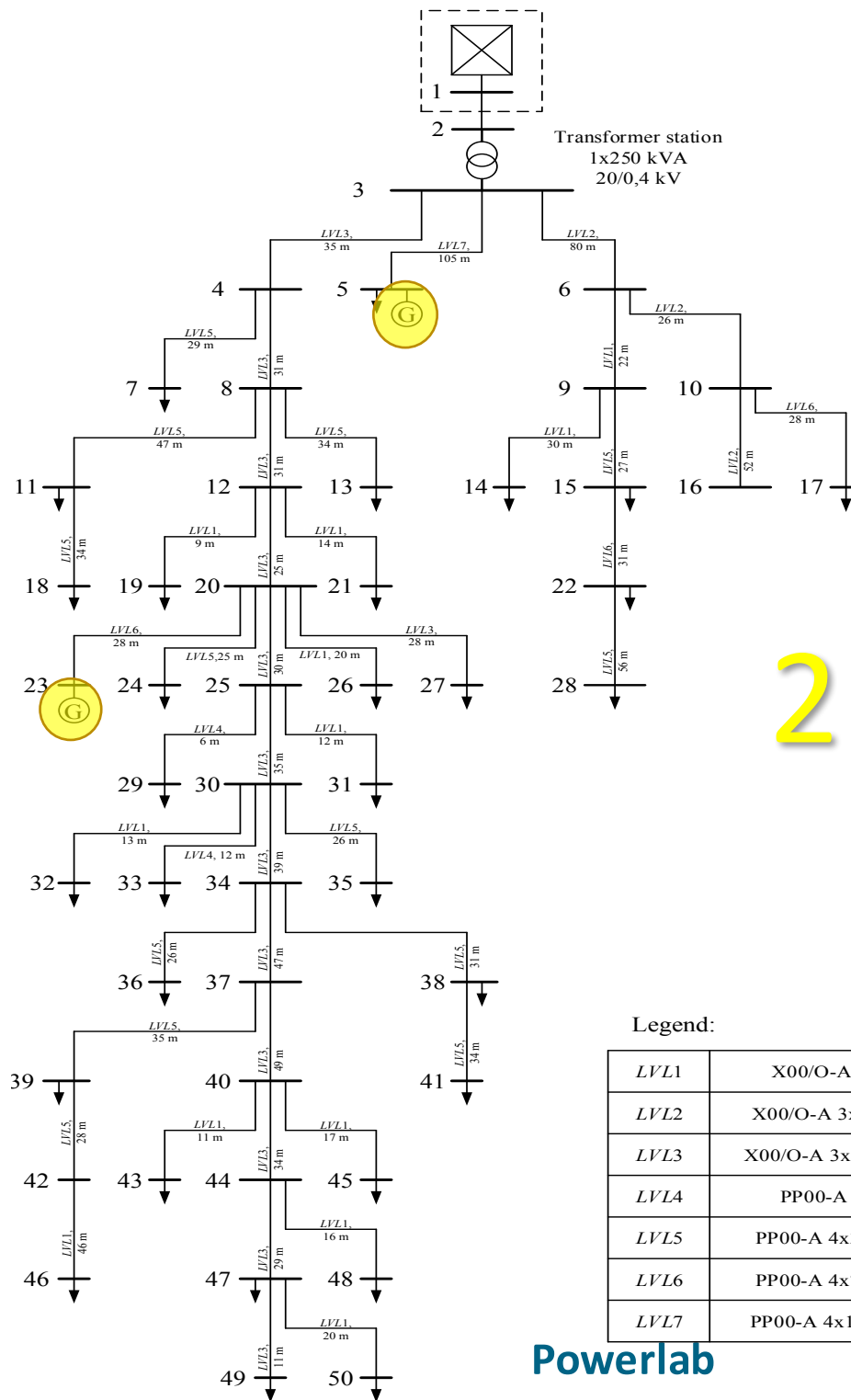
Legend:

L.1	Al/Fe 25/4
L.2	Al/Fe 35/6
L.3	Al/Fe 50/8
L.4	Al/Fe 70/12
L.5	AXCES 3x70
L.6	PAS 1x35
L.7	XHE49-A 1x150 20kL
L.8	XHE49-A 1x20 20kL



Low voltage distribution network

2 x 50 kWp



Legend:

LVL1	X00/O-A 4X16
LVL2	X00/O-A 3x35 + 70
LVL3	X00/O-A 3x70 + 71,5
LVL4	PP00-A 4x16
LVL5	PP00-A 4x35 + 2,5
LVL6	PP00-A 4x70 + 2,5
LVL7	PP00-A 4x150 + 2,5

Powerlab

Medium voltage distribution network

27 x PV

power plants

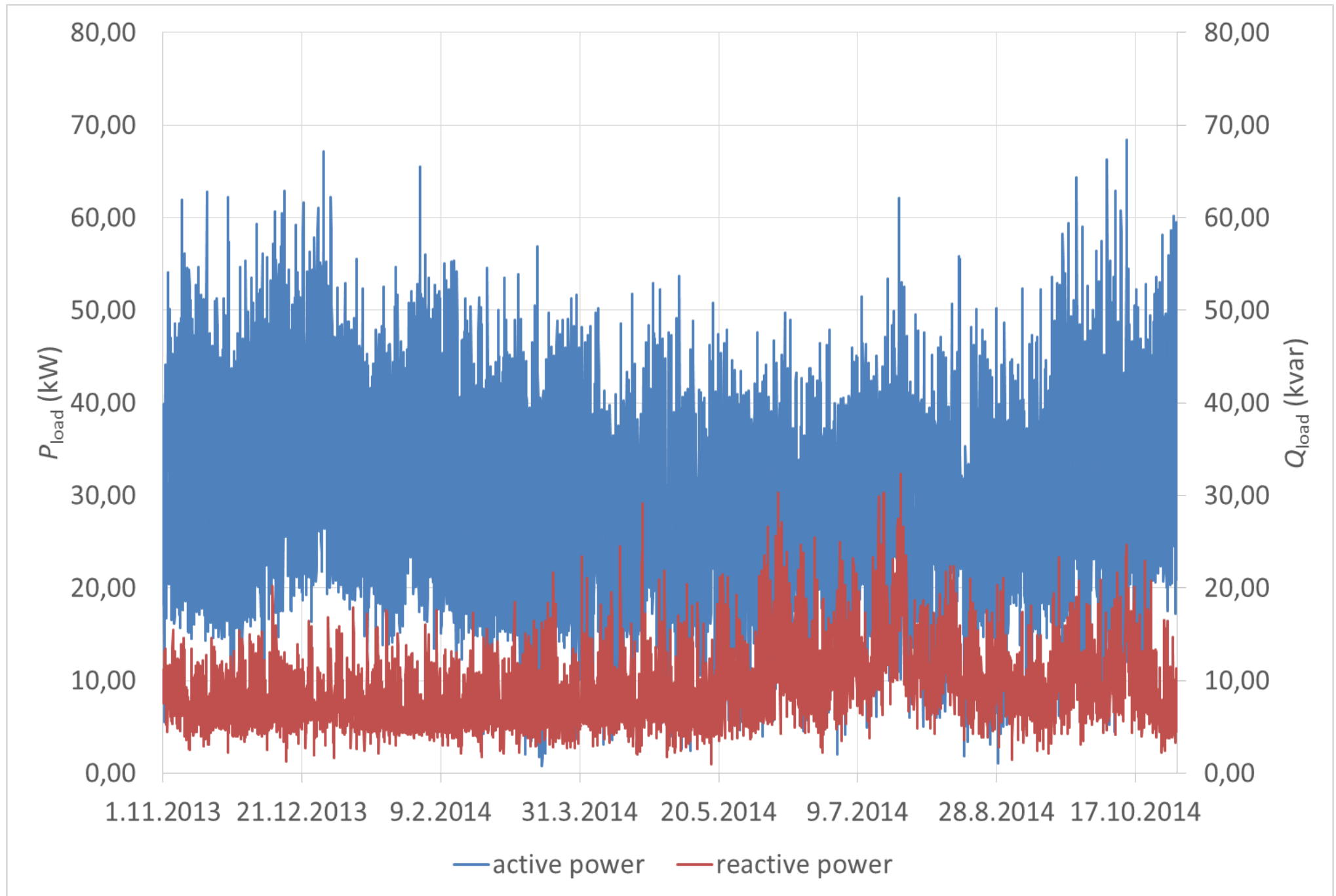
Σ 2 MWp

Legend:

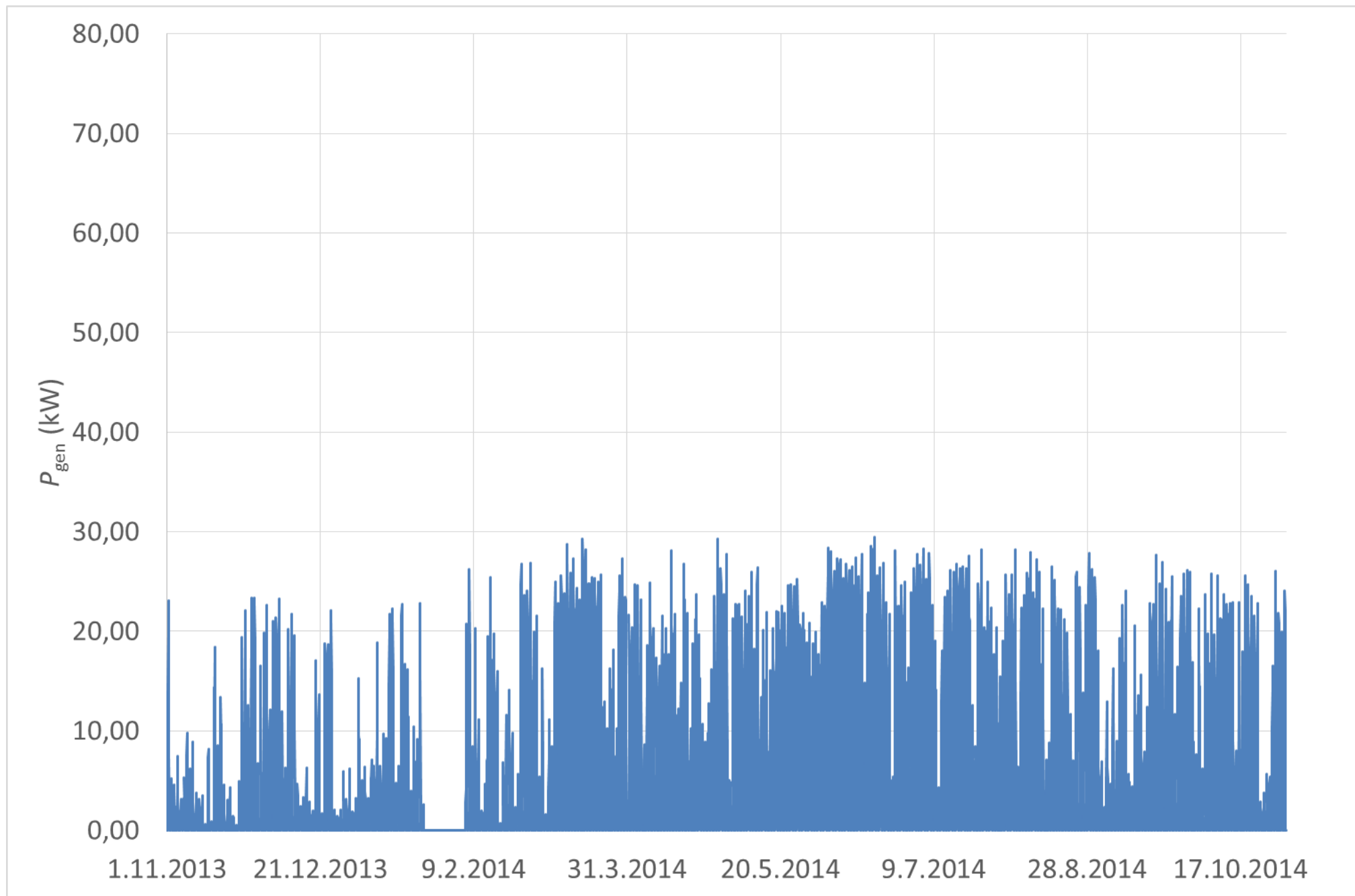
L1	Al/Fe 25/4
L2	Al/Fe 35/6
L3	Al/Fe 50/8
L4	Al/Fe 70/12
L5	AXCES 3x70
L6	PAS 1x35
L7	XHE49-A 1x1 50 20kL
L8	XHE49-A 1x20 20kL



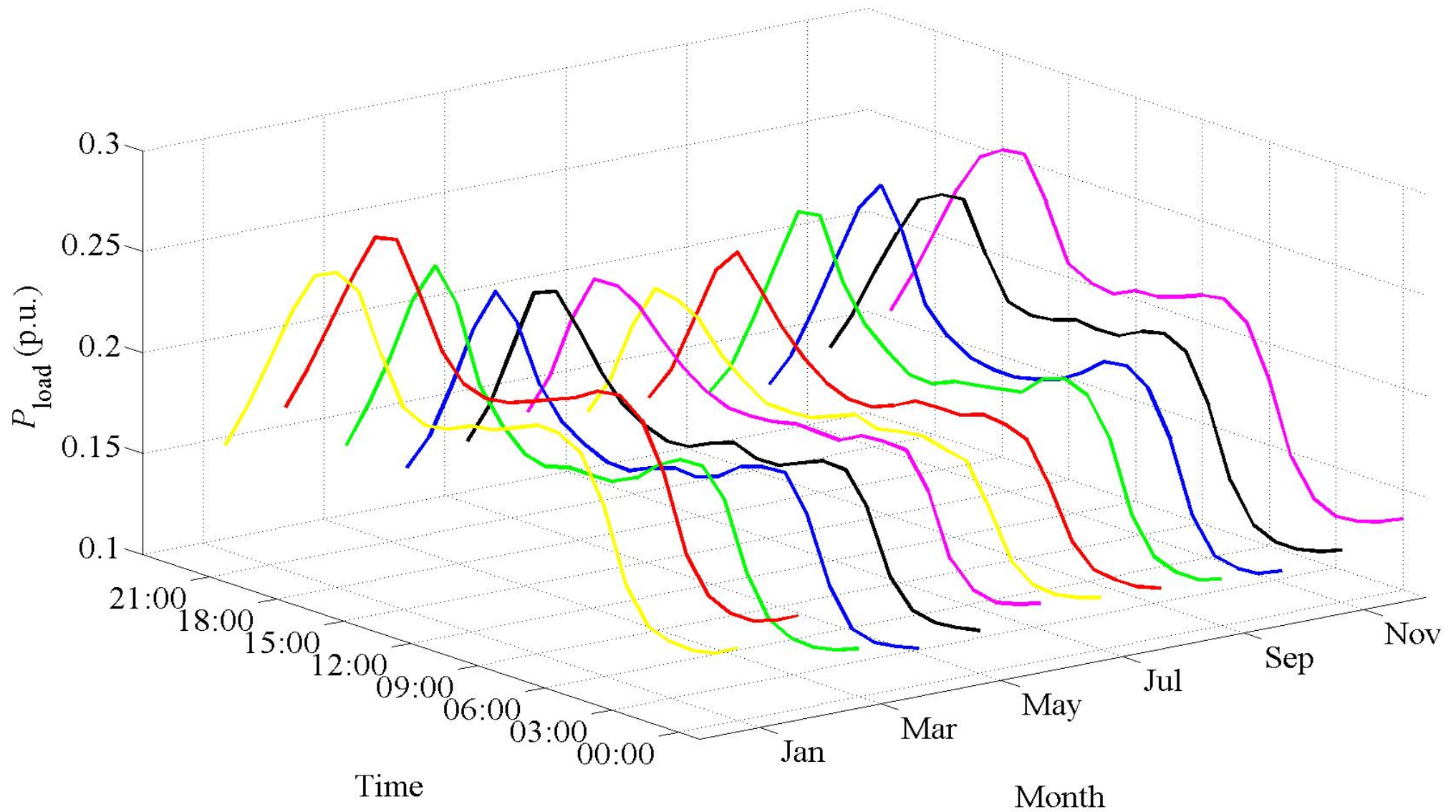
Annual measurements of active and reactive power consumed



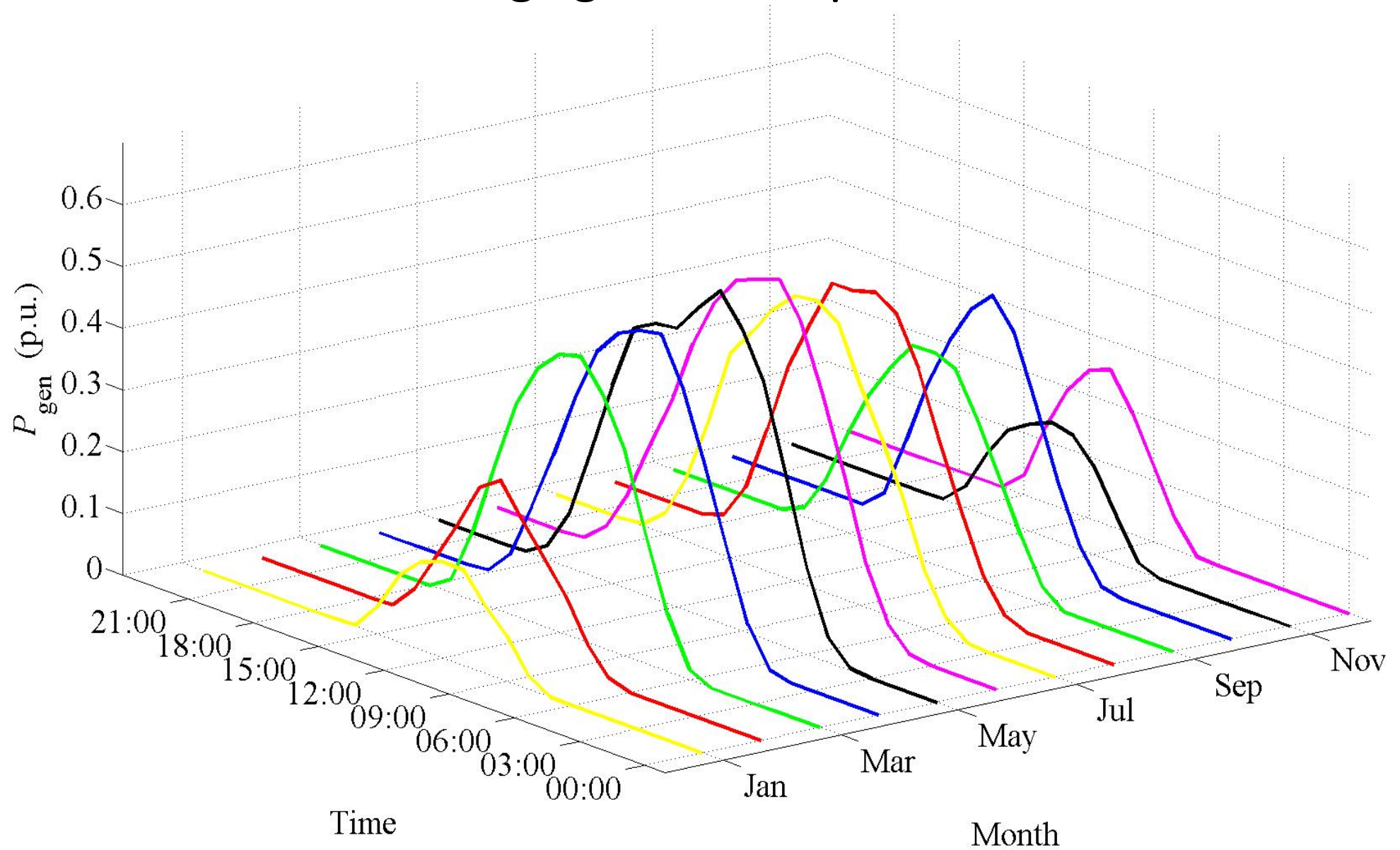
Annual measurements of active power generated



Average loading profiles



Average generation profiles



Annual power consumed and required sum of rated powers

DN	$W_{\text{load,annual}}$	P_{PV}	Operating hours
Test LV DN	204,97 MWh	252,58 kWp	812 h
Test MV DN	9,80 GWh	11.40 MWh	860 h

Change in annual network losses

DN	ΔW_{loss} (kWh)	ΔW_{gen} (kWh)
Test LV DN	7.23	-2.02
Test MV DN	81.25	-0.32

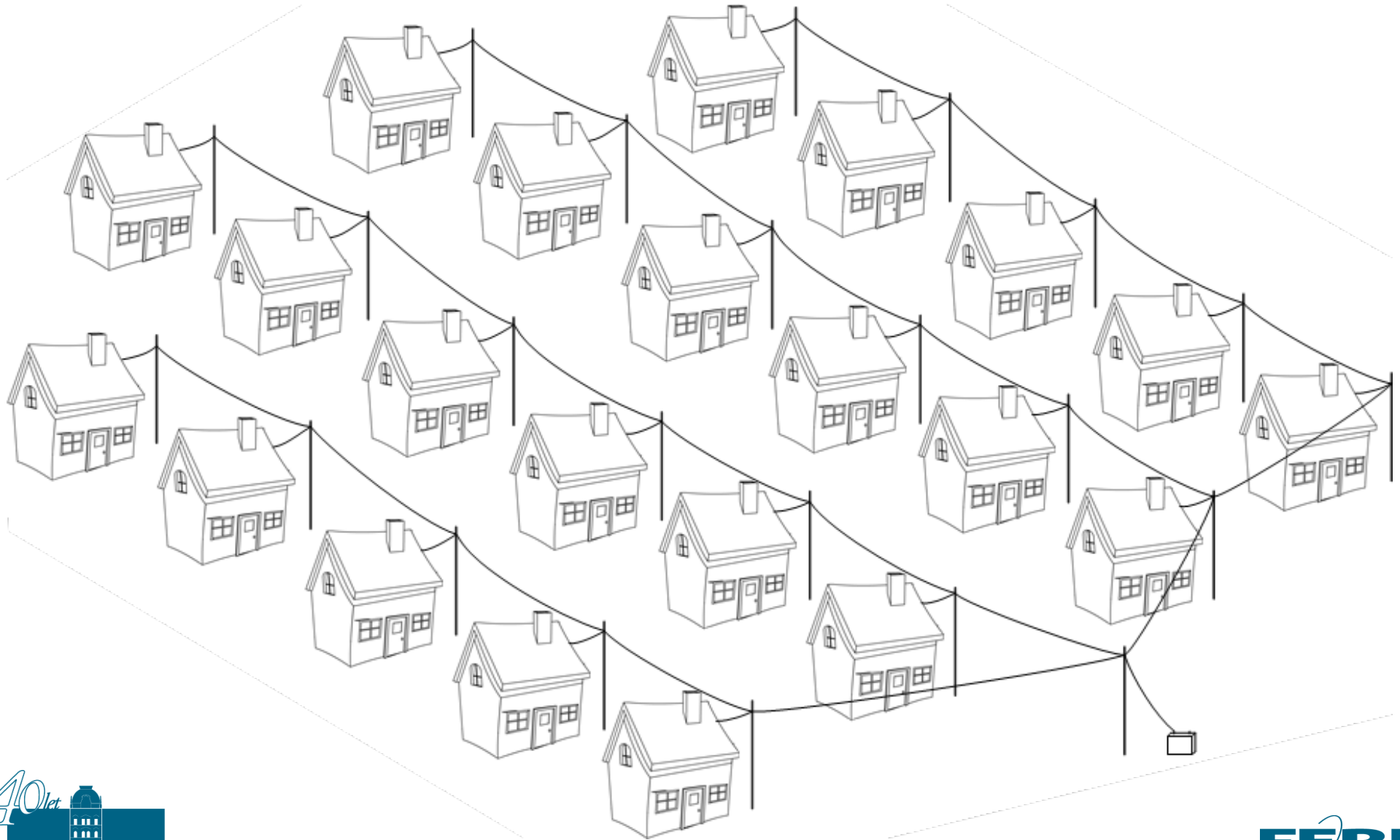
Change in annual network losses

DN	Reactive power generation distribution	ΔW_{loss} (kWh)	W_{gen} (kWh)
Test LV DN	equal	-44.98	-76.58
	unequal	-49.76	-63.86
Test MV DN	equal	-5925.70	-3552.50
	unequal	-6200.10	-4752.50

Change in annual network losses

DN	Scenario	ΔW_{loss} (kWh)	ΔW_{gen} (kWh)
Test LV DN	A	-1.29	-12.98
	B	-92.90	-72.10
Test MV DN	A	-0.194	-1.276
	B	-9.981	-4.056

How many micro PV plants can be installed?



Thank you!