Electric Vehicle and Heat Pump Hosting Capacity Assessment for a German 25,000-noded Distribution Network

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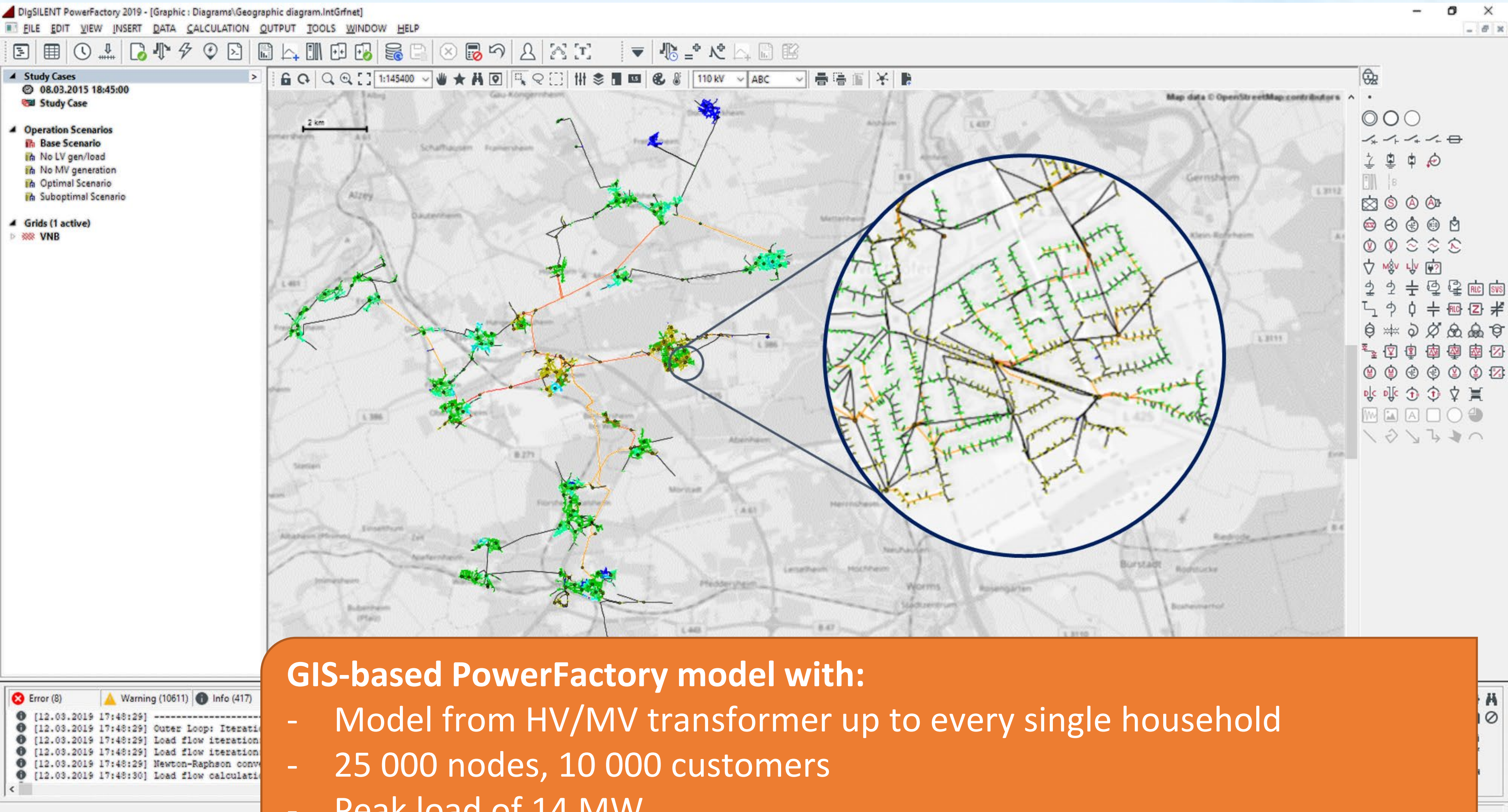
Motivation

- Model a large-scale distribution network up to the last household
- Probabilistic analysis of electric vehicle (EV) and heat pump (HP) impact
- Evaluation of overloading and undervoltage problems for all network levels

→ Readiness level of the distribution grid regarding EV/HP growth

Detailed modelling



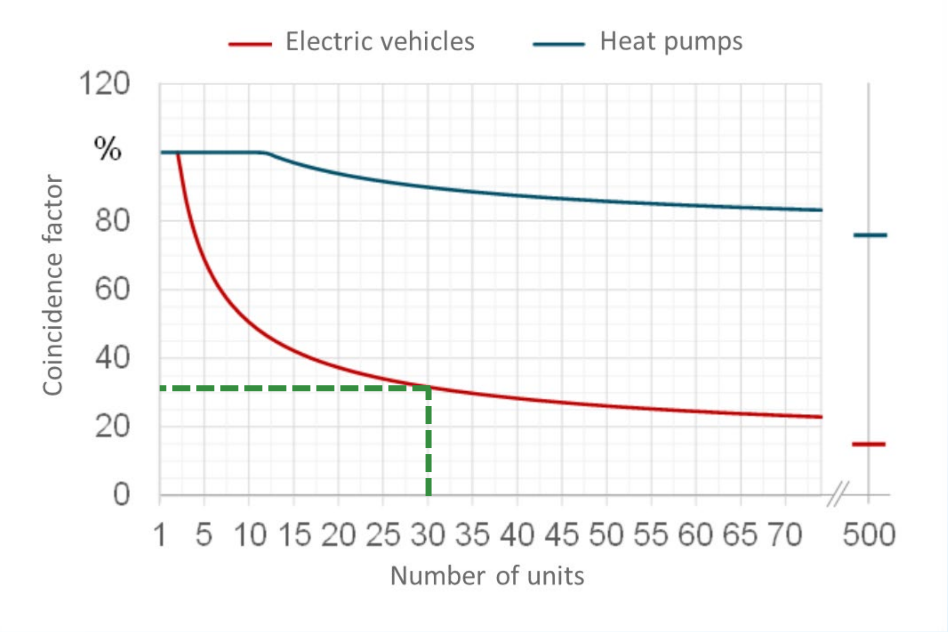
GIS-based PowerFactory model with:

- Model from HV/MV transformer up to every single household
- 25 000 nodes, 10 000 customers
- Peak load of 14 MW

EV and HP coincidence factors

Idea: <u>Simple strategies</u> for distribution system operators to estimate the impact of electric vehicles and heat pumps

➔ Coincidence factors based on probabilistic modelling or actual EV/HP data if available



If 30 EV owners ➔ Simultaneous charging of up to 10 EVs

If 30 HP owners ➔ Simultaneous operation of about 27 HPs

dena Study Integrated Energy Transition / dena-Leitstudie Integrierte Energiewende (p.145)

Technical assumptions

Electric vehicles (EVs):

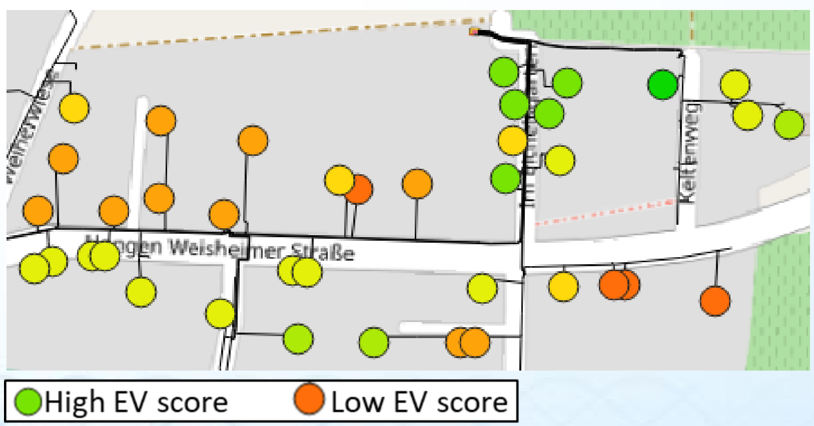
- 11 kW charging power
- cosphi = 0.98 lagging

Heat pumps (HPs):

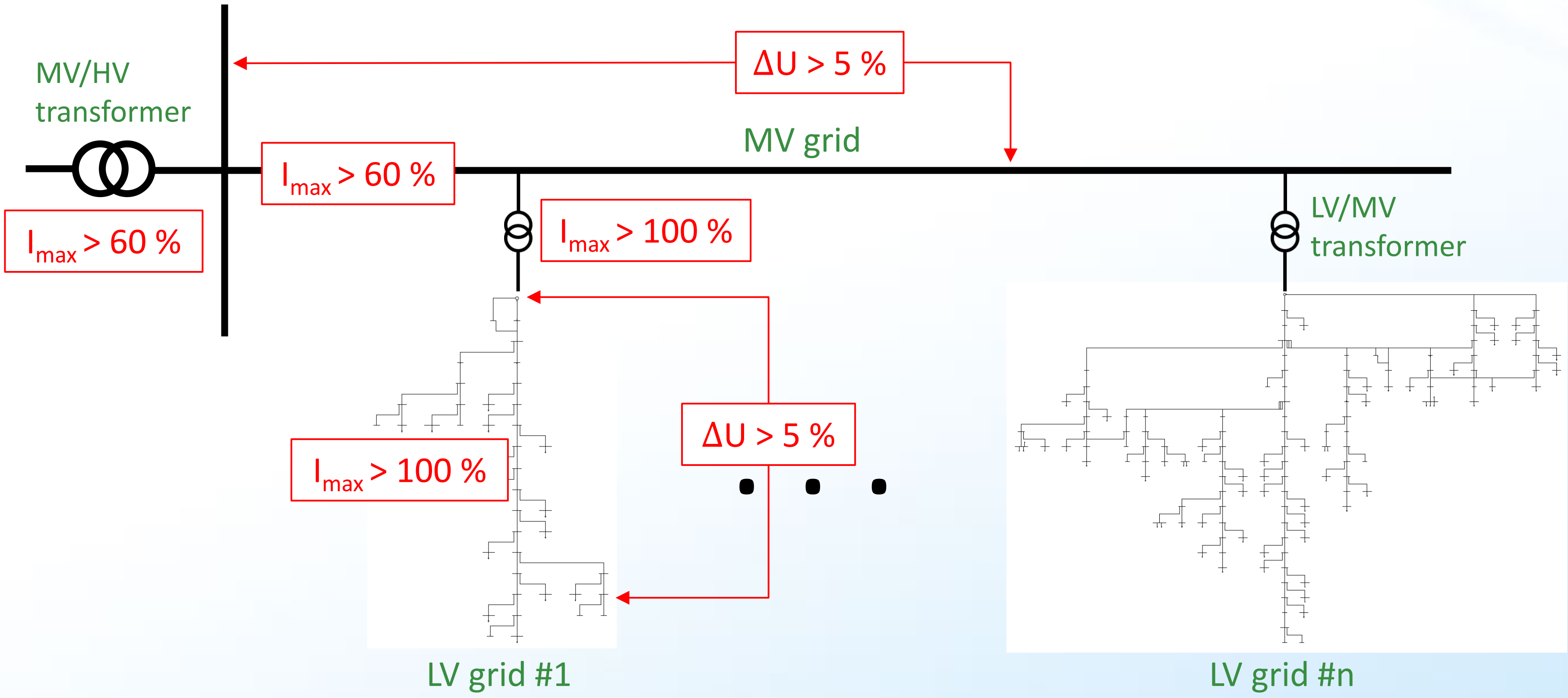
- 4.6 kW_{el} power input
- cosphi = 0.8 lagging

- Random distribution of EVs on households, relative on EV score
- EV score is based on socio-economic characteristics of households

- Random distribution of HPs on households



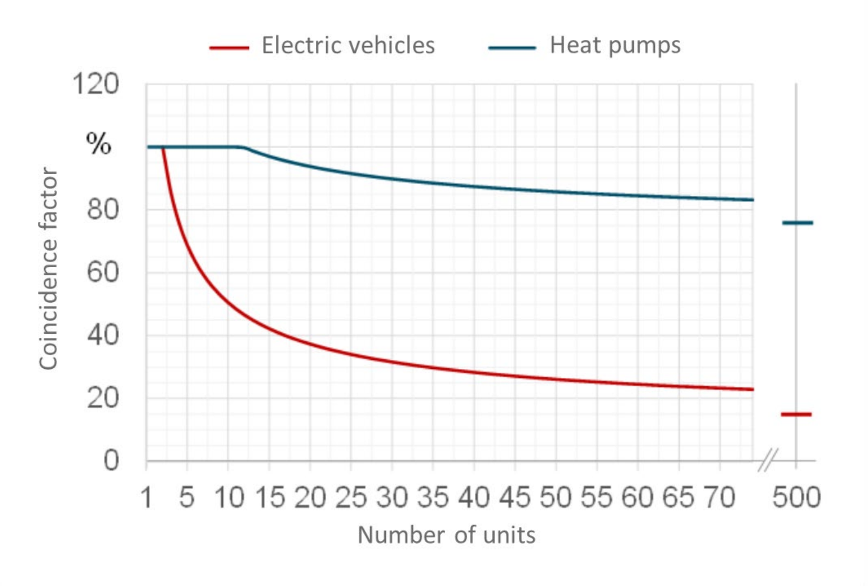
Evaluation across multiple voltage levels (1)



Evaluation across multiple voltage levels (2)

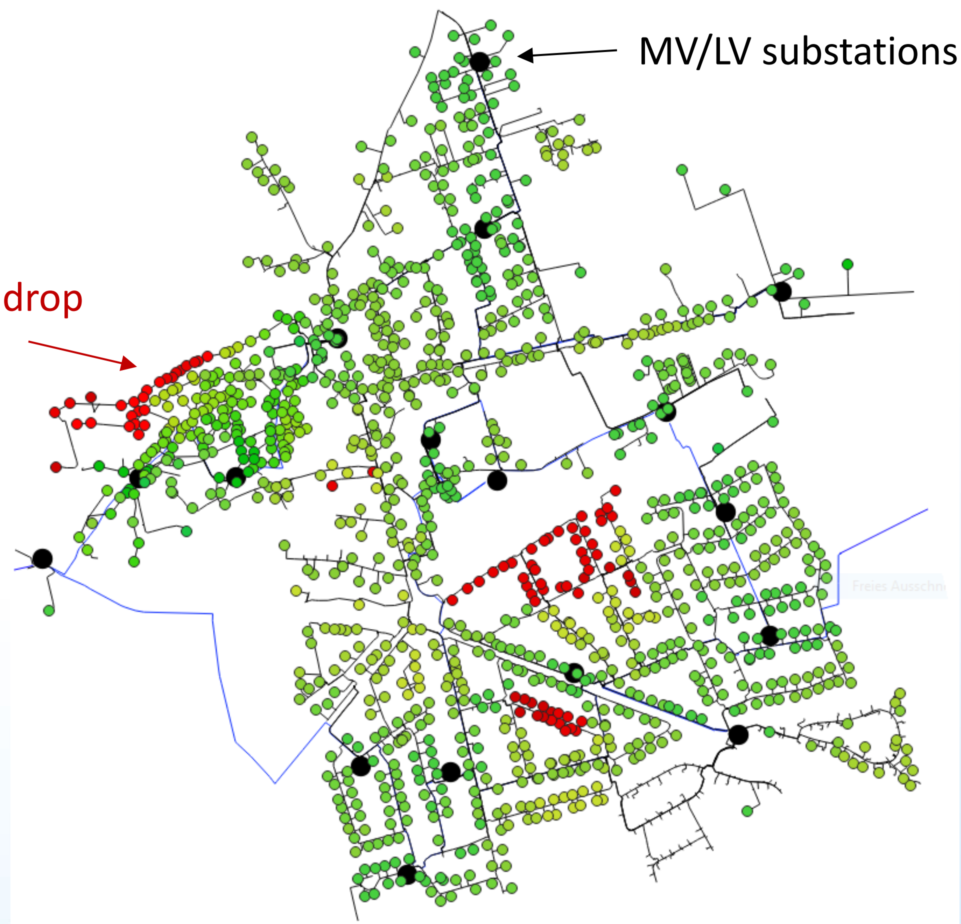
For the different voltage levels, different coincidence factors need to be taken into account:

- **Single LV feeder → Few # of units → High simultaneity for worst-case scenario**
- **Entire MV grid → High # of units → Low simultaneity for worst-case scenario**



Results – Example

Households with undervoltage problems in one of the LV grids



Undervoltage visualization for 100% EV / 0% HP penetration

Results – Summary

EV penetration →, HP penetration ↓

LV_U	0%	20%	40%	60%	80%	100%
0%	0%	0%	0%	1%	3%	5%
20%	0%	0%	2%	5%	8%	13%
40%	0%	2%	6%	10%	15%	20%
60%	1%	7%	12%	17%		
80%	4%	13%	19%			
100%	9%	20%				

MV_U	0%	20%	40%	60%	80%	100%
0%	0%	0%	0%	0%	1%	13%
20%	0%	0%	1%	8%	23%	31%
40%	1%	5%	19%	28%	39%	44%
60%	17%	29%	37%	44%		
80%	39%	43%	47%			
100%	47%	50%				

LV_I	0%	20%	40%	60%	80%	100%
0%	0%	0%	0%	0%	0%	0%
20%	0%	0%	0%	0%	0%	1%
40%	0%	0%	0%	1%	1%	3%
60%	0%	0%	1%	2%		
80%	0%	1%	2%			
100%	1%	2%				

MV_I	0%	20%	40%	60%	80%	100%
0%	0%	0%	0%	1%	2%	6%
20%	0%	0%	1%	5%	10%	15%
40%	1%	3%	8%	13%	17%	19%
60%	7%	13%	16%	18%		
80%	16%	18%	19%			
100%	19%	22%				

MV/LV	0%	20%	40%	60%	80%	100%
0%	0%	1%	5%	15%	26%	40%
20%	1%	12%	23%	33%	44%	50%
40%	8%	30%	39%	48%	55%	62%
60%	25%	45%	53%	61%		
80%	40%	56%	65%			
100%	54%	65%				

HV/MV	0%	20%	40%	60%	80%	100%
0%	0%	0%	0%	0%	0%	0%
20%	0%	0%	0%	0%	0%	0%
40%	0%	0%	0%	0%	0%	0%
60%	0%	0%	0%	0%		
80%	0%	0%	0%			
100%	0%	0%				

LV_U = Voltage violations in the LV grid; LV_I = Overloading in the LV grid; MV/LV = Overloading of MV/LV transformers; MV_U = Voltage violations in the MV grid; MV_I = Overloading in the MV grid; HV/MV = Overloading of HV/MV transformers

Results – Impact of coincidence factor

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EV penetration →, HP penetration ↓

LV_U	0%	20%	40%	60%	80%	100%
0%	0%	0%	0%	1%	3%	5%
20%	0%	0%	2%	5%	8%	13%
40%	0%	2%	6%	10%	15%	20%
60%	1%	7%	12%	17%		
80%	4%	13%	19%			
100%	9%	20%				

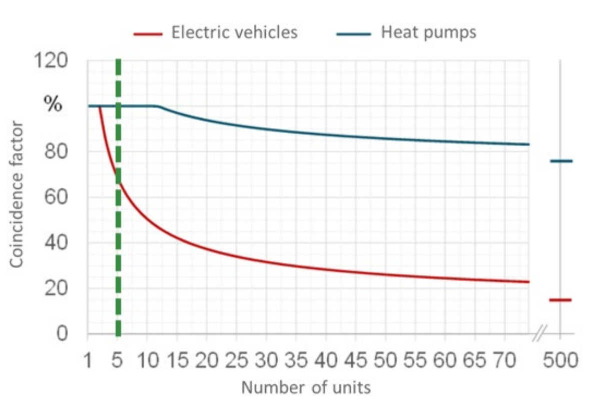
EV penetration →, HP penetration ↓

MV_U	0%	20%	40%	60%	80%	100%
0%	0%	0%	0%	0%	1%	13%
20%	0%	0%	1%	8%	23%	31%
40%	1%	5%	19%	28%	39%	44%
60%	17%	29%	37%	44%		
80%	39%	43%	47%			
100%	47%	50%				

	5 EVs	5 HPs	500 EVs	500 HPs
Coincidence factor	70%	100%	15%	76%
Power output	11 kW	4.6 kW	11 kW	4.6 kW
Combined power output	39 kW	23 kW	814 kW	1737 kW

x 1.7

x 0.5



Conclusions

- Possible to model large-scale distribution networks of up to multiple 100,000 nodes
- Simplified methods to analyze the readiness level of distribution grids towards electric vehicles and heat pumps
- Visual inspection of vulnerable grid sections
- Evaluation across multiple voltage levels to determine both small- and large-scale impact

- The analyzed network showed that problems would arise mainly in MV/LV transformers and MV grid. Less critical for LV grid.
- Network is not representative for Germany ➔ But method easily applicable to other distribution networks

Discussion

- **Biggest challenge: Accurate GIS data with few errors on connections, line types, etc.**

- **Advanced voltage control concepts with increased distribution grid monitoring can expand current voltage drop limitations of 5 %**
- **n-1 redundancy may be subject to discussion as the power output of controllable loads could be limited during n-1 events ➔ reduced oversizing of MV assets**

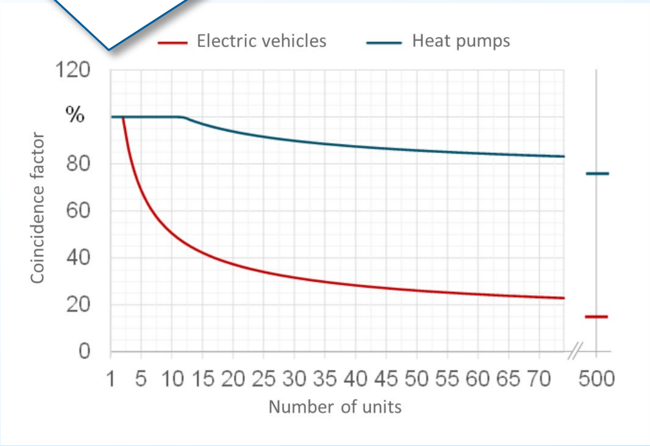
EV penetration →

HP penetration ↓

MV/LV	0%	20%	40%	60%	80%	100%
0%	0%	1%	5%	15%	26%	40%
20%	1%	12%	23%	33%	44%	50%
40%	8%	30%	39%	48%	55%	62%
60%	25%	45%	53%	61%		
80%	40%	56%	65%			
100%	54%	65%				

Worst-case estimation because assumed EV and HP peak demand will rarely be at the same time

Smart control of EVs and heat pumps will affect coincidence factors



Thank you for your attention!

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