Grid Load Relief by Smart Charging of Electric Vehicles

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Agenda

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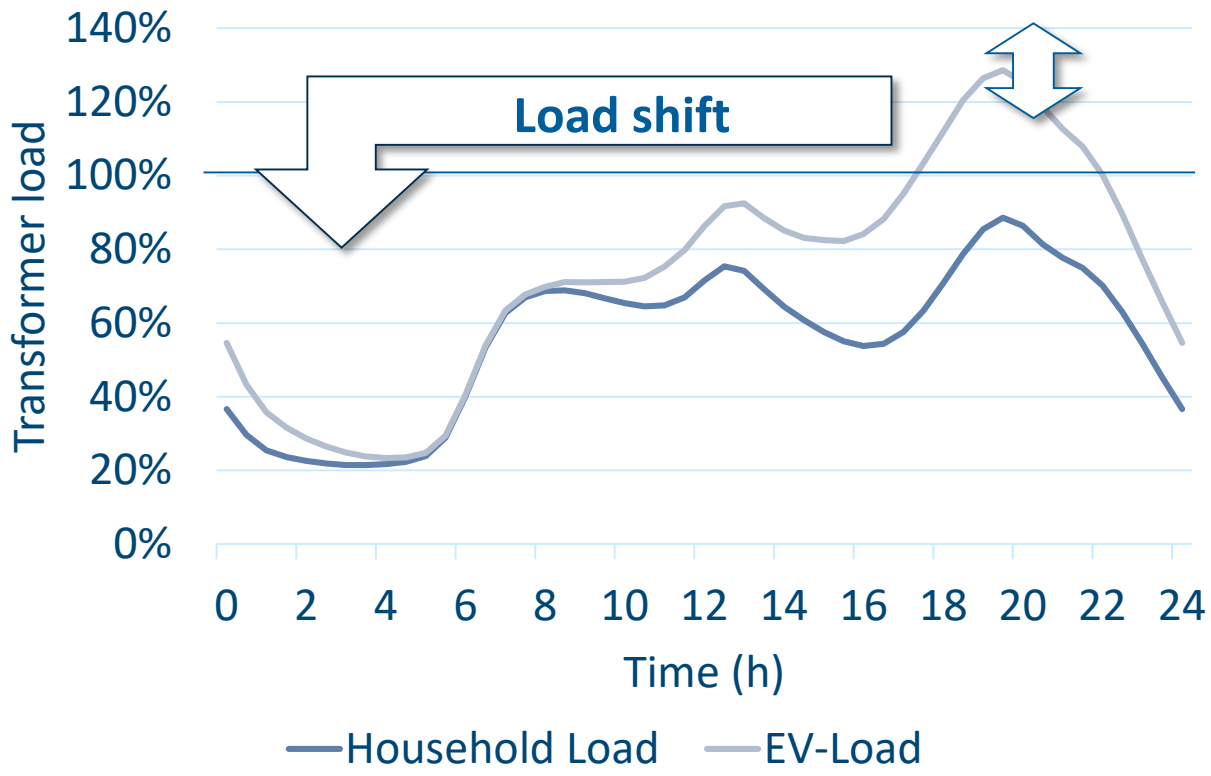
1. Introduction
2. Communication
3. Charging Algorithm
4. Simulation Design
5. Results
6. Conclusion

1. Introduction

1. Introduction

Increase in grid load especially in evenings

- Load shifting instead of grid expansion
- Probabilistic modeling to include load accumulation



2. Communication

2. Communication

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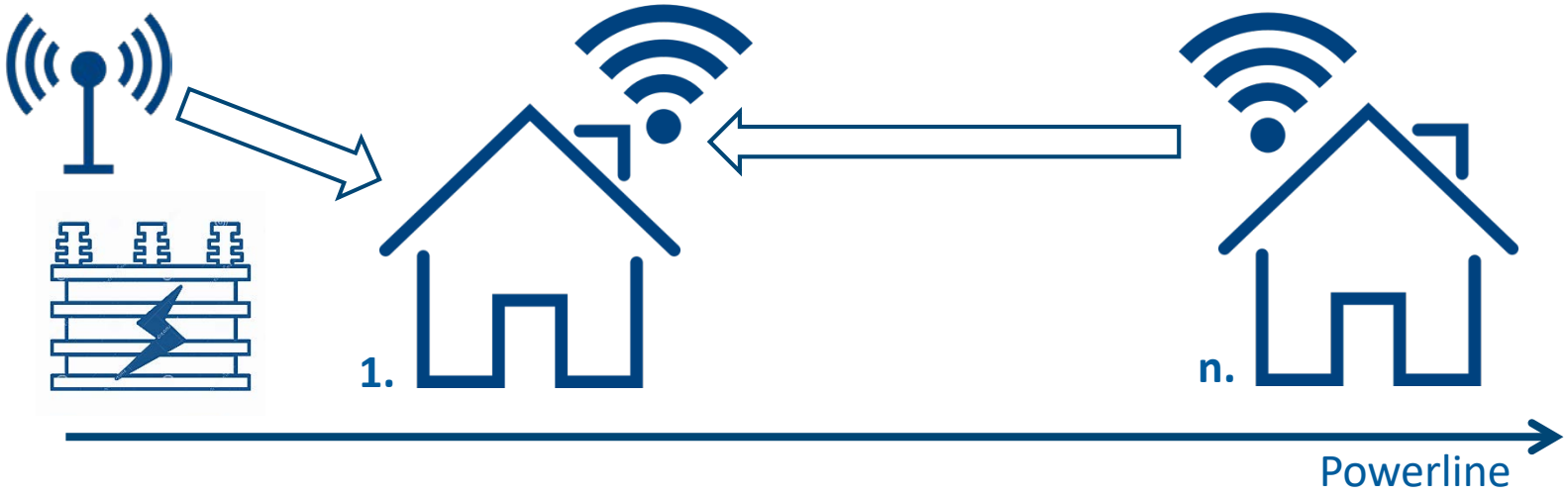
Communication Effort

- No Communication (local voltage)
- Uni-Directional (transformer load)
- Bi-Directional (global voltage, line load)



3. Charging Algorithm

3. Charging Algorithm

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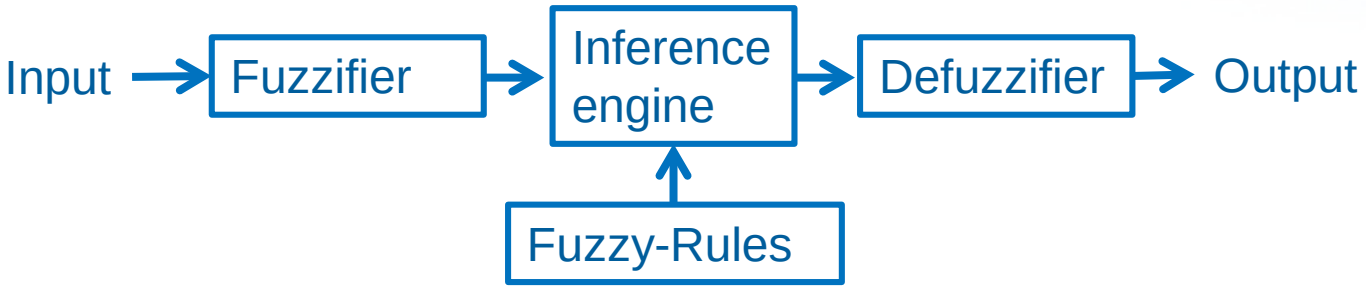
Fuzzy Control:

- **Process based**
- **Multidimensional input transferred into 1-D output**



Reactive Power Control:

- **cos(φ)U-dependency for local voltage stabilization**

3. Charging Algorithm

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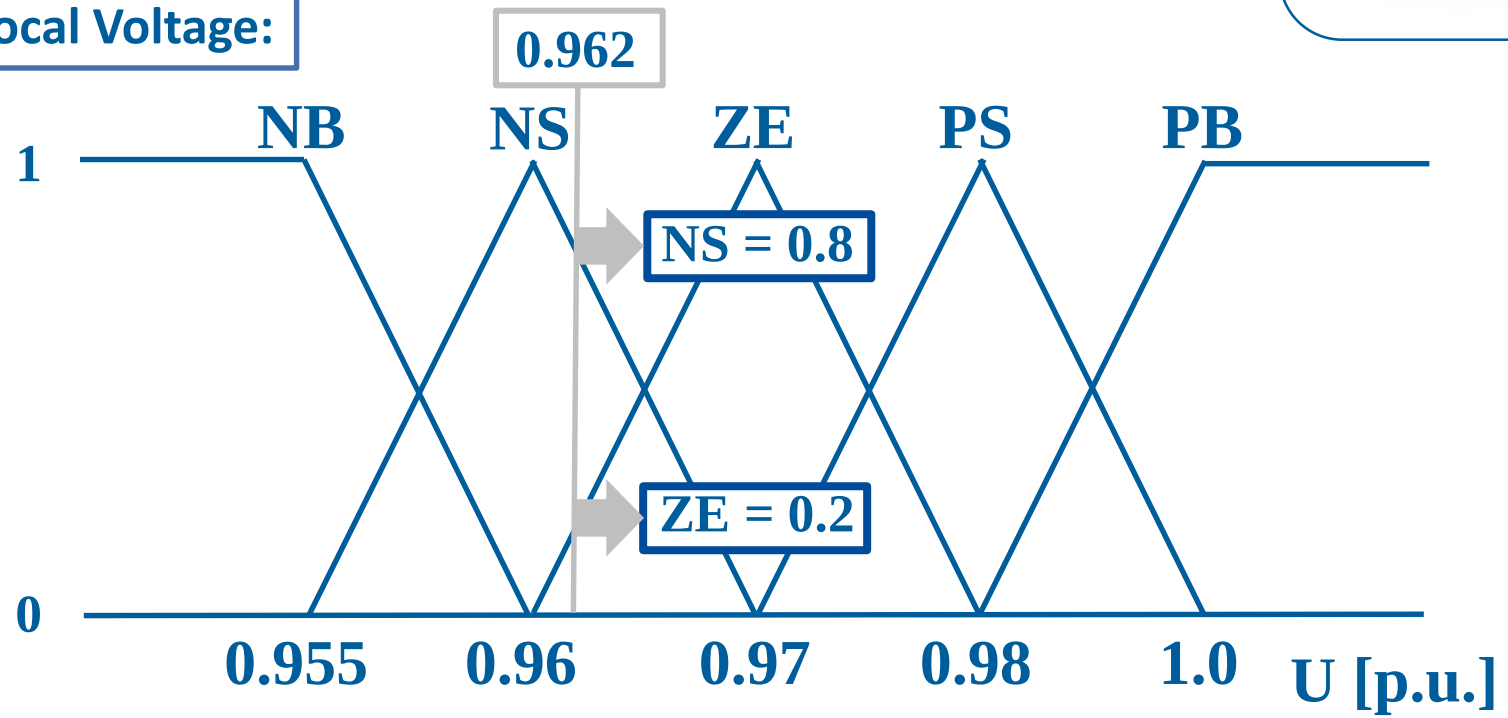
Voltage:
NS = 0.8
ZE = 0.2

Fuzzy Control Fuzzifier

- **Input Data into Fuzzy-areas**
- **“Negative Big” to “Positive Big”**

Local Voltage:



3. Charging Algorithm

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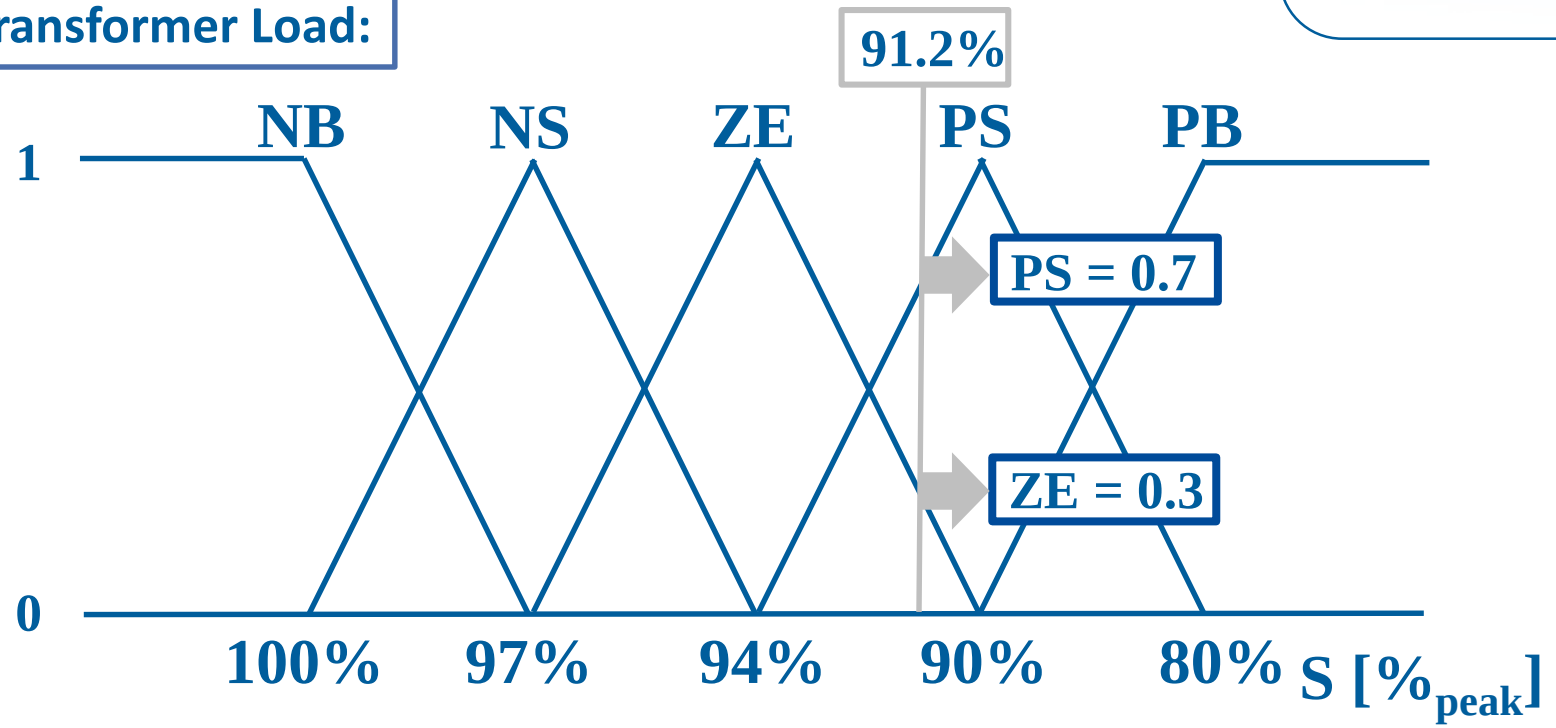
Fuzzy Control Fuzzfier

- **Input Data into Fuzzy-areas**
- **“Negative Big” to “Positive Big”**

Voltage:
NS = 0.8
ZE = 0.2
Transformer:
PS = 0.7
ZE = 0.3

Transformer Load:



3. Charging Algorithm

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Inference Engine:

$$\mu_{\min,i} = \min(\mu_{V,i}\ ;\ \mu_{TB,i})$$

Fuzzy Rules:

Voltage	TB NB_T	NS_T	ZE_T	PS_T	PB_T
PB_V	ZE_L	PS_L	PB_L	PB_L	PB_L
PS_V	NS_L	ZE_L	PS_L	PB_L	PB_L
ZE_V	NB_L	NS_L	PS_L	PB_L	PB_L
NS_V	NB_L	NS_L	PS_L	PB_L	PB_L
NB_V	NB_L	NB_L	PS_L	PS_L	PB_L

Voltage:
NS = 0.8
ZE = 0.2
Transformer:
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ZE = 0.3

$$\mu_{min,PB_L} = \min(0.8\ ;\ 0.7)$$

$$\mu_{min,PB_L} = 0.7$$

3. Charging Algorithm

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PS_V	NS_L	ZE_L	PS_L	PB_L	PB_L
ZE_V	NB_L	NS_L	PS_L	PB_L	PB_L
NS_V	NB_L	NS_L	PS_L	PB_L	PB_L
NB_V	NB_L	NB_L	PS_L	PS_L	PB_L

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3. Charging Algorithm

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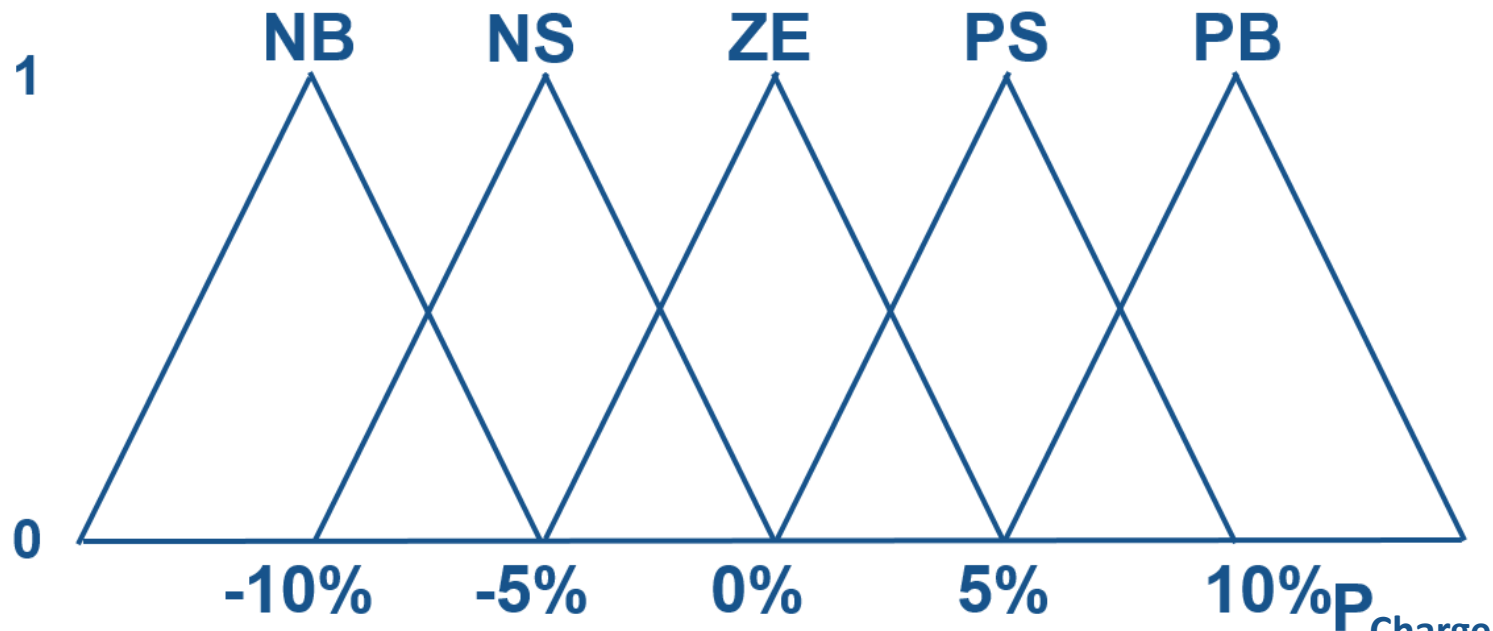
Defuzzfier

Charging Power:



$\mu_{min,PB_L} = 0.2$

$\mu_{min,PS_L} = 0.2$

3. Charging Algorithm

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$$\mu_{min,PB_L} = 0.7$$
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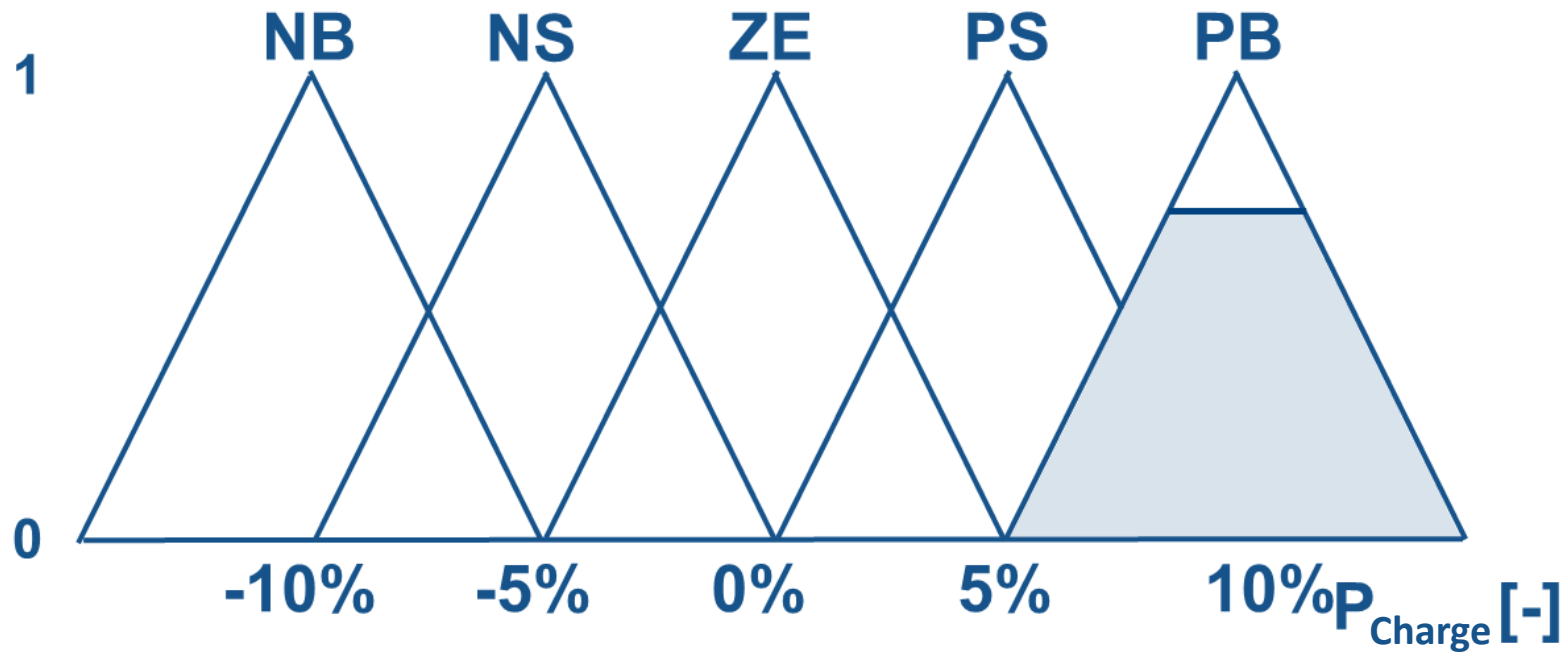
Defuzzfier

Charging Power:



3. Charging Algorithm

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$\mu_{min,PB_L} = 0.7$

$\mu_{min,PS_L} = 0.3$

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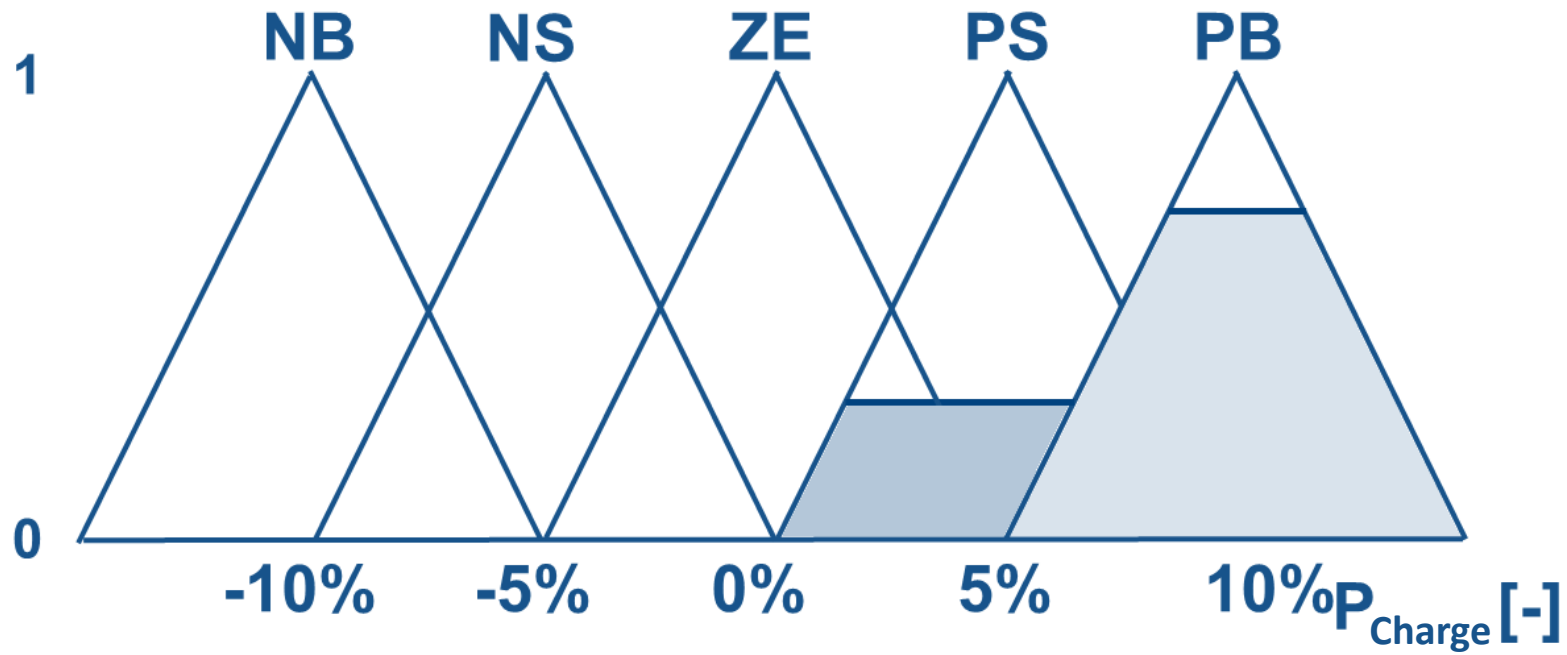
Defuzzfier

Charging Power:



3. Charging Algorithm

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$\mu_{min,PB_L} = 0.7$
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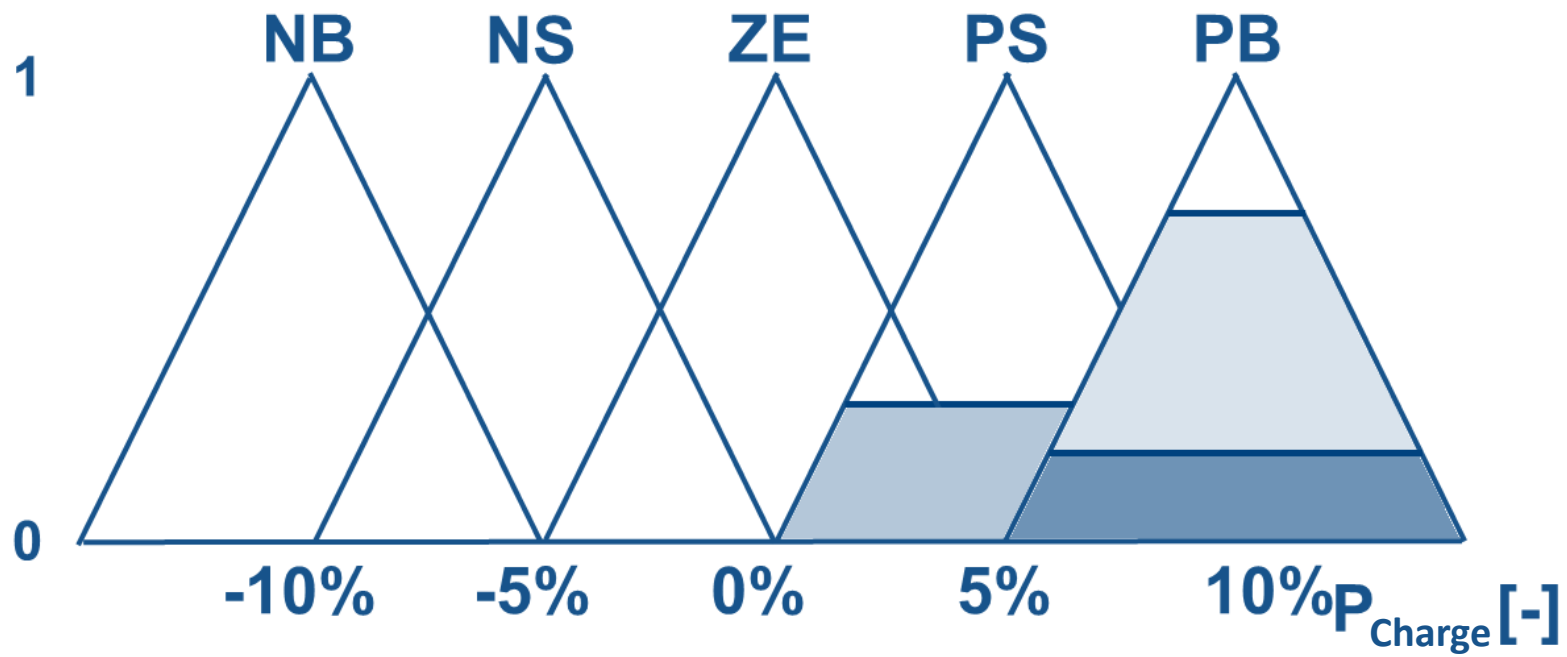
Defuzzfier

Charging Power:



3. Charging Algorithm

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$\mu_{min,PB_L} = 0.7$
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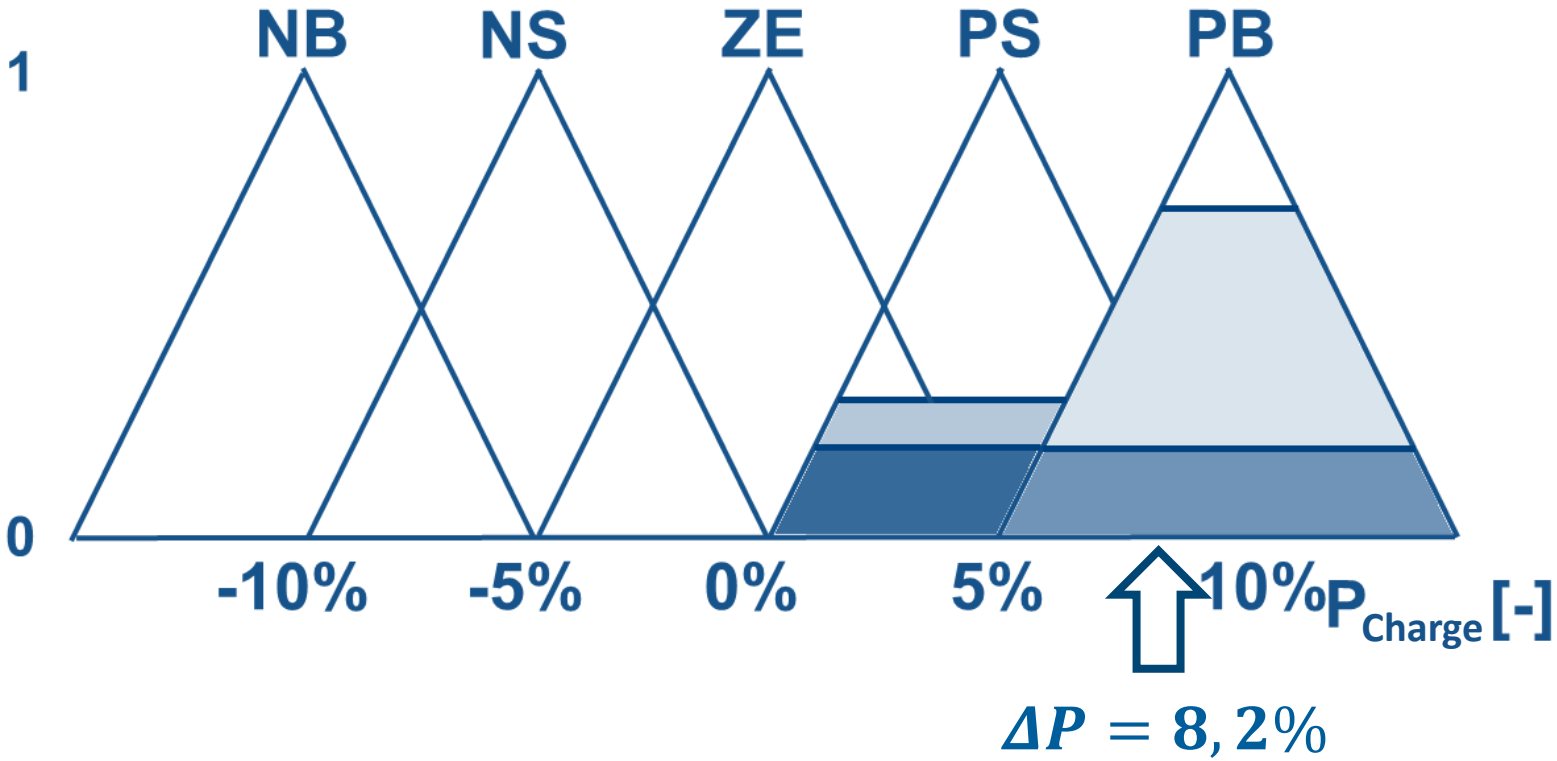
Defuzzfier

Charging Power:



$\Delta P = 8,2\%$

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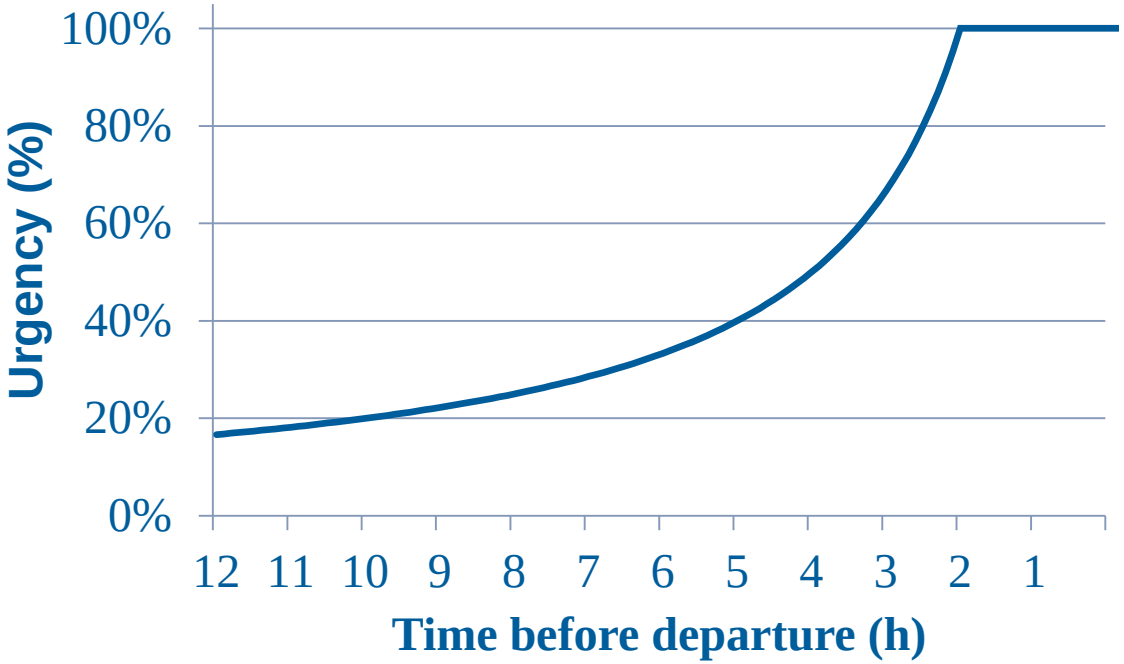
Urgency-factor

$$Urgency = \frac{Min.\,charging\ time}{Time\ until\ departure}$$



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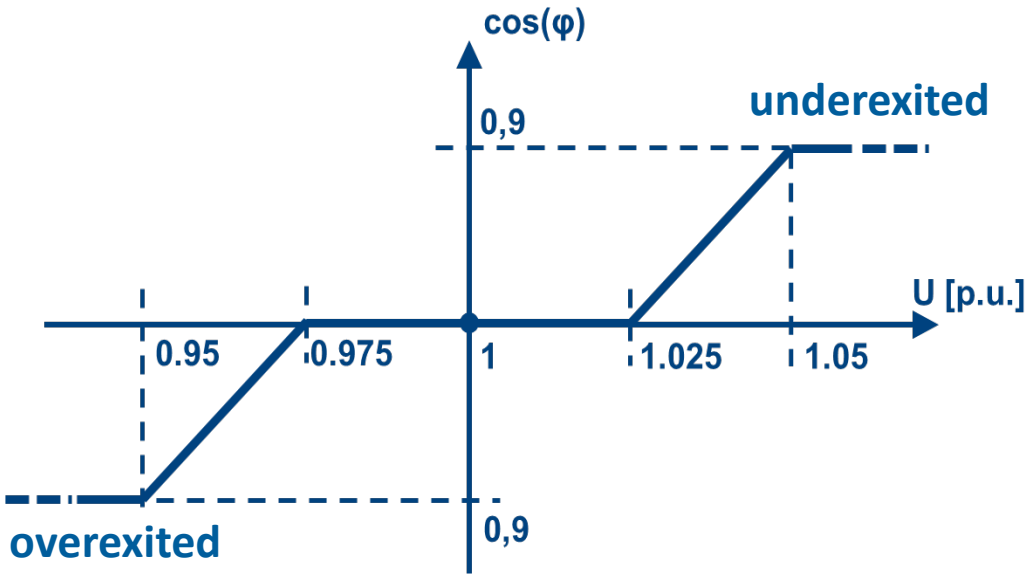
Reactive power control

- **Grid voltage stabilization**
- **Cos(φ)U-Dependency**



4. Simulation Design

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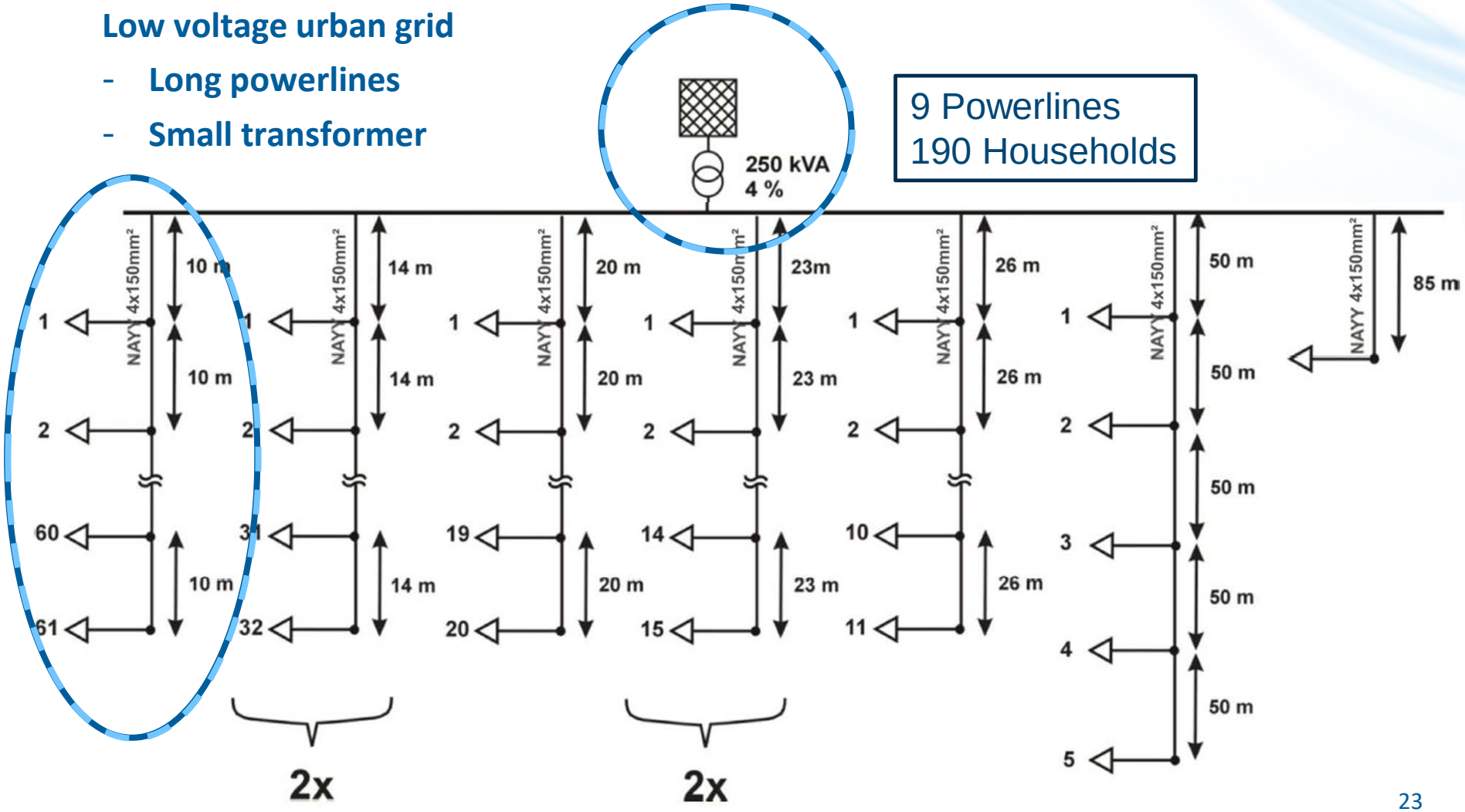
Low voltage urban grid

- **Long powerlines**
- **Small transformer**



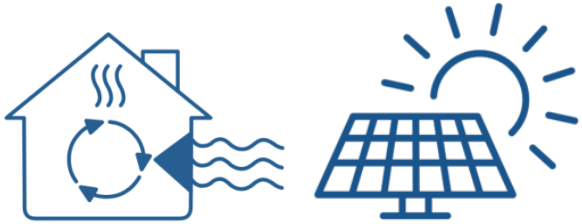
4. Simulation Design

Controlled vs. uncontrolled charging:

- **SOC < 55% & 30 minutes**
- **Next journey SOC to low**
- **AC-DC Efficiency 94%; 11 kW nominal**

Probabilistic influence factors:

- **Driving Profiles**
- **Household loads**
- **Heat pumps**
- **Photovoltaic systems**



5. Simulation Results

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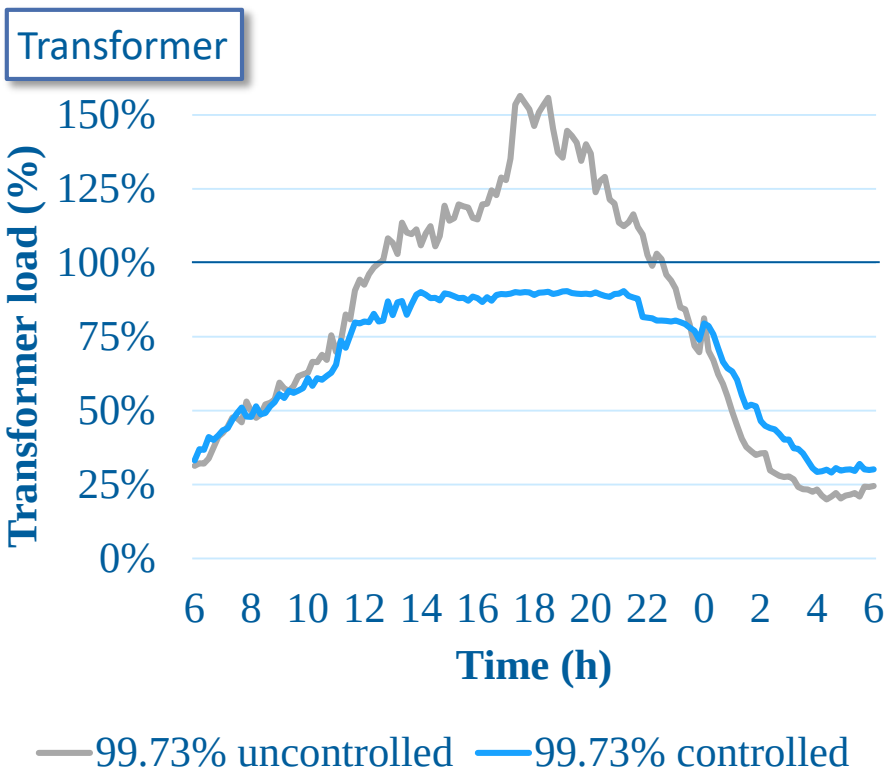
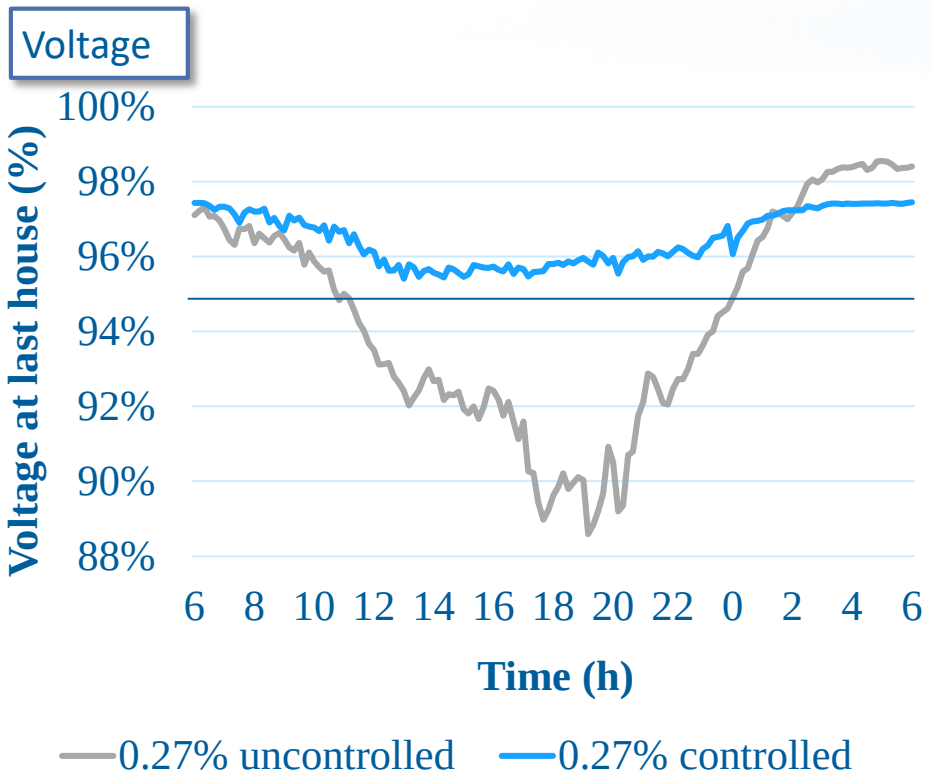
Controlled vs. Uncontrolled Charging of 100% EV on weekdays

- **Quantils for better evaluation**





5. Simulation Results

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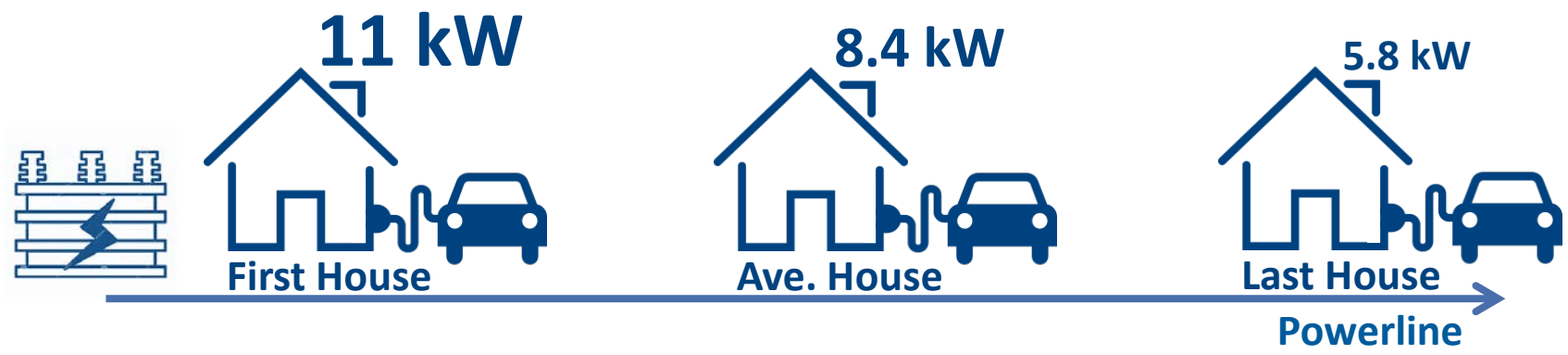
Controlled vs. Uncontrolled Charging of 100% EV on weekdays

Further influence of controlled charging:

- Powerlines within boundaries
- No additional car owner restrictions
- 24% average charging power reduction (8.4 kW)
- Location dependency

Algorithm successful

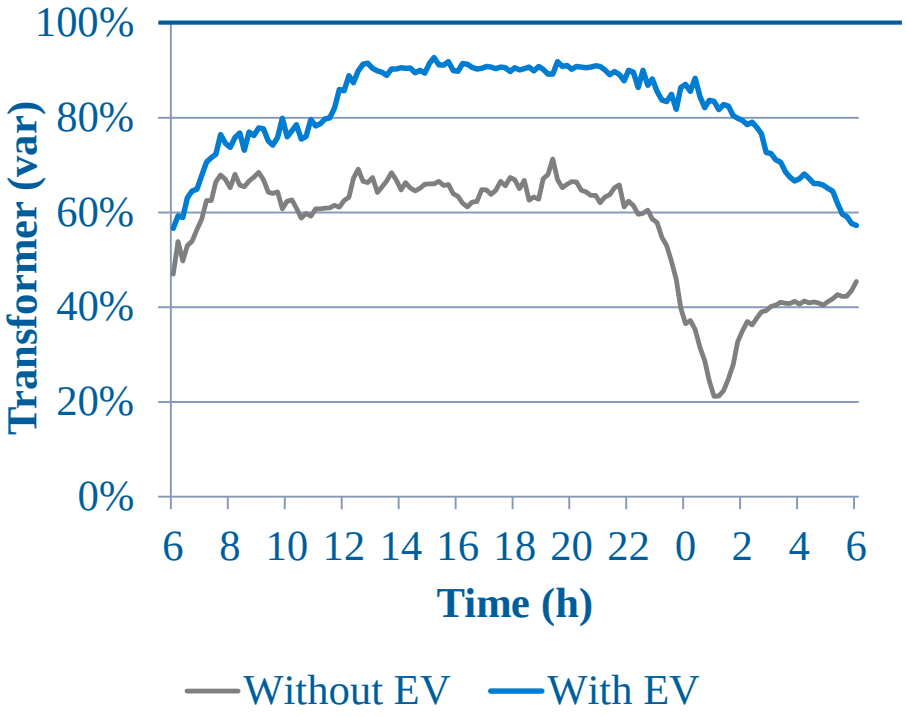


5. Simulation Results

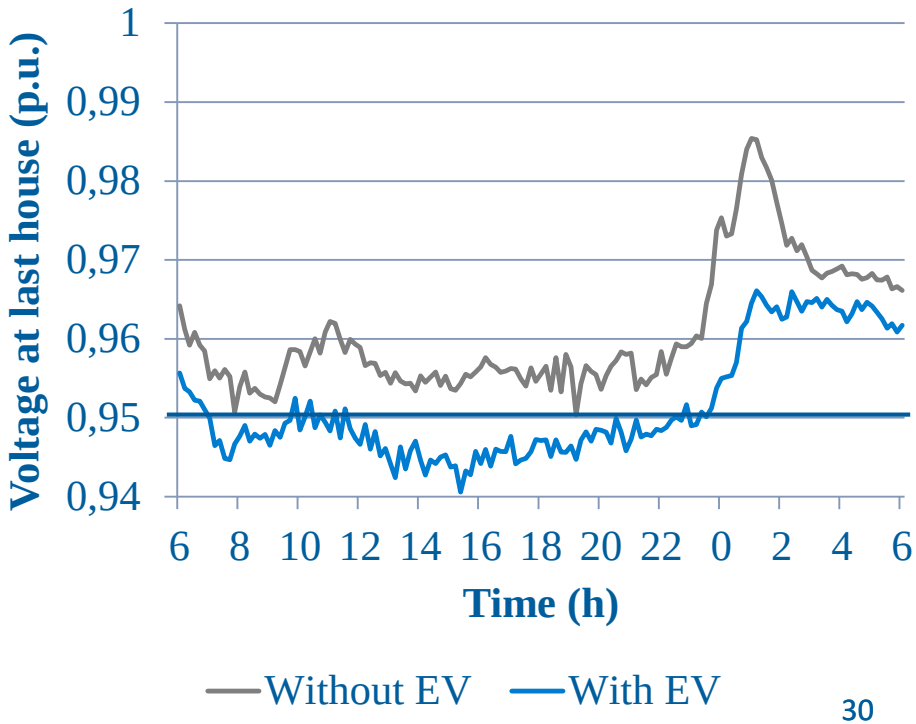
Controlled charging of 100% EV plus 20% HP on weekdays

- **Grid close to voltage boundary**

Transformer



Voltage



5. Simulation Results

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Controlled charging of 100% EV plus 20% HP on weekdays

Further influence of controlled charging:

- **Powerlines within boundaries**
- **Car owner restrictions**
- **78% average charging power reduction (2.5 kW)**

Inclusion of PV does not prevent grid expansion caused by load factors

- **Cloudy Sky; Night**

6. Conclusion

6. Conclusion

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Fuzzy Controller:

- **One dimensional communication**
- **Transformer load, Local voltage, Urgency factor**

Reactive Power Controller:

- Cos(ϕ)U-Dependency

Urban low voltage grid:

- Long powerlines; Small transformer

Results:

- Successful implementation as long as voltage margins exist

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Thank you for your attention!

Sources

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Literature:

- See paper: “Grid Load Relief by Smart Charging of Electric Vehicles”

Icons:

https://meteor-nofer.de/leistungen/

https://www.detmersons.com/why-is-a-heat-pump-a-good-choice/

https://www.onlinewebfonts.com/icon/447723

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